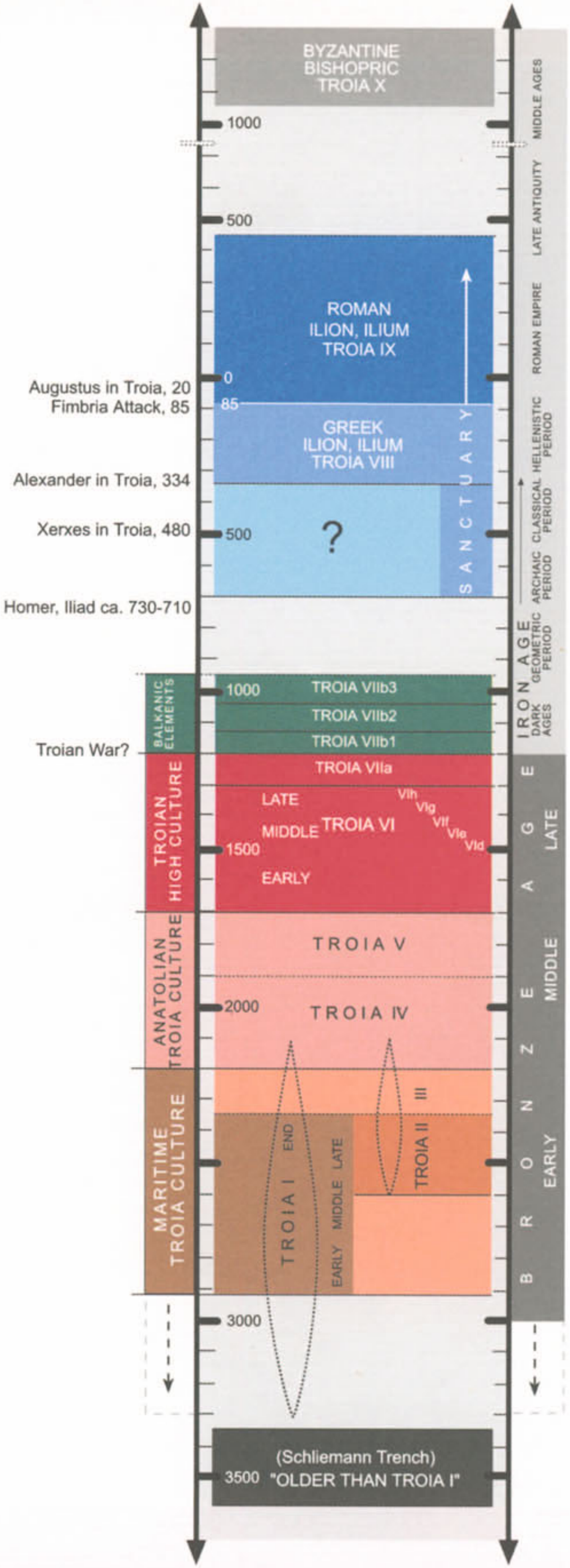

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IRON AGE
BRONZE AGE
LATE
MIDDLE
EARLY

Natural Science in Archaeology
Series editors: B. Herrmann, G. A. Wagner

Springer-Verlag Berlin Heidelberg GmbH

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Editors

Troia and the Troad

Scientific Approaches

With 135 Figures, 36 in colour, and 23 Tables

Springer

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ISBN 978-3-642-07832-3

Library of Congress Cataloging-in-Publication Data
Troia and the troad : scientific approaches / Günther Wagner, Ernst Pernicka, Hans-Peter Uerpmann (editors).
p.cm. – (Natural science in archaeology)
ISBN 978-3-642-07832-3 ISBN 978-3-662-05308-9 (eBook)
DOI 10.1007/978-3-662-05308-9
1. Troy (Extinct city) – Congresses. 2. Greeks – Turkey – Troy (Extinct city) – Antiquities – Congresses. 3. Excavations (Archaeology) – Turkey – Troy (Extinct city) – Congresses. I. Wagner, Günther, 1941- II. Pernicka, Ernst. III. Uerpmann, Hans-Peter, 1941- IV. Series.

http://www.springer.de

Originally published by Springer-Verlag Berlin Heidelberg New York in 2003
Softcover reprint of the hardcover 1st edition 2003

Typesetting: Fotosatz-Service Köhler GmbH, Würzburg
Cover design: design & production, Heidelberg
Printed on acid-free paper SPIN 10837378 32/3141/as 5 4 3 2 1 0

Foreword

It is my pleasure to welcome you here on the occasion of the International Symposium, "Landscape Troia between Earth History and Culture".

The topic Troia has stimulated many scientists, historians and experts in the history of arts to interpret data and adjust concepts regarding the development of early Troia. In the past two decades the Heidelberg Academy of Sciences and Humanities has supported several research activities which are related to the Troia project.

One of the aims of the archaeometry laboratory is to localize Aegean and Anatolian sources for the procurement of prehistoric metals such as gold, silver, lead, copper and tin. In particular in the Troad, numerous mining and smelting sites have been found and characterized, allowing one to investigate to which extent they might have been exploited by the acient Troians. When analytically comparing ores and slags with Troian metal artifacts, early trade connections can be traced.

The landscape around Troia underwent rather fast and drastic changes. The natural embayment was silted up over the past 7000 years, forming the present Troian plain, so that the shoreline moved about 8 km away from Troia. Obviously, the reconstruction of this development is crucial for understanding the role of ancient Troia. For this purpose, a luminescence technique was developed which enables the dating of the sediments that filled the embayment. In addition, numerous thermoluminescence ages of ceramics from Troia I levels at Beşiktepe were supplied by the archaeometry group in order to improve the Early Bronze Age chronology.

The archaeometry laboratory of the Heidelberg Academy of Sciences and Humanities has played a key role in the past in the procurement of prehistoric metals over more than three decades. It is hosted by the Max-Planck-Institut für Kernphysik in Heidelberg. The Academy gratefully acknowledges the support given to this laboratory by the Max Planck Society.

Another group, also supported by the Heidelberg Academy of Sciences and Humanities, is the radiometry laboratory of the University of Heidelberg, which investigated numerous samples from Troia and which also plays a leading role in the calibration of radioactive age scales.

The radiocarbon laboratory is involved in the dating of Troia and neighboring sites. Altogether 159 radiocarbon dates of Troia I to VIII and Kumtepe, ranging from the late sixth millenium to ca. 840 B.C., have been contributed. These data provide a firm base for the prehistoric chronology of the northeastern Aegean and for the settlement history of Troia.

Using the thorium/uranium disequilibrium method, the radiometry laboratory succeeded in dating individual calcite layers that grew on the walls of artificial water-supply tunnels underneath of the hill of Troia. The results indicate that the tunnels must have been built during the Early Bronze Age and were used also during the Late Bronze Age as well as during the "Homeric" and Roman periods.

I am pleased that this International Symposium will collate the present knowledge of this field of science and provide unambiguous data for the discussion on the development of ancient Troia.

I wish you a successful meeting.

Prof. Dr. Dr. h.c. mult. Gisbert Freiherr zu Putlitz
President of the Akademie der Wissenschaften, Heidelberg

Preface

When reconstructing the past as thoroughly as possible, the archaeologist needs to take into account all kinds of relevant information. This is of particular importance when dealing with prehistoric periods for which no written evidence is available. In such cases all findings, pits, ditches and architecture, pottery and other artefacts, human and animal bones, sediments, soils or even the whole landscape around a site need to be evaluated. In order to exploit such silent sources, the natural sciences play an indispensable role, since they reveal a wealth of information that remains hidden to the archaeologist's naked eye. Troia is a remarkable site in this respect as well. Already the first excavator, Heinrich Schliemann, invited scientists to join him, among them the renowned pathologist, Rudolf Virchow. The present Troia project, under its director Manfred Korfmann, integrated various disciplines of natural sciences into its program from the beginning in 1988. These include geoarchaeology, archaeobotany, zooarchaeology, anthropology, geophysical prospection as well as chemical and technological studies of metal, stone and pottery. There is hardly any other archaeological project that is supported so intensely and on such a broad scale by archaeometric investigations as the international research at Troia. This unusually broad co-operation turned out to be very fruitful and yielded a wealth of – otherwise irretrievable – insights of which most have already been published in the monograph series of *Studia Troica*.

Since these investigations require specialists from various fields with their own terminology and concepts, it often happens that their results do not become immediately clear to others to whom they may concern. This is, of course, not specific for Troia, but a general difficulty of interdisciplinary projects. One evening in summer 1999 – when watching the sunset over the Troian plain – we discussed this situation with Manfred Korfmann, and the idea to organize a symposium was born, with the aim of scientific interaction and synopsis of the various disciplines engaged in Troia.

With the substantial support of the *Heidelberger Akademie der Wissenschaften*, the International Symposium "*Lebensraum Troia zwischen*

Erdgeschichte und Kultur" was held from 2–5 April 2001 in Heidelberg. Together with the *Heidelberger Akademie der Wissenschaften*, the symposium was organized by the *Gesellschaft für Naturwissenschaftliche Archäologie – Archaeometrie* and the *Troia-Projekt der Eberhard-Karls-Universität Tübingen*. About 100 researchers and students attended the conference. At the end of the symposium it was agreed to publish the results jointly. The present volume, *Troia and the Troad – Scientific Approaches*, contains most of the contributions presented at the symposium.

The contents of the book is organized according to the main topics of the symposium, "Historical and Geological Context of the Troad" with eight contributions, "Mineral Deposits and Materials" with five, "Archaeobiology" with six, and "Landscape Change of the Troian Site and Plain" with five contributions. We are grateful to Professor Dr. Gisbert zu Putlitz, president of the *Heidelberger Akademie der Wissenschaften*, for the Foreword and Professor Dr. Manfred Korfmann, director of the *Troia-Projekt*, for the Introduction to this book.

As the contributions to this volume underwent a refereeing process, we would like to acknowledge the advice of the following colleagues: Prof. Dr. A. Aksu, St. John's, Prof. Dr. K. W. Alt, Mainz, Prof. Dr. H. Brückner, Marburg, Prof. Dr. H. Hauptmann, Heidelberg, Dr. P. Jablonka, Tübingen, Dr. H.G. Jansen, Tübingen, Prof. Dr. J. Latacz, Basel, Dr. W. Neubauer, Wien, Prof. Dr. Ryan, Palisades, and Prof. Dr. B. Schröder, Bochum.

The publication was generously supported by the *Heidelberger Akademie der Wissenschaften*, which is gratefully acknowledged. Springer-Verlag kindly accepted this book in its series *Natural Science in Archaeology*.

Heidelberg, Freiberg and Tübingen,
February 2002

Günther A. Wagner
Ernst Pernicka
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Chapter 1

Introduction – Troia and the Natural Sciences

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From its earliest beginnings archaeology has been preoccupied with Troia. The first excavation was conducted there in 1871. After a lapse of 50 years, excavation was resumed in 1988. The year 2001 represented the 14th excavation season of the current Troia Project; the 130th year after Schliemann began also marks the 30th excavation at Troia. That same year – 2001 – also saw the inauguration in Stuttgart of "Troia – Dream and Reality", an exhibition on a grand scale that moved on to Braunschweig and Bonn. It represents, among other things, a sort of interim report made to a broader public on what has been done to date. The exhibition has extended into 2002 and has been seen by about 850,000 visitors. The palpable interest shown by the public in the ancient world is also due to the circumstance that a myth is linked with Troia. Since almost all myths need a setting with which they are associated – in the present instance it has been, since antiquity, the old hill settlement which is now called the Mound of Hisarlık – archaeology is profiting from this, whether it will or not.

Viewed against the backdrop of this long tradition, Hisarlık is one of the places where "archaeology" began. It is also a place where pioneering experiments with new methods have been conducted. To call Hisarlık a conventional archaeological excavation site is, on the one hand, correct. One realizes this at the latest, after a week or two in the field, when one's initial enthusiasm at finally "being part of the Troia team" has given way to the normal everyday routine of excavation: a 12-h work day with the full complement of heat, dust, sweat and exhaustion, etc. During the 14 years of the most recent series of excavations, this has been an experience shared by more than 350 men and women scholars, scientists and technicians. What is at stake is the scientific investigation into aspects of human history at a site which was very important, geopolitically, for the space of several millennia. The thirteenth century B.C., much cited for the obvious reason that this was allegedly the time of the "Trojan War", has become only one aspect of a multifaceted complex.

On the other hand, this same point exposes the assumption that this is a conventional excavation site as fallacious because many scholars of antiquity (among them, unfortunately, scholars from related disciplines and, not least, quite a number of non-specialists in such fields) evidently believe they, too, are competent to say something about Troia and the work that goes on there or even feel a compulsion to do so. In addition, the range of possibilities and motives is broad. Emotions are part of the mix and, not least, prejudices and even articles of faith, which have always, as we well know, given rise to vehement strife.

For more than 100 years there have been numerous issues and events linked with the context of the scholarly and scientific Troia complex which, in retrospect, have proved to be mere episodes. In this context, I recall a soldier, now almost forgotten, one Captain Bötticher, who confronted Schliemann and Dörpfeld with the accusation that both really knew that what they were working on was not the site of an ancient settlement, but rather a large necropolis with cremation burials. That was the charge levelled by a "merchant of death" dealing in wars and casualties. It took two academic conferences on site in Troia to make it clear, even to those not immediately concerned, how peculiar those accusations were. About 10 years ago, a practitioner of a natural science, the geologist Eberhard Zangger, advanced the hypothesis that Troia was Atlantis. He reproached us with concentrating our efforts with pick-axe and trowel solely on the settlement mound, although we should have known better and should instead have deployed high-tech resources down below in the Scamander plain to search for evidence of the megalopolis ringed by vast canals in concentric circles and ports that, he claimed, was the hub of the known world in its heyday. That was a self-styled "specialist in landscape reconstruction", carried away by Plato's philosophical œuvre. Those working in Troia have, however, not altered their research strategy, particularly since the surrounding countryside here has been more thoroughly investigated than almost any other archaeological site in the world. In 2001 a specialist in ancient history, Frank Kolb, burst onto the academic scene with a claim which, compared with the Atlantis theory, represented an extreme stance: that Troia was not at all on a grand scale or even a city, but rather a place which was at best third-class; nor could there be any question of trade worthy of the name there. That was an "armchair specialist in devising such definition criteria" as those pertinent to "cities" and "trade" from the safe distance of his desk. What all these accusations addressed to those accountable in Troia have in common is that their advocates have come forward with theories couched not only in terms revealing scientific or scholarly training, in fact, literally dazzling with the erudition thus flaunted, but also barbed with imputations which one might view as *ad hominem* vilification. The public has become involved each time with all the lively interest one might expect.

It is common knowledge that the archaeologist's activities disclose the realities of the past. The stone foundation of a house or a domed kiln, a refuse pit or midden or, of course, a grave all represent facts, are snapshots of events and processes which once took place. The final state of a process or a monument is what is again brought to light. The next step is decoding the processes imaginable, the events which led up to each such finding. Via archaeology we are confronted with the greatest possible variety of examples, not only of exceptional, but also of entirely normal situations from life, i.e., with its legacies distributed across a broad range of social strata. Consequently, "knowledge of the ruling classes" (for instance) is not all that is thus imparted as is, in contrast, nearly always the case with early written sources. This presupposes, naturally, that the findings and finds have survived as "archives in the soil". A find from the soil is an historical source imparting a remarkable kind and degree of objectivity. Just as a pathologist dissects a body that was once alive in order to gain insights into the aetiology and pathology of human disease, so archaeologists investigate in the soil the events leading to an end state which can be verified there as a "finding".

Archaeology is usually concerned with the legacies left by human beings. Not everything achieved by human beings can be compressed into a predetermined pattern of inquiry or even defining criteria. This holds especially for the type of archaeology dealing with times in which there were virtually no written sources that might give us hints of lifestyle or prevailing emotions. When dealing with such periods, archaeology is primarily cultural anthropology, palaeoanthropology, as it were. Its co-ordinates are aligned with the basic constants of human existence. All those who work in this area contribute their individual experience, giving themselves, very much in the manner of a criminological investigation, enough scope for interpretation within the limits called for to verify any particular finding. Otherwise, one might only speak of "walls," "pots" and "skeletons", eschewing any attempt at interpreting such finds. Then we would know virtually nothing about, let us say, "the Neanderthals" or "the Neolithic makers of the Bandkeramik" ware notable for its ribbon-like curvilinear decoration.

It goes without saying that archaeologists are also historians, but they are historians who draw on other sources, i.e., their methodological approach is of necessity different to that employed by historians. As an archaeologist dealing with prehistory, I do not look at Hisarlık as an excavation site in isolation for its own sake alone. Instead, I study it from the angle of western Anatolia as well as, and more especially, from the perspective of the contemporaneous (!) cultures of south-eastern Europe and the Black Sea region. Viewed from these last perspectives, the importance of this place, which is so tremendously impressive because of its favourable geographical situation and its stone architecture, must be assessed entirely differently to the way it would be if viewed from the perspectives of central Anatolia or even Mesopotamia. So much for the geographical components. If one adds the chronological component, Troia cannot be compared with ancient Rome, medieval Tübingen or the modern megalopolis that is New York. On the contrary, Troia can only be properly understood within its own temporal context and its prehistoric – in the upper strata partly already historical – cultural environment.

Our work and methods should not be measured by the standards applying to other disciplines dealing with the ancient world which also have a voice in connection with Troia, such as the fields of philology, classical archaeology or ancient history. Each field has its own distinctive qualities and ways of viewing the material with which it is concerned. Our paramount concern is working by analogy before attempting to put a name to things rather than verifying precisely preset definition paradigms.

Understanding the other disciplines can be difficult and a lack of knowledge of them is prevalent. Nonetheless, one can piece knowledge together in so far as one may trust the competence of individual specialists who are respected as scholars and scientists in their own disciplines, no matter what these disciplines may be.[1] That is standard practice in both the arts and humanities and the sciences and this productive collaboration also contributes to the present volume. Respect must start among scholars dealing with the arts and humanities. Cultural legacies, i.e., pieces of evidence for history, merge fluidly to form an organic whole – with occasional disruptions. One might, to revert to the medical analogy, illustrate this in the following terms: a GP (general practitioner) does not normally interfere in the operating methods used by a surgeon, but instead admits that he would not be able to do so. The GP will rely on the accuracy of the report of an operation sent to him. I myself would never interfere in the issue of whether Homer is historical or not; nor would I in the question of equating Troia with Wilusa or Dardaniya. I can acknowledge the theories advanced by distinguished exponents of the two independent disciplines, Homeric scholarship and the branch of Near-Eastern studies focusing on ancient Anatolia, to the effect that our excavation site at Hisarlık – which the ancient Greeks and Romans, for that matter, equated with Troia/Ilios(n) – must

[1] Specialist disciplines in the arts and humanities which play an important role in Troia include the following: prehistoric archaeology, classical archaeology, Near-Eastern archaeology, Byzantine studies, ancient Anatolian studies (Hittitology), classical languages and literatures (Greek and Latin), Mycenology, history of architecture, ancient history, epigraphy, numismatics, etc.

have been an important place with the attendant characteristics of status as early as the thirteenth century B.C. and this would in fact indicate (W)Ilios(n) or Wilusa/Truisa. Confronted with this, on the basis of the archaeological findings, I can say with heartfelt conviction: why not!? Hisarlık was important at the time in question. At any rate, at the present state of our knowledge, I would not contradict this. Of course, on the basis of our work alone, one cannot say anything, either on the question of whether the *Iliad* has a historic core or on the Hittite vassal (city) state of Wilusa, which evidently took part as Dardaniya in the inconclusive Battle of Qadesh (1275 B.C.).

Because professionalism is at stake here, only trained archaeologists, not ancient historians, Hellenists, etc. may conduct excavations in most countries and this is for a good reason. It holds for Turkey as well. Archaeology attracts numerous know-alls who feel called upon to get in on the act. However, hardly any scholars of the humanities interfere in the natural sciences which are drawn on by archaeology as related disciplines. Admittedly, such scholars usually have no inkling of the natural sciences. However, findings made by the natural sciences are incorporated in those made in the humanities. The statements issuing from an archaeological excavation are pieced together from a great many findings from specialist research in a multiplicity of disciplines, including a wide range of physical and natural sciences, the latter represented by both the life sciences and the earth sciences. At the Heidelberg Symposium, the earth sciences predominated.[2]

The inclusion of the natural sciences in archaeology continues a truly interdisciplinary tradition, one inaugurated by Heinrich Schliemann, who, in this as in so many other respects, was far ahead of his time. It is well known that Schliemann consulted competent exponents of various specialist disciplines and he was always receptive to any knowledge which would promote the cause of archaeology.

As a result, the Troia excavation was exemplary even in its first three excavation seasons (1871–1873) and this was due entirely to Schliemann's initiative.[3] Metal finds were investigated to reveal alloys and potsherds to determine the physical properties of their clay body and their paint or glaze.

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[2] Specialist disciplines in the sciences which figure prominently in Troia include the following: the natural sciences (life sciences), director Professor Dr. Dr. H.-P. Uerpmann (Tübingen): palaeobotany, physical anthropology, genetics, etc. The physical sciences (earth sciences), director Professor Dr. E. Pernicka (Freiberg, Saxony), include: archaeometallurgy, geochemistry, geophysics, geography and palaeogeography, geodesy and surveying, hydrogeology, sedimentology, mineralogy, ecophysics, dendrochronology, meteorology, etc.

[3] See the Korfmann foreword in "Heinrich Schliemann, Bericht über die Ausgrabungen in Troja in den Jahren 1871–1873", Artemis Verlag Munich and Zurich, 1990 (new edition Dusseldorf and Zurich 2000).

Alongside organic and anorganic chemistry, both human and veterinary medicine were consulted so that both human and animal bones might be properly evaluated. Rudimentary "statistics" were involved. Even the weight of finds was occasionally recorded and not merely for the purpose of identification, but just as importantly, to further interpretation. Finds were restored not just for conservation reasons, but also to facilitate scientific and scholarly study. The thickness of the various settlement deposits was related to the periods of time they spanned and, finally, the inclusion of the landscape and the exploration and surveying of it played an important role. The science of excavation took a long time to attain the standards set by Schliemann.

The scholars and scientists currently working in and with Troia report yearly to the academic public in the annual *Studia Troica* and this is generally welcomed. We have the possibility of doing this thanks to, among other sources, funding from the University of Cincinnati and not least from James H. Ottaway in New York. After carefully weighing the alternatives of not publishing anything for years at a time or regularly informing the public on a provisional basis in "preliminary reports", we decided on the latter course; in the past important findings were all too often never published because, for various reasons, they were never written up. In opting for the preliminary-report procedure, one must, however, accept that changes may have to be made later. Historians conducting research based on other traditional and, therefore, often well studied (written) sources which cannot be added to may find the above procedure unusual. On the other hand, anyone, who has, let us say, worked for a governmental department of excavation is thoroughly familiar with this approach. Excavations can take decades and large-scale projects often outlive those who inaugurated them and worked on them in the early years. Each excavation season sees the accretion of fresh sources or may open up new perspectives as a consequence of collaboration with related disciplines. The vast amount of data available to it leaves archaeology as a discipline at a great advantage. A variety of academic fields are interested in the work that goes on in Troia and the progress it makes. In addition to the annual preliminary and other reports, material is also presented in association with congresses and symposia such as the one held in April 2001 in Heidelberg, where representatives of the natural sciences whose work deals with Troia convened. All in all, we will have to wait patiently for the "final reports" on work done at Troia until all data and facts have been studied, evaluated and published just as would be the case with any excavation, large or small-scale. The present publication also represents "preliminary reports" in this sense.

The number of disciplines related to the natural sciences participating nowadays in archaeology or with the potential of doing so is very large and is increasing yearly. Sometimes the range is so broad, yet the special issues focussed on within it are so narrow in scope that one runs the risk of losing sight of the wood for the trees. As archaeologists, therefore, we must keep reminding our colleagues from the natural and physical sciences that what we *are concerned with is humankind and our living space between geology and culture*! That is what motivates us to collaborate with the sciences. Moreover, we welcome the fact that individual representatives of the natural sciences may have particular and very legitimate interests connected with their own specific disciplines and actively support those interests. Incidentally, it should be noted that often the quite sophisticated and, therefore, costly analyses archaeology calls for would otherwise be prohibitively expensive. As everyone knows, copious funding does not tend to be available to the arts and humanities.

The occasion for the symposium held by the Heidelberg Academy of Sciences was the Troia Exhibition mounted at the same time in Stuttgart. The scope of that exhibition extended conceptually far beyond archaeology. Since the overarching theme was "a book and its consequences", the exhibition covered themes ranging from Homer to the present, with the excavations as well as the exhibition interpreted as forming part of the history of Homeric reception. Even the debate which raged in autumn 2001 between two clashing factions on the importance of Troia in the Late Bronze Age might still be grouped under that heading. What the natural sciences work out, however, can rarely be conveyed in visual terms at exhibitions. Understandably, finds have pride of place there although occasionally, models or reconstructions of how one might imagine the landscape to have looked at a particular time may also figure prominently at exhibitions. The symposium on "*Lebensraum Troia zwischen Erdgeschichte und Kultur*" might, therefore, be thought of as a sort of additional event, a bonus, so to speak.

Universities are home to many academic disciplines. There is hardly anyone who can claim to master all or even several of them equally. Nevertheless, specialists in the arts and humanities as well as scientists occasionally want to dabble on the side in work properly done by archaeologists. In my capacity as an archaeologist looking back on many years' practical experience in the field, I should like to recommend my fellow academics to think of themselves in their own professional fields within an interdisciplinary approach as symbolized by the device of Tübingen University, the "Attempto Palm":

The palm has many roots, some of which must penetrate deep into the soil to find nutrients. One root may be stronger, the other weaker yet the juices unite to rise up through the trunk to nourish the tree so that, in the crown of the tree, which is turned to the light, fresh fruits may be provided for anyone to pluck who dares rise to such lofty heights. It appears particularly meaningful to us as archaeologists working on the fringes of the Near East that this device, which has been known in Tübingen since the time of the founder of the university Graf Eberhard 525 years ago, should be a southern tree, a date-palm. Finally, one should remember that research can entail risky ventures. That has always been just as true of Troia: Attempto (which was and will be the motto of people connected with Tübingen University: "I dare it").

Certainly the Heidelberg Symposium, some of whose fruits are now in print, has contributed to making all of us, those of us who are specialists in the humanities and those who are scientists, aware of a *Universitas* as symbolized by our "Attempto Palm" in Tübingen.

CHAPTER 2

The Case for Historical Significance in Homer's Landmarks at Troia

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Abstract

Intensive deep-coring of the alluvial plain of the Menderes (ancient Scamander) River in the vicinity of Hisarlık (ancient Troia) has established the approximate position of the shoreline in the Late Bronze Age (ca. 1250 B.C.). At that date the Menderes flowed into a marine embayment that extended northwards to the Hellespont (Dardanelles) from, or near, the latitude of Troia. This palaeogeographic reconstruction has removed the basis for Schliemann's and Leaf's placing of the Greek Camp and Ship Station on the present coastline, and revived former speculation about the significance of the Beşik Bay anchorage to the south-west of Troia at the time of the Trojan War. The author reviews the topographical indications in Homer's Iliad, and concludes that they presuppose an east–west, rather than a north–south, axis for the fluctuating fighting that Homer pictures. He argues that this tends to support the historicity of Homer's 'military topography', and gives reasons, based on the Iliad, and Strabo's account of the Troad, for placing the Greek camp and ship station, not at Beşik Bay, but at a then existing salt lagoon (now known as the Lisgar swamp or Kesik plain) that formed a westward extension of the Troia embayment in the neighbourhood of ancient Sigeion.

In this Symposium where earth scientists are clearly in the majority, a representative of the humanities feels particularly honoured to have been asked to present the first paper. Nor do I make any apology for having given Homer such prominence in my title. Homeric poetry underpins our gathering since it is the Iliad that has made the name of Troia as famous as that of Athens or Rome. The 'tale of Troy divine' remains a potent cultural force in the modern world, new translations of Homer proliferate, and his epics probably now command a wider readership than in any previous age. Therefore, as we attempt to gain a better understanding of the Trojan environment through a judicious combination of "Erdgeschichte und Kultur", we should, I suggest, listen with particular care and sympathy to what Homeric poetry has to tell us about the landscape of the Troad and the environs of Troia itself.

In the year 1810 Lord Byron spent some weeks in the neighbourhood of Troia. The exact site of the city had not yet been identified, but he was im-pressed enough by Homer's scene-setting to claim that the Iliad embodied 'the truth of history and of place'. In this he was echoing the attitude of the ancient Greeks, for whom Homer was not merely the supreme poet, but also an important exponent of historical and geographical knowledge. Contemporary Homeric scholarship in Britain and the USA has made considerable advances in the understanding of Homer's poetic technique, but, in my opinion, it can be criticised for its comparative neglect of Homeric realien. An important recent publication (Morris and Powell 1997) with contributions from thirty scholars, devotes over 700 pages to various aspects of the subject without a single mention of the Troad, Mount Ida, or the Hellespont, and contains only one paragraph on Professor Korfmann's excavations at Troia. May I express the hope that our Symposium will prove to be a timely counterpoise to this unduly narrow trend.

My own first visit to Troia over 40 years ago left me with the indelible impression of a site of immense historical and geographical significance. Memories of Xerxes and Alexander, of the final stages of the Peloponnesian War, of the Gallipoli campaign, all came crowding in as I stood on the ancient walls, looked across from Asia to Europe, and reflected on the significance of the sea route from the Mediterranean to the Black Sea. Later came the stimulus of the new geomorphological understanding of the plain of Troia pioneered by a team of geologists, two of whom are present on this occasion. In their preliminary publication, Kraft et al. (1980 a) suggested that Homeric scholars might like to 'reconsider some of their interpretations' in the light of their new findings. This was a challenge to which I attempted to respond, first in a short article (Luce 1984), and more recently, in a volume on Homer's landscapes (Luce 1998), which also takes into account the great advances in our understanding of the extent and fortification system of Troia itself as revealed by the Troia Projekt. Professor Korfmann, the Director of the Project, holds the view that Homer's picture of Troia is 'surprisingly like' the major Bronze Age city that excavation has revealed at Hisarlık. He has strongly stated that "none of the [sceptical] counter-arguments of archaeology retain any countervailing force" (Korfmann 1997). I believe that Homer towards the end of the eighth century B.C. did visit the Troad and the site of Troia (Luce 1998), but I do not think that after the lapse of some 500 years he could have derived such a detailed and accurate picture of the ancient city by personal observation alone. What he saw must, I suggest, have been consolidated and amplified for him by the oral tradition on which his art as a rhapsode depended. Professor Latacz has recently presented a powerful argument for the preservative power of hexametric formulae (Latacz 2001). In the mouths of skilled bards these formulae could transmit information unchanged for hundreds of years. This, as I have argued elsewhere, was the principal source of Homer's knowledge of the layout and architectural characteristics of Bronze Age Troia (Luce 1998). And if 'truth of place', may we not risk following Byron and add 'truth of history' too?

It was the unanimous view of the ancient world that the Trojan War was an historical event, and in the light of our modern understanding of Late Bronze Age civilisation in Greece and Asia Minor, one can say that there is nothing inherently improbable about an Achaean expedition sailing to besiege Troia. This is the basis on which I venture to direct your attention to what I make bold to call the military topography of the Iliad.

My aim is to emphasise certain critical details of the course of the fighting as described by Homer with a view to showing that the topographical picture that emerges from the Iliad makes good military sense, and is consistent with what we know about the nature of the terrain in the Late Bronze Age, and with the archaeological knowledge of Troia itself gained in the course of the current and previous excavations.

A too superficial examination of the alluvial plain of Troy led Schliemann to believe that there had been no change in the position of the shoreline since the traditional date of the Trojan War some 3000 years before his day. Therefore, when he read in the Iliad that after their attacks on the city the Greek returned 'to the ships and the Hellespont', he naturally assumed that their camp and ship station lay north of Hisarlık along the extensive sandy shore that now fronts the Dardanelles. This view was accepted and reinforced by Walter Leaf in his classic topographical study of Troy and the Troad (Leaf 1912), and in his monumental edition of the Iliad. The topographical ideas of Alfred Brückner, which were tested without a positive result by Dörpfeld's and Mey's excavations at Beşik Bay in October 1924, failed to dislodge the Schliemann-Leaf view, which continued to dominate Homeric topography well into the 1970s of the last century. J.M. Cook was almost a lone voice, in the English-speaking world at least, in his robust statement that "for an army with a thousand ships the north end of the Trojan plain on the narrows is an impossible camping site, and must surely have been so three thousand years ago" (Cook 1973).

A major difficulty for the Leaf–Schliemann view lay in Homer's references to a ford over the river Scamander crossed by armies on the retreat, and also used by Priam when he drove his mule cart to and from the Greek camp to ransom and recover Hector's corpse. Given that the main channel of the river anciently followed much the same course as it does today, it is clear that the Scamander (now called the Menderes) would not have obstructed passage to a Greek camp lying north of Troy on the shore of the Hellespont (Dardanelles). Furthermore, the evidence of deep-coring on the plain since 1977 has shown beyond any doubt that the camp site postulated on the Leaf-Schliemann view did not exist at the time of the Trojan

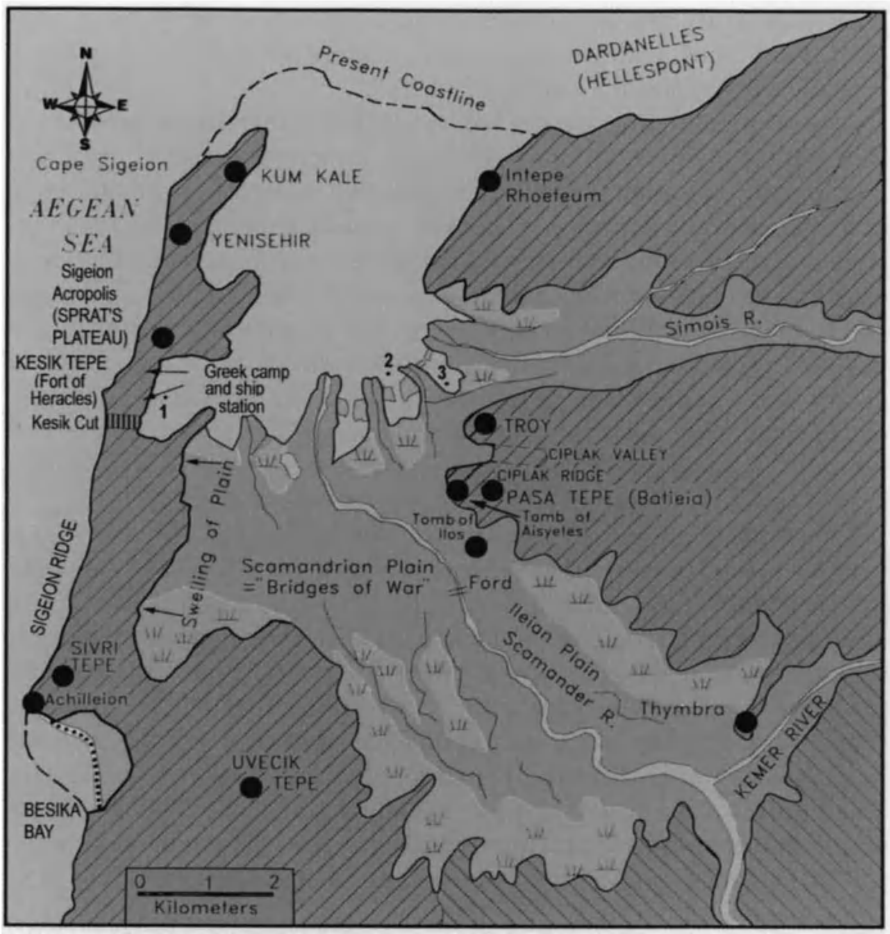

Fig. 1. The environs of Troia, with the shoreline of 'Troia Bay' and the Scamander–Simoeis delta reconstructed from the data of deep coring in the alluvium. (After J.C. Kraft)

War (see Fig. 1), and so a believer in the historicity of the war must look elsewhere for a Greek encampment. The only realistic possibilities are either at some location along the east facing flank of the Sigeion Ridge, or at Beşik Bay. One must then accept that the axis of the fighting did not run (as Schliemann and Leaf supposed) on a north–south line, but rather on an east–west one.

How does this affect the interpretation of the Homeric topography? My answer is that the Homeric picture appears to become significantly more intelligible in relation to all the landmarks mentioned by Homer, and this result, if granted, must tend to enhance the historicity of his tradition.

Let us consider first the location of the tomb of Myrinē, and the tomb of Aisyetes, which Homer mentions to lend precision to his account of the defensive position taken up by the Trojan army in response to the first offensive mustering of the Achaeans as described in Iliad, book 2. These two landmarks are named in the bridge passage that links the Greek Catalogue to the Trojan Catalogue. A strong case can be made for the historical antiquity of both Catalogues (Latacz 2001), so it will not be surprising to find an old topographical tradition embedded in this setting.

The scene-setting of the Trojan muster is elaborate as befits the importance of the occasion, and opens with an ancient and stately formula much favoured by Homer in descriptions of landscape (2, 811–15):

Ἔστι δέ τις προπάροιθε πόλιος αἰπεῖα κολώνη,
ἐν πεδίῳ ἀπάνευθε, περίδρομος ἔνθα καὶ ἔνθα,
τὴν ἤτοι ἄνδρες Βατίειαν κικλήσκουσιν,
ἀθάνατοι δέ τε σῆμα πολυσκάρθμοιο Μυρίνης.
ἔνθα τότε Τρῶές τε διέκριθεν ἠδ' ἐπίκουροι.

There is a steep-sided hill in front of the city,
apart in the plain, with open ground on this side and that,
which men call Batieia,
but the immortals know it as the tomb of leaping Myrinē;
here then the Trojans and their allies were mustered in their ranks.

The first line finds a close parallel in 11,711:

Ἔστι δέ τις Θρυόεσσα πόλις αἰπεῖα κολώνη ...

There is a city named Thryoessa, a steep-sided hill...

In view of this parallel, it seems that the 'steep-sided hill' of the earlier passage could refer to the whole area, and not just to the conical tumulus, anciently known as the tomb of Myrinē, which surmounts it. Batieia, which I take to be an alternative designation of the whole area, is derived from βατός (=bramble), and so signifies something like Bramble Hill, just as Thryoessa is derived from θρύον (= rush). These rushes will have occupied low ground below the city on its steep hill (Hainsworth, ad loc, in Kirk 1985, vol. 3, p. 302). In the same way we need not look for brambles all over the muster site that I am proposing, but dense patches of thorny scrub are still a distinctive feature of the vegetation that clothes the area round the tumulus.

Where then was Bramble Hill? Only one area in the vicinity of Troia answers well to all the points in Homer's description. This is the western

Fig. 2. View from the Unterstadt of Troia south-west across the Çıplak brook to New Kalafat on the Çıplak Ridge, with Uveçik Tepe on the horizon

portion of the Çıplak Ridge, a minor elevation some 500 m to the south of Hisarlık, which is now occupied by the modern village of Kalafat (Fig. 2). On the spine of the ridge not far to the east of the village stands a large tumulus now known as Paşa Tepe. This tumulus (Fig. 3) was excavated by Sophie Schliemann in 1873, and again by Schliemann himself in 1890. As J.M. Cook noted (Cook 1973: 133), sherds from this latter excavation were certainly housed in the Schliemann collection in Berlin in 1902 when Winnefield (Troia und Ilion 545) reported that they all showed a close relationship with Troy VI–VII. This report gives us good grounds for dating the tumulus to the Late Bronze Age.

Unfortunately, however, a problem arises from the fact that W. Lamb, whose comprehensive survey of the Schliemann sherds appeared in 1932 (Praehistoriche Zeitschrift xxiii, pp. 111–131), could not find the Paşa Tepe group noted by Winnefield. Lamb, however, was able to inspect a quantity of Late Bronze Age grey ware of Troy VI–VII date labelled as from the 'Tumulus of Priam'. This particular name had once been attached to one of three mounds on the hill of Ballı Dağ; when that location was believed to be the site of Troy. Schliemann had dug there when he first came to the Troad, and considered that the pottery he found in the mound dated from his later 'Aeolic phase'. The name 'Tumulus of Priam' was of course a complete misnomer. The structure that Schliemann excavated was probably not a tomb at all, and it certainly had no connection with Troia or the Late Bronze Age. Cook, therefore, plausibly surmised that "the answer may therefore be that

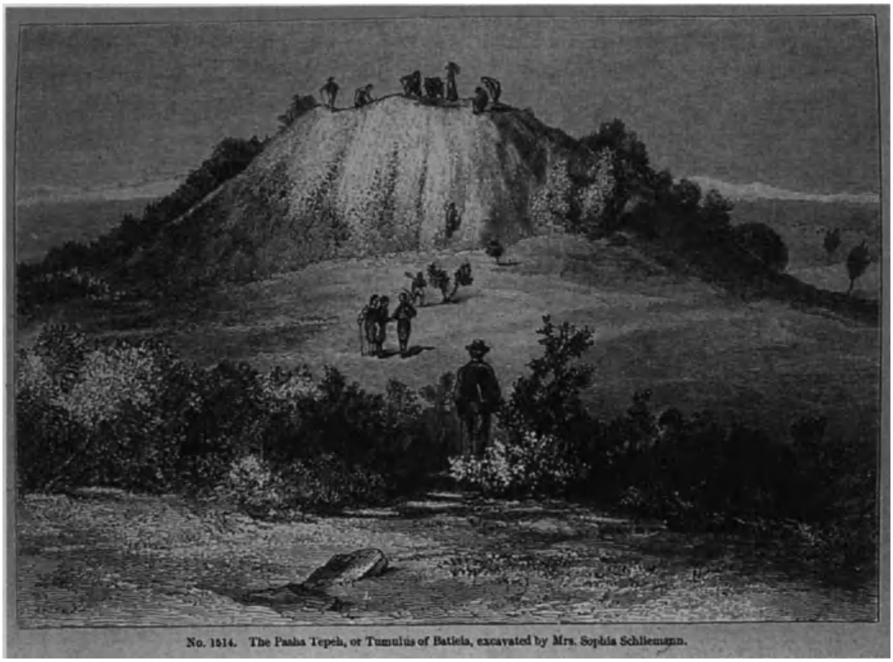

Fig. 3. Paşa Tepe under excavation by Sophie Schliemann. (After Schliemann, Ilios, Fig. 1514)

an error had occurred in the labelling [my italics] before Lamb's visit to Berlin, and that her 'Tomb of Priam' sherds are the missing ones from Paşa Tepe" (Cook 1973).

This surmise of Cook is important because if it is correct, we have in Paşa Tepe the only tumulus in the wider neighbourhood of Troia that dates from the heyday of the city. Excavation has shown that the tumuli at Yenişehir towards the northern end of the Sigeion Ridge date from the sixth to fifth centuries B.C. (Cook 1973). Kesik Tepe midway on the ridge is a natural outcrop. Sivri Tepe near Beşika Bay has been shown by excavation to be a Hellenistic structure though it may encapsulate an older monument. The tumulus of In Tepe on the Rhoeteum promontory is of Hadrianic date, and the great mound of Uveçik Tepe, so prominent on the horizon when one looks south-west from Hisarlık (Fig. 4), was erected by the Roman emperor Caracalla in honour of his favourite Festus.

Cook's suggestion about the 'missing' sherds needs to be emphasised because of G.S. Kirk's note on 2, 813–14 (Kirk 1985, vol. 1, p. 247) in which he states that "Cook (108) is cautiously more inclined to an archaic date for the mound and its burial." This I believe to be a misinterpretation of Cook's

Fig. 4. The mound in the foreground marks the western end of the Çıplak Ridge – a possible location for the look-out post of Polites on the 'tomb of Aisyetes'. The dirt road in the flood plain beyond the mound indicates the probable line of the Roman road from Troia to Alexandria Troas. The road runs down to the Scamander ford, the line of the river being marked by the trees in the middle distance. Above the road, Uveçik Tepe is visible on the horizon

analysis. If one follows through from this earlier passage to Cook's resumed discussion of the problem (133f) one must surely conclude that the reverse is true, and that Cook in fact comes down in favour of the prehistoric date.

On the assumption, then, that Paşa Tepe antedates the Trojan War, its equation with Homer's Tomb of Myrinē, alias Batieia, gains greatly in plausibility and significance. There are three other cases in the Iliad where Homer gives alternative 'divine' and 'human' names, the best known being the doublet Scamander/Xanthos. Kirk (1985,- vol. 1, p. 94) in an overview of these passages concludes that none of the linguistic explanations proposed, such as Greek/non-Greek, covers all cases. The Homeric scholia on our passage record the view that Batieia was the common name, while Homer, they think, was airing his antiquarian knowledge in mentioning Myrinē. They also state that the name Myrinē, like Smyrna, was of Amazonian (and so possibly Hittite?) origin, a tradition entirely consistent with a prehistoric date for the monument. In this connection it is of interest to note that Myrina occurs as a place name in Lemnos, and also on the coast

Fig. 5. The south-west flank of the Çıplak Ridge rising steeply from the 'open ground' of the flood plain. Paşa Tepe lies behind the houses on the *left*

of S Aeolis 10 km north of Kyme. This latter place, reputedly founded by Myrrhinē, conquering Queen of the Amazons, became an important city in the Aeolian League, and must have been known to Homer. Tradition placed a 'harbour of the Achaeans' in a lagoon 5 km north of it.

The Çıplak Ridge rises quite steeply from the flood plain on its southern flank, and that plain surrounds it on three sides, a point indicated, I suggest, by Homer's phrase περίδρομος ἔνθα καὶ ἔνθα (Fig. 5). Its general location is also given accurately enough in the phrase "outside the town and some way off in the plain". We now know that the fortified and gated perimeter of Troia's Lower Town lay close to the northern flank of the small valley traversed by the Çıplak brook. Therefore, when Hector gave the order for the advance 'all the gates of the city' would have been opened as Homer says (2, 809), and the troops would have streamed across the few hundred metres of level ground that separated them from the muster point on the Çıplak Ridge. Here, their massed ranks facing out from the ridgeline would have been appropriately drawn up to face an enemy army approaching Troia, as they must have done, across the main flood plain from the south-west.

Notice of the Greek advance had been given to the assembled Trojans by the messenger goddess Iris in the guise of Priam's son Polites who, as Homer tells us (2, 792–4):

> used to sit as sentinel for the Trojans, trusting in his swiftness of foot, on the top of the tomb of old Aisyetes, on the watch for an Achaean advance from the ships.

Precise data for the location of the tomb of Aisyetes are found in Strabo (13, 1, 37):

> The tomb now pointed out as that of Aisyetes is 5 stades (= 1 km) distant from the city *on the road to Alexandria* [my italics].

It is a reasonable presumption that the Roman road from Lampsacus to Alexandria Troas (as indicated in N.G.L. Hammond, Atlas of the Greek and Roman World in Antiquity, Noyes Press, New Jersey, 1980, map 26a) passed down from New Ilion into the Çıplak valley, and then skirted the Çıplak Ridge, whose western end is indeed about 1 km south of the city boundary. The road will have gone on to cross the Scamander in the vicinity of the present-day ford, where formerly a Roman bridge may have stood (Luce 1998). No ancient monument is now to be seen in the area, but as one stands on the last projecting spur of the Çıplak Ridge one commands a splendid view over the plain towards Beşik Bay and the Sigeion Ridge (Fig. 4). Here, or hereabouts, would have been an excellent post for a Trojan sentinel on the watch for a Greek advance, and from there he could have sprinted quickly back to the city to raise the alarm if an attack appeared imminent. Once again, we see that the location is strategically and tactically appropriate for an east-west axis of the fighting.

A 'tomb of Aesyetes' in the 'Scamandrian plain' was one of the Homeric sites shown to visitors in the Hellenistic period (Strabo 13, 1, 34), so it must be preferable to look for traces of something corresponding to it in the area rather than to follow Kirk's suggestion that it, like 'the hill called Batieia', may have been 'created as required' by Homer's imagination (Kirk 1985, vol. 1, p. 245).

The remains of the now deserted village of Old Kalafat lie in the flood plain about 1 km due west of the end of the Çıplak Ridge. C.T. Newton, travelling on behalf of the British Museum, visited the place in 1853, and observed "a small mound, the top of which forms a level area; its north side is a steep bank running down to the plain below. Here fragments of black Hellenic pottery are found" (Travels and Discoveries in the Levant, London 1865, vol. 1, p. 125). Cook (1973) was unable to locate such a mound amid "the hummocks which have grown over the ruins of the old village", but notes that "it seems likely to have lain close to the road leading from Ilion to Alexandria Troas...and should therefore come into consideration as a candidate for Strabo's 'Tomb of Aisyetes'". Further search in the area seems desirable, but even if the mound is rediscovered it will not suit the measurement of 5 stades distant from the city given by Strabo, since Old Kalafat lies about double that distance from the southern boundary of Hellenistic Ilion, and well to the west of the conjectured line of the road to Alexandria Troas.

Charles Maclaren shows a tumulus in the location I favour at the extreme western end of the Çıplak Ridge (Fig. 4), and suggests it may have marked the grave of Hector [Dissertation on the Topography of the Plain of Troy, 1822, map 1 (letter S), and p. 251]. It is also worthy of remark that Professor Forchammer, who accompanied T.A.B. Spratt on the British Admiralty survey of the Trojan plain in August 1839, saw 'a low flat tumulus' in the 'small valley [that] separates the site of Ilium recens from the ridge of the Pasha-Tepe' ['Observations on the Topography of Troy', Journal of the Royal Geographical Society xii (1842), 40]. Neither of these monuments is now to be seen, but either would seem a stronger candidate for the tomb of Aisyetes than Newton's mound.

The problem of The Tomb of Ilos is next to be considered. This tomb is mentioned four times in the Iliad, and forms a significant signpost to the course of the fighting. Homer pictures it as lying close to the Scamander ford, but on the right, or Troia, side of the river (24, 349–51). Therefore, it is in the part of the plain which Homer elsewhere calls 'Ileian' (21, 558). In an earlier passage (10, 414–16), Hector is said to have set up his command post there well in the rear of his forces who were already encamped to the west of the river and menacing the Ship Station. This datum forms part of the information revealed under duress by the captured Trojan spy Dolon. In the course of further interrogation, Dolon proceeds to reveal the general disposition of the Trojan allies, with five contingents 'on the seaward side' of the line, and four more 'on the Thymbra side' (10, 428–431). Strabo (13, 1, 35) knows of a 'shrine of Apollo of Thymbra' standing near the junction of 'the Thymbrian river' with the Scamander, but the precise location of a city of Thymbra remains problematic (Cook 1973:118–123). However, Strabo's 'Thymbrian river' has to be the river now known as the Kemer, an important tributary which flows into the Scamander some 8 km to the south-east of Troia (Fig. 1). Hence, at least a Thymbrian locality is identifiable, and this enables us to give a plausible geographical interpretation of Homer's picture of the Trojan battle front as strung out along a north-westerly line between there and the sea. This picture is very much of a piece with my proposed muster point on the Çıplak Ridge, and is also of course consistent with an east-west axis for the fighting, as Hainsworth sees (ad loc in Kirk 1985, vol. 3, p. 195).

When Hector's advance was repulsed by Agamemnon, the routed Trojans retreated past the tomb (11, 166–68), but then the fighting again swung back after the wounding of Agamemnon, and Paris is pictured using the stele on its top to steady his aim as he shoots at Diomedes (11, 369 ff.). Therefore, the Tomb of Ilos, the royal grandfather of Priam (20, 236–37), is appropriately used by Homer as a central landmark in the fluctuating fortunes of the fighting in his Ileian plain. It is surely a reasonable assumption that such a tomb was known to the early Aeolic colonists in the area, and probably before that to the Achaean host, and that it became part of the Homeric tradition, together with Paşa Tepe and the Aisyetes monument, as a significant and man-made feature of the landscape.

In 1801, E.D. Clarke discovered and described a small tumulus in the area of the plain indicated by Homer's references (Travels in Various Countries of Europe, Asia, Africa, 4th edn., London 1817, Part II, Section 1, pp. 121–123). After investigating the large tumulus now known as Paşa Tepe, he and his party 'rode along the top of the Mound of the Plain (i.e. the Çıplak Ridge) in a south-western direction towards Callifat' (i.e. Old Kalafat: the modern village of Kalafat was not built until 1928) "On descending into the plain", his account continues, "our guides brought us…to notice a tumulus, less considerable than the last described, about three hundred paces from the Mound, almost concealed from observation by being continually overflowed, upon whose top two small oak trees were then growing." He suggests a possible identification with the 'sepulchre of Myrrina'.

Clarke's 'Petit Tumulus' appears on the Plan d'Ilium Recens et de ses Environs published in Count Choiseul Gouffier's Voyage pittoresque de la Grèce (Paris 1822, vol. 2, 381 = Planche 35). It is mapped in the plain some 350 m south of Çıplak Ridge, and is located very close to the right bank of the flood channel (= Choiseul Gouffier's Kimar) that originates in a marsh near Thymbra and becomes the modern Kalıfatlı Asmak.

W. Gell (The Topography of Troy and its Vicinity, 1804, p. 56 and plate XIV) also describes and maps what seems to be the same tumulus. His location agrees with that given in Choiseul Gouffier, and he adds the point that it is 'connected with a rising ground of easy ascent, and is insulated with regard to other eminences in the vicinity. He confidently identified it with the 'monument of Myrinne'.

I have used the data provided by the above references to locate the now missing monument as the 'Tomb of Ilos' on my Fig. 1. The unfortunate proximity of the flood channel, which may not have run so close to the monument in ancient times, accounts for Clarke's 'continually overflowed', and probably also for the subsequent disappearance of the tumulus. It had certainly disappeared by the time of Forchammer's survey in 1839, for he states categorically that no artificial tumuli stood in the main flood plain (art. cit., p. 36).

Clarke's description of two small oak trees growing on top of his tumulus has an intriguing resonance with a statement in Pliny (N.H. bk.16, Chap. 88) that "oaks are said to have been sown on the tumulus of Ilos near the city when it began to be called Ilium." Clarke could not see his new tumulus as the 'tomb of Ilos' because he had already cast Paşa Tepe in that role. However, I in no way press the point in favour of my own identification, which rests solely on Homer's indications. Valonia oaks grow freely in the vicinity of Troy, and their presence on Clarke's tumulus is most likely to have been coincidental. It may, however, be worth pointing out that there is evidence that local speculation had begun as early as 1742 in relation to the Simoeis/Dümbrek equation (Cook 1973: 66, n.1). Cook suggests that "literate Greeks of the neighbourhood" may have been responsible for this interest in Homeric topography. Therefore, it is not perhaps out of the question that there may have been a well informed antiquarian in Old Kalafat, a Greek village, who amused himself with some nostalgic Ilian tree-planting on a nearby tumulus! Gell records that the inhabitants of Old Kalafat believed that 'the city of Priam once decorated the spot now occupied by their huts' (Gell 1804, p. 57).

Kesik (Demetrios) Tepe is a prominent conical mound on the Sigeion Ridge mid-way between Kum Kale and Beşik Bay (Fig. 6). Its size, shape, and position, especially when viewed from a distance, encourage belief

Fig 6. Kesik Tepe on the gently rising eastern flank of the Sigeion Ridge

that it is a man-made tumulus, and most of the earlier travellers identified it as the tomb of Antilochus. It is, however, a natural feature, being a limestone outcrop or butte, which means that we can be sure it was an equally prominent landmark in antiquity. Professor Kayan has described it as a 'natural hill which has been shaped artificially by man' (Kayan 1995: 228). It commands excellent views of the whole extent of the outer beaches along the Sigeion Ridge, and also of the Trojan plain. Choiseul Gouffier took it to be Homer's ' mounded and lofty fort of godlike Herakles' (20, 145 ff.), and I believe this identification to be correct. The mythology of Herakles, Hesione, and the sea-monster is associated with the area, and, as Homer says: 'The Troians and Pallas Athena had fashioned it for him as a refuge from the monster whenever it should chase him back from the beach towards the plain.'

I have argued in detail elsewhere that 20, 144–52 forms a topographical doublet with 20, 47–53, and that the 'resounding headlands' (ἀκτάων ἐριδούπων) of line 50 should be identified with the line of cliffs that front the Aegean on the western side of the Sigeion Ridge (Luce 1998). In the course of the argument, I also pointed out that the Fort of Herakles (= Kesik Tepe) and the hill Kallikolonē (= Kara Tepe, some 8 km due east of Troia) are 'antithetical viewing points' in the sense that a line drawn from one to the other passes through Hisarlık. This line also passes through the slopes surrounding the now drained Lisgar swamp (Fig. 1), which I envisage as a salt lagoon opening off the main Troia embayment, and capable of providing a sheltered anchorage for shipping in the Late Bronze Age.

The work of Kayan (1995) seemed to indicate that the Lisgar swamp, which he calls the 'Kesik plain', ceased to be a harbour ca. 2000 B.C. However, a radiocarbon date from one of his bore-holes in the area indicates the presence of marine organisms there in the fourteenth century B.C., and J.C. Kraft (this Vol.) agrees that this datum is significant. Kraft's typology of 'sheltered embayments' where the advance of the deltaic alluvium is markedly irregular, allows, I think, for the area to have been open to shipping at the time of the Trojan War (ca. 1250 – 1200 B.C.)

It is worthy of note that Strabo in his introductory remarks about the coastline from Rhoiteum to Sigeion writes as follows (13, 1, 31):

ὅ τε Σιμόεις καί ὁ Σκάμανδρος ἐν τῷ πεδίῳ πολλὴν καταφέροντες ἰλὺν προσχοῦσι πὴν παραλίαν καί τυφλὸν στόμα τε καὶ λιμνοθαλάττας καὶ ἕλη ποιοῦσι.

"The rivers Simoeis and Scamander in the plain bring down large quantities of silt, advance the coastline, and create a blind mouth, salt lagoons, and marshes."

This account of the alluviation of the plain seems to provide strong confirmation for Kraft's understanding of the alluvial process in the ancient Bay of Troia.

The data that Strabo gives for the location of the coastline in his day (ca. 2000 years ago) are also of great interest, and the passage deserves to be quoted in full (13, 1, 36):

ἔστι γὰρ τὸ ναύσταθμον πρὸς Σιγείῳ, πλησίον δὲ καὶ ὁ Σκάμανδρος ἐκδίδωσι διέχων τοῦ Ἰλίου σταδίους εἴκοσιν. εἰ δὲ φήσει τις τὸν νῦν λεγόμενον Ἀχαιῶν λιμένα εἶναι τὸ ναύσταθμον, ἐγγυτέρω τινὰ λέξει τόπον ὅσον δώδεκα σταδίους διεστῶτα τῆς πόλεως, (τὸ πρὸ τῆς πόλεως) ἐπὶ θαλάττῃ πεδίον συμπροστιθεὶς, διότι τοῦτο πᾶν πρόχωμα τῶν ποταμῶν ἐστιν ὥστ' εἰ δωδεκαστάδιον ἐστι νῦν τὸ μεταξύ, τότε καὶ τῷ ἡμίσει ἔλαττον ὑπῆρχε.

"For the ship station is at Sigeion, and the Scamander flows out nearby at a distance of 20 stades (= 4 km) from Ilios; but if someone maintains that the so-called Harbour of the Achaeans is the ship station, he will be speaking of a place that is too close [to the city], being about 12 stades (= 2.4 km) distant from the city, when one reckons in the plain extending from the city towards the sea, because this consists entirely of river-borne alluvium; so that if the distance is now 12 stades, then [i.e. at the time of the Troian War] it would have been half that."

To understand the drift of Strabo's argument here, one must bear in mind that the local authorities he was using, namely Demetrios of Scepsis and Hestiaea of Alexandria (both mentioned by name at 13, 1, 36), did not accept New Ilion's generally accepted claim to be on the same location as Homeric Troia, nor the received view there that the Greek ship station was beside the Achaeans' Harbour. In a laudable wish to render the strategy of the Trojan War more intelligible, they proposed a location for ancient Troia well back from the alluvial plain and the Hellespont at a place called the 'village of the Ilians', 30 stades (= 6 km) to the east of Hisarlık (13, 1, 35). Demetrios' involvement in the argument seems to have been partly motivated by local animosity between his ancient native city Scepsis and 'upstart' New Ilion. Its conclusion need not be taken seriously because of the absence of any Bronze Age remains at the so-called village of the Ilians. In the light of modern knowledge about Bronze Age Troia it has clearly become an untenable hypothesis. However, such considerations should not lead to neglect of the valuable data about the Scamander mouth and the progressive alluviation of the plain that Strabo has here preserved.

Two place names frame Strabo's discussion: Sigeion and the Harbour of the Achaeans.

Sigeion, as Strabo later notes (13, 1, 39), had been 'razed to the ground' by New Ilion, possibly in the mid-third century B.C., and its site has not been precisely identified. Since the early travellers it has generally been looked for in the area known as 'Spratt's plateau' (Fig. 1), but Cook (1973) argues strongly for placing it further north at Yenişehir. However, the figure of 20 stades that Strabo gives for the distance from Troia to the mouth of the Scamander, when combined with his remark that the river flowed out 'near Sigeion', seems to me to tell in favour of the 'Spratt's plateau' location for at least the southern outpost of the city. Cook (1973) indeed allows that Spratt's plateau could have been 'some sort of proasteion of Sigeum'. This area, where Spratt saw 100 ft. of substantial walling still in position, is the natural acropolis of the Sigeion Ridge. It, rather than the lower ground further north on the ridge, would have provided the strong defensive position that the Athenian colonists of Sigeion needed in their long struggle with the people of Mytilene, who were operating from their forward base at Achilleion, now definitely identified with Beşik Burnu at the south end of the ridge. Herodotus (5, 65) calls Sigeion 'the city on the Scamander', and also informs us (5, 94–95) that the Athenians claimed territorial rights in the area because of their participation in the Achaean siege of Troia, a claim nicely consistent with Strabo's firm statement that the Achaean ship station was 'at Sigeion'.

The 'so-called Harbour of the Achaeans' known to Strabo was in my opinion located north of Troia on the In Tepe Asmak near the south-western tip of the Rhoetean promontory. Korfmann states that excavation in the alluvial plain of the Simoeis north of Hisarlık would probably reveal "a small Greek or Roman harbour, possibly at a depth of 3–6 m" (Some observations on equating Troia with the Atlantis Myth, Festschrift für Ufuk Esin, Istanbul [in press]). This conjecture is supported by a find made by a local farmer in 1989. While digging an irrigation ditch for his fields, the farmer found "a pithos ... next to an ancient concrete wall at a depth of 3.5 m below the surface of the plain approx. 1.8 km north of Troia in the direction of Kumkale" (i.e. Yenikumkale). This find is obviously not datable with any precision, but 1.8 km north of Troia is in the range of Strabo's figure of 12 stades for the so-called Harbour of the Achaeans in his day.

Its Strabonian designation as the 'so-called harbour' must be viewed against the background of the controversy about the site of ancient Troia outlined above. Strabo's sources were arguing against a current identification of the harbour as the landing place of the Achaeans, and also as the site of their permanent camp and ship station. Such an identification, we may presume, was, in part at least, a product of the 'tourist trade' at New Ilion.

Simoeis, Scamander, the battlefield on the plain, and the Greek ship station could all be conveniently pointed out to visitors from the city walls. The Ilians doubtless also reminded their guests how their great patron Alexander had crossed the Hellespont from Elaeon on the European shore, landed at the harbour where tradition claimed his Achaean ancestor Achilles had landed, and crossed the short extent of plain to go up to 'steep Ilios', and make propitiatory sacrifice to Athena and the ghost of Priam (Arrian, Anabasis Alexandri I, 11, 6 – 8).

The counter arguments of Demetrios and Hestiaea turned on their appreciation of the alluviation process and their estimate that the coastline and therefore the harbour and the supposed ship station there would have been only 6 stades (= 1.2 km) from ancient Troia in the Late Bronze Age – too close to make military sense. They also pointed out that the Ilians' view conflicted with significant Homeric indications that the Greek camp was 'well away' from the city, and in particular that it made nonsense of Polites' look-out point 5 stades (= 1 km) south of the city (13, 1, 36–37).

The Homeric formula that brings the Achaeans back from Troia 'to the ships and the Hellespont" points strongly to a location somewhere on the shores of the Troia embayment, since Homeric usage, as I have elsewhere argued (Luce 1998; cf. also Kirk 1985, vol. 2, p. 48, n. 26), precludes us from attaching the designation 'Hellespont' to the portion of the Aegean off Beşik Bay. As we now know, a broad arm of the Hellespont lay between Troia and the Sigeion Ridge, and we should, I suggest, envisage the ship station around the Lisgar swamp (Kesik plain) on the east-facing slopes of that ridge. In such a position the station would agree with the Homeric indications that it was on rising ground and that it looked directly on to the main battlefield down on the Trojan plain. These indications do not suit Beşik Bay, which in any case would not have been easy to secure against an enveloping Trojan chariot offensive from the south-east. By contrast, the Lisgar swamp site would have been much easier to defend, needing only a short wall and ditch thrown across the broken ground to its south (Luce 1998).

In keeping with his usual narrative procedures, Homer gives his most detailed picture of the ship station at the moment when it is coming under serious threat from the Trojan offensive spearheaded by Hector (14, 30 – 36):

The ships had been beached on the shore of the surging sea well away from the fighting. They dragged the first ones inland and built a wall at their sterns. For the beach, though broad, could not contain all the ships, and the fighting men were cramped for space. So they ranged the ships in rows, and filled all the long mouth of the shore between the enclosing headlands.

It is known that the great Homeric scholar Aristarchus wrote a monograph entitled 'On the Ship Station'. This work is no longer extant, but we learn from the ancient scholia on this passage that he compared the rows of ships to 'seats in a theatre' and 'rungs of a ladder' – a clear indication that in his opinion the ship station was on rising ground.

I also think it possible that Aristarchus associated his location for the camp with a feature that by Strabo's time had apparently been given special status in the Homeric traveller's list of places to be seen. This is the 'Salt Lagoon' (στομαλίμνη) listed with the 'Ship Station, the Achaeans' Harbour, the Achaean Camp and the Mouths of the Scamander' in Strabo 13, 1, 31. Strabo later (13, 1, 34) explains that the Scamander and Simoeis, after joining "a little in front of Ilion, then *debouch over against Sigeion and make the Salt Lagoon* [my italics]". This is good evidence for the existence there of a lagoon that attracted the attention of people interested in Homeric topography. It is certainly not inconsistent with my proposal that the area of the Lisgar swamp was in fact the Ship Station.

Στομαλίμνη does not appear in our received text of the Iliad, but it was a well attested variant in 6,4. We learn from the scholia that Aristarchus favoured it in his first critical edition of the Iliad, but, as Kirk remarks (1985, vol. 2, p. 156), "afterwards preferred the vulgate version which better suited his views on the position of the Achaean camp." I am not sure that Kirk anywhere suggests what those views may have been, but Kirk's own view as to where Homer located the Ship Station is in close conformity with the Schliemann–Leaf view (which indeed was the majority view prior to 1980). Writing towards the end of the 1980s he recognised that 'in the context of historicity' Professor Korfmann's excavations at Beşik were "perhaps giving fresh support to the idea, propounded by A. Brückner in 1924 and supported by Dörpfeld, that the Achaean camp must have been at Beşik Bay, and not on the Hellespontine shore to the north of Troy.". However, so far as the text of Homer was concerned, he concluded that "the Iliad account still firmly envisages the Achaeans as encamped on the Hellespont at the mouth of the Scamander" (Kirk 1985, vol. 2, pp. 48– 50). Hence, his editorial view was that the fluctuating fighting of Iliad 6,2 will have ranged on a north–south axis over the comparatively short stretch of plain between the Hellespont and Troy. This corresponds with Aristarchus' revised view when he removed στομαλίμνη from his second edition and read what appears in our present vulgate:

μεσσηγὺς Σιμόεντος ἰδὲ Ξάνθοιο ῥοάων

between the Simoeis and the streams of Xanthos (= Scamander).

A location for the fighting close to the city walls fits the circumstances of Bk 6 well, and recalls the topographical datum in the previous book (5, 773–74) about the confluence of the two rivers at Troia. Nor is it inconsistent with an east–west axis for the fighting, with the Achaean forces crossing the Scamander above its junction with the Simoeis, and then advancing on the city. Aristarchus originally located the skirmishing:

μεσσηγὺς ποταμοῖο Σκαμάνδρου καί στομαλίμνης

between the river Scamander and the Lagoon,

If his στομαλίμνη, as I suspect, was the same lagoon as that located by Strabo near Sigeum, this would give a location for the fighting on the west bank of the Scamander, which would have meant that the Trojans rather the Achaeans were on the offensive.

The beach at Beşik Bay is, and was, far larger than the Lisgar swamp location. Even the traditional 1186 ships would not have been cramped for space there. Nor is it backed by a 'theatre' of rising slopes that looked out on the main battlefield. Professor Korfmann (Korfmann 1984) has emphasised its historical significance as a sheltered haven for shipping waiting for favourable conditions to accomplish the difficult passage against wind and current into the Dardanelles. Here, if anywhere, he suggests, one should look for the Achaean ship station. I would not deny that the harbour at Beşik Bay probably did play an important role in the Trojan War as a supply port for the Achaean expedition. Professor Korfmann's excavations on the headland of Beşik Burnu (Cape Troy of the older maps, and recently re-named Yassı Tepe), and his important discovery of a cemetery close to the beach, have, I think, demonstrated that there was a strong Mycenaean presence in the area in the thirteenth century B.C. However, for the reasons indicated above, I believe that it is unconvincing as a candidate for the Achaean camp and ship station (Luce 1998).

I have commented on the defensive potential of the striking feature known as the Kesik Canal or Cut (Figs. 7 and 8) that runs across the Sigeion Ridge from the sea coast to the innermost southern recess of the Lisgar swamp (Luce 1998). It appears to be a natural feature that has been enlarged by human agency. Professor Kayan has shown that it can never have been a water channel (Kayan 1995). Dr. Zangger in his contribution to the Symposium (this Vol.) made the novel and interesting suggestion that it may have functioned like the well-known *diolkos* (slipway) on the isthmus of Corinth as a portage route for shipping that would avoid the necessity to round the cape of Sigeion, and provide a short-cut into what he designated as a 'naval harbour'. Brückner suggested that the Lisgar

Fig. 7. The Kesik Canal (Cut) from the west

swamp area may have provided Sigeion with its naval port, and if such a facility existed we should look seriously at the possibility that the Pisistratids may have enhanced it with a *diolkos* for their triremes on the Corinthian model.

For my final point I take up a portion of the epic tradition that figures only very obliquely in Homer, but is given considerable prominence by Pindar (O.8, 30–42) in his victory ode for the boy wrestler Alkimedon of Aigina. In the course of the ode Pindar emphasises Alkimedon's descent from the glorious hero Aiakos, son of Zeus and the nymph Aigina. Aiakos was grandfather of Achilles through his son Peleus, and of Ajax and Teucer through his son Telamon. This pedigree dates him well before the generation of heroes who fought at Troy. Pindar relates how Aiakos, the major hero of the island of Aigina, was called into partnership by Apollo and Poseidon as a fellow worker in the construction of the great circuit of walls at Troia. Legends about this earlier epoch of the city are associated with Priam's predecessor Laomedon, and so stem from an earlier phase of contact between Mycenaeans and Trojans. The story went that Apollo and Poseidon, working under duress as a punishment from Zeus, completed most of the circuit to 'divine' standards, but one shorter and weaker section – we have this on the authority of the Pindaric scholia – was fashioned by Aiakos. Pindar relates how a portent of three menacing snakes, one of

Fig. 8. A glimpse of the steep western flank of the Sigeion Ridge, with the Kesik Canal in the foreground, and Kesik Tepe in the middle distance

whom scaled the wall, accompanied the completion of the work, and caused Apollo to prophesy as follows: "The Pergamos [=citadel of Troia], O hero [=Aiakos], is taken through the work of your hands.".

Dörpfeld (1902, 608) was the first to note that an older and weaker section of the great Troy VI wall is, in fact, located in the north-western sector of the fortifications, precisely at the point where a Greek assault, coming, as we now know it must, from the south-west, would have been launched at the city's defences. The slope of the ground and the ditch guarding the western flank of the Unterstadt would have channelled the attackers up to an important roadway that led down from the citadel through a (blocked-up) gateway, and funnelled them into the small valley now occupied by the later Greek sanctuary immediately below the blocked gate (Fig. 9).

The case for the identification of this gate with Homer's Scaean Gate, and its linkage to the famous passage in Iliad 6 (431–39) where Andromache ventures to give some military advice to her husband Hector, as

Fig. 9. A view over the 'weak section' of the Troia VI wall south-west across the plain to Beşik Bay. The valley with the Sanctuary buildings lies immediately below the wall and the blocked up (Scaean?) gate

commander of the Trojan forces, seems strong, particularly in view of the most recent excavation findings in that area (Luce 1998; Korfmann 2001). The pair are standing on the walls near the Scaean Gate, and Andromache speaks of this area as the point 'where the city is most approachable and the wall may be overrun'. She reminds Hector of three previous attacks there 'to test the defences', and suggests that these probing assaults may have been inspired 'by one who knew the prophecies'.

The resonance of this last phrase with the prophecy recorded by Pindar is very striking, and seems to indicate that Homer knew the tradition about Aiakos and the weak segment, but played it down in favour of the much more colourful story of the wooden horse. The stratagem of the horse strains our credulity, but the idea of a weak link in the famous walls is archaeologically valid, and, from a strictly military viewpoint, seems eminently acceptable.

CHAPTER 3

The Relationship Between Man and Landscape in the Troad During the Ottoman Period

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Abstract

Two diseases – the plague and malaria – have had a large impact on the role between man and the landscape in the Troad. Since the eighteenth century, European travellers have repeatedly mentioned these two afflictions. However, recently, scholars have often overlooked or ignored the historical impact of these diseases. If one examines the evidence for the plague in the Troad, the sudden abandonment of so many towns becomes clear. The acute threat of malaria, in particular, around the swamp areas explains the function of the canals, some of which date back to early times.

1 Introduction

This paper intends to discuss not only the interdependent relationship between the landscape and the people who inhabited its space, but also the changes which resulted. When transferred to the case of the Troad, such a topic presents a complex series of problems both in the chronological as well as in the topographical sense. A precise presentation of the subject, thus, requires a certain temporal and spatial definition. As the title of my presentation reveals, I plan to focus on the Ottoman period – not the Ottomans specifically, but the Troad in the Ottoman period. Geographically, I will concentrate on the area of the Troia National Park or rather the lower Scamander plain, primarily because this region illustrates the complexity between the landscape and man, not only in the past, but also continues to do so in the present.

2 When the Relationship Between Man and the Landscape Becomes a Fight for Survival

The Turkish occupation of the Troad began in 1306 (Cook 1973). In 1332, Umur Bey and his fleet arrived at Gallipolli, which he would later in 1341 lay under siege. The power of the Emirat Karesi was finally brought to an end by the conquest of the region by the Ottomans, who under Orhan, were able to establish permanent control of the Dardanelles (İslam Ansiklopedisi 1993, vol. 8). The actual area around Troia itself, however, was not densely populated during the Turkish era[1] (Fig. 1). This area only became more heavily populated at the beginning of the seventeenth century. In 1659, new so-called forts were built at Kumkale at the same time as the Seddülbahir (Utkular 1954). In the eighteenth century, additional settlements were established in the lower Scamander plain, such as Çıplak, Pınarbaşı, Dümrek, and Yeniköy. This development, then, signalled what would continue to be an increase in non-Muslim elements in the region (Cook 1973). Despite the many brief descriptions by travellers over the centuries, the settlement history of the Troad during the Ottoman-Turkish period remains unclear. For example, the abandoned towns present a problem for those studying the history of the Troad (Höhfeld 1989). This problem was already identified on the maps of Forchhammer (from 1842) and also on that of Schliemann (from 1884), which show different cemeteries in the vicinity of the Troad without any associated villages (Forchhammer 1842; Schliemann 1884). Turner noticed this phenomenon in 1812 (Turner 1820) as well as Chandler in 1764 (Chandler 1776), Gelzer in 1871 (Gelzer 1873), and Prokesch in 1824 (Prokesch 1836).

Indeed, such 'townless' cemeteries testify to a possible period of abandonment, since in contrast to the habitation areas, 'werden die Gräber in der Türkei als geheiligter Boden betrachtet und nie angerührt' (Schliemann 1881). This observation by Schliemann is still valid today. Gelzer (1873) adds that „*Noch in der frühen Türkenzeit war, wie es scheint, dieser Theil der Ebene wohl bevölkert. Viele Dörfer sind spurlos verschwunden, nur die grossen Friedhöfe sind noch übrig und die Grabsteine mit wucherndem Gestrüpp überzogen.*" This problem was examined by Volker Höhfeld at the end of the 1980s (Höhfeld 1989), but the abandonment of the villages itself, however, could only be partially addressed within the scope of that

[1] Cook reports that his son visited the archive in Ankara and examined the tax documents from the years 982–1574. In addition to the Scamander plain, only Kalafatlı and Halileli were marked on this map (Cook 1973). Other towns such as Yerkesik, Pinarbasi, Dümrek, and Çıplak were not registered. Cook has no explanation for this, but believes that the lower Scamander plain must not have been visited for a particular reason. In the recently published tax lists from Biga Livasi from the year 1530, I have been able to isolate the following settlements: Kumköy, Halileli, and Kalafatlı (Hakan-i Defter-i Dizisi 1995).Therefore, at that time, one travelled up to the tip of the Biga peninsula. In my opinion, there were actually no settlements here, or they were so small that they did not need to be registered.

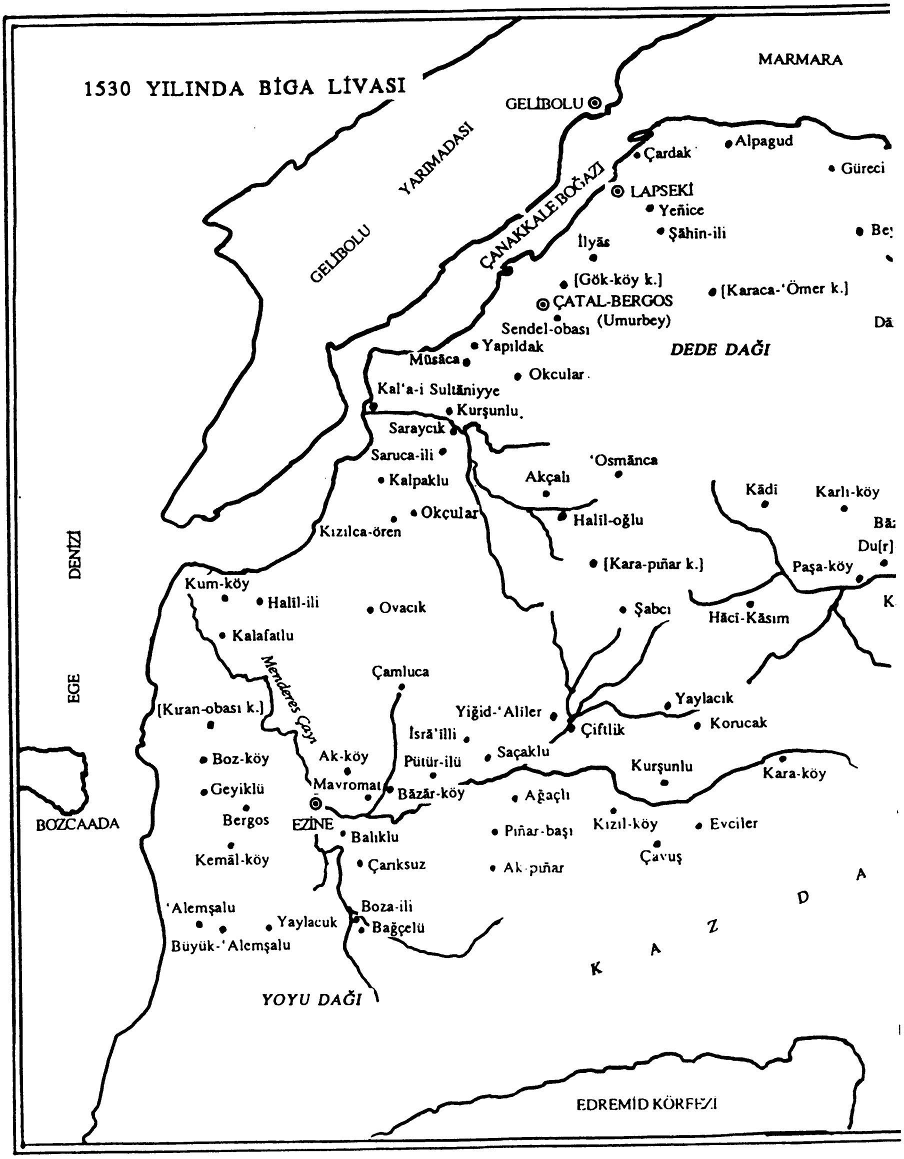

Fig. 1. Settlements in the lower Scamander during the Ottoman Period. (Defter-i Hakani Dizisi 1995)

study. Therefore, the same question from previous centuries remains, namely, what caused the settlements to be abandoned so suddenly leaving only the cemeteries behind.

2.1
The Role of Disease in the Relationship Between Man and the Landscape

Many publications have discussed the strategic and geopolitical location of Troia during the Bronze Age, and no doubt the subject will remain a focal point for discussion in the future. The key position of the site on three waterways (the Aegean, the Sea of Marmara, and the Black Sea) and at the crossing between two continents (Europe and Asia) brought numerous advantages (Korfmann 2001). During the period following the middle of the eighteenth century, intensive trade networks were established in the Mediterranean (Panzac 1996), which brought just as many benefits as serious disadvantages. One example of the latter was the introduction of diseases, the worst and most devastating of which was the plague.

In Antiquity and the Middle Ages, trade was a major catalyst for the spread of the plague and other diseases (Schimitschek and Werner 1985). The plague reached its height in Europe between 1347 and 1352. During this period, approximately 25 million people died from this disease – a quarter of the total population (Schimitschek and Werner 1985). In the seventeenth century, the plague was eradicated from Western Europe and has not appeared since 1718 in northern and middle Europe. However, at this time, areas within the Ottoman Empire (including the Balkans, Anatolia, and the Near East) were hardest hit by the plague (Panzac 1985). The connection between the trade contacts and the spread of the plague becomes even more evident if one compares maps showing settlement distribution before and after this disease-stricken period (Panzac 1996).

2.1.1
The Plague and Its Impact on the Lower Scamander Plain

The first written reference to the plague in the Troad dates from 1742, when the French Consul at Corfu, writes in a letter that several sailors on the warship *La Venise* had become infected with the plague. The Consul describes how the sailors, upon finding the Turkish houses on the islands completely deserted, looted many old things from these houses and thus became exposed to the pestilence (Panzac 1985). The second plague epidemic erupted in the area of Çanakkale in 1780 (Panzac 1985). Lechevalier notes that he had to live 3 months in Istanbul under the ominous threat of the plague (Lechevalier 1800). This epidemic most likely included the area of the

Troad (Panzac 1985). In the lower Scamander plain, almost all villages were beset by the plague.

The town of Kalafatlı, which was mentioned in 1801 by Gell as being prosperous (Gell 1804) is described 7 years later (1808) as almost completely extinct (Turner 1820). According to Choiseul-Gouffier, the village was struck by the epidemic once again in 1814 (Choiseul-Gouffier 1822).

Concerning the town of Akça Köy, which is marked on Lechevalier's map, Gell notes that like Kalafatli it is a pleasant spot, but is devoid of any inhabitants (Gell 1804). Turner states that the town was abandoned shortly before 1815 and residents retreated to the mountains (Turner 1820). Calvert further describes that the entire town was depopulated by the Plague (Calvert 1881). In addition, Akça Köy was devastated in 1814 (together with Kalafatlı) by the epidemic (Choiseul-Gouffier 1822).

According to Hobhouse, the Greek town of Yeniköy in 1810 had 200 houses. However, Napier comments that already in 1839, a third of the town inhabitants died from the plague (Cook 1973). Moreover, the old Turkish village of Halileli suffered a similar fate. Indeed, Turner notes that in the previous year, 1811, a number of people died of the plague (Turner 1820).

Kalafatlı, Akça Köy, Halileli, and Yeniköy were towns hardest hit by the plague. Indeed, if one examines all towns located in the geographical area covered by this paper, it becomes apparent that in these decades of the eighteenth and nineteenth centuries more than half of the inhabitants succumbed to the plague. For a landscape encompassing an area of 12 × 12 km, this statistic must have had dramatic consequences. This wave of disease, which took hold within the Ottoman Empire around 1701, came to an abrupt end in 1850. The plague would emerge again only in isolated cases until the end of the nineteenth century (Panzac 1985). Ultimately, the methods used to contain the disease, such as quarantine, appear to have triumphed.[2] When Schliemann arrived in the Troad in 1868, this terrible epidemic had already passed over the landscape, but not without having left behind visible traces of its destruction.

With respect to the question placed at the outset of this paper, it is clear that scholarship has so far not taken into account the devastating impact the plague had on the abandonment of settlements. To be sure, this epidemic was not the sole reason for the retreat from countless villages, but it was certainly a major contributing factor.

[2] Ibid., p. 416. In 1834 in Canakkale, a quarantine was called for the first time in the Ottoman Empire. The designated building was located at the site of the present Tusan Hotel (Sarıyıldız 1996).

2.2 Malaria

Malaria was another disease appearing in the Troad, which left its virulent mark not only on the people, but on the landscape morphology. On malarial conditions in the Mediterranean, Braudel emphasizes that the fight for survival depended upon the 'conquest' of the plains (Braudel 1994). After a flood, the water usually remained behind in the low-lying areas to form swamp lands. These conditions, in turn, were fertile for breeding malaria, and thus what was usually valued as life-giving water became a synonym for death: *aqua, ora vita, ora morte* (Braudel 1994).

In order to re-conquer and control the plains, the disease-inducing water had to be removed from the landscape. However, water was still essential for irrigation and had to be re-introduced into the landscape (Braudel 1994). Swamp areas were transformed into plough land by drainage and irrigation canals, but any neglect of this canal system could once again permit malaria to reappear. It was (and is) a constant battle for survival of man against nature (or the landscape in which they live). The fight against malaria began early and has been described and handed down to us since antiquity (Schimitschek and Werner 1985). The broad impact of malaria in the Troad specifically is perhaps best illustrated by the fortunes of the excavator of Troia himself, Heinrich Schliemann.

2.2.1 *Schliemann's Latent Cause of Death?*

In 1785, Lechevalier notes that the residents of Yenisehir used the famous victory inscription as a sacred stone against the fever (Lechevalier 1800). In other words, the inhabitants of the lower Scamander plain had a 'sanctuary' to combat the fever, or rather malaria. These measures, however, were of course not enough. The people needed drainage and irrigation systems and dams in order to make the landscape inhabitable, a task in which they were successful. If we first examine the danger of malaria in the vicinity of Troia, then we can discuss the broader results of man's intervention in the landscape.[3] Wood in 1750 and Chandler in 1764 already comment

[3] It is necessary to mention here that the 1988–1999 studies of the Byzantine graves from the thirteenth and fourteenth centuries at Troia revealed that almost all the skeletons exhibited clear traces of malaria. Virchow also demonstrated that many skeletons from Troia and surrounding sites (Ophryneion, Hanaytepe) show signs of malaria (compare Virchow 1883). In this connection, it is also important to cite the report of L.R. Müller concerning malaria in Çanakkale in 1916 (Müller 1919).

that the swampy lands of the lower Scamander plain repeatedly made life difficult (Wood 1775; Chandler 1776).

This situation had not radically changed in Schliemann's day. He states, that „*Mit dem Verschwinden der fleissigen Bevölkerung, welche früher die Troas bewohnte, müssen die Sümpfe allmählich an Ausdehnung zugenommen haben…Ein wenig mehr nach Südwesten sehen wir das grosse Christendorf Jeni Kioi, in prachtvoller Lage auf einer über das Meer hinausragenden Klippe von 203 Fuss Höhe. Trotz seiner hohen Lage ist dieses Dorf mehr als irgendeine andere Ortschaft der Troas vom Fieber heimgesucht, was der nahen Nachbarschaft der grossen Sümpfe zuzuschreiben ist. Manchmal sind alle Einwohner von Jeni Kioi fieberkrank*" (Schliemann 1881). Schliemann is even struck by the same fever: „*Die Ausgrabung in Hisarlik beendete ich gegen Ende Juli, hatte aber eine Woche zuvor das Malariafieber bekommen; ich vertrieb dasselbe zwar mit Chinin und schwarzem Kaffee, es kam jedoch bald wieder und hat mich vier Monate lang geplagt*" (Schliemann 1884). In his ambition to reach his goals without interruption by illness, Schliemann continued to take quinine liberally and even distributed it sometimes to the locals (Schliemann 1881). Virchow was also struck by a similar fever and overcame it with the help of quinine (Virchow 1881). In his writings, Virchow repeatedly stresses the connection between the swamp land and malaria and points out that the disease can alter human appearance.

Both Virchow and Schliemann were unaware of the side-effects of quinine. Schliemann often mentions that he is taking quinine and since he had travelled a great deal since his youth, we can assume that he became acquainted with quinine at an early age (Carvalho 1992). Some of the dangerous side-effects of this 'wonder drug' reported in recent studies include: headaches, dizziness, psychological shifts, and above all after long use, a ringing in the ears and deafness (Blume 2000). Tinnitus is caused by the closing up of the outer auditory canal by a foreign body or extoses (e.g., bone projections; Westhofen 2001). We know that Schliemann died due to complications following an ear operation which was supposed to help against deafness caused by extosis.

After this brief description of the diseases which not only had an impact on Schliemann, but people in the Troad over a considerable period, we need to return to the landscape and see how it was altered as a result.

3
Channel Systems

Since the eighteenth century, people have written about the various attempts to control the swamps and flooded areas around Troia. The first serious topographical studies were initiated in 1740 by Pococke (Pococke 1745). Ten years later, Wood conducted even more detailed examinations, in which the channel near the Pinarbasi Su is mentioned for the first time. He states that the channel was built by the Turkish governor with the purpose of draining the water from the swamp area into the Aegean (Wood 1775). At one point, Choiseul-Gouffier in 1773 and 1776 confirms or perhaps even directly copies the observation made by Wood (Lenz 1798). In 1785 Lechevalier describes the location of the channel in less detailed form and publishes the canal for the first time as the Menderes channel on the map of Cassas (Lechevalier 1800). Choiseul-Gouffier includes the reference that Lechevalier (1792) heard that the channel was built by Hassan Pasa. Moreover, Hunt (1817) describes how the water was first directed from Pinarbasi to the Hasan Pasa Ciftlik and then afterwards conducted to several mills. He continues to say that the channel was built in 1720 by Hassan Pasa (Walpole 1818).

Äkerbald (1800; in Lechevalier 1800) argues for the first time, though not quite intelligibly, that the channel was not built by the Turks. Rather, because of its complexity, it surely existed already in Pliny's day (Lechevalier 1800). At a later time, the channel was described as Pliny's channel when the site of Ballı Dağ was identified as that of Troia (Gell 1804). Forchhammer (1850) interprets the channel also as having a drainage function (Fig. 2). Maclaren (1863) examined the channel and concluded that it was for drainage and rejected the theory that „*Der Kanal sei kompliziert, deswegen kann nicht von den Türken sein*". Instead, he made the critical observation, that these „complicated channels are partly natural, partly artificial". Virchow (1880) published his significant reports for the Troad and disproved those threadbare arguments such as those of Maclaren: „*Dass ein Türke einen solchen Canal, auch wenn er stellenweise in den Felsen eingehauen ist, nicht angelegt haben würde, ist eine sehr angreifbare These....Freilich wird Hassan Pascha noch andere Gründe gehabt haben, als die Anlegung einer Mühle und einiger Bäder...Führt doch Hr. Forchhammer selbst an, daß die Beschika-bay in neuren Zeit öfter zum Ankerplatz für Flotten gewählt sei, theils weil das Sigeion Schutz gegen die Nordostwinde biete, theils und besonders, weil der Bach von Bunarbaschi treffliches und zu jeder Zeit reichlicher fliessendes Trinkwasser gewährte...Gegenwärtig ist übrigens das Gut Erkessi Köi, zu welchem die ganze Umgebung das Canals gehört, Staatseigenthum und wird direct von der Militärverwaltung besorgt.*" Furthermore, Schede (1929) noticed a mill associated with the Besik channel having some sections distinguished by cuts in the natural rock.

These observations clearly demonstrate that this channel and its associated water system actually belongs to an entire network extending from the Pinarbasi water spring up to the Besik Bay. The function of this system

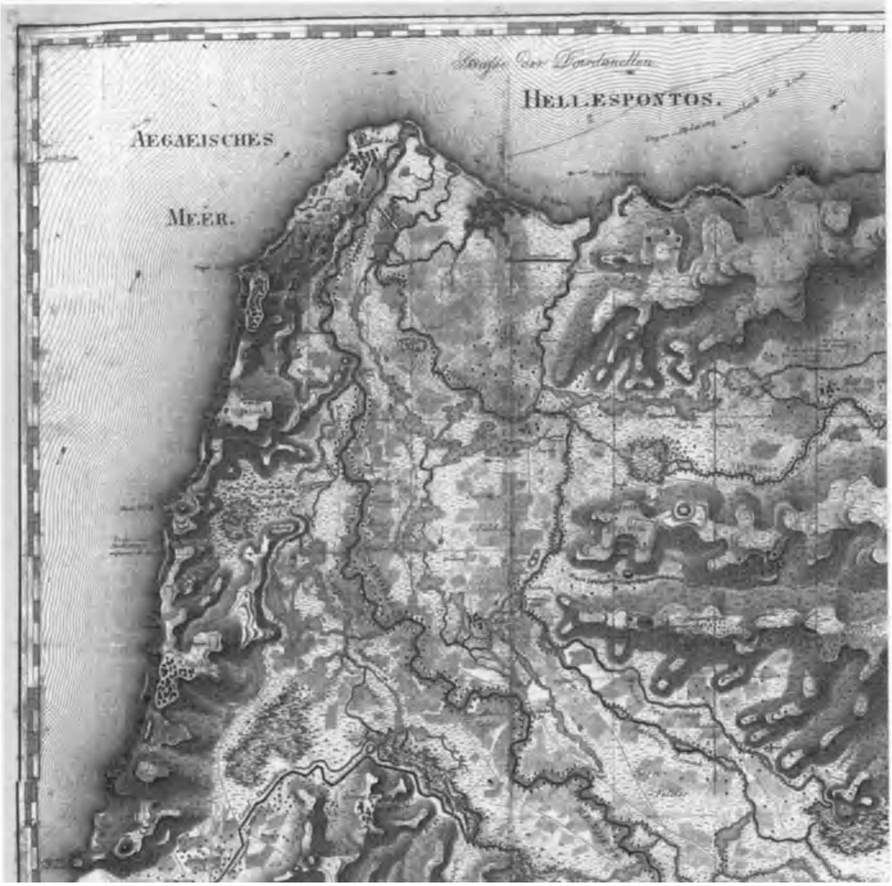

Fig. 2. The Plain of Troia as surveyed in 1839. (Forchhammer 1850)

is also certain, namely, that water from the plain be directed outward to sea and not in the reverse direction.

A second conspicuous channel is the so-called Kesik channel (cf. Kayan et al., this Vol.). It is mentioned for the first time by Lechevalier in 1785 and is described as a type of defensive ditch used in the Trojan war (Lechevalier 1800). In a later description, Hunt (1817), who gets his information from an earlier guidebook, mentions that the channel was intended for ship passage during bad weather. According to Hunt, the channel appears to have been a wadi during the summer (Walpole 1818). Prokesch maintains that the channel was the product of an earthquake (Prokesch 1831). For Forchhammer (1850), „*war* [*er*] *offenbar angelegt um die Gewässer des Lisgar und der winterlichen Überschwemmungen des Bunarbasi Su abzu*leiten" (Fig. 2). Virchow (1880) believed the channel to have had the same function. Cook (1973) associated it with Constantine's building program for a new capital and thought it to have been left incomplete. If one examines Forchhammer's map, a subterranean water channel is drawn in on the northern end of the so-called Lasger (Lisgar) swamp. This channel was begun in 1825, but never brought to completion.

Another channel is noted by both Gell (1804) and by Forchhammer (1850) as a drainage channel. The purpose of this channel was to facilitate the carrying away of flood water from the Menderes. Virchow (1880) confirms Forchhammer's conclusion and even adds that the straight line made by the ditch and the direction of its course directly contrary to the current proves that it was planned and designed for the drainage of excess water in the plain. Virchow holds not the local population, but the government or rather the central controlling authorities responsible for the neglect of the channel system. Schliemann (1881) also describes the channel in a similar way. Additional proof for the existence of this drainage system is the presence of stone-built dams which undoubtedly were linked to the channels (cf. Fig. 2).

With the exception of the Kesik Channel and the incomplete subterranean channel, all other examples mentioned above, as we know from traveller's descriptions, were definitely functioning in the winter months and operating already during the Ottoman period. We must, then, picture a drainage system employed repeatedly over the course of centuries.

3.1 The Çiftlik Phenomena

Another phenomenon in the Troad relating to the question of abandoned settlements involves a series of sites often marked as graves on maps, even though they actually represent ciftliks. Based on Forchhammer's map, there are at least seven ciftliks in the plain of Troia. The significance of these specific sites for the landscape will be discussed in the following segment.

Braudel has already discussed the 'ciftlik phenomena' and posits the same interpretation as Busch-Zanter, who does not consider the ciftlik an old village dating back to the Middle Ages. Instead, he argues that this form of ciftlik emerged from the young towns of the sixteenth century which later became even more widespread in the seventeenth century. Thus, we appear to be dealing with a town connected with modern colonization of (melioration??) and a site located deep in the plain near the seas and valleys and, thus, frequently exposed to floods. According to Braudel (1994), this opinion is also supported by Ömer Lutfi Barkan. From Ottoman documents, we know that the foundation of the çiftlik at the beginning of the sixteenth century is related to the increase in central authority (Akdağ 1975). The introduction of this type of village also initiated a general 're-organization' of the landscape which involved the addition of channels, dams, and other larger projects such as the construction of a water channel system during the Ottoman period.

The last large re-shaping of the Troad landscape was carried out between 1956 and 1965 by a central controlling authority, namely, the Turkish government. During these years, dams were constructed along the Menderes within the plain of Troia, so as to direct the flow of water better (Akarca 1978). The result of this recent construction program is most clearly expressed in the statistics. Since the 1960s, the death rate for malaria reached its lowest level.[4]

4 Conclusion

In this paper, I have explored the connection between man and the landscape by examining the role and impact two epidemics – the plague and malaria – had on the Troad during the Ottoman period. Since 1700, residents and visitors to the Troad both observed and were confronted with what was often a life and death struggle against these two diseases. Not only did the plague and malaria have a decided impact on the population, but they had a direct influence on the topography of the landscape itself. As the evidence from the Ottoman period illustrates, inhabitants of the Troad were continually faced with the challenge of trying to adapt to the landscape, or rather, to adapt the landscape to meet their own survival needs.

[4] During the course of fieldwork I conducted in the Troad between 1992 and 2000, I was repeatedly told by local residents that the death rate for children had been high. In many cases only one child of four in a family survived. This illustrates that the population in the region has not increased, despite the high immigration from Bulgaria, Rumania, and Russia since 1890.

Heidelberg radiocarbon dates for Troia I to VIII and Kumtepe

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Abstract

Based on a total of 159 radiocarbon dates, we present a time frame of Troia I–VIII and Kumtepe, ranging from the late sixth millennium to ca. 840 B.C. We discuss the limitations imposed by the 'old-wood' problem of charcoal samples, and evaluate the date clusters of the Troia subdivision towards a 'minimal age' limit. We document the evidence that the beginning of Troia I coincides with a widespread cooling event in the North Atlantic.

1 Introduction

The Heidelberg Radiocarbon laboratory has been involved in the dating of Troia and related sites throughout the Troia Project. In 1993, we published an overview of the work up to that time (Korfmann and Kromer 1993). Since then, we have obtained more than 100 additional dates from Troia and neighbouring sites, which we present here. First, we discuss some issues relating to the interpretation of charcoal dates and ^{14}C age plateaus. We then show the dates according to Troia phases as attributed by the excavators, and discuss the chronological framework as evident from our collection.

2 Remarks on Sample Material and Radiocarbon Calibration

Almost all samples from Troia are charcoal; hence some comments on the well-known 'old-wood' problem are necessary. With radiocarbon we determine the year(s) of formation of the tree ring(s) that ultimately provided the sample. For archaeological purposes later events (felling of the tree, use as timber or firewood, destruction of timber) usually are of interest. The time interval between growth and the archaeological context generally is

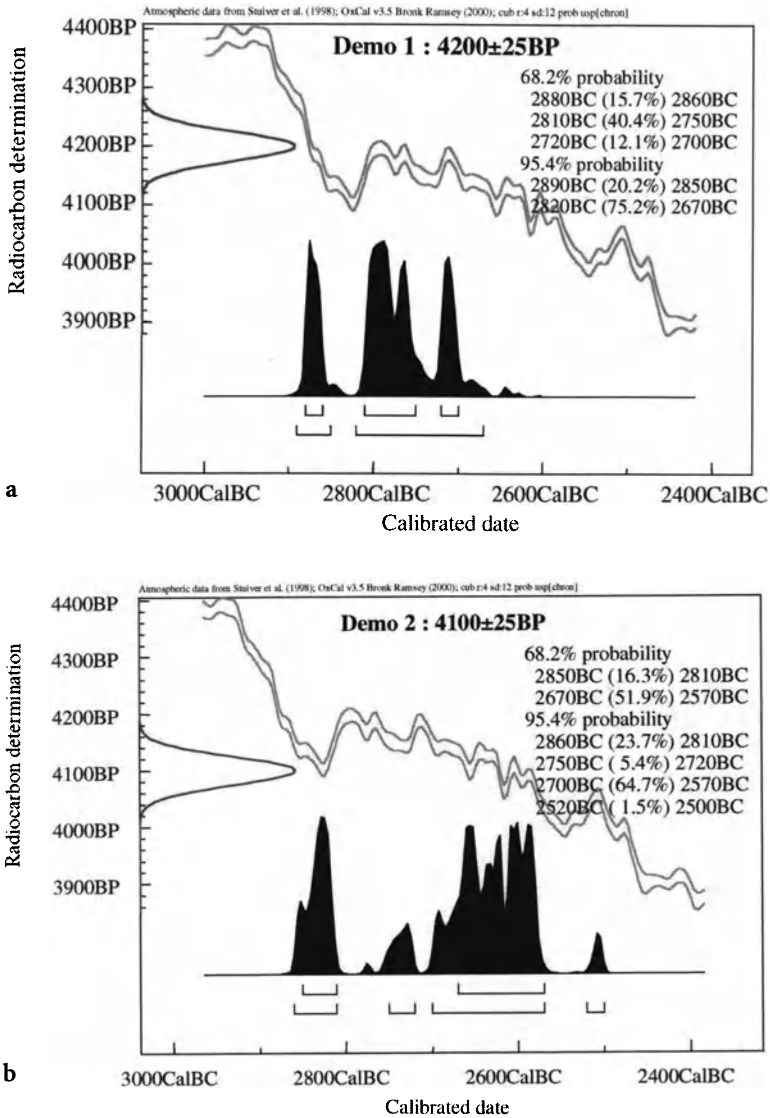

Fig. 1. **a** Calibration example of a hypothetical sample grown at 2900 cal B.C. (^{14}C age 4200 ^{14}C B.P.). Even with a fairly high precision of the ^{14}C measurement of ± 25 years the calibrated age range (1σ) is 180 years. **b** Same as **a**, but for a sample grown at 2600 cal B.C. The high end of the calibrated interval is almost identical to the one of **a**

not known, and it has to be estimated from other evidence, such as probable use of the wood, typical number of rings of a tree species in the area and probable position of the charcoal sample within a tree-section.

One may assume that wood specifically collected for firewood (twigs, branches) provides dates close to its archaeological context, whereas charcoal identified as part of timber, if it came from the pith of a long-lived tree, could yield dates up to several centuries older than the date of the felling of the tree, the date of which could itself be decades or even centuries older than the date of the conflagration in which the tree/timber was burned. Hence, in a series of samples we expect to see 'outliers' to older ages, which are interpreted as 'old wood', and more coherent clusters of ages corresponding to wood with low ring counts.

For some of the Troia samples the excavators noted the probable origin of the charcoal. We thus organize the graphical presentation of our results in groups according to these criteria.

Especially for Troia I and II, the shape of the calibration curve poses limits to the age resolution that we can provide with radiocarbon. The situation is best shown using two examples. We consider two hypothetical events, well defined by single-year material, such as grain, of 2900 and 2600 cal B.C. The respective ^{14}C ages, as read from the calibration curve, are 4200 and 4100 ^{14}C B.P. In these ^{14}C age ranges the calibration curve is characterized by a strong ^{14}C age inversion centred at 2850 cal B.C., and a slightly sloping ^{14}C age plateau ending around 2600 cal B.C. Assuming that we determined the ^{14}C age of the two grain samples to 4200 ± 25 and 4100 ± 25, respectively, we obtain calibrated results as shown in Fig. 1a, b. Due to the many possible 'hits' of the radiocarbon age range with the calibration curve, we arrive at a broad range for the calibrated age between of 2900 and 2600 cal B.C. Hence, for any samples in this age range we cannot, with radiocarbon dating of single samples, resolve the true age to better than three centuries, nor determine the duration of phases within this interval.

3
Kumtepe

The results of the samples from Kumtepe, a Neolithic, Chalcolithic, and Bronze Age site some 10 km northwest of Troia, are shown in Fig. 2. We plot the 1σ-range as bars from the lowest to highest calibrated age (i.e., no further subdivision according to the probability-transformation, contrast the internal probability distribution in Fig. 1). The label attached to each bar gives the laboratory reference (Hd-nnn), the archaeological context as assigned by the excavators, and the site coordinate.

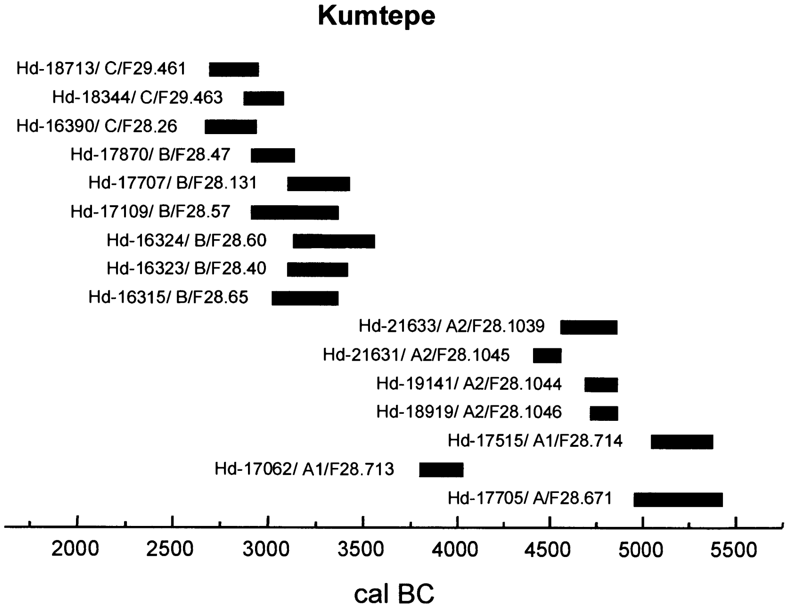

Fig. 2. Calibrated age ranges (1σ) for the samples of Kumtepe A–C. The label attached to each *bar* gives the laboratory reference (Hd-nnn), the archaeological context as assigned by the excavators and the site coordinate. All samples are charcoal, expect for the bone samples. Not shown: Hd-17073-C2-F28.105, 1750–1510 cal B.C.

Kumtepe A1 is represented by two samples, of which Hd-17062 is considered an outlier. From Kumtepe A2 we dated three bone samples, which do not suffer from the 'old-wood' problem of charcoal. Together with the fourth sample (material not reported) they constrain this interval to 4805–4370 cal B.C.

The dates of Kumtepe B cluster between 3370 and 2910 cal B.C. The three samples of Kumtepe C appear slightly younger, with a minimum age of 2670 cal B.C. However, here we already touch the ^{14}C age plateau as shown in Fig. 1; hence, the true lower limit could be as high as 2900 cal B.C. (Gabriel 2000).

These dates document a much longer occupation of Kumtepe than previously thought. Starting towards the end of the sixth millennium B.C. (cemetery of A1) and continuing into the fifth millennium, we note a gap in the settlement for most of the fourth millennium (a hiatus phenomenon noted elsewhere in the Aegean region; Maniatis and Kromer 1990; Manning 1995), based on the area excavated so far. The site is again occupied in the first centuries of the fourth millennium, and continues into the Late Bronze Age (LBA; Kumtepe C).

4 Troia Phases

We show the results of the Troia samples as separate plots according to the Troia subdivision. The samples are labelled as explained above. For those samples where the excavators provided details about the probable origin of the charcoal we append a suffix to the label, with 's' for single-year sample, 'b' for branches or twigs and 't' for timber. If present in a subphase, we start with the s/b samples and finish with t samples at the top of the cluster.

We also include the dates already published by Korfmann and Kromer (1993); for new data the laboratory numbers are higher than Hd-15407.

4.1 Troia I

Troia I early (Ia–Ic) has ^{14}C ages of 4300 to 4100 ^{14}C B.P.; hence, the dating resolution is limited due to the ^{14}C age inversion at 2850 cal B.C. and we can only give rather broad limits for this phase (Fig. 3). The minimum lower

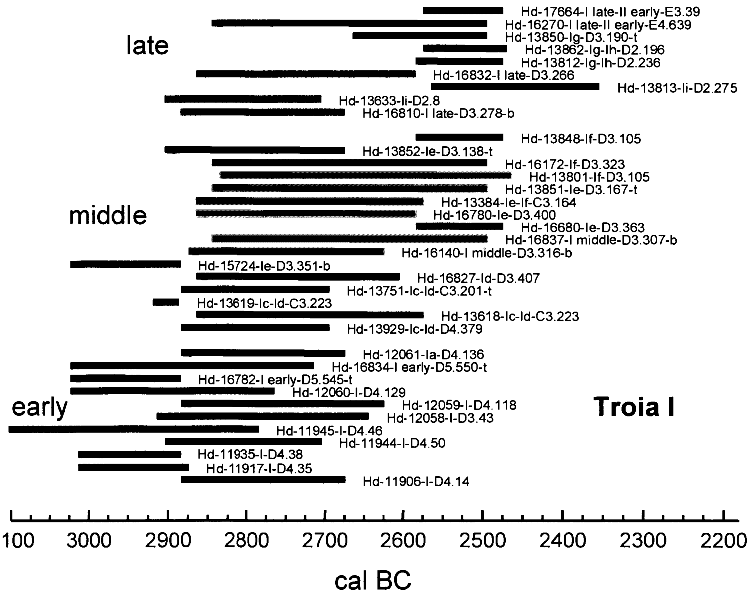

Fig. 3. Calibrated dates of Troia I. The label attached to each *bar* gives the laboratory reference (Hd-nnn), the archaeological context as assigned by the excavators and the site coordinate. A suffix is attached to those samples where the excavators noted the probable origin of the charcoal, with *s* single-year sample, *b* branches or twigs and *t* timber. If present in a subphase we start with the *s*/*b* samples and finish with *t* samples at the top of the cluster

age is ca. 2650 cal B.C. We note that the wiggle-matching of the ^{14}C sequence from the pine tree D5.365 leads to a maximum age of Ic of 2699 ± 15 (plus missing rings towards the bark); (for details see pp. 155–156 of Korfmann and Kromer 1993 and Manning 1997).

For samples of the Troia I middle phase (Id–If) we find minimum ^{14}C ages down to 4040 ^{14}C B.P., which lead to calibrated ages in the latter half of the ^{14}C age 'plateau'. Again, the age inversion at 2550 cal B.C. may lead to a false estimate of the end of this phase which is younger than the true end, e.g., 2480 cal B.C. ('young' side of the inversion) instead of 2580 cal B.C. This suspicion is supported by the surprisingly uniform cluster of the Troia I-late dates, which coincide with the minimum calibrated ages of the middle phase.

4.2 Troia II

For Troia II (Fig. 4), some of our new data show minimum calibrated ages of 2300–2200 cal B.C. The large scatter, with dates up to 3000 cal B.C., demonstrates the 'old-wood' problem (discussed previously by Manning 1997): samples Hd-14573, Hd-14561, and Hd-14008 all come from roof beams of Megaron IIB. The building itself could have been much younger than the strong – and long-lived – trees that had to be used in the construction of its roof. Hd-19823, Hd-19822, Hd-20040, Hd-19672 are from planks belonging to the floor of another building. In this case, wood of a different age has been used, and only the more recent dates are considered to be close to the period of construction.

For a detailed study of excavations in the center of Troy II, see Mansfeld (2001).

4.3 Trioa III–V

Troia IV (Fig. 5) does not appear to be younger than Troia III. Most of the dates indicate a plausible minimum calibrated age of 2150–2200 cal B.C., with five dates down to 2020 cal B.C. The calibration curve is essentially flat between 2300 and 2200 cal B.C., followed by an age inversion at 2170 cal B.C. and drops sharply to younger ^{14}C ages around 2150 cal B.C. Hence, the observed pattern of the calibrated ages may reflect this particular sequence.

The dates of Troia V cluster around 1750–1950 cal B.C., with two single-year samples (suffix -s) at the old end of the range.

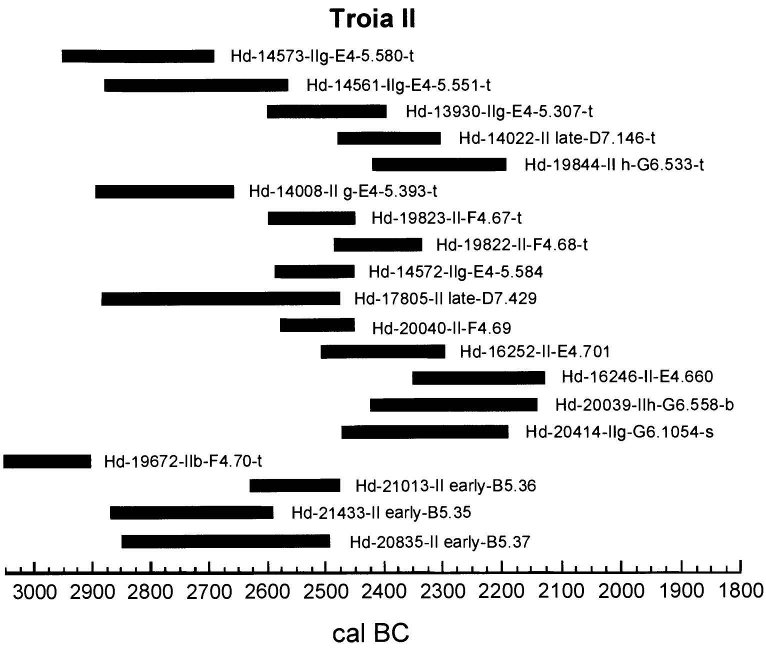

Fig. 4. Same as Fig. 3, but Troia II. Sectors E4–5 and F4 are part of the central area of the citadel with monumental buildings where roof beams had a span of 10 m and more

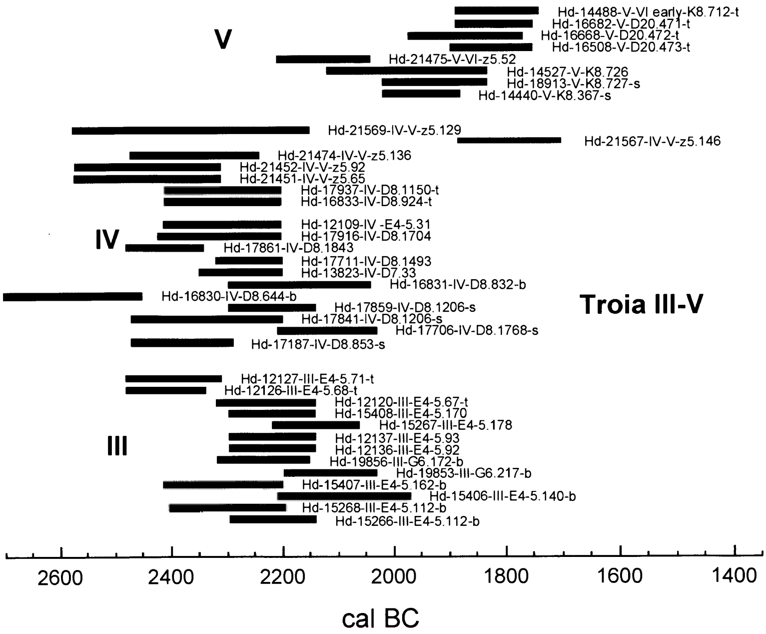

Fig. 5. Troia III–V. See Fig. 3 for notes

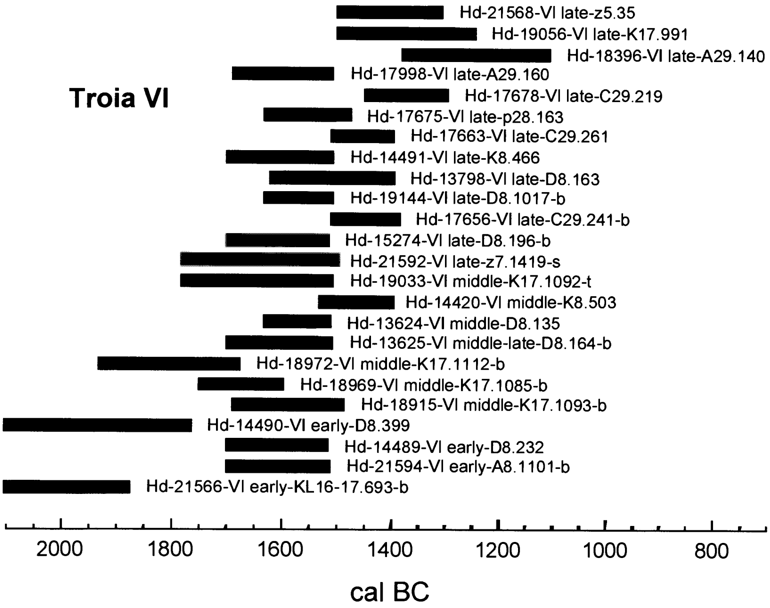

Fig. 6. Troia VI. See Fig. 3 for notes

4.4
Troia VI

For Troia VI (Fig. 6) we now have 24 dates, 16 more than in Korfmann and Kromer (1993). The majority of the dates are between 1700 and 1500 cal B.C.; the four VI late dates have ranges extending down to 1300 cal B.C. or even later (ca. 1200–1100 cal B.C.).

4.5
Troia VII–VIII

With Troia VII (Fig. 7) we reach the end of Bronze-age Troia (samples D9 from VIIb). A slight ^{14}C age inversion at 890 cal B.C., followed by an age plateau, may again lead to an erroneously low date of the end of this phase, i.e., we cannot, with ^{14}C, distinguish between 920 and ca. 840 cal B.C. (e.g., samples Hd-17860 and 17869) as the lower limit of this phase.

From Troia VIII we only have three dates so far, whose lower limit is well constrained by the rapid decline of ^{14}C ages, starting at ca. 840 cal B.C. From an archaeological point of view they seem between half a century and a century too old, which once again might be caused by the presence of old-wood. Nevertheless, the Troia VIIb and VIII samples from D9, coming from

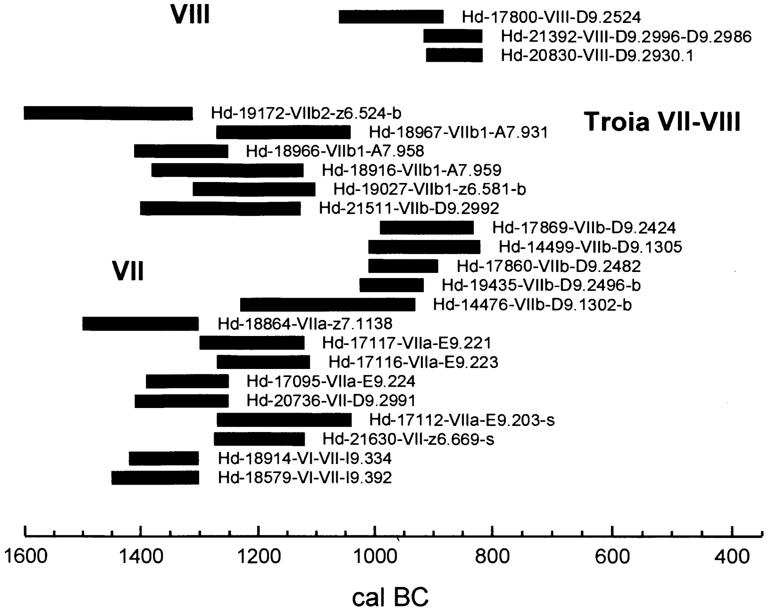

Fig. 7. Troia VII and VIII. See Fig. 3 for notes

one stratigraphic sequence, help to answer an important question concerning the settlement history of Troia: was there a rather long gap (hiatus) in the occupation of Troia between Troia VII and VIII? C.W. Blegen suggested a break of up to 400 years (Blegen 1963, pp. 172, 174). From our series of ^{14}C dates a gap of several centuries between the two phases does not seem likely. If there was a break, its duration must have been shorter than the resolution of radiocarbon dating.

4.6 Troia Summary Graph

Figure 8 is an overview of all Troia dates presented separately above. One may ask if the data document a continuous occupation of the site, or if we can demonstrate gaps in the settlement. Due to the systematic limitations of dates based on charcoal, as discussed above, a convincing answer may not appear possible. We may be able to provide minimum ages of a certain phase, as we have done above, but the quite likely occurrence of re-use of wood, or submission of ring sections grown close to the core of a tree, precludes a reliable estimate of the upper boundary.

We note at the transition of Troia IV–V a lack of dates, with just one sample (Hd-21475, Fig. 5) offering a potential bridging candidate.

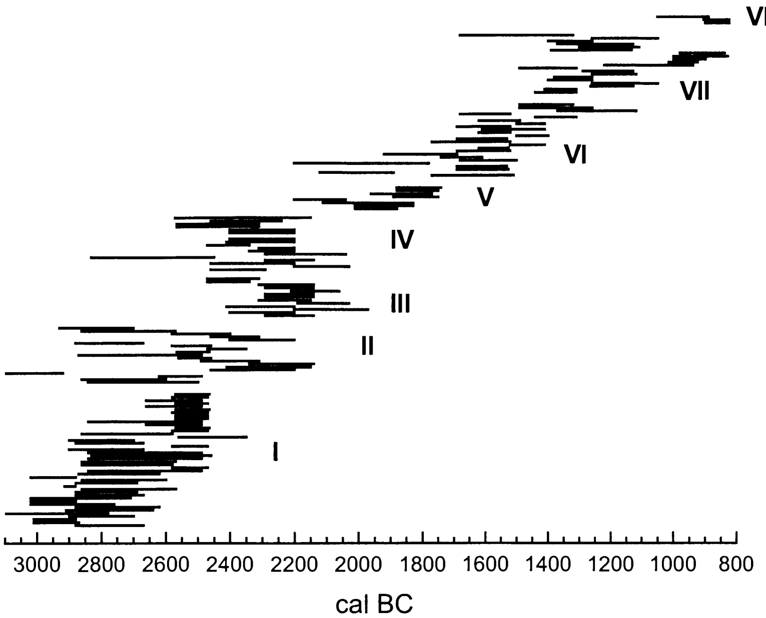

Fig. 8. Summary graph of all dates of Figs. 2–7

5
Radiocarbon Fluctuations and Climate Variability

Drastic distortions of the radiocarbon time-scale, such as shown in Fig. 1, are caused by fluctuations of the ^{14}C level of the atmosphere. It has long been noted (Eddy 1977) that the most recent series of peaks of the atmospheric ^{14}C level coincided with the absence of solar sun spots and widespread cooling, best documented in central and northern Europe, but also elsewhere. Thus, a link between times of low solar activity (low sunspot numbers) and climate anomalies has been suggested. The instrumental record of the solar 'constant', as registered by satellites over the most recent two 11-year solar cycles, does not confirm changes in insulation required to cause notable cooling, but the record is too short to cover longer, possibly 'deeper' cycles of solar activity.

It can be shown that the ^{14}C record from millennia-long tree-ring chronologies and the flux of ^{10}Be can serve as a proxy of solar activity throughout the Holocene (Stuiver and Braziunas 1993). Earlier attempts to link high levels of ^{14}C (in the radiocarbon calibration curve equivalent to the intervals of strongly declining ^{14}C ages and subsequent ^{14}C age plateaus) with evidence of climate anomalies (e.g., Magny 1993) were not

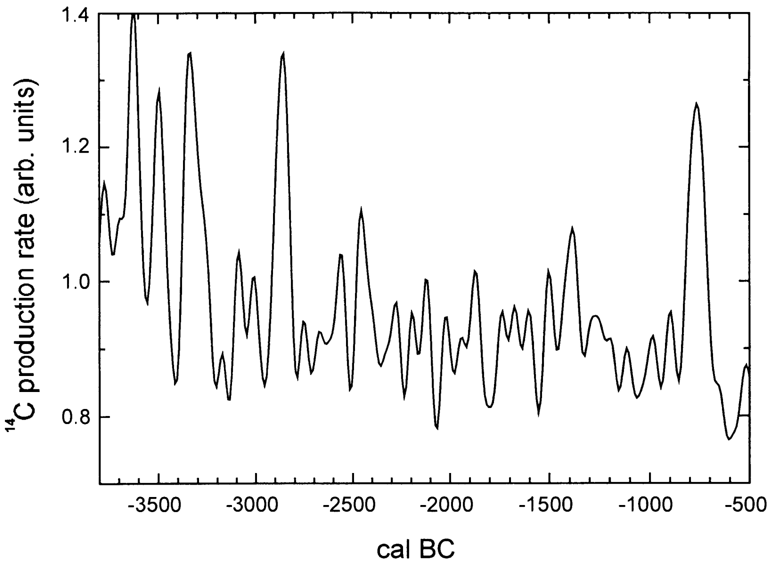

Fig. 9. ^{14}C production changes 3700–500 cal B.C. The data have been calculated from INTCAL98 using a Siegenthaler/Oeschger box model of the carbon cycle (Siegenthaler et al. 1980). The strong production peak at 2850 cal B.C. leads to the shape of the calibration curve as shown in Fig. 1

accepted unanimously, partly due to insufficient age control of the climate data.

Recently, the evidence has been shown to be much stronger (Bond et al. 2001). From high-resolution marine sediments in the North Atlantic we have proof of nine wide-spread cooling episodes in the Holocene, starting at 10,400 cal B.P. with the most recent one synchronous to the general cooling in mid- and high latitudes of the northern hemisphere between the fourteenth and seventeenth centuries A.D. These century-scale events of iceberg advances into the North Atlantic are in excellent agreement with major ^{14}C maxima (Bond et al. 2001). Hence, we can with confidence use the record of strong ^{14}C production change to mark periods of solar-induced climate change.

For the period covered by our Troia dates the record of ^{14}C production is shown in Fig. 9. We observe a series of strong maxima of ^{14}C production between 3700 and 2850 cal B.C., a more 'quiet' period of solar activity in the third and second millennia, and again a strong solar activity minimum at ca. 800 B.C. The latter has been connected to cool and humid phases in central and northern Germany (van Geel et al. 1998), whereas the strong events in the second half of the fourth millennium still need to be investigated.

It is outside the scope of this contribution to search for evidence of climate change in the eastern Mediterranean prior to, and during, Troia I. It needs to be shown how a cooling in the North Atlantic sector would have affected the eastern Mediterranean. Reconstructions for the sixteenth century have been attempted (e.g., Jacobeit et al. 1999), but clearly more work is needed to identify terrestrial evidence comparable to the marine record.

Acknowledgements

The ^{14}C production data were calculated using a Siegenthaler/Oeschger-carbon model as coded by M. Born. The Heidelberg Radiocarbon laboratory is supported by the Heidelberg Academy of Sciences. We thank Maryanne Newton, Mary Jay Bruce, Peter Ian Kuniholm and Sturt W. Manning for helpful comments and discussion.

Seismotectonics and Geology of Troia and Surrounding Areas, Northwest Anatolia

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Abstract

The Troia area and the surroundings, in northwest Anatolia, are located between two most active fault zones. These zones have developed under the influence of the north Anatolian fault system coupled with the Aegean N-S extension.

These active fault systems have caused several severe earthquakes which damaged the Troia area.

The morphology and geology of the region have evolved under strong tectonic control. Major morphological features of the region such as the gulfs of Saroz and Edremit, the Çanakkale (Dardanelles) Strait and the Kazdağ high are young, post-early Pliocene entities. They formed when the transtensional tectonic regime in the Aegean began. One of the major products of this system are the listric normal faults. They caused back-tilting of the down-thrown blocks which, in turn, diverted the major drainage to the north. As a result, increasingly more clastic materials have been transported to the Troia area where a large alluvial plain has developed.

1 Introduction

This paper describes the tectonics and associated seismicity of the Troia area, which is situated in the northwestern tip of the Biga Peninsula (Fig. 1). These two subjects require treatment on a large scale, because they cannot be restricted to the size and limits of a small dwelling. Therefore, tectonics and associated seismicity of the region will be discussed, together with the Troia area within the limits of the available data.

Initially, tectonic forces that presently affect the region will be discussed. This will show how the region is deformed to, how these forces cause earthquakes, and then the geology of the region will be described in order to explain how the region has evolved through time.

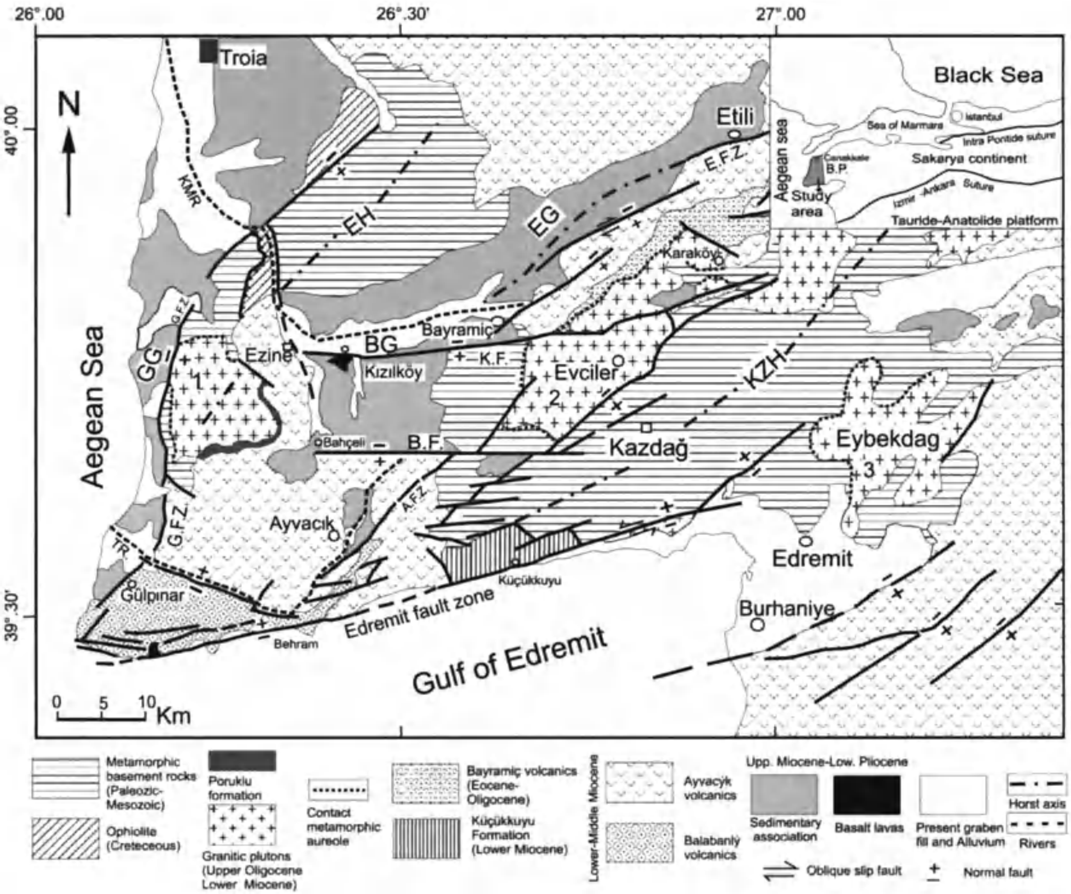

Fig. 1. Simplified geological map of the region to the north of the Gulf of Edremit. *GG* Gülpınar graben, *EH* Ezine horst, *EG* Etili graben, *KZH* Kazdağ horst, *BG* Bayramiç graben, *BF* Bahçeli fault, *KF* Kızılköy fault, *GFZ* Gülpınar fault zone, *AFZ* Ayvacık fault zone, *EFZ* Etili fault zone, *KMR* Karamenderes River, *TR* Tuzla River. *1* Kestanbol pluton, *2* Evciler pluton, *3* Eybek pluton, *BP* Biga Peninsula. The *inset* shows the study area within the context of the tectonic divisions of Turkey. (After Yılmaz & Karacık 2001)

2
Tectonics and Seismicity

The Aegean region represents one of the rapidly extending continental regions of the world (McKenzie and Yılmaz 1991 and the references therein). It extends in an approximate north–south direction. Major products of this continental extension are a number of grabens which run approximately E–W in the southern regions and ENE–WSW in the northern regions. The grabens are bordered by a set of either normal faults or oblique faults which have considerable strike-slip components. Around these structural depressions seismic activity is intense and has been recorded instrumentally (Fig. 2).

Determination of the time of initiation of the modern graben basins can be estimated from the present strain rate and the total amount of extension. Using a variety of techniques, the present rate of extension has been calculated to be of ca. 2.5–6 cm a^{-1} over a distance of ca. 800 km between Bulgaria and the Mediterranean (LePichon and Angellier 1979; Jackson and McKenzie 1988; Exström and England 1989; Main and Burton 1989; Sellers and Cross 1989; Westaway 1994). The β-factor of extension has been calculated from various sets of data, including: (1) topographic data, employing the Airy isostatic balance; (2) gravity data (Makris and Stobbe 1984; Meissner et al. 1987) and (3) seismic data (Makris and Stobbe 1984; Mindevalli and Mitchell 1989), obtained particularly from the wide grabens of western Anatolia (i.e., the Büyük Menderes and Gediz Grabens). This ranges from 1.2 to 1.6 in the land areas to 2 in the Aegean Sea. Using these data sets, the time period extrapolated for the amount of extension is less than 5 Ma.

Among the tectonic processes responsible for the Aegean extension, the major force is the westward extrusion of the Anatolian plate from the Karlıova area in eastern Anatolia, where the northward convergence between the Arabian plate and the East Anatolian accretionary prism (Şengör and Yılmaz 1981) has been continuing since their collision in the late Eocene (Yılmaz 1990; Fig. 3).

The westward escape of the Anatolian plate began to transfer the gravitational potential energy stored in the thickened East Anatolian crust, (38 to 50 km; M. Borazangi and N. Türkelli, pers. comm.) for approximately the last 3–4 Ma. The retreat of the Hellenic trench is viewed as another force being responsible for the Aegean extension, but this is secondary compared to the westward escape of Anatolia. According to Le Pichon (2000), the role of this secondary force in the Aegean extension is viewed as not more than one fifth of the total forces involved.

The present-day kinematics of the Anatolian-Aegean system are well constrained by GPS (Global Positioning System; Fig. 3) and SLR (Satellite

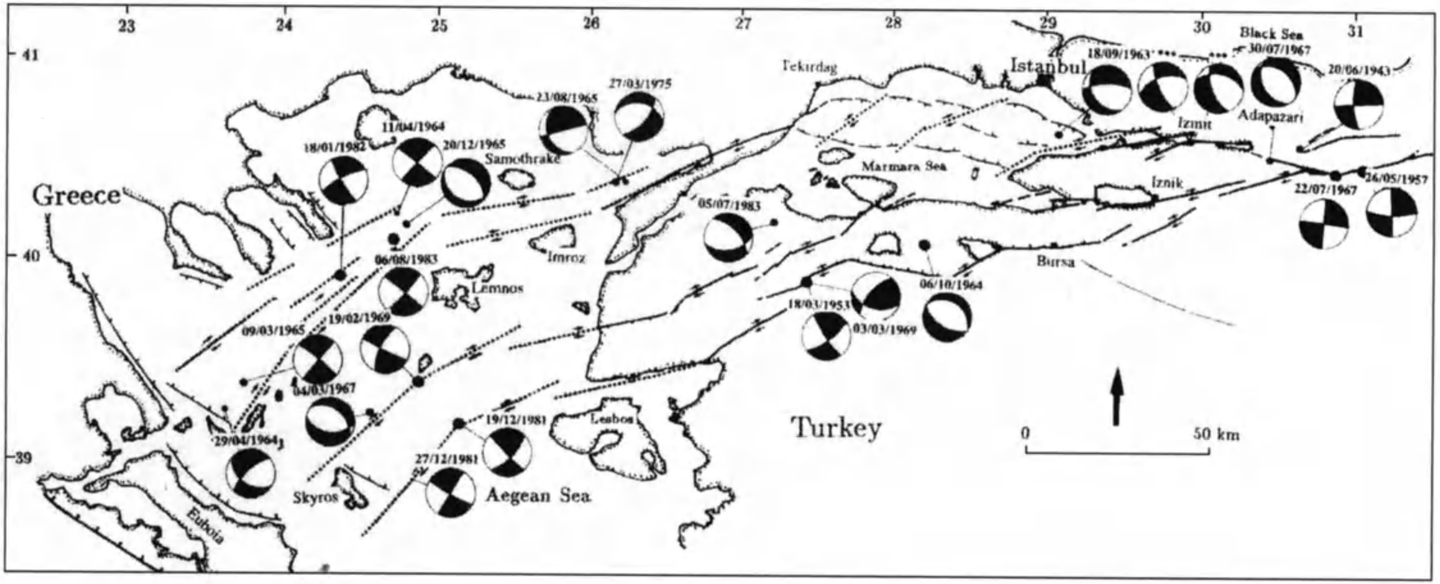

Fig. 2. Tectonic and seismicity map of the northern Anatolian-Aegean region, showing major fault zones and the fault plane solution of the big earthquakes. (After Barka 1992)

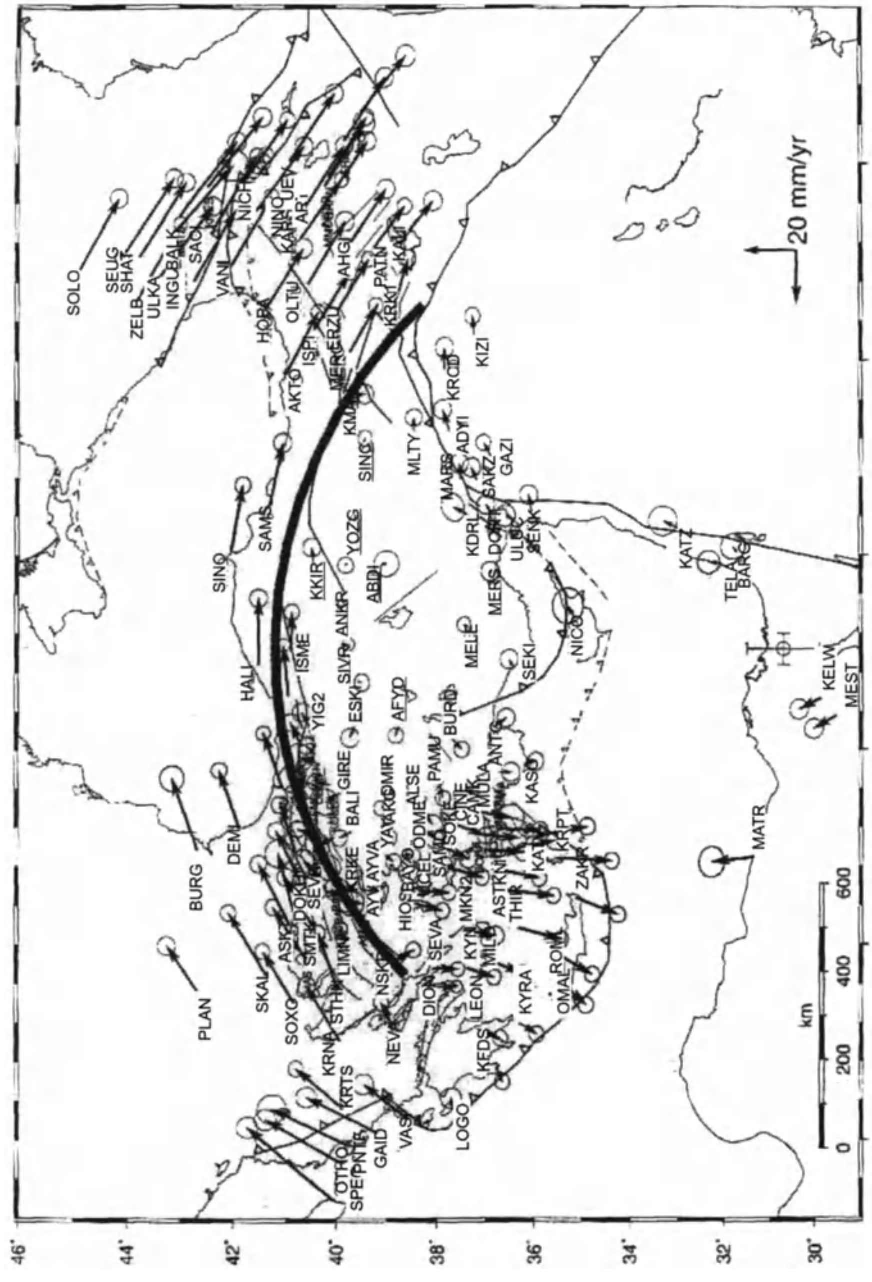

Fig. 3. The GPS vectors in the Anatolia and the Aegean region showing the present kinematics. (After McClusky et al. 2000)

Laser Ranging) measurements (Le Pichon et al. 1995; Reilinger et al. 1997) which indicate clearly that the Anatolian plate that is bounded by the north and east Anatolian fault zones is moving westward at a rate of about 20 mm/a. This motion makes a relatively sharp turn to SW around 30°N meridian. In western Turkey the motion has increased up to 40 mm/a due to the retreat of the Hellenic subduction.

The North Anatolian Fault (NAF) splays into two major branches before it enters into the Marmara region (Fig. 2) where it is buried under the waters of the Marmara Sea, and then appears again as a single trace in the Ganos-Saroz fault zone in the west. The southern branch is traced continuously to the eastern part of the Marmara Sea. From thereon, the fault splay is more complicated and does not extend as a single trace. Major strike-slip branches of the NAF are taken up by a zone of diffuse transtensional deformation. A number of subparallel, right-lateral strike-slip fault branches are formed in northwestern Anatolia. One of these fault branches trends toward the Edremit area (Fig. 2). Strike-slip motions, which prevail in the Marmara region according to field and seismic data (Barka 1992), are replaced by an oblique slip motion entering the Aegean Sea, where the Aegean extensional regime becomes dominant. Therefore, in this region, the oblique slip faults having major dip-slip motion coupled with strike-slip motion are common structural features (Taymaz et al. 1991). This region has strong background seismicity and major faults that have produced numerous earthquakes. Distribution of the earthquakes obtained from the historical data (Ergin et al. 1967) and from the United States Geological Survey (USGS) and National Earthquake Information Centre (NEIC) catalogues are displayed in Fig. 4 and tabulated in Table 1. The data, evaluated collectively, cover a 2000-year period and display clearly that the earthquakes are clustered along two tectonically most active zones. These are the Saroz bay and its western prolongation toward the North Aegean Trough in the north, and the western part of the Gulf of Edremit in the south (Fig. 2). Since geology and seismicity of these zones are detailed elsewhere (Taymaz et al. 1991; Yılmaz et al. 1999), they will not be repeated here again.

The conclusion of the seismological data may be summarized as follows. The city of Troia is situated within a tectonically active region, occurring between these two seismically most active fault zones of the region (Fig. 2). The city is surrounded by a number of active small faults; it is only about 50 km away from these two major fault systems. These major fault zones have produced many earthquakes greater than magnitude 6 in the past (Table 1). Periodicity of these big earthquakes may be estimated to be about 110 a. The earthquakes with a magnitude between 5 and 6 appear to have occurred in 25–30-year intervals. Any earthquake greater than magnitude

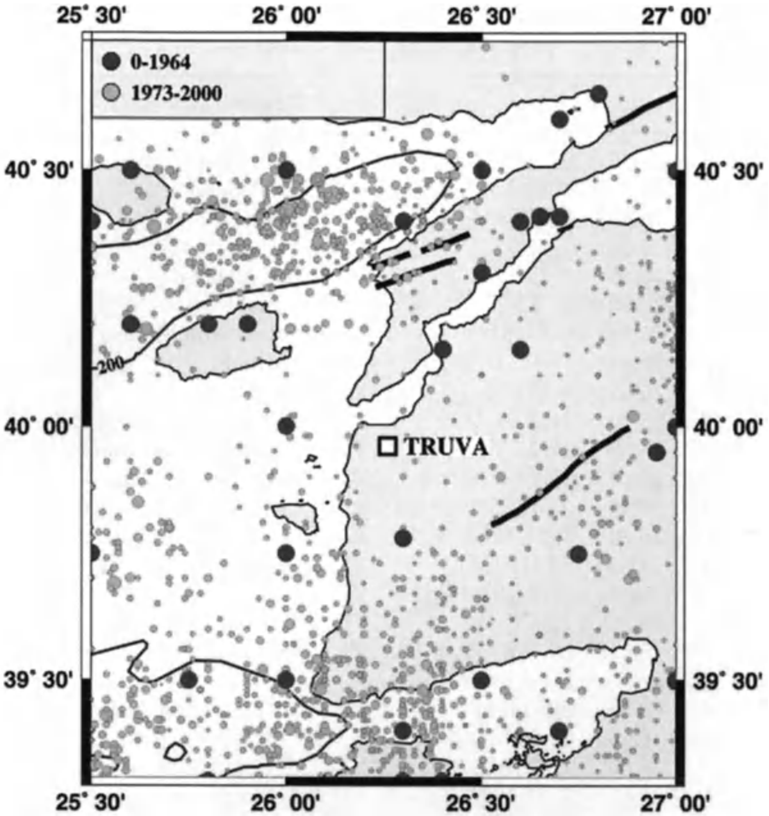

Fig. 4. Seismicity map of northwestern Anatolia and the surrounding regions (prepared by O. Tan and T. Taymaz). Data on the historical period are derived from Ergin et al. (1967), and for the instrumentally recorded earthquakes, from the Kandilli observatory (KOERI)

5 in and around these zones is assumed to have caused severe damage in the Troia area.

3
Morphology and Geology

Geology and morphology of the Biga Peninsula will be summarized from two regions, which are complimentary to one another, and both give a more complete history of the region. Firstly, the region north of the Gulf of Edremit will be described. In this region, the basement rocks and the early to middle Miocene units are exposed more extensively. Then the northern region surrounding the Çanakkale (Dardanelles) Strait will be presented.

Table 1. Major earthquakes recorded in the Troia and surrounding regions. (Data obtained from the catalogue prepared by Ergin et al. 1967)

No.	Lat.	Long.	Date	Io	Region
10	40.60	26.70	93	VI	Gelibolu peninsula
16	40.15	26.40	138	VI	Çanakkale
170	39.30	26.30	VIII-1384	VII	Lesbos
256	39.40	26.30	12-VI-1754	VI	Lesbos
264	40.15	26.40	2-XI-1762	VI	At Çanakkale
314	40.15	26.60	25-XI-1835	VI	Çanakkale
330	39.30	26.30	9-X-1845	VI	Lesbos and Manisa
334	40.41	26.65	19-IX-1846	VI	Gelibolu
336	40.41	26.65	4-VII-1847	VI	Gelibolu
364	40.20	25.80	21-VIII-1859	IX	Imroz
368	40.41	26.65	17/22-VIII-1860	VIII	Gelibolu, Chios and Edirne
381	40.30	26.50	10/14-VI-1864	VI	Gelibolu and Çanakkale
384	40.15	26.40	23-II-1865	VIII	Lesbos and Çanakkale Region
395	39.30	26.30	7-III-1867	VIII	Lesbos, Foca, Edremit and Ayvalik
396	40.41	26.65	20-III-1867	VI	Gelibolu
397	39.30	26.30	27/31-III-1867	VI	Edirne and Lesbos
398	39.30	26.30	22-VII-1867	VI	Lesbos
399	40.15	26.40	23-IV,17-V,30-VII, 5-VIII-1868	VI	Çanakkale
408	40.50	26.50	8-I-1870	VI	Vicinity of Saros Bay
419	40.41	26.65	11-X-1871	V	Gelibolu
425	40.30	26.50	13-XII-1872	VI	Gelibolu and Çanakkale
429	40.50	25.60	9-XI-1873	VII	Samotraki Island
439	40.15	26.40	III-1875	VII	Çanakkale
444	40.15	26.40	X-1875	VI	Çanakkale
453	40.15	26.40	25-X-1876	VI	Çanakkale
483	39.78	26.30	23-I-1884	VI	Ezine
511	39.30	26.30	III-1887	VI	Lesbos
529	39.30	26.30	13/15-VIII-1889	VI	Lesbos
530	39.30	26.30	13/25-X-1889	VII	Lesbos, Chios and Izmir
532	39.30	26.30	25-IV and 5-V-1890	VI	Lesbos
553	40.50	25.60	28-I-1893	VII	Samotraki Island
566	40.41	26.70	14-I-1895	V	Gelibolu and Edirne
652	40.15	26.40	IV-1910	V	Çanakkale
663	40.50	27.00	9-VIII-1912	X	Murefte, Sarkoy
675	39.30	26.40	1,17-V-1914	V	Lesbos
681	39.30	26.40	26-IV-1916	V	Lesbos
684	39.30	26.40	4-XII-1916	V	Lesbos Island
688	39.30	26.30	20-VIII-1917	VI	Lesbos
693	39.30	26.30	XI-1920	VI	Lesbos
729	40.65	26.80	3-V-1928	VII	Saroz Bay
761	39.50	26.00	12-VII-1931		
849	39.50	26.00	6-VII-1937	III[a]	Io: Thessaloniki

Table 1 (continued)

No.	Lat.	Long.	Date	Io	Region
887	39.95	26.95	1-I-1939	VI	Candarlı
1089	39.40	26.70	6-X-1944		Ayvalık
1090	39.40	26.70	6-X-1944	X	Edremit Bay and villages in
1091	39.40	26.70	7-X-1944		its vicinity
1135	40.20	25.60	12-IV-1947		Bayramiç
1136	40.20	25.60	12-IV-1947		
1277	39.30	25.80	8-VII-1950	VII[a]	Aegean Sea
1306	40.20	25.60	13-XII-1951	IV[a]	Aegean Sea Io: Lemnos
1309	40.20	25.60	3-II-1952	VI[a]	Aegean Sea Io: Samothrace
1379	39.50	27.00	9-VI-1953		West Turkey
1412	39.50	25.75	17-V-1954	V[a]	Aegean Sea. Felt at Dikili and Çanakkale. Io: Lesbos
1469	40.40	26.30	6-I-1956		Aegean Sea, east of Gallipolis Island. Io: Alexendropolis
1519	39.26	26.27	20-XI-1956	IV[a]	Aegean Sea Io: Lesbos
1596	40.00	27.00	11-X-1957		Northwestern Turkey
1616	39.75	25.50	24-I-1958	VI[a]	Aegean Sea
1735	40.00	26.00	22-IV-1959		Northern Aegean Sea
1848	40.50	26.00	9-III-1960		Northern Aegean Sea
1956	39.75	26.00	11-V-1961		Near the west coast of Turkey
1979	39.50	26.50	30-VII-1961	IV[a]	Aegean Sea Io: Lesbos
1980	40.00	27.00	1-VIII-1961		Northwest Turkey
1984	39.75	26.75	24-VIII-1961		Western Turkey
2011	40.20	25.90	28-XI-1961		Western Turkey
2054	40.40	25.50	29-IX-1962		Samotrake Island
2080	40.40	26.60	29-III-1963	VI	Turkey, Io: Lapseki and Ayvacık

[a] Earthquakes epicentered in the Aegean Sea.

In this latter area, late Neogene and younger rocks occur widely. In the southern areas the western Anatolian extensional regime is more prominent while in the north, the north Anatolian fault system plays a more dominating role.

In the development of the landscape and drainage system of the region, tectonic control is evident. Some major morphological features and distinct lineaments draw attention. Among those, the approximately ENE–WSW trending Saroz bay in the north and gulf of Edremit in the south are very prominent (Fig. 2). They are joined by an approximately north–south trending rather straight fault-bound Aegean shoreline (Fig. 1). The Çanakkale (Dardanelles) Strait, which is situated between the two major sea depressions, is a zigzagging shallow seaway bounded by linear and steep cliffs.

On the land there are also distinct morphological entities, such as the Kazdağ and Ezine highs intervened by the Bayramiç depression (Fig. 1). They correspond to horst and graben structures. Toward these the gulf of Edremit as the widest graben depression trends obliquely (Fig. 1). The linear coastlines are commonly fault-bounded.

The Edremit graben is one of the largest ENE–WSW trending grabens of western Anatolia (Fig. 1). It is about 80 km long and enlarges westward from about 5 km to more than 30 km. The graben is asymmetrical. The topography along the southern margin is subdued, forming many bays and inlets. The northern margin is bounded by a linear mountain front, which elevates to Kazdağ Mountain, over 1100 m. In the eastern part of the northern margin, there is a big, steep cliff along the coastline corresponding to a clear fault scarp (Fig. 5), which is commonly well exposed. Various drainage patterns on the down-slope side of the fault such as beheading, misaligned paired stream channels indicate important left lateral offset along the fault.

To the west of Küçükkuyu the topography along the western part of the northern margin of the Gulf of Edremit is more subdued. Big, steep cliffs are rare. The faults are oblique to the coastline, making narrow angles. At the intersection of these valleys with the coastline small alluvial fans have developed. A trellis drainage pattern with roughly parallel strike streams has been produced due mainly to multiple fault strands, shutter ridges and the associated back-tilting (Fig. 5). Rapid vertical movement along the faults are also evident in the central part, where elevated marine terraces and beaches occur, lying about 80–100 m above sea level between Küçükkuyu and Behram (Fig. 1). Paton (1992) identified lithophage borings about 2 km west of Behram, which were uplifted to the height of 8 m above the sea.

The topography on the different slopes of the Kazdağ; Mountain is distinctly asymmetrical. It is steep in the south, but relatively smooth along the northern slope, where there are E–W trending, north-dipping (>60°) normal faults (Figs. 1 and 5). On the steep southern slope fluvially eroded landscapes have not yet fully formed. Headward erosion along the stream valleys across both slopes of Kazdağ Mountain, particularly in the southern slope is in a very incipient stage. No major, deeply incised valleys have formed to drain the smoothly north-dipping plateau, which is over 350 m above the sea, into the gulf, because the major linear mountain front of the Kazdağ Mountain and the terraces at the top have been slightly back-tilted to the north (Fig. 5). Therefore, the Kazdağ Mountain forms a barrier in front of the southerly directed drainage preventing it from reaching the gulf in the shortest distance possible (Fig. 5). As a result, the drainage is diverted northward toward the Aegean Sea, and along this direction the main rivers, the Karamenderes and Tuzla Rivers follow courses more than 40 and 25 km, respectively, before reaching the sea (Fig. 5).

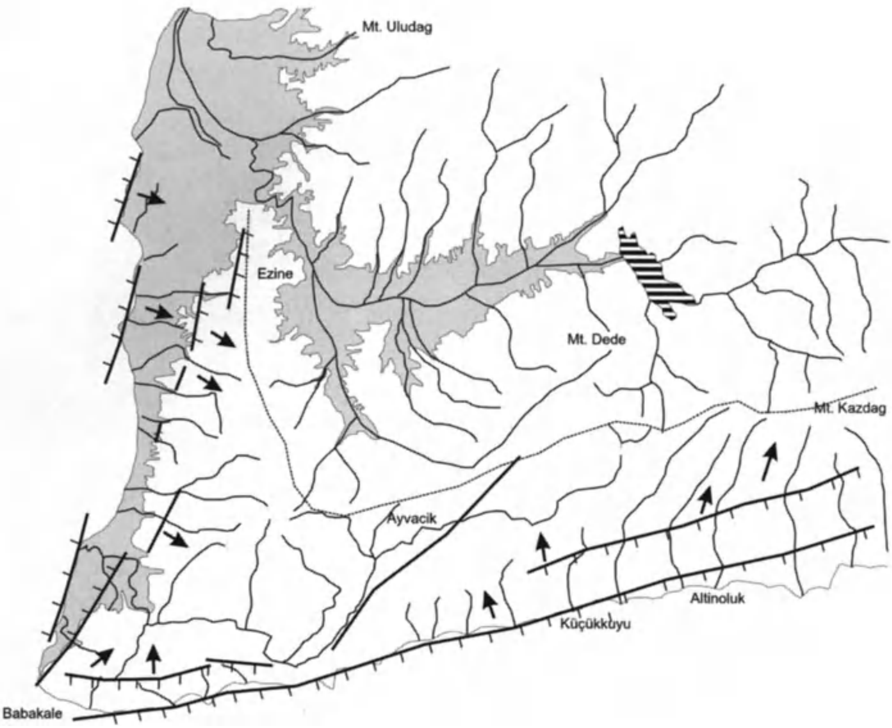

Fig. 5. Map showing drainage pattern and major fault zone in the western part of the Biga Peninsula. The *arrows* indicate the tilting direction of the fault blocks. The *hatched areas* indicate downthrown side of faults. The *dotted thin line* is the water divide

At the top of the Kazdağ Mountain remnants of a flattop plateau representing a severe phase of erosion are recognized (Erol 1992). On the northern slope, near the top, a cuesta is visible due to modest north tilting of this erosional surface. The remnants of this surface can also be recognized as small buttes at the top of the fault-bounded blocks in the northern part of the mountain range. Due to the back-tilting in the west and the south, the Menderes River makes a sharp turn as it is forced to flow northward and reaches the sea in the Troia region (Fig. 5). The present morphotectonics of the area is displayed in the simplified block diagram (Fig. 6). Continuous uplift of the Kazdağ with an approximately 2 mm/a concomitant erosion increasingly supply alluvial materials transported to the sea. This appears to be an important reason for the rapid growth of the alluvial plain which fills the Troia area, causing its progressive dissection from the sea.

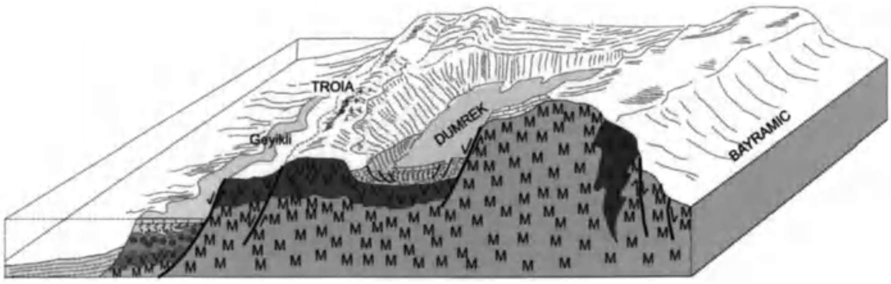

Fig. 6. Schematic block diagram showing major morphotectonic features of the Troia area and the surroundings

4 Stratigraphy

The stratigraphy of the region will be documented below from the horsts and grabens separately, because they have rather different successions.

4.1 The Ezine and Kazdağ Horsts

The two horsts share many similar geological features. The stratigraphic sequences in the horsts are displayed in Fig. 7. At the base of the sequence, metamorphic rocks of Paleozoic to Triassic ages are exposed (Bingöl et al. 1973; Okay et al. 1990; Öngen 1994; Genç and Yılmaz 1995; Yılmaz 1997; Karacık and Yılmaz 1998).

Plutonic rocks were emplaced into the metamorphic rocks during the late Oligocene–early Miocene period, i.e., the Karaköy-Evciler and Kestanbol plutons (Fig. 1). They are dated by the Rb/Sr method at 25 ± 0.2 Ma (Birkle and Satır 1995) and 28 ± 0.88 Ma (Fytikas et al. 1976), respectively. The plutons are elliptical with long axes lying in NNE–SSW directions as revealed by the map pattern of the contact metamorphic aureoles (Fig. 1). The plutons were emplaced using the faults and fractures trending NE or NNE, formed under an approximately ENE–WSW extension. There are close temporal and spatial associations of the plutonic and surrounding hypabyssal rocks, which in turn, are also intermingled with the surrounding volcanic rocks of Lower Miocene in age, the Ayvacık and Balabanlı volcanics (Fig. 1).

The lowermost rocks of the cover succession form a sedimentary sequence, the Küçükkuyu formation, represented by alternating shale, siltstone and sandstone. The shales dominate the sequence. This unit was ap-

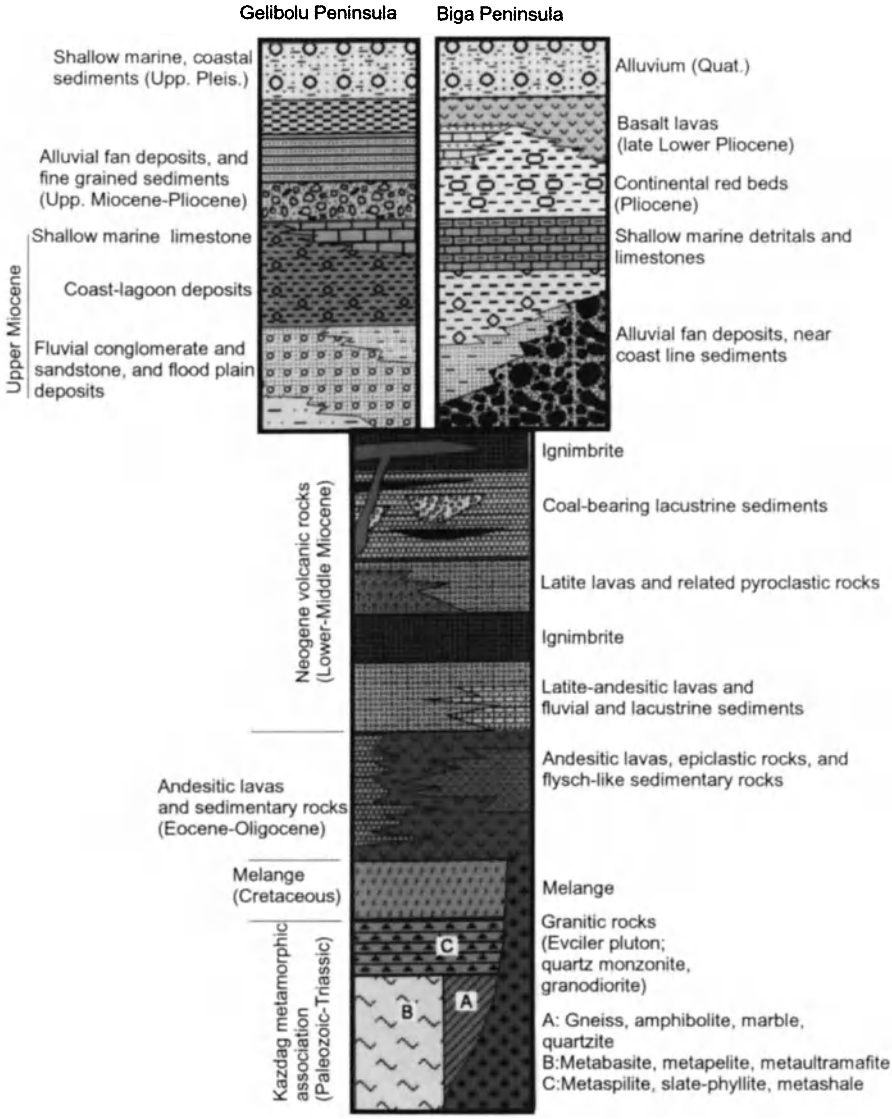

Fig. 7. Generalized stratigraphic sections for the Gelibolu and Biga peninsulas displaying the rock units around the Troia area

parently deposited in a low-energy lacustrine environment (Siyako et al. 1989). However, due to the flysch-like nature, it may be regarded as a unit deposited on a smoothly inclined slope (Fig. 8). According to the sporomorph association obtained from the shales, the Küçükkuyu formation is dated by İnci (1984) as the Lower Miocene. Above this, volcanic rocks, mostly pyroclastic beds, occur within the sequence. To the northwest of Kazdağ near the Kızılyar village the sequence begins with internally chaotic, red-colored coarse conglomerates. They were deposited in front of a NNW–SSE trending, closely (<1 km) spaced, en echelon oblique slip-fault zone, which had lateral slip and dip-slip components. The sediments are debris flow and lateral fan deposits, derived from the fault-elevated blocks. The conglomerate passes laterally and vertically into beige sandstones and gray shales, interfingered with the volcanic rocks.

The sequences in which the volcanic rocks dominate are known as the Ayvacık volcanics, which consist mainly of intermediate lavas and pyroclastic rocks. The petrological and field characteristics of these volcanic rocks are elaborated by Karacık and Yılmaz (1998) and Genç (1998). The lavas were formed close to the axis of the horsts. They are replaced gradually by lahars and pyroclastic flow deposits and pyroclastic fall deposits away from the axes of culminations (Fig. 8). The pyroclastic units were graded depending on their proximity to the volcanoes. This distribution pattern may be inferred to indicate that the NE trending volcanoes were developed above the plutons from the faults and cracks, formed in association with the granite emplacement. The pyroclastic and the epiclastic deposits are more voluminous in the southern areas (the Balabanlı volcanics) than in the northern areas (the Ayvacık volcanics). However, they interfinger on every scale.

The sediments intercalated with the Ayvacık volcanics are paleontologically dated, based on the Eskihisar sporomorph association as the late Burdigalian-early Serravallian in age (Ediger 1988; Benda and Meulenkamp 1979). This is in agreement with the K/Ar ages, obtained from the intermediate lavas, which range from 15.9 ± 0.4 to 21.5 Ma. (Borsi et al. 1972; Ercan et al. 1995). The Lower–Middle Miocene successions were deformed by folds and faults and later uplifted and eroded, prior to the deposition of the Upper Miocene units.

4.2 The Etili Graben

Deposition of the Upper Miocene rocks was restricted to the graben basins. They rest on top of the Küçükkuyu formation and/or the Ayvacık volcanics over a surface of unconformity. The Upper Miocene sediments are delimited commonly by NE–SW trending faults (Fig. 1).

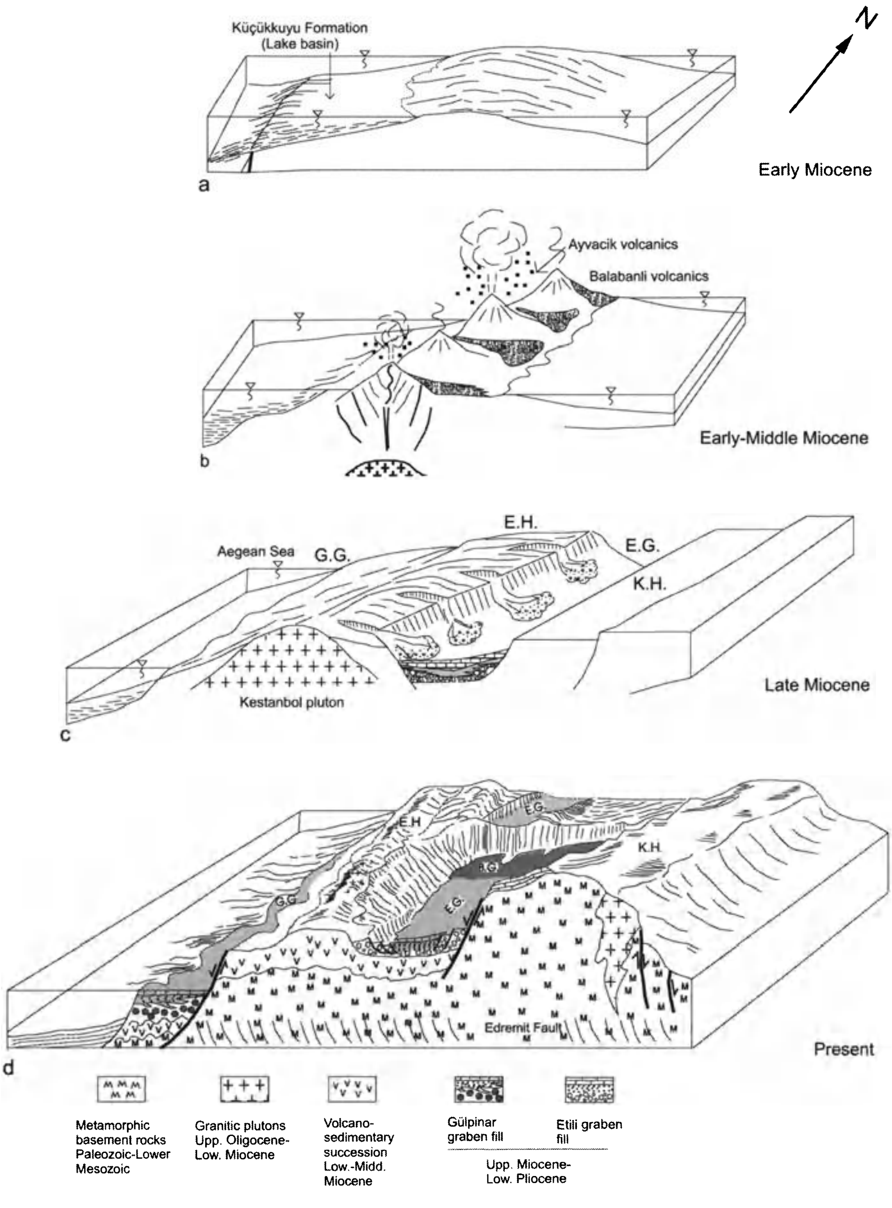

Fig. 8a–d. Schematic block diagrams showing consecutive stages of morphotectonic evolution of the western part of the Biga Peninsula from Early Miocene to the present. The Edremit fault represents the northern boundary of the Edremit graben. *GG* Gülpınar graben, *EH* Ezine horst, *EG* Etili graben, *BG* Bayramiç graben, *KH* Kazdağ horst

At the base of the sequence are thick, brown to red-colored, coarse conglomerates lying in front of the upthrown blocks. They are internally chaotic, and were formed as debris flow and fanglomerates. Away from the fault zone the conglomerates give way to fine-grained clastics, which in turn, are gradually replaced by white, medium to thickly bedded, clayey limestones having, in places, abundant fresh water gastropoda-rich fauna. Only a few scattered alkaline basalt lavas, dated at 9–3 Ma (Yılmaz 1997), are observed to be interbedded with the fine to coarse clastic rocks of the graben.

At higher levels in the sequence the lacustrine limestone overlap the upthrown blocks of the faults. The overlying succession may be traced southward toward the top of the Kazdağ Mountain. This suggests that during this period the Kazdağ Mountain was not yet elevated to the present position. The western boundary of the Etili graben is the Ezine horst. The Upper Miocene lacustrine succession is delimited by this elevation.

4.3
The Gülpınar Graben

This graben separated from the Ezine horst by the Gülpınar fault zone (Fig. 1), along which the Ezine high rises to over 300 m. The graben fill rests unconformably on the Ayvacık volcanics beginning with a 30–40 m thick conglomerate, followed by a sandstone-siltstone alternation (Fig. 7). They pass upwards into a 20–30 m thick, gently west-dipping, white limestone sequence. The western boundary of this unit is buried under the Aegean Sea. The succession at the base is represented by lacustrine facies sediments, which is replaced gradually by shallow marine units. Şamilgil (1966), Ozansoy (1973), Tekkaya (1973) and Kaya (1982) listed the following fauna from the limestones: *Pecten praebenedictus, Pecten pseudo-beudanti, Ostrea fibriata, Ostrea aff. edulis, Ostrea aff. Gryphoides*, which yield the Upper Miocene–Lower Pliocene age range. The facial and faunal characteristics reveal that the limestones represent a transitional environment of deposition, between marine and lake environment.

4.4
The Edremit, Bayramiç and Saroz Grabens

Three seismic sequences are clearly distinguished in the grabens. The lower and the middle units correspond to the Lower-Middle Miocene and the Upper Miocene-Lower Pliocene successions. Only the upper unit consisting generally of poorly consolidated clastics belongs to the present graben deposition. They are fan deposits and fluvial deposits, originating from the hills in the footwall. The age of the graben fill is not precisely dated. However, it may be estimated using the comparative stratigraphic data as the post Early Pliocene.

The small stream valleys across the northwestern slope of Kazdağ carry a huge amount of material into the Bayramiç graben. Large pebbles and boulders have accumulated along the southern edge of the graben as more than 50 m thick, unconsolidated or poorly consolidated conglomerates. Large clast size and poor sorting indicate proximity to the source revealing that a high rate of erosion from the Kazdağ high on either side of the horst has occurred only recently. The clasts are predominantly of metamorphic origin. Among the pebbles are also clasts of the Upper Miocene–Lower Pliocene limestones.

The geology and structural map of the region to the north of Troia is displayed in Fig. 9. On the map a fairly complicated fault pattern can be seen. Most of the faults have been formed after the Early Pliocene period as evidenced by the following data; the faults cut and postdate the Upper Miocene–Lower Pliocene limestones, cropping out at the plateau regions on both sides of the Çanakkale Strait. Two sets of oblique faults control the present zigzagging pattern of the Çanakkale Strait, causing abrupt changes in the trends of the strait. These faults are mostly transtensional in character, having strike-slip coupled commonly with dip-slip components. The straits were formed under these transtensional deformational forces. A number of normal-listric faults have been formed on both sides of the Çanakkale Strait, on the fault-elevated blocks which supply clastic materials on the downthrown blocks commonly as lateral fan deposits or debris flows.

The major fault sets are coeval, because they cut and offset one another and their development is compatible with a north–south extensional, east–west compressional deformation pattern. The consequent structural features have formed under an ongoing simple shear.

The rock sequence of this region is described in some detail by Önal (1986), Yazman (1996) and Yaltırak et al. (1998) and is summarized in Figs. 7 and 10.

As seen in Fig. 10, a gradual transition from a lake to a shallow sea occurred from the east to west through a lagoonal environment during the latest middle to late Miocene period. The sea gradually invaded the present coastal region during the late Miocene-early Pliocene period. The coastal environment is seen to have been established during Pleistocene-Holocene as evidenced by the presence of beach sands.

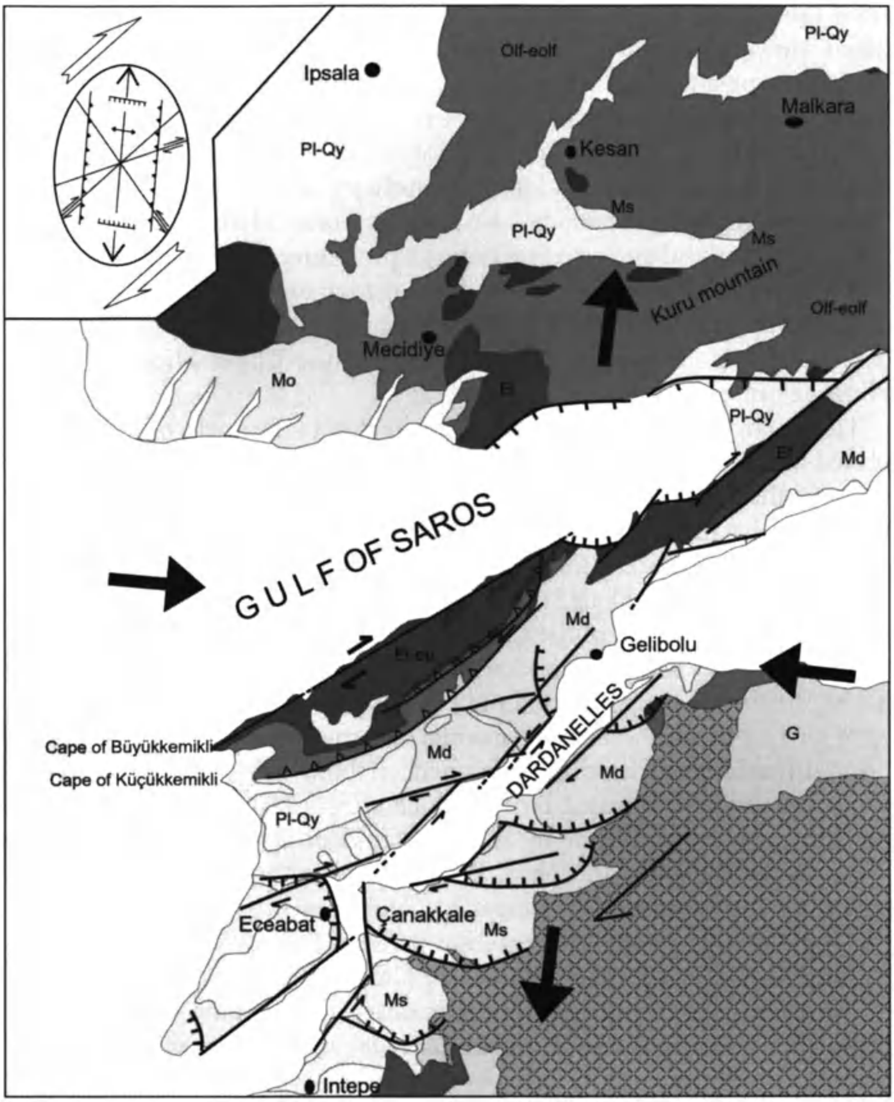

Fig. 9. Geology and structural map of the region around the Çanakkale strait. *Arrows* indicate compression and extension directions. The *inset* shows the deformation ellipsoid for a simple shear under which the region has deformed deformation

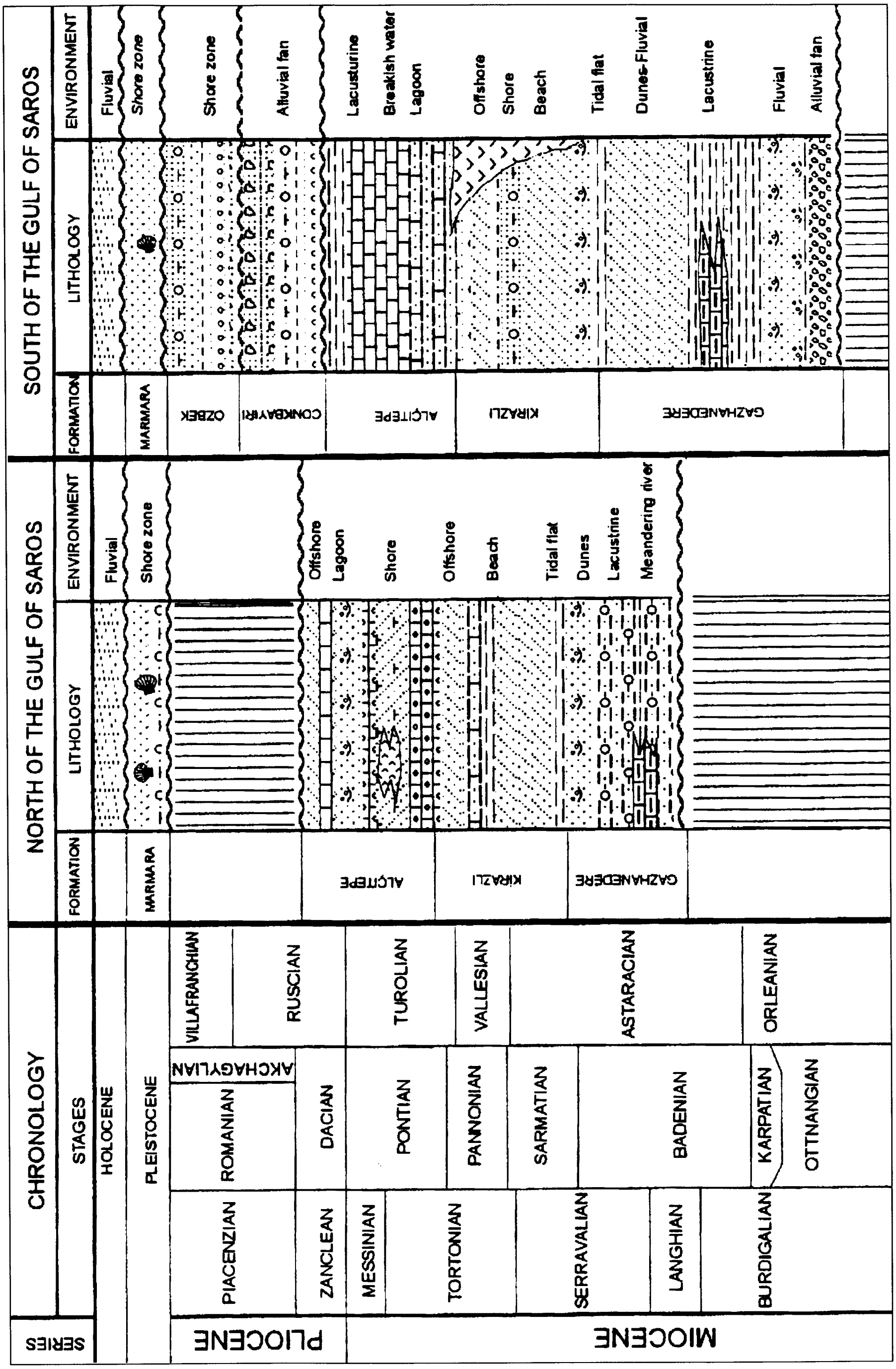

Fig. 10. Generalized stratigraphic sections for both sides of the gulf of Saroz. (After Yaltırak et al., 1998)

5 Discussion and Conclusions

When evaluated collectively, the rock sequences from the south to the north of the region studied, as illustrated in Figs. 7 and 10, suggest the following geological evolution (Fig. 8). During early Miocene, the western part of the Biga Peninsula was represented by a continental environment, covered by interconnecting lakes. Within the lake basins low energy lacustrine sediments, dominated by shales were deposited. A severe volcanic activity began during the early Miocene. The volcanoes were aligned along the north–northeast trending extensional faults. The volcanic alignment formed hill-like barriers and divided the lake basins. The pyroclastic rocks were transported away from the volcanoes and interbedded with the lake deposits. Widespread coal seams and beds of Neogene basins formed within these lakes.

The volcanic activity waned with the beginning of middle Miocene and the region was smoothened erosionally. This was followed by new tectonic activity. During this phase north–northeast trending major horsts, namely, the Kazdağ Mountains and the Ezine horst, began to elevate for the first time. Bounded by the transtensional oblique faults, the Etili graben and Gülpınar graben, intervened by the horsts, began to form as cross-grabens. Development of these basins are elaborated in Yılmaz et al. (2000) and Yılmaz and Karacık (2001).

These structural highs and lows were considerably obliterated after the early Pliocene time during a severe phase of denudation, and consequently a region-wide erosional surface was developed above all the units up to and including the Upper Miocene-Lower Pliocene lacustrine limestones. This erosional surface may be viewed as a peneplain, because a lateral transition from the continental deposits formed on the land toward the marine sediments within the present Aegean Sea, is generally gradational, which suggests a smooth topographical passage across the coastal zone.

The present elevation of the Kazdağ postdates this erosional phase. Remnants of the erosional surface are seen at the top of the Kazdağ Mountain, and the depositional equivalent of this uplifting is seen along the adjacent depressions as unconsolidated, poorly sorted coarse clastics accumulated rapidly above the Upper Miocene-Pliocene lake sediments (Yılmaz and Karacık 2001). The Kazdağ has been uplifted between the east–west-trending oblique fault system having major strike-slip motion coupled with considerable dip-slip component. These younger fault sets have formed under the influence of the North Anatolian Transform Fault zone, which is known to have dispersed within a large region in the Biga Peninsula (Yılmaz et al. 2000; Yılmaz and Karacık 2001; Güney et al. 2002).

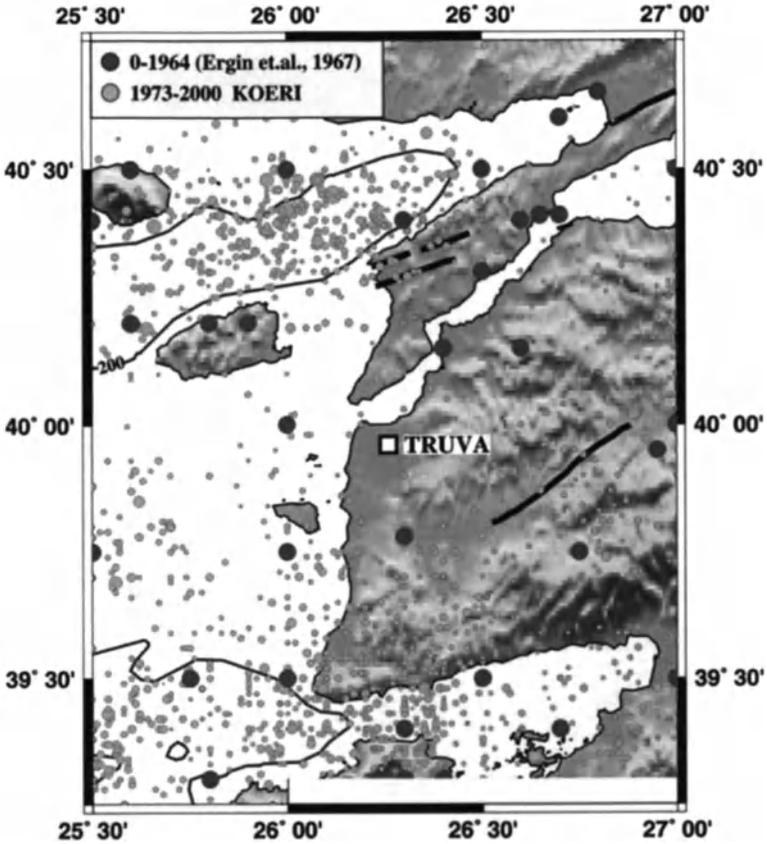

Fig. 11. Morphological map of the Troia area and surroundings

The north–northeast-trending Etili graben is also cut and bounded by a set of east–west-trending oblique faults which divert the trend of the basin to the east–west, and this newly developed asymmetrical basin formed at the western tip of the Etili graben is known as the Bayramiç graben.

The morphotectonic position of the Troia area, formed during the latest stage of the tectonic development of the region, is illustrated in Figs. 6 and 11.

The back-tilting due to the E–W and N–S striking faulting which controlled the drainage pattern, diverted the trends of the major rivers to the north and thus a large alluvial plain formed at the north of the Menderes river. The continuous uplift of the Kazdağ under the on-going transtensional regime supplies increasingly larger amount of materials into the alluvial plain.

Acknowledgements. I extend my sincere thanks to Prof. Dr. Tuncay Taymaz and Mr. Onur Tan for providing Figs. 4 and 11.

Chapter 6

The Link Between the Black Sea and the Mediterranean since the End of the Last Ice Age: Archaeology and Geology

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Abstract

To understand Troia's role as a "trading city between two continents and seas" one needs to look at the connection between the Mediterranean and the Black Sea, from both a geological and archaeological point of view.

In this contribution recent geological changes of this link are discussed. The new hypothesis of a catastrophic flooding of the Black Sea around 5500 B.C. has not been accepted by most authors working in the area. From 3000 B.C. onward, navigable passages, currents, and winds are similar to the present conditions. Archaeological evidence shows that contacts actually existed during the Bronze Age.

1 Introduction

In their popular science book, *Noah's Flood* (Ryan and Pitman 1998), the two American marine geologists, William Ryan and Walter Pitman, describe how the Black Sea, in their opinion, was an inland sea which was not connected to the Mediterranean until the close of the sixth millennium B.C.[1] Not until then, they maintain, did the post-glacial rise of world ocean sea-levels reach the level of the threshold in the Bosphorus. Since the water level in the Black Sea basin at that time was nearly 100 m lower than it is today, the waters of the Mediterranean would have, they claim, overflowed into this basin. The catastrophic flood thus caused would have inundated an area covering 100,000 km^2 and driven out the people living on this land. The catastrophe would have had profound consequences for the prehistory of Europe, and indeed for large parts of the ancient world. The biblical tradition of the Flood would reflect these dramatic events.

[1] B.C./A.D. are calendar years before Christ and after Christ. B.P. means years Before Present. ^{14}C dates have been calibrated with OxCal v2.18, calibration data Intcal98. With marine samples from the Black Sea 460 years have been subtracted to compensate for the reservoir effect (following Jones and Gagnon 1994).

However, according to the traditional view (e.g., Ross et al. 1970; Stanley and Blanpied 1980), the water level of the Mediterranean had reached the height of the threshold in the Bosphorus by about 9000 B.P. (ca. 8250 B.C.). The water level of the inland lake contained in the Black Sea basin was at that time roughly the same. A gradual exchange of water between the Mediterranean and the Black Sea began. Salt water, which is denser and, therefore, heavier than freshwater, began to sink down to the seafloor. From about 7000 B.P. (ca. 5980–5800 B.C.) anoxic conditions developed in the basin (Deuser and Ross 1974; Jones and Gagnon 1994). Starting on the bottom of the basin, then spreading to the sides, sapropel (a jelly-like ooze with >2% organic carbon by weight) began to build up.

Once formed, the connection was apparently never again severed since the sea level of the Mediterranean continued to rise. Other connections than the Bosphorus, such as the route via the Gulf of Izmit, the Sapanca Gölü and the Sakarya river valley, cannot be completely ruled out. Even a temporary closure of the waterway through the Bosphorus as recently as only a few millennia ago has been discussed (Özdoğan 1998: Fig. 3).

The link between the Sea of Marmara and the Mediterranean was formed earlier, since the Dardanelles are deeper than the Bosphorus.

As archaeologists we have been reminded by Ryan and Pitman's volume that history is not set on an immovable stage, but in a dynamic, variable environment. Working in Troia, a "Trading city between two continents and seas" (Korfmann 1995b), we must be attentive to recent geological changes between the Mediterranean and the Black Sea. Since the two geologists mentioned have extensively dealt with archaeology, I hope I shall be forgiven if I, in my turn, look into geology. In the present case, the conclusions reached are new and controversial, as even a cursory glance into publications on the subject reveals. To form an opinion, even the nonspecialist in the field must, therefore, return to the data and the line of reasoning behind the scenario provided by the interpretation.

To evaluate to what extent Troia was affected by geological changes between the Mediterranean and the Black Sea, we must answer the following questions:

Since when has a link existed between the Mediterranean and the Black Sea? Did it come into being as a gradual change in conditions, or as a sudden, catastrophic flood? Has the link changed over the course of time, or was it obstructed again? What were other effects of these changes; how, for instance, have winds and currents changed? What did these geological events mean for the people who lived in the area; were the consequences as dramatic as Ryan and Pitman (1998) claim?

2 Geology

2.1 The Black Sea

The Mediterranean, the Sea of Marmara and the Black Sea form three basins separated from one another by underwater thresholds in the Dardanelles and in the Bosphorus. During the last glacial period (Last Glacial Maximum, LGM, ca. 18,000 B.P.), the water level of the world's oceans had dropped so far, due to the trapping of large volumes of water in ice, that these basins were separated from one another by land bridges. That is undisputed – the question is, however, exactly when and in what manner the link which exists today came into being.

The Black Sea with the Sea of Asov, but not including the Sea of Marmara, covers an area of about 460,000 km^2. The water volume is about 530,000 km^3. Its greatest depth is more than 2210 m. Especially along the western and northern shores it has a broad shelf. A distinctive feature of the Black Sea basin is that, 100–200 m below the surface, circulation and inflow of freshwater cease entirely. From this depth, there is virtually no oxygen; hydrogen sulphide content is high; plant and animal life cannot be sustained. The entire floor of the Black Sea is covered with sapropel.

All authors agree that today more low-salinity surface water flows through the Bosphorus and the Dardanelles from the Black Sea into the Mediterranean than, conversely, high-salinity (and, therefore, heavier) deep water flows from the Mediterranean back into the Black Sea. Figures on the hydrologic balance, however, differ greatly (e.g., Degens and Ross 1974; Jopp and Hanle 1971: 446; Hanle 1973: 458). An acceptable estimate gives the following result:

$$\text{Freshwater inflow} + \text{precipitation-evaporation} \approx 400 + 155 - 385 \approx 170\ km^3.$$

The outflow of surplus water from the basins of the Black Sea and the Sea of Marmara into the Mediterranean creates currents which, together with the prevailing winds, force sailing vessels to stop at the Dardanelles during voyages from the Mediterranean into the Black Sea. Troia could owe its role as a trading port to these conditions (Korfmann 1995b).

Just how stable are these conditions? For the current to come to a complete standstill, freshwater inflow from rivers and precipitation would have to be reduced by half or, conversely, evaporation would have to double. This could only happen if major climate changes took place in the Black Sea catchment. However, during the Holocene, precipitation in Anatolia, for instance, has not differed by more than 15 % from the present volume (most recently: Bryson and Bryson 1999).

From Greco-Roman antiquity there is evidence that wind and current conditions were similar to those prevailing at present. Even in the second millennium B.C. there is no evidence for large-scale climate change across the continent. These observations do not, therefore, suggest that conditions were different during the Troia VI and VII periods (Neumann 1991). Results of marine science studies confirm this. The countercurrent and conditions similar to those prevailing today emerged from about 7200–7000 B.P. (ca. 6000 B.C.) in the Dardanelles (Lane-Serff et al. 1997; Aksu et al. 1999: 299) and by 4000 B.P. (ca. 2500 B.C.) at the latest in the Bosphorus (Çağatay et al. 2000).

The hypothesis that the Black Sea was suddenly flooded by a great volume of water from the Mediterranean is based on the premise that the water level of the Black Sea was substantially lower than that of the Mediterranean at the time of the conjectured flood. However, that cannot be accepted as a matter of course since more, rather than less, water inflow than today must be estimated for the end of the last Ice Age, due to the melting of glaciers and the Scandinavian-Baltic ice sheet. Later, the early Holocene was not completely arid. It seems more plausible that the inland lake in the Black Sea had reached the level of the Bosphorus earlier than the Mediterranean and that freshwater at first flowed out into the Sea of Marmara. Later, the direction of the flow reversed when sea levels in the Sea of Marmara and the Black Sea gradually rose the remaining 35 m from the floor of the Bosphorus to present day levels, approximately concurrent with world oceans.

Ryan et al. (1997) do not deal with this problem at all, yet in their later volume (Ryan and Pitman 1998: 159–163) they elaborate on the subject. They maintain that the first meltwater runoff at the close of the last Ice Age (from ca. 12,500 B.C.) led to the inflow of a large volume of freshwater via the rivers and the depression between the Caspian and the Black Sea so that the basin was filled up. The surplus water flowed off through the Bosphorus into the Mediterranean. A second meltwater runoff (from about 9400 B.C.), however, would not have reached the Black Sea since a periglacial bulge formed by isostatic uplift diverted the water from the Scandinavian-Baltic ice sheet into the North Sea – and this happened after the switch to subarctic cold occurred during the Younger Dryas. Hence, the lake would have dried up so that its water level at the time of the flood would have been about 100 m below the present sea level.

Runoff from the water trapped in the Baltic glacial lake must indeed have caused the Black Sea waters to rise quickly to very high levels. Even if the changed European watersheds later reduced the volume of water in the upper reaches of the Ukrainian and Russian rivers, they nonetheless did not entirely dry up (Kalicki 1995). Moreover, quite a volume of water still reached the Black Sea by way of the Danube and other rivers. The regional effects of the switch to subarctic cold during the Younger Dryas are not entirely understood; however, they definitely did not lead to extreme aridity or desertification in most of the Black Sea catchment area. During the early Holocene, a rather dry steppe flora may have prevailed along the northwestern shores of the Black Sea until ca. 5000 B.C. (Atanassova and Bozilova 1992), but this certainly did not affect the entire catchment area of the rivers.

One can conduct a thought experiment in which one imagines the Bosphorus closed off by a barrier and the Black Sea drained dry. Then, under present conditions, it would take about 2600 years for the basin to fill up to sea level through freshwater inflow alone. The top 100 m would, however, take only 200 years to fill up. To bring this freshwater surplus to a halt, one would have to reduce the present freshwater inflow by half, or to cut off the inflow of ca. 200 km^3/year (Jopp and Hanle 1971) from the river Danube completely. Consequently, one would predict a slowing down, or at most a slight reversal in the post-glacial sea level rise, but not a return to Ice Age lowstands during the early Holocene.

Unfortunately, direct observations of coastal changes and sea-level curves constructed from them pose problems (for a discussion see, for instance, Pirazzoli 1991, 1996; Williams et al. 1998: 107–122; Cronin 1999: 287–408). Sea level – defined as perpendicular to the earth's gravitational field – is anything but level. At any point in time and space it is influenced by numerous factors changing at different rates. For this reason, the observable, "relative" sea level can reach different heights in different places at the same time, or the height of an ancient coastline as observed today can have changed since it was formed.

A compilation of a dozen sea-level curves from different parts of the Black Sea (from Pirazolli 1991: plates 26, 27; 1996: Fig. 68) shows considerable regional differences. Nothing else can be expected for an area of such diverse tectonic composition which is as large as the Black Sea. There also seem to be both methodological and dating problems in some cases. Therefore, a summary curve for the entire Black Sea can only be approximate. Nevertheless, some facts are clearly visible (Fig. 1).

During the maximum extent of the last Ice Age about 18,000 B.P. (LGM; Last Glacial Maximum), the Black Sea was a lake with no outlet whose shores were 100–150 m below the present sea level. In the north and west there were large alluvial and loess plains cut by deep river gorges (Pirazolli 1996: 71–74). After that there was a rise in the water level from –110 m (17,000 B.P.) to –45 m (12,000 B.P.). Until about 10,000 B.P. the water level re-

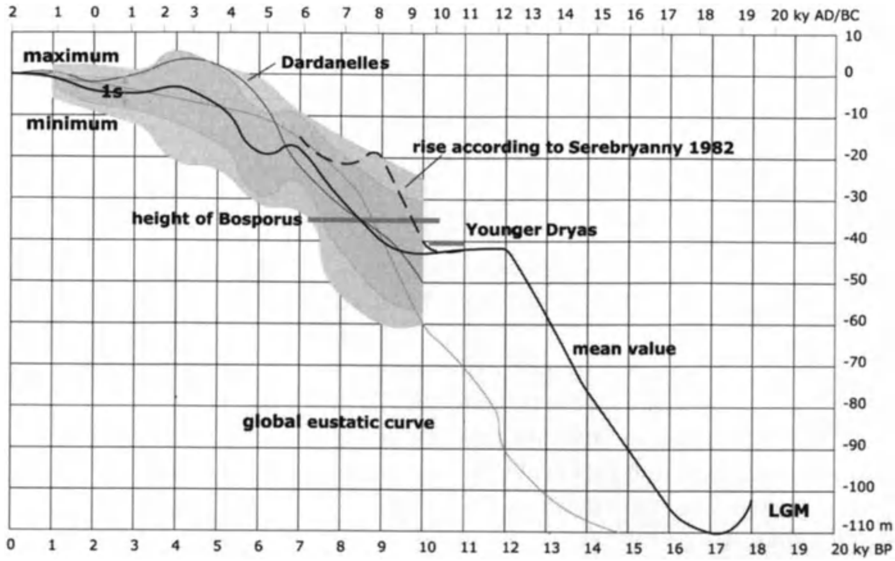

Fig. 1. Relative sea-level curve for the Black Sea during the past 20,000 years. From 10,000 B.P., mean of 12 individual curves (Pirazolli 1991: pl. 26, 27), 10,000–18,000 B.P. curve by Serebrianny 1982 (Pirazolli 1996: Fig. 68). In addition, a regional curve at the Dardanelles (Kraft et al. 1982; Kayan 1995) and a global eustatic curve are shown. (Fairbanks 1989)

mained constant and then rose again to about –20 m until 9000 or 7000 B.P. Until 6000 B.P. it stayed at this level, only to rise once again and to fluctuate within a few metres of the present level. There may possibly have been a slight regression from 6000 B.P., (Pirazolli 1991: 99–104; 1996: 92). All these figures are approximate averages of several regional relative sea-level curves. Actual conditions may have been different in parts of the basin, and a rather large error margin must be allowed for (as shown in Fig. 1).

As to be expected for a comparatively small basin the rise at the end of the Ice Age was both earlier and more rapid than in the world oceans. This is partly due to the rapid melting of glaciers in the Alps (Wohlfarth 1993) and in the Caucasus. The noticeable levelling off, possibly even a slight drop, at –40 m (9000–12,000 B.P.), is due to drought and cessation of glacier melt during the Younger Dryas. It probably also indicates that, at least at the beginning of this period, surplus water ran off into the Sea of Marmara. After the rise to –20 m between about 9000 and 8000 B.P., the water level of the Sea of Marmara also reached the threshold of the Bosphorus and a permanent outflow of the Black Sea into the Mediterranean was established. After that fluctuations follow the sea level of the oceans. The wider range is due to strong deviation between individual curves. Local fluctuations of about 10–20 m are possible. The possibility that the connection with the Mediterranean was once again cut off can, however, be ruled out.

Dated archaeological sites, which are presently under water, give the maximum sea level for the time when they were formed. The Bulgarian coasts seem to have tilted to the south in the Holocene: sites in the Dobrudsha dated ca. 4000 B.C. are today on dry land, in Lake Varna at –3 to –4 m and near Sozopol at about -6 m below the water surface (Draganov 1995: 225, 233-235, 239). The Early Bronze Age settlement (3000–2800 B.C.) in Urdoviza Bay at Kiten is today covered by 8–10 m of water (Porožanov 1991; Görsdorf and Bojadžiev 1996: 157f.; Kuniholm et al. 1998). No submerged archaeological finds or settlements dating to the period before the supposed flooding of the basin have been found.

The youngest sediments in the Black Sea can be divided into three units (Ross et al. 1970; Jones and Gagnon 1994; Ryan et al. 1997):

1. In the basin mud, on the shelf ooze (New Black Sea, Holocene III).
2. In the basin and on the shelf sapropel (Old Black Sea, Holocene II).
3c. On the shelf, on the surface of 3, an erosion surface with fragmented freshwater molluscs.
3b. On the shelf gravel, beneath it strata of sand and clay with intact freshwater molluscs (Neoeuxine, Holocene I).
3a. On the shelf alluvium (Würm II).
In the basin unit 3 consists entirely of mud and clay strata with silt and sand. The erosion surface (unit 3c) is visible as a seismic unconformity (Ryan et al. 1997: 121). River valleys, terraces, loess, alluvium and littoral deposits at depths from –93 to –122 m (unit 3a) are dated from 17,780 ± 200 – 9660 ± 70 B.P. and, therefore, indicate the size of the Ice Age freshwater lake (Ryan et al. 1997: 121). The shore of the lake has been found on the south coast of the Black Sea near Sinop at a depth of –155 m (Ballard et al. 2000).

Sapropel covers the basin floor and slopes up to depths of about 150–200 m evenly. Its deposition began synchronously at all depths and is not limited to the conditions of anoxia which do not prevail in depths of less than 200 m (Jones and Gagnon 1974). Ryan et al. (1997: 124) assume that the depositing of sapropel set in at the same time as the appearance of the marine molluscs. They maintain that an indication of this is the lack of sedimentation on the outer edge of the shelf from the period between ca. 9500 and 7150 B.P. Other writers are of the opinion that sapropel formation did not set in until 1500–2000 years after the Mediterranean and the Black Sea had been connected, since saline deep water and conditions of anoxia developed only gradually (e.g., Jones and Gagnol 1994: 552–554). Neither salt-water nor marine organisms could have reached the Black Sea before, since a surplus of outflowing freshwater prevented a flow in the opposite direction (Aksu et al. 1999: 298 f.; Lane-Serff et al. 1997 imply a rapid flushing of the freshwater reservoir by Mediterranean water). The end of sapropel deposition (boundary between units 1 and 2) is dated to 315 ± 60 A.D. and 770 ± 160 B.C. (Jones and Gagnol 1994: 548, Fig. 7). Whether sapropel is a product of anoxia, or of increased primary productivity, is the subject of an ongoing debate.

Freshwater molluscs occur in unit 3 (Neoeuxine). The species also occur in river deltas and in the less saline parts of the Sea of Asov and the Caspian Sea (Ryan et al. 1997: 121). Fragmented molluscs in the gravel strata in unit 3c date from 8250 ± 35 B.P. and earlier (Ryan et al. 1997: 121 give no details on precise places and depths). From unit 3b there are readings of freshwater molluscs of the species *Dreissenia rostriformis* ranging from 14,700 ± 65 to 10,400 ± 55 B.P. Freshwater molluscs of late date, some of them from great depths, have been reported (Ballard et al. 2000, Table 5; IFREMER 2000;). However, the question is whether some of them at least may have come from sediment which slid down to the edge of the shelf. Deposits of this kind (turbidites) occur in unit 3. Typically, Ballard et al. (2000: 259) have been able to recover freshwater molluscs (from 15,550 B.P.), marine molluscs (from 6820 B.P.) and remains of wood (3580 B.P. and later) "from the same dredge holes" at depths of –140 to –170 m. Therefore, primary, not resedimented contexts cannot always be assumed.

Marine molluscs first appear at the base of the sapropel (unit 2). The species are also known from the Mediterranean (Ryan et al. 1997: 121). Radiocarbon dating of these molluscs from water depths between –49 and –123 m results in an age of 7150 ± 100 B.P. (5780 – 5470 B.C.; Ryan et al. 1997: 123). This tallies approximately with the readings of 5590 ± 130 B.C. (Jones and Gagnol 1994: 550, Fig. 7) from depths of –200 to –2200 m and with dates on the south coast of the Black Sea (Ballard et al. 2000).

The transition from freshwater to marine mollusc species took place about 7000 B.P. However, sites and depth readings in which dated molluscs were found cannot simply be used to reconstruct ancient shorelines. Moreover, fresh or brackish coastal environments, today at depths of –20 to –30 m, existed even after the link with the Mediterranean was formed. When this water passage was formed can, therefore, not simply be inferred from the age of the most recent freshwater molluscs.

Other data confirm a change from freshwater to brackish or marine conditions around 7000 B.P. However, not until 3000 B.P. had marine conditions been fully established everywhere in the Black Sea (Ryan et al. 1997: Fig. 3).

2.2 The Bosphorus

Today, the Bosphorus (the Strait of Istanbul) is 31.7 km long and at least 600 m across. Maximum and minimum depths are about 92 and 40 m (Hanle 1973: 86).

As a result of a net outflow of surface water from the Black Sea, and an inflow of saline deep water from the Sea of Marmara, there is a strong surface current from the Black Sea and a deep current flowing in the opposite direction.

The region around the Bosphorus (see Gökasan et al. 1997) rose by about 200 m from the Miocene on into the Quaternary. Along the Bosphorus there are still active fault lines. Through tectonic forces the channel broke into where it is today and received its present formation through erosion and sedimentation. During the Pleistocene the watershed ran to the north of the Bosphorus. From there a small river flowed into the Black Sea basin. In the south a depression formed, which was alternately a brackish lagoon and a bay of the Sea (or lake) of Marmara. Finally, at the end of the last Ice Age, the water level of the Black Sea rose until it was above the watershed.

Drillings have shown a sequence of marine and freshwater sediment deposits. The oldest marine sediment at the entrance to the Golden Horn is dated to about 5400 ± 1300 B.C. (Gökasan et al. 1997: 190). In the middle of the Bosphorus the oldest marine mollusc (*Ostrea*) has been dated to 5340 ± 125 B.P. Afterwards, there is a continuous sequence of marine deposits (Çağatay et al. 2000).

Older marine sediments in the Bosphorus could have been washed away by erosion. An earlier passage, which must have existed before this time as numerous data for marine conditions in the Black Sea show, could also have run somewhere else (Çağatay et al. 2000: 204). One possible connection lies to the east along the Sapanca Gölü and the Sakarya River. A water passage through the Sakarya Valley existed earlier during the Pleistocene (several contributions in Meriç 1995). Mehmet Özdoğan (1985a, 1998, 1999a) seems to be the only author to have suggested this link between the Black Sea and the Sea of Marmara and a temporary closure of the Bosphorus for the time until about 4000 B.C. Considering the dating of marine sediments in the Bosphorus and other data from the Sea of Marmara and the Black Sea, this seems impossible.

2.3 The Sea of Marmara, the Dardanelles, and the Aegean

The Sea of Marmara covers an area of 11,500 km^2. Its maximum depth is 1355 m. It is roughly 200 km (W-E) long and 80 km (N-S) wide (Hanle 1973: 257). The Dardanelles (the Straits of Çanakkale) are about 65 km long and at least 1.3 km wide. Near Çanakkale the minimal depth is about 65 m (Aksu et al. 1999: 295). The volume of low-salinity surface water flowing from the Sea of Marmara into the Aegean is 587 km^3/year and, conversely, about 381 km^3/year saline deep water flows from the Aegean into the Sea of Marmara. The net outflow is, as in the case of the Bosphorus, ca. 200 km^3/year (Hanle 1973: 108).

The sediment consists of marine deposits (unit 1) with 1–2 sapropel strata and below them sediment from a freshwater lake with fauna similar to the neo-euxinian Black Sea (unit 2; Çagatay et al. 2000). A mixed stratum between the units dates to ca. 12,000 B.P. The lower sapropel was deposited between ca. 10,600 and 6400 B.P. and may indicate an outflow of freshwater from the Black Sea basin (Çagatay et al. 2000). Further sapropel (sapropel S1) deposits formed between 9600 and 6400 B.P. in the Aegean (Aksu et al. 1999: 297).

In the western part of the Marmara basin there are shorelines of the Ice Age freshwater lake at –90 m (Ergin et al. 1997). By about 11,000 B.P. the water level of the Aegean had reached the level of the Dardanelles; salt water flowed into the Sea of Marmara so that from then on its water level rose synchronously with that of the Aegean (Aksu et al. 1999). Between about 9500 and 7000 B.P. there again could have been a unilateral flow towards the Aegean, carrying with it surplus freshwater from the Black Sea. Not until after that the saline deep current began to flow from the Aegean into the Black Sea. Ancient sources and climatic indicators suggest that, after this change took place, current and wind conditions similar to those prevailing today set in at the Dardanelles (Neumann 1991; see Sect. 2.1).

There were probably further fluctuations as a result of regional uplift and subsidence of coasts. South of the island of Avşa there is a submerged Bronze Age site (third to second millennium B.C.; Özdoğan 1999b: map 2).

At the Dardanelles the sea level was –50 m at about 10,000 B.P., it rose to today's level by 6000 B.P. and since then has only fluctuated by about 2 m (Pirazolli 1991: plate 25; ; Kraft et al. 1982; Kayan 1995). Locally drawn sea-level curves tally quite well with predictions from model calculations (Lambeck 1996: Fig. 4). The silting up of the bay at the mouth of the Scamander at Troia was due to a loss of energy and accelerated sedimentation at the river delta, not to a drop in sea level (Kraft et al. 1982).

2.4 Conclusions

The hypothesis that the Black Sea was suddenly flooded has been rejected by Aksu et al. 1999, and Çağatay et al. 2000, and very cautiously adopted by Uchupi and Ross 2000. Arguments in favour of a flood ca. 5600 B.C. are (Fig. 2):

- the first appearance of marine organisms and the onset of sapropel formation occur simultaneously with the formation of a waterway between the Black Sea and the Mediterranean.
- The marine organisms at the base of the sapropel are of the same date at all depths; sapropel is present at all depths.
- Transgressive or sediment deposits showing progress with coastal overlap from the period between 9500–7100 B.P. do not occur on chirp sonar images of the Black Sea shelf.
- The cold fluctuation of the Younger Dryas and dry conditions afterwards caused the Black Sea to dry up in 7100 B.P. to a depth of –100 m.

Evidence against this hypothesis is:

- Relative sea-level curves in the Black Sea and the Dardanelles and the eustatic rise of the oceans indicate that a threshold level in the Bosphorus as well as a high water level in the Black Sea had already been reached by ca. 8000–9000 B.P. (ca. 6500–8200 B.C.).
- From considerations based on the modern hydrologic balance and past climate it seems unlikely that the water level in the Black Sea could have dropped to Ice-Age lowstands ca. 5600 B.C.
- There is circumstantial evidence of a strong outflow of surplus freshwater from the Black Sea and the Sea of Marmara in the direction of the Aegean from ca. 10,000–5300 B.C. based on letting this light-weight water cause a density stratification for sapropel sedimentation.
- Since surplus freshwater flowed out of the Black Sea, some time must have elapsed after the connection with the Mediterranean was established before the first marine organisms appeared and sapropel began to form.
- The dating of freshwater and marine molluscs gives the time when freshwater fauna was replaced by marine fauna, but not necessarily the date of a flood event and the water level implied for this event.
- Archaeological data in favour of the flood hypothesis (submerged finds from the time before the supposed flooding) are still missing in spite of extensive searches (Ballard et al. 2000; contrary to what the title of their paper suggests).

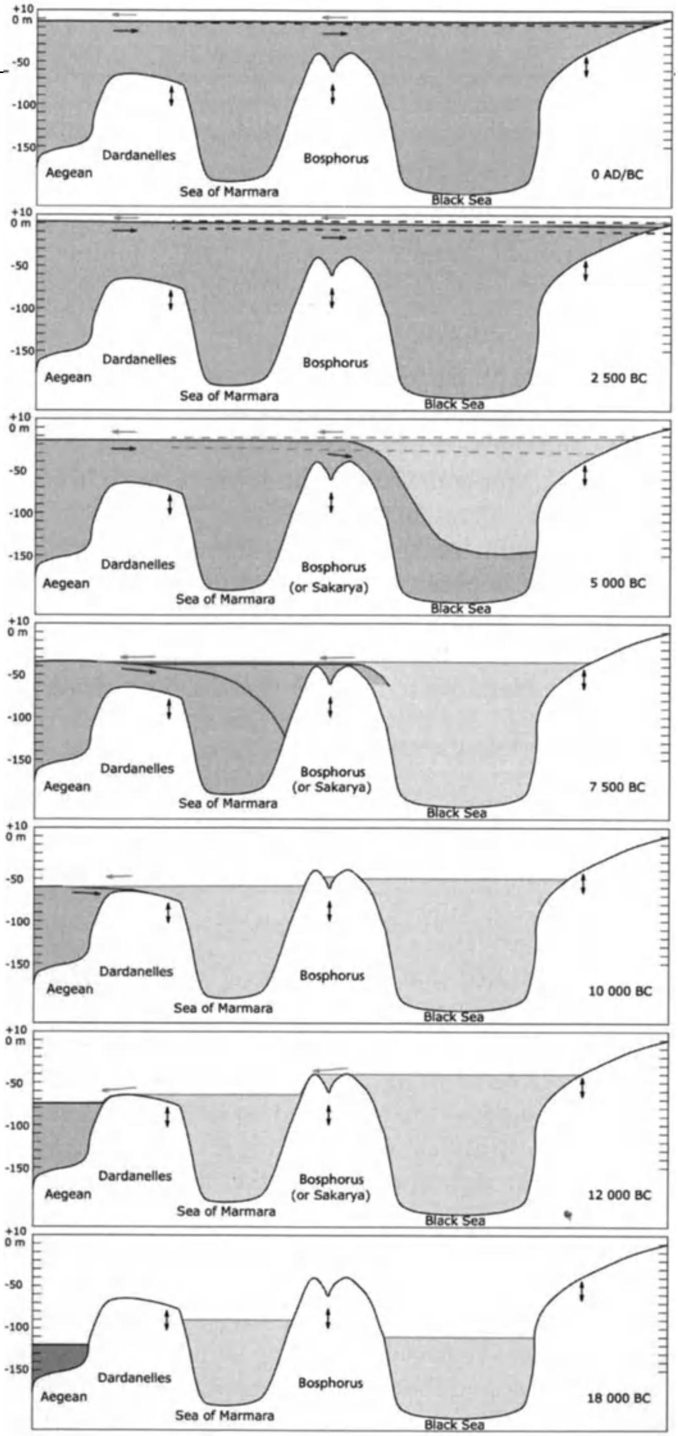

Fig. 2. Proposed scenario for the development of the connection between the Mediterranean and the Black Sea since the end of the last Ice Age. All dates and heights approximate. See text for details and sources

Undoubtedly, an impressive body of data on the recent history of the Black Sea have been assembled by Ryan et al. (1997). However, a sudden catastrophic flooding of the Black Sea basin is not the only possible interpretation of this data. Global and regional sea level curves seemingly contradict the hypothesis, no traces of the event have been found in other data, e.g., the archaeological record from the Black Sea; and from considerations based on hydrological balance, or climate history, it seems unlikely that necessary requirements for the event (a water level of –150 m at ca. 5500 B.C. in the Black Sea Basin) can be met.

Instead, with other authors (Aksu et al. 1999; Çağatay et al. 2000), I find a modified traditional scenario as shown in Fig. 2 to be most likely. This can only be regarded as an attempt made by a nonspecialist to form and express an opinion in a field where even experts do not agree.

During the last Ice Age, the Aegean had sunk to approx. –120 m. The Dardanelles represented a barrier which lay high above sea level. On the other side was the Sea of Marmara, an inland lake with a water level at approx. –90 m. The Bosphorus, too, was a land bridge. The Black Sea was an inland lake with a water level at –100 to –150 m.

By about 12,000 B.C. the freshwater lake in the Marmara basin had reached the level of the Dardanelles (–65 m); the water level in the Black Sea basin had reached the level of the Bosphorus. The cause of the rise in water level was the incipient melting of the Scandinavian-Baltic ice sheet and Alpine glaciers. Freshwater flowed out of the Black Sea basin into the Marmara basin and from there into the Aegean.

Somewhat later an exchange of water between the Mediterranean and the Sea of Marmara began. Approximately 10,000 B.C., due to aridity and a decrease in the meltwater runoff during the Younger Dryas, the Black Sea may have sunk once again, to below the level of the Bosphorus threshold, but not lower than approx. –50 m.

By ca. 7500 B.C. the water level in the Aegean and the Sea of Marmara had reached the level of the Bosphorus sill. The water level in the Black Sea basin could not have been much lower at that time simply because the hydrologic balance would still have been positive even if there was no increased inflow of meltwater from the north. That is confirmed by more than ten regional sea-level curves from various places round the Black Sea. Therefore, freshwater was once again flowing from the Black Sea basin so marine organisms could not yet invade the Black Sea basin.

Just about 5500 B.C. an exchange of water set in. The first Mediterranean marine molluscs migrated into the Black Sea; further indications of marine conditions appear. Sapropel formation began. Until ca. 1000 B.C. Black Sea waters were still partly brackish. Local fluctuations in the water level of the Black Sea of up to 10 m were still possible during the past 5000 years. At the latest by about 2500 B.C. the present two-way-current had become established.

3
Archaeological Evidence for Contacts Between the Mediterranean and the Black Sea Region

Early contacts between the Mediterranean and the Black Sea region may have been routed as follows (Fig. 3):

1. Overland from the northern Aegean via the Vardar (Axios) and Struma (Strimon) Valleys to the Balkans.
2. Overland from the northeast corner of the Aegean via the Maritsa (Meriç, Evros) Valley and Thrace.
3. By water through the Dardanelles and from the Tekirdağ area overland to the north.
4. By water through the Dardanelles and the Bosphorus.
5. From the Mediterranean coast through Anatolia; from the Levant coast through Anatolia to the Black Sea or via the Caucasus; from the Levant coast through northern Syria and via the Caucasus.
   The situation of Troia and the Troad is, to say the least, favourable for routes 2–4; for 3 and 4 it is of decisive strategic importance.

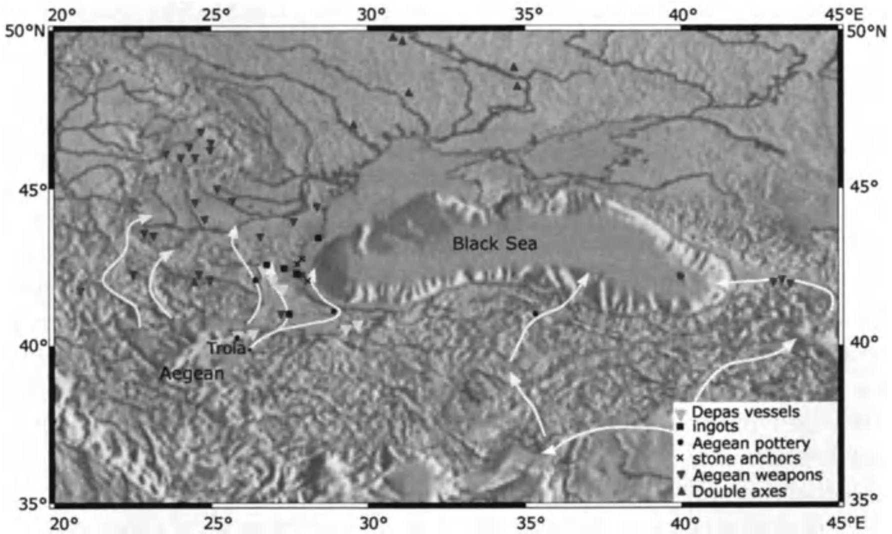

Fig. 3. Archaeological evidence for Bronze Age contact between the Mediterranean and the Black Sea and possible routes. See text for details and sources

River valleys running north from the Aegean played an important role in the spread of the Neolithic. Relations between Thrace and the adjacent regions of Bulgaria were close. Overland links between Greece, Thrace and the neighbouring regions to the north seem to have been used. Ornaments made from the Mediterranean marine mollusc *Spondylus gaederops* appearing in Neolithic Europe after 6000 B.C. (most recently Müller 1997; Kalicz and Szénászky 2001) show that goods travelled along these routes. The people of the Neolithic Fikirtepe Culture may have skirted the coasts of the Sea of Marmara and the southwestern Black Sea region by ship. Neolithic sites and, in the Black Sea region, Eneolithic sites as well (until ca. 4000 B.C.) may be submerged today, or buried under recent sediments in the river deltas and have, therefore, not yet been discovered.

Not until the Bronze Age were sea levels and currents similar to what they are today. The Bosphorus was open. There may be several reasons why hardly any Bronze Age sites have been discovered in its vicinity until now. In the built-up and industrialised areas round Istanbul and on the Gulf of Izmit they may well have been destroyed before archaeologists could find them. Along the coasts they may be under water or covered with alluvium.

The "acropolis" of Kanlıgeçit near Kırklareli in Thrace (third millennium B.C.; Özdoğan 1999b) is a small-scale replica of the citadel of Troia. Diagnostic Early Bronze Age "Anatolian" pottery has been found to the north as far as Bulgaria (Spanos 1972: pl. 1). There are several cultural links in the third millennium B.C. between northwestern Anatolia, the Aegean, Thrace, Bulgaria and the southern Balkans (pottery, clay anchors, etc.; cf. Buchholz and Wagner 1987).

Moreover, it has been suggested that Early Bronze Age tin and lapis lazuli – materials which have been found in Troia – reached Anatolia and the Mediterranean from their region of origin in central Asia not only via Iran and Mesopotamia, but also via the steppe region and the Black Sea. However, some links in the chain which would confirm this conjecture are still missing.

In the second millennium B.C., finds which prove contacts between the Mediterranean and the Black Sea region are sparse yet they nevertheless do exist. At least some of these finds must have travelled by ship, as anchors and an object from the Black Sea region found on a shipwreck in the Mediterranean strongly suggest.

Stone anchors of Aegean type and Cretan copper ingots have been found in Bulgaria (Bouzek 1985; Buchholz 1987: 162). Double axes of the Aegean type occur at the mouth of the Danube and in southern Russia (Bouzek 1985: 45–47; Buchholz 1987: 287). Swords of Mycenaean type have been found in Bulgaria, Romania and in Georgia (but not on the Black Sea coast there; Bouzek 1985: 30–35; Lichardus et al. 2000: 179 f.). All these finds tend to be early – viewed from Troia, they must be dated to the Troia VI period.

Mycenaean pottery hardly occurs in the Black Sea region at all. No Mycenaean pottery has hitherto been found in the Marmara region. At the entrance to the Dardanelles there is Mycenaean pottery from Troia and from Bademlihüyük on Gökçeada (Haghios Floros Tepe/Imbros). Cypriot and other pottery from the second millennium B.C. has been found in Istanbul (Firatli 1978: 571–574). In Drama (southeast Bulgaria) there are evidently some sherds of Late Mycenaean pottery, possibly also "Trojan" pottery (Grey Minyan or Tan Ware; Lichardus et al. 2000: 155–157). The interpretation of signs on a clay spindle from Drama as Cretan Linear A script will have to await scholarly discussion (Lichardus et al. 2000: 160–162). A number of wheel-made vessels, which were probably imported from Anatolia, were found in Galabovo, Bulgaria (Özdoğan 1993: 158). The stirrup jar as well as other Aegean and Cypriot finds from Maşat Höyük and other Hittite sites could have reached Hittite territory by sea via Samsun (Buchholz 1987: 165; 1999: 78).

A hoard found in Kozman Deresi Mevkii (Şarköy, Tekirdağ) on the Sea of Marmara (twelfth century B.C.?) contains Aegean weapon types (daggers, spears, double axes) and a fragment of an oxhide ingot, the form in which copper was traded during the second millennium B.C. in the eastern Mediterranean (Harmankaya 1995).

Not just objects from the Mediterranean came into the Black Sea region – barter goods and cultural influences must also have travelled in the opposite direction. The first appearance of the horse in Troia VI, innovations in bridles for the horse which occur in the northern Pontic steppe region as well as in Mycenae (Parzinger 1998: 477) and bone arrowheads in Troia VII are indications of the influence from the Black Sea region on cultures in Anatolia and the Aegean. However, it is also possible that innovations associated with the horse and arms, which come from the steppes to the north and east of the Black Sea, reached Anatolia and the Mediterranean via the Caucasus and the Near East.

A stone sceptre of a type that occurs in Bulgaria and Romania was found in the Ulu Burun shipwreck (fourteenth century B.C.) off the Mediterranean coast of Turkey (Buchholz 1999).

In the Late Bronze Age, there are contacts between Troia VIIb, the northeastern Aegean and southern Bulgaria and the northern Pontic region (Lichardus et al. 1999). Finally, pottery with comparable Romanian and Bulgarian types (Bouzek 1985: 194–195) occurs in Troia VIIb$_2$.

With the founding of Greek colonies on the Black Sea coasts in the eighth century B.C., contact becomes regular and frequent. Trade is no longer restricted to a few, precious goods: in the Classical period, Athens also imported grain from the Black Sea.

The appearance of the alga *Emiliana huxleyi* in the Black Sea for the first time ca. 770 B.C. may be an indicator of the onset of regular shipping. This alga lives in the surface water of the Mediterranean and could hardly have succeeded in battling the strong current flowing from the Black Sea, but may have reached it in the wake of Greek ships (Ryan and Pitman 1998: 149–150).

Ancient sources record a trick which was used by mariners to take advantage of the strong currents in the Bosphorus and the Dardanelles. They were well aware that a strong current on the surface towards the Mediterranean made it difficult to travel to the Black Sea and that, on the other hand, the deep current flowed in the opposite direction. To counteract this effect, baskets filled with stones were let down on ropes from ships to dangle in the water. In this way ships were drawn towards the Black Sea by the deep current (Ryan and Pitman 1998: 58).

4
Further Thoughts on *Noah's Flood*

In his critique of *Noah's Flood* (Ryan and Pitman 1998), Mark Rose (1999) is right in asking: if someone told you that the biblical Flood took place in the Black Sea during the Neolithic and caused, among other things, the spread of agriculture in Europe after 6000 B.C., Indo-European migrations, the presence of fair-haired Bronze Age mummies in China in about 2000 B.C., and the emergence of the civilizations of both Egypt and Mesopotamia before 3000 B.C. – would you be inclined to believe all that? Facts are missing here which might support all these bold conjectures.

For the Neolithic on the Black Sea and in southeastern Europe there is no need to assume migrations from the Black Sea. Direct evidence for this has hitherto not come to light. Archaeological finds from greater depths of the Black Sea before the Bronze Age are not known. If there was a highly developed Neolithic culture on what is today the flooded shelf of the Black Sea, one wonders why no trace of it has been observed in the adjacent coastal areas. Accepted explanations for observed changes at the time before and after the conjectured flood are a spread from the Balkans of Neolithic cultures engaging in agriculture as well as a population growth due to this form of economy, and the adoption of the Neolithic life-style by neighbouring Mesolithic hunter and gatherer populations (cf. Bailey and Panayotov 1995; Levine et al. 1999; Price 2000).

There is no evidence at all that Neolithic populations had retreated to the coasts in the Black Sea region, driven by aridity from 6200–5800 B.C., or that agriculture was even invented there (Ryan and Pitman 1998: 167–194); on the contrary, the Neolithic was flourishing everywhere at this time in the Balkans and in Anatolia (cf. Özdoğan and Başgelen 1999), despite the end of settlement at Çatal Hüyük after 6500 B.C. Nor need we assume that the Neolithic itself first arose in the Black Sea basin since we can trace its entire development from Palestine over northern Syria and as far as southeast Anatolia. From there the Neolithic spread across Anatolia and Greece to the Balkans and by 6000 B.C. to the Adriatic coast and the western Mediterranean (Jacomet and Kreuz 1999: 284–287). The same holds for Iran and Transcaucasia.

The sea level rose in both the Mediterranean and the Black Sea even without a sudden flood from ca. 8000–5000 B.C. by approx. 1–2 cm/year. That led to a steady, gradual loss of space so that the transition to a way of life which could sustain a larger number of people through agriculture must certainly have been advantageous.

Flood myths have been handed down throughout the world, for instance by the Sumerians, in the Bible, by the ancient Greeks, the Persians, in Hinduism, in Buddhism, by the Tamils, in Japan, China, by the Celts, ancient Germanic tribes, the Finno-Ugric peoples and by the Indians of North, Central and South America (cf. index in Grimal 1967). Anyone who wishes to believe that myths have a real core may be fairly safe in assuming a collective memory of the rise in sea level that took place after the last Ice Age or else various memories of the countless catastrophic floods that occurred in so many places.

However, there is no convincing link of the particular Flood story associated in the Bible with Noah in person, with a particular flood in the Black Sea – if such an event ever took place. Leonard Woolley, for example, was looking for traces of the Flood mentioned both in the Bible and in the Mesopotamian epic of Gilgamesh in his excavations at Ur (southern Iraq), and not on the shores of the Black Sea.

Filtered through the media, speculation of this kind percolates to the public in the following form: American geologists prove that the Bible is right. It is above all American scientists who nowadays have to do battle against groups who want to have the Bible placed on an equal footing with the results of serious scientific study. Anyone who is unwilling to promote such tendencies should not choose to advance a line of reasoning consisting in a specious blend of geology and biblical tales.

CHAPTER 7

On the Oscillations of the Black Sea Level in the Holocene Period from an Archaeological Viewpoint

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Abstract

The author presents and discusses from an archaeological perspective the results of research on oscillations in the level of the Black Sea that have been carried out in the area of the former Soviet Union, Romania and Bulgaria. Controversies over the time of the first intrusion of salt water into the Black Sea depression are emphasized as well as the problem of the reliability of the chronological diagrams developed by Russian researchers. Archaeological data are then presented, which confirm the existence of the so-called Fedorov Transgression and justifies its more precise dating in the fourth millennium B.C.

1 Introduction

To a great extent, archaeological research shows that the cultural and historical development of the larger part of southeast Europe and northern Anatolia in prehistoric times was under the strong influence of the transformation of the Black Sea from the so-called New Euxinian freshwater lake to a basin of "semi-marine" water. A more precise chronological determination of this transformation, as well as the precise dating of the numerous oscillations of the water level which followed, should be one of the basic preconditions for the reconstruction of the natural environment and a comprehensive study of the cultural and historical development of this region. However, the identification of changes in sea level and consequential fluctuations of the coastline represent a complex undertaking. In most cases, traces of these changes could not be found in their primary positions due to the fact that they had been exposed to various disturbances, whose effects are very difficult to determine and calculate. For this reason, many disagreements among researchers continue regarding research methodology as well as the interpretation of collected data.

The following text will address the research on sea-level oscillations conducted in the east, north and west part of the Black Sea, i.e., the coasts of the former Soviet Union, Romania and Bulgaria. P.V. Fedorov, A. Chepalyga, A. Bolomey, A.B. Ostrovsky, K.K. Shilik as well as other researchers, whose work is not widely known in archaeological circles, conducted the studies. This paper will present the previously mentioned research, seeking to establish the extent to which they can be used in archaeological work. As part of this short, parallel analysis of research, possibilities will be considered for an interdisciplinary archaeological and archaeometric cooperation in this sphere.

2
Research on Oscillations of the Black Sea since 1977

The majority of the aforementioned research supports the opinion that today's Black Sea was an isolated lake at the time of the last glacial maximum (ca. 20,000–18,000 B.C.) with a water level approximately 110–120 m below that of today (Shilik 1997). The transformation of this freshwater lake into a "semi-marine" basin occurred in the early phases of the Holocene period as a consequence of the glacial eustatic increase in the world ocean. The increase of water in the Black Sea is generally seen as a continuous process including definite oscillations. According to the paper by A. Chepalyga in 1984, in which the results of Soviet research in this region were summarized, the first transgressive phase in the basin of today's Black Sea occurred during the late glacial period before 12,000–11,500 B.P. At that time, the water level reached a point 60 m lower than that of today. However, this transgression was not followed by salinity, which means that the increase of water was a consequence of the melting of ice from the Arctic and Caucasus region. The meltwater was carried by the Danube, Dniester, Bug, Dneper and Kuban rivers into the Black Sea. This transgression was followed by a water-level decrease of –80 to –85 m (Chepalyga 1984).

According to Chepalyga, the first transgression, followed by the appearance of the oldest sea fauna and a process of salinity, occurred at the beginning of the Holocene period. At that time, seawater from the Mediterranean entered the Black Sea depression via the Bosphorus channel, reaching a level of –45 m. This intrusion of salt water is indicated by the emergence of sea snails (*Cerastoderma lamarcki*, *Chione galline* and *Spisula subtuncata*), which was confirmed in the area of Pitsunda on the east cost of the Black Sea (Abchasia). Russian researchers cite a great number of radiocarbon dates that ensure a relatively precise dating of that phase in the period between 10,350 ± 190 B.P. and 10,130 ± 180 B.P. (10,950–9,050 B.C. cal. according to Stuiver et al. 1993). During the subsequent regression, the water level fell from –55 to –70 m (Fig. 1).

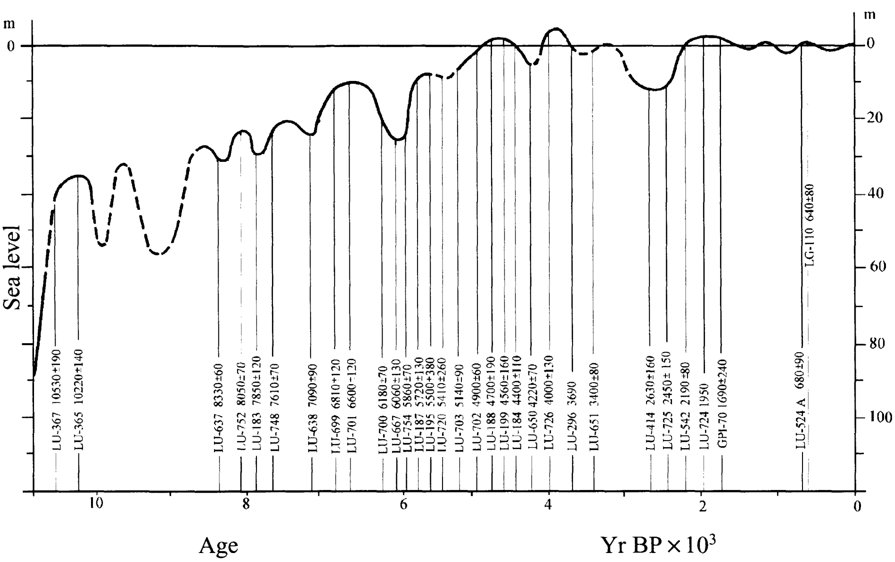

Fig. 1. Fluctuations in the level of the Black Sea during the Holocene. (After Chepalyga 1984)

However, this early intrusion of salt water into the Black Sea depression remains problematic, since the majority of studies outside the former Soviet Union do not register it at all, although G.A. Jones and A.R. Gagnon place the establishment of links between the Black Sea and the Mediterranean at roughly the same time (ca. 9800 B.P.). However, according to Jones and Gagnon (1994), freshwater overflowed from the Black Sea through the Bosphorus channel into the Mediterranean and not vice versa. A similar conclusion was drawn by Aksu et al. (1999). According to these authors, the overflow of freshwater into the Mediterranean occurred around 9500 B.P. The two-way flow and the intrusion of salt water into the Black Sea basin were placed at 7150 B.P. by Aksu et al. (1999). Chepalyga himself compromises in his conclusion by leaving the possibility open that during the subsequent regression, after the presumed earlier intrusion of salt water, the establishment of a closed freshwater lake is quite possible (Chepalyga 1984).

Consequently, it can be accepted that the earliest links between the Black Sea and the Mediterranean with the world ocean were indeed established at the beginning of the Holocene period, as presented in Russian sources. However, there are no further confirmations of the alleged early inflow of salt water into the Black Sea depression, but rather the potential case of a freshwater intrusion towards the Mediterranean. The early emergence of sea snails on the east coast of the Black Sea, backed by a large series of radiocarbon dates, remains a problematic fact that is very difficult to explain.

In 1983, the Romanian archaeobotanist A. Bolomey mentioned one strong and fairly early transgression that occurred before the sixth millennium B.C., as early as the Boreal period, with a water level 5 m above the present-day level (Bolomey 1983). At the time of that transgression, the region from the Danube delta to Braila, the whole of Dobrudža and the lower Danube to its tributaries the Vedea and the Jantra must have been submerged. Bolomey supports this assumption with archaeological evidence, whereby the absence of early Neolithic sites in the flooded region represents a determining argument. During the fifth millennium B.C., the reverse process took place, since at that time the settlements of Dudeşti, Hamangia and other late Neolithic cultures could have been located closer to the present-day Danube bank. This hypothesis by Bolomey can be connected to the most recent research conducted by the American geologists W. Ryan and W. Pitman (1998). According to them, the abrupt overflow of salt water through the Bosphorus channel into the Black Sea basin happened in the middle of the sixth millennium B.C., leading to extensive floods, which the authors interpret as the flood described in the Bible. Accordingly, this mythological and perhaps historical event that could turn out to be the oldest mentioned in written sources was for the first time located in the Black Sea.

Bolomey's thesis about an early transgression, which exceeded the present-day water level, as well as the Ryan and Pitman's placement of "Noah's Flood" in the sixth millennium B.C. do not have convincing support from either archaeological or geological material. The permanent alternation of transgressive and regressive phases during the Holocene period makes the existence of a flood of Biblical proportions credible. At the same time, however, it hinders the possibility of a precise determination and dating of this event. Floods of greater or lesser proportions were obviously common occurrences in the Black Sea basin during the Neolithic period as well as in later periods of prehistory. Hence, the question as to which of these phenomena could have been the flood described in the Bible remains unanswered.

According to the results of Russian research, the fluctuation of transgressive and regressive phases was especially intense during the first 3500 years after the establishment of the first link between the Black Sea and the world ocean. In this period, a relatively rapid increase in water level – an average of 5 mm/year – was recorded. As a result of this process, in 8050 B.P. (ca. 7300 B.C. cal. according to Stuiver et al. 1993) the water level increased by 18 m, which means ca. 20 m below and not, as Bolomey assumed, 5 m above the present-day level. The first transgression that exceeded today's

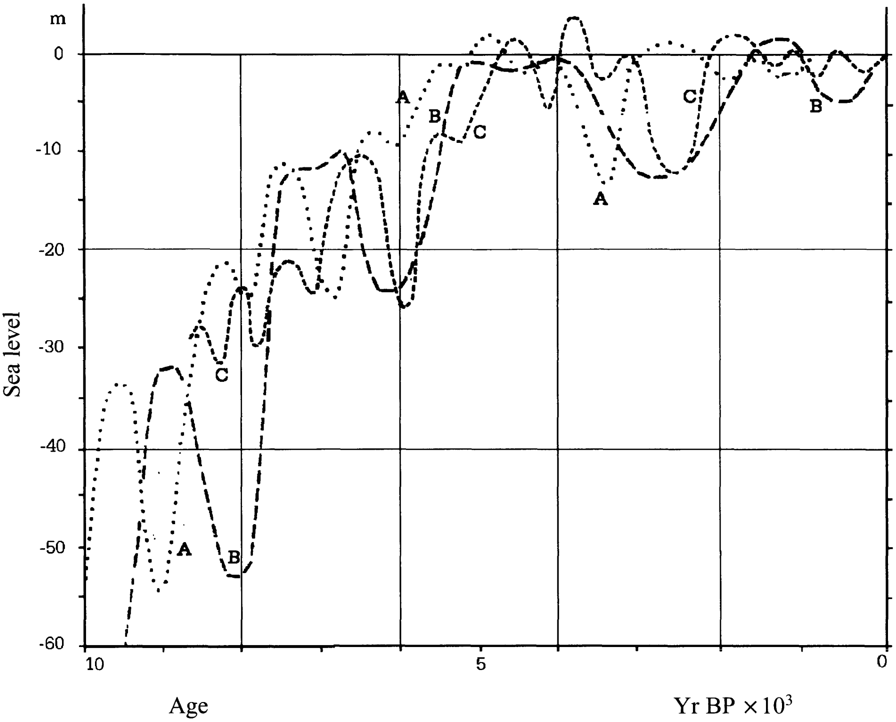

Fig. 2. Relative sea-level changes in the Black Sea. *A* Balabanov et al. (1988); *B* Ostrovsky et al. (1977); *C* Chepalyga (1984). (After Pirazzoli 1991)

level occurred later. According to a diagram made by Chepalyga (1984), its maximum was reached at approximately 4560 ± 160 B.P. (3380–3030 B.C. cal. according to Stuiver et al. 1993; Figs. 1, 2C). That same dating, according to Balabanov et al. (1981), was placed a short time earlier, but also within the fourth millennium B.C. (Fig. 2A). In Russian treatises, this great increase in sea level was marked as the first new Black Sea transgression: "Fedorov transgression" (Fedorov 1977; Chepalyga 1984; Shilik 1997).

Explorations of the sea coast in the area of Kolchide, as cited by Shilik, show that the level of the east coast of the Black Sea was approximately -11.5 m in 5825 ± 215 B.P. (5219–4316 B.C.), and -6 m in 5240 ± 90 B.P. (4258–3928 B.C.). Conversely, in roughly the same period, 5370 ± 60 B.P. (4339–4041 B.C. cal. after Stuiver et al. 1993), the water level in the area of ancient Olbia, on the northwest coast of the Black Sea, should have been just 1.6 m lower than the present-day level (Shilik 1997).

These data suggest that the water level in the late fifth millennium B.C. was significantly lower than that of today. This is in affirmation with the chronological determination of Chepalyga and Balabanov, which supports the date of Fedorov's transgression in the following period – the fourth millennium B.C. However, great and inexplicable differences in the water level, according to which the northwest coast would have been 4 m higher than the east at roughly the same time, lessen the validity of the previously cited data to a great extent. Therefore, the question arises as to whether inexact estimation is a consequence of uncertain dating or whether other, more complex factors are involved. The vague criteria as to paleo-sea-level indicators have proven to be problematic as well.

Recently, Pirazzoli (1991, 1996) has worked on this problem in detail. He cites an array of methodological objections to past research on the oscillations of the Black Sea level and the world ocean in general. He finds especially problematic the attempts to develop widely applicable schemes and diagrams based on compiled data from different and often very distant sites without regard for the factor of local tectonics. Further, Pirazzoli rightly concludes that these data should not be evaluated in the same manner, since the regions in question were most often subject to varying tectonic movements. As an example of an incorrect methodological starting point, Pirazzoli cites the fragmented oscillations in diagrams made by Shilik, Balabanov, Ostrovsky and Chepalyga. In Pirazzoli's opinion, these represent consequences of the different tectonic history of particular areas, not fluctuations of sea level.

As a whole, Pirazzoli's remarks on methodology are justified and must be taken into account when evaluating past research, especially in attempts to make detailed diagrams of wide significance on the basis of compiled data from different areas. Starting from this point of view, it can be stated that the unexplained differences in sea levels on the northwest and east coasts of the Black Sea cited by Shilik are not necessarily consequences of bad dating. Rather, they were caused by subsequent disturbances at the coast in one or both of the mentioned areas. It is possible that these were oscillations of the continental platform or differences in local tectonics; however, it is very difficult to determine the extent of these disturbances in relation to their primary state.

3
Discussion of Sea-Level Fluctuations since the End of the Fifth Millennium B.C.

To a great degree, one can rely on the existing diagrams when the identification of basic transgressive and regressive tendencies are in question. These tendencies can be found in the schemes of most researchers, although with considerable chronological divergencies (Fig. 2). Confirmation of such a development is provided in some newer archaeological data. Thus, graves of the Varna culture in Durankulak on the west coast of the Black Sea, which at the time of excavation were about 1 m below sea level, show that at the end of the fifth millennium B.C. the water level on the northwest coast was at least 1–2 m below the level of today. This is in accordance with data presented by Shilik (Todorova 1993, 1998; Shilik 1997). Settlements from the late Copper age in Bulgaria also confirm this. These settlements on the southwest coast of the Black Sea are located approximately 3–5 m below the present sea level (Todorova 1993; Draganov 1995).

In any case, all of these dates testify that the end of the fifth millennium B.C. is the *terminus post quem* for the beginning of the first new Black Sea transgression, i.e., the Fedorov transgression. According to H. Todorova, this transgression reached its maximum in the mid-fourth millennium B.C. (Todorova 1993), which is in accordance with the diagrams published by Chepalyga and Balabanov (Figs. 1, 2). Thus, the first half of the fourth millennium B.C. can be regarded as the period of the increase in water level and the second half as the period when the water level reached its maximum. The end of the Fedorov transgression can be placed in approximately 3000 B.C. or a short time later.

On the other hand, the difference between today's water level in Durankulak (–1 to –2 m) and the southern settlements of Sozopol and Ropotamo (–3 to –5 m) led H. Todorova to view it as the confirmation of tectonic movements of the European platform caused by an increase of melting Arctic ice during the Atlantic period. Due to the abrupt release of ice, the platform rose in the north and descended in the south (Todorova 1993). Through these changes and the further impact of natural factors, archaeologists are attempting to explain the cultural and demographic explosion in the northern Balkans and neighbouring regions during the second half of the fifth millennium B.C., as well as the cultural collapse that occurred after this climatic optimum (Todorova 1993). The negative effects of the increase in levels of surface and subsurface waters (floods, humidity etc.) in the eastern Balkans and the north of the Black Sea became apparent during the fourth millennium B.C., which coincides with the time of the previously mentioned cultural collapse. Thus, one may conclude that in this case archaeological and archaeometric data are in accordance, and to a great extent are mutually supplemented. They show the aggravation of natural conditions and cultural collapse in the greater part of the Circumpontic region during the fourth millennium B.C.

As shown by ^{14}C dates from Chepalyga's collective diagram, an increased fluctuation of sea level in 4400 and 3400 B.P. (ca. 3300–1700 B.C. cal. after Stuiver et al. 1993) can be assumed. Regression first occurred, followed by a rapid increase of water level to +2 m. This increase was again followed by a drop and then elevation of the water level (Fig. 1). In connection with further fluctuation of the Black Sea, it is worth paying attention to one rapid and relatively strong regression during which the water level fell 10–15 m below the present-day level. This is the so-called Fanagorian regression, dated in the late sub-boreal period, ca. 1500–50 B.C. (Fedorov 1977; Ostrovsky et al 1977; Chepalyga 1984). It was followed by the Nymphean transgression, which reached a level of 1–2 m above the present-day one (Fig. 1). According to Chepalyga (1984), this transgression could be approximately dated to the first half of the first millennium B.C. However, considerable incongruencies can be noted in the chronology of these oscillations, for example with reference to the Fanagorian regression during which, according to Balabanov, a transgression took place (Fig. 2A). On the other hand, comparable fluctuations were ascertained in the central Mediterranean, the Aegean and other areas of the world's ocean (Pirazzoli 1996). With great probability this represents deviations caused by additional tectonic disturbances of the ancient coastline.

4 Conclusion

Summarizing the data cited, one can conclude that precise results regarding the oscillation of the sea level in the Black Sea basin are only plausible in more narrow, local frameworks. Every compilation of data from the wider geographical region decreases the possibility to perceive the real state. In other words, the objective image of the oscillations of sea levels cannot be reached based on the collective data from different regions. This is not because various regions had a different regime of water levels, but due to the unpredictability of additional tectogenesis of the coastline and coastal area. The level of the Black Sea, like any other large water surface, has to be – on principle – equalized in all its parts. From the moment of compound with the Mediterranean Sea it became – according to the principle of joint containers – liable to the eustatic regime of the world ocean. Of course, in both cases the law of gravity is the determining factor, since the surface water level is formed according to the gravitational force. Accordingly, deviations in water level should be sustained in the same way as waters under the same regime. From this point of view, the regions whence the data originate should be irrelevant. However, finding good sea-level indicators in the first place (e.g., the top set/forset contact in deltas, bioerosion notches, bioconstruction features, feet of paleo-cliffs, peak of the marine transgression pebbles, archaeological evidence etc.) is easier said then done. It is especially difficult to found and date the regression minima. Consequently, the strong diachronisms found by Russian authors, observable in three curves presented in Fig. 2 are not surprising: for nearly every relative maximum peak in one curve is a relative minimum peak in another one.

In this context, it is justified to raise the issue of the extent to which data from past research on the oscillations of the Black Sea level are of any use in archaeological work. The way in which the diagrams were made in the past, based on the compiled data from various regions, has been proven methodologically inadequate, and in terms of results, uncertain for use in archaeological research. It seems that only local diagrams with clear paleo-sea-level indicators can give a precise notion for a specific region. The representative sample may be obtained through repeated datings and comparisons of these dates. It is believed that this may be the direction of future research. What we have at our disposal now can only be used as raw material; in other words, a semi-finished product according to which basic tendencies can be anticipated. We can agree that the transformation of the present-day Black Sea from a freshwater lake into a "semi-marine" pool was a long-lasting process, which occurred as a consequence of global climatic changes and a glacioeustatic increase in the world ocean. The oscillations in that process represented in shifts of transgressive and regressive phases, undoubtedly had a direct impact on the cultural development of the surrounding area. The biblical flood, which most probably describes dramatic prehistoric events, still not located in time or place, could be seen as a paradigmatic example of these impacts.

If the biblical flood, as assumed by the American geologists Ryan and Pitman (1998), can be linked to the Black Sea region, then the time of the first new Black Sea, i.e., the Fedorov transgression, would offer much better geoarchaeological support for that event than the mid-sixth millennium B.C. as cited by them. As we have seen, this transgression took place during the fourth millennium B.C., the early sub-boreal period. Thus, at the time of its maximum (approximately mid-fourth millennium B.C.), which in general European chronology according to J. Lichardus is the time of transition from the early to middle Chalcolithic (Lichardus 1991), we maintain that vast areas of the west, north and east Pontic regions were flooded. All settlements close to the sea coast and river mouths had to be deserted. In fact, these floods represented only the peak of a long and slow development. It could be perceived in a wider framework through the elevation of the levels of subsurface waters and increased humidity of the soil. For a long period of time, living conditions were drastically aggravated not only in flooded areas, but also in the wider environs. This situation led to the cultural collapse registered in the development of the west and northwest Black Sea region, the disappearance of the Gumelniţa and Varna cultures at the turn of the fifth to fourth millennium B.C., and especially during the first half of the fourth millennium B.C. From an archaeological and palaeoclimatic point of view, this period appears to be a time of great disturbances that far exceed earlier ones and confirmed cataclysms in this region.

The chronological and territorial determination of the biblical flood in the time of the Fedorov transgression of the Black Sea, thus, seems plausible and acceptable. However, since a clear methodological approach still does not exist with reference to this mythological/historical event, this determination remains as one more assumption that stands between science and speculation. It is obvious that the time of the Fedorov transgression was a period of great cataclysms. What were the proportions of those cataclysms, how many of the archaeological objects and sites from that period and preceding periods have been destroyed, and to what extent have the archaeological archives and thereby, the possibility of prehistoric research of this region been erased? These are questions that, just as the problem of the Biblical flood, for now stand at the border between science and speculation. We can only anticipate the answers.

Chapter 8

The Black Sea, the Sea of Marmara and Bronze Age Archaeology: An Archaeological Predicament

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Abstract

A survey of the archaeological evidence from the Marmara region, northwestern Turkey, presents significant problems concerning the Bronze Age cultures of the region. One of the striking results is the total absence of Bronze Age settlements along the eastern coast of the Sea of Marmara and of the Bosphorus. The absence of sites in this region, when considered together with the presence of submerged Bronze Age sites in the Black Sea, orients questions towards the water exchange system between the Black Sea and Marmara.

1 Introduction: The Archaeological Background of the Problem

The Sea of Marmara, together with its two long, narrow straits – the Dardanelles and the Bosphorus, defines the boundary between Europe and Asia. However, the Sea of Marmara being a relatively small inland sea, does not constitute an obstacle in crossing from one continent to the other. The terrain on either side of the Marmara is devoid of topographical barriers, being rich in sources of water, it is easily approachable from inland. Moreover, it enjoys a mild Mediterranean climate, thus providing a hospitable environment for settlements. Accordingly, the region around the Sea of Marmara not only provides the easiest land-route between southeastern Europe and Anatolia, it is also located at the narrow neck of the main maritime route connecting the Aegean with the Black Sea. Due to this critical geographic location, the region around the Sea of Marmara has been looked upon by cultural historians as a potential area for long-distance cultural interaction.

In spite of its importance for understanding the past relations between Anatolia and the Balkans, the region has remained archaeologically unexplored until recently, thus giving way to a number of unbased speculative interpretations. To fill this lacunae in knowledge, an extensive survey and excavation program was launched in 1979 by the University of Istanbul, revealing a considerable amount of new data on the prehistoric cultures in the region[1]. This, however, does not imply that our work in the region has been conclusive; the number of unresolved problems are much more then those that we have been able to clarify. Nevertheless, now at least it is possible to formulate questions that are based on concrete facts.

Our work has been carried out on both the Asian and the European parts of the Marmara region. It is far beyond the scope of this paper to go into the details of cultural assemblages; here, we shall limit our presentation to a synoptic survey of the cultural sequence, so as to provide background information to the problems that will be discussed.

Most of our work has been concentrated on the problems related to the Neolithic and Chalcolithic cultures of the region. At the present state of our research, it could be stated that, from the early beginnings of the Neolithic Period, that is, from Pre-Karanovo I up to the Karanovo V Period in Balkan terminology, there is a marked coherence between our results and those already known from Anatolia and the Balkans[2]. Through most of that period, the Sea of Marmara seems to be a cultural bridge between Anatolia and the Balkans, both areas sharing similar cultures. However, beginning with the early stages of the fourth millennium B.C. cultural contacts between Anatolia and the Balkans seem to have been interrupted. Later, during the fourth millennium, cultural formations on either side of the Marmara are notably different from each other. Thrace, the European side of the Sea of Marmara, becomes a part of the so-called Balkan cultural sphere – or the Karanovo VI Gumelnitsa culture. On the other hand, northwestern parts of Anatolia, together with the littoral areas along the Aegean, under the impact of Near-Eastern cultures, go through a process of urbanization. Thus, the orientation of cultural connections during the fourth millennium B.C. is notably different from the preceding periods.

With the onset of the third millennium B.C., that is the Early Bronze Age, the already established zones of cultural interaction seem to have held their position: the Asian part of the Marmara region is integrated with the newly developed urban societies of Anatolia and the Aegean. In Thrace, however, as in most parts of the Balkans, a more pastoral lifestyle takes over. What happens later on, during the second millennium B.C., is more difficult to understand; during this time, the centralized states of Anatolia and the Aegean, the Hittites and the Myceneans have been expanding

[1] For a conspectus on the results of our work in the region, see especially Özdoğan (1996, 1997, 1999), Özdoğan et al. (1997), Parzinger and Özdoğan (1996), and Parzinger et al. (1999).

[2] For an overview on the Neolithic and Chalcolithic cultures of the region, see especially Özdoğan (1991, 1998b).

throughout northwestern Anatolia; what is strange is that on the European side of the Sea of Marmara, we could neither find any evidence indicating the presence of these powers, nor any other material that could safely be dated to the second millennium B.C.[3].

As can be gathered from this short presentation, the cultural characterization during the third and the second millennium B.C. in Thrace is extremely problematic. This is of interest, as this is the time when our knowledge of Anatolia and the Aegean is most satisfactory. Troia, the type site of the Aegean Bronze Age, is located by the Dardanelles and throughout the southern Marmara, there are numerous Bronze Age mound sites. On the other hand, further inland in the Balkans, in Bulgaria, the Early Bronze Age has been extensively studied through type sites such as Ezero, Sveti Krilovo and Mihalic[4]. However, the absence of concrete data from the interim zone, that is from eastern Thrace, has considerably blurred the overall picture regarding the relation between Anatolian and southeast European Bronze Age cultures.

During the last decade, a substantial amount of new data concerning the Bronze Age cultures was brought to light, both from the littoral areas of Bulgaria and from northwestern Turkey. However, at present, there are substantial difficulties in interpreting this evidence. The present paper will try to display the discrepancies between these two regions; we are conscious of the fact that the solutions that will be presented in the final part of the paper are somewhat controversial, nevertheless we anticipate that these will help to stimulate further interest to these problems.

2
Thrace and Northwestern Anatolia During the Bronze Age: A Prelude to the Problem

Correlation of Anatolian-Aegean Bronze Age cultures with those of the Balkans has always been a matter of dispute. Even a simple comparison would reveal the apparent differences between the cultural assemblages, settlement organizations, architectural practices and subsistence patterns of the Anatolian-Aegean cultural complex with those of the Balkans. Nevertheless, the presence of some seemingly similar elements between these two regions have always induced scholars to seek for possible connections.

[3] For a survey of literature on the second millennium B.C. of the Marmara Region, see Özdoğan (1993).

[4] For an overall assessment of the Bulgaria Early Bronze Age cultures, see especially Nikolova (1999); Panayatov (1989, 1995).

However, there is no general agreement as to whether the presence of similar elements was due to some sort of interaction, or to the random exchange of commodities; likewise, there is as yet no consensus on the correlation of Balkan chronological sequence with that of Anatolia.

In spite of the apparent disconformity between Anatolian and Balkan Bronze Age cultural sequences, Anatolia and the Aegean have developed almost on similar lines. This does not imply that the assemblages all around the Aegean were similar and that there were no regional differences. The similarity between Anatolia and the Aegean lies more in their social systems. The presence of small, fortified settlements, the use of the potters wheel, the emergence of an elite ruling class, increased number of status objects, technologically developed metallurgy, the invention of tin-bronze etc. are all indicative of an urban society at a pre-state stage of development. In this respect, it should still be noted that the "urban" centers of the Aegean and Anatolia are extremely small and provincial in comparison to those in Syro-Mesopotamia.

In Thrace, as in most parts of the Balkans, elements that are suggestive of urbanization do not exist. Even the most significant Bronze Age sites of Bulgaria, such as Junatsite or Ezero can best be described as large villages. Thus, the Sea of Marmara, which was a cultural bridge between Anatolia and the Balkans throughout the Neolithic and Chalcolithic Period, became a barrier delimiting these two regions for the entire span of the Bronze Age.

What appears as a strict cultural discontinuity between the Balkan and northwestern Anatolian Bronze Age cultures is hard to conceive, as the geographical features of neither the Bosphorus nor the Sea of Marmara can hamper interaction between Thrace and Anatolia. Considering that during the Bronze Age the roots of an extensive maritime trade network were being established all around the Aegean and the Dardanelles, it is rather strange that no evidence of such an action along the Bosphorus has been brought to light. If the break in cultural connections between Anatolia and Thrace had been a short-lived phenomenon, it would have been easier to find answers. However, this break seems to have sustained for almost 2000 years and in cultural terms it is difficult to justify such a long-lasting lack of contact between two neighbouring regions. For a better understanding of the problem, it is worth having a brief survey of the archaeological evidence from either side of the Sea of Marmara.

3 The Archaeological Evidence

The Early Bronze Age cultures of northwestern Anatolia are relatively well documented; besides the major Bronze Age sites like Troia, Demirci

Höyük, Beşiktepe, Kumtepe and Yortan cemeteries, more recent operations such as Orhangazi Hacılartepe[5], Seyitömer Höyügü (Topbas 1993) and Early Bronze Age cemetery sites at Sariket (Seeher 1991, 1992), Küçükhöyük (Gürkan and Seeher 1991) as well as a number of surface surveys[6] have increased our knowledge considerably. Here, it is worth noting that our surface surveys have covered almost all of the Marmara coast, including the Dardanelles and the Bosphorus; but were less intensive along the Aegean coast of Thrace.

It is not the purpose of this paper to go into the details of the cultural assemblages. In a synoptic view based on the distribution and formation of sites and on the composition of artifactual assemblages, we can roughly define five cultural zones:

3.1 The Asian Side of the Sea of Marmara

Northwestern Anatolia seems to have been extensively inhabited during the Bronze Age. Even though the number of Early Bronze Age sites on the alluvial plains are more common, sites can be found on all geographic settings from intermountain valleys to high plateaus (Fig. 1; Korfmann et al. 1994). Most of the sites are multilayered mounds, indicating continuous occupation; however, there is a marked decrease in the number of sites towards the end of the Early Bronze Age. Likewise second millennium B.C. sites are also rare, but wherever they occur, the sites are considerably bigger, possibly indicating a further step in the development of urban centers. It is also possible, however, that we recognized the fine ware belonging to that period and that smaller settlements using non-diagnostic local pottery went unnoticed during the survey.

In all of northwestern Anatolia, including the coastal areas, the Bronze Age pottery belongs to the traditions of the mainland. We have not been able to record any sherd that could with any confidence, be related to the Balkanic Bronze Age cultures.

On the coastal strip, Bronze Age sites are present from the entrance of the Dardanelles, where Troia and Kumtepe are located, up to the isthmus of the Kapidag peninsula. However, on the eastern part of Kapıdağ, up to the Bosphorus, we have not been able to find any Bronze Age site along the coast.

[5] For short notes on the recent work at Hacilartepe, see Roodenberg (1993, 1994).

[6] For a survey of eastern Marmara, see Özdoğan (1983, 1984, 1985b), and for the Balıkesir-Bandırma region, Özdoğan (1990).

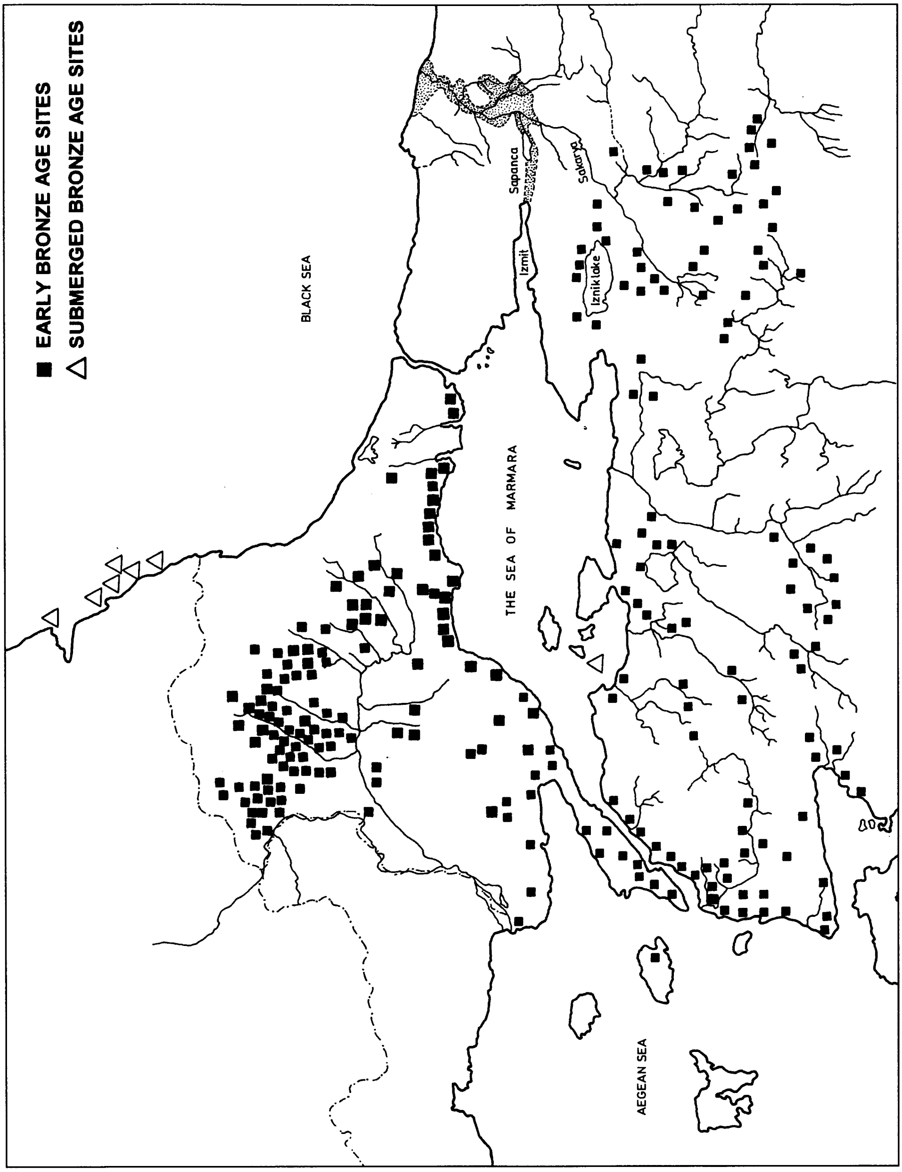

Fig. 1. Distribution of Early Bronze Age sites in northwestern Turkey

3.2
Thracian Coastal Strip Along the Sea of Marmara

Throughout the southern coastline of Thrace, from the tip of the Gelibolu peninsula up to Istanbul, there is a homogeneous distribution of Bronze Age mounds. Most of these sites are mound sites, large or small, but still indicate an "Anatolian" type of site formation[7]. The coastal area seems to be rather densely inhabited, and there is an evident preference for site locations on small promontories by the inlets of small streams. Unless destroyed by modern building activity, a Bronze Age site was found in every such location.

The material yield of these Bronze Age sites is rather uniform, suggesting that they are all contemporary, being part of the same cultural sphere and that most of them lived only a single cultural phase. The most abundant ware can be linked directly with Anatolia, datable in general terms to Troia I horizon, with very few, if any, sherds that would definitely be related to the Ezero assemblage of Bulgaria. Sites with pottery that can be associated with Troia II–V are extremely rare along the coastal strip of the Marmara, but occur rather frequently in the Gelibolu peninsula (Özdoğan 1986a). Further inland, not only do the mound sites disappear, so do the typical pottery assemblages that are confined to these sites[8]. Sites datable to the second millennium B.C., like those of late Early Bronze Age, are also restricted to the Gelibolu peninsula and the coastal strip by the Aegean[9].

Even though there are a few small sites yielding Late Bronze-Early Iron Age transitional wares, the next clear evidence of settlements along the coastal area is from the Middle Iron Age, i.e., with the Greek colonization. Needless to say, it seems rather strange that the coastal zone should be deserted, or very sparsely occupied throughout the second millennium B.C.

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7 Only one Early Bronze Age site, Menekse Catağı has been excavated on the Marmara coast.

8 This is apparent in the littoral areas of the Marmara; however, along the Aegean, i.e., in the area between the isthmus of the Gelibolu peninsula and the delta of the Meric (Evros/Maritsa), Bronze Age mounds can be found as far inland as Keşan.

9 Along the northern coast of Marmara, at Karaevli, located to the east of Tekirdağ, we encountered some black burnished sherds – similar to those found at Galabovo (Lestakov 1993b), which with some reserve, we were inclined to consider as belonging to the second millennium B.C. However, it became evident at Kanligecit that this ware belonged to the very end of the Early Bronze Age, to the "megaron layer".

3.3 Eastern Marmara and the Bosphorus

Throughout our surveys along the eastern Marmara, including the Bosphorus, even in areas where we intensified our research, we were not able to find a single sherd datable to the period between the Neolithic and Middle Iron Age.

Considering the presence of numerous Bronze Age sites along the Dardanelles, the total absence of fourth, third and second millennium B.C. sites along the Bosphorus is very strange. Here, it may also be argued that Istanbul being a vast metropolis for over a millennia, all prehistoric sites may have been destroyed. However, most of the areas around the Bosphorus were void of intensive settlements during the Byzantine and Ottoman periods, and when we surveyed the region, a number of Paleolithic sites were still available on the surface. Moreover, in spite of the intensive building activity that took place around the Bosphorus during the last decade, not a single prehistoric sherd has been reported.

In the eastern part of the Marmara region, the distribution of Bronze Age sites is also rather peculiar. Coming from the south, all the way up to the Iznik basin, and including this area, there are numerous Bronze Age sites, most of them being sizeable mounds, and all of them yield typical Anatolian material. However, on the large terrain lying between the Iznik Lake and the Black Sea no Bronze Age sites, either small or large, have ever been recorded. More specifically, the rich alluvial plains like the basin of the Sapanca Lake, the catchment of the Gulf of Izmit, the alluvial plain of Adapazari, the terraces along the delta of the Sakarya river etc. are all void of Bronze Age habitation. Neither are there any Bronze Age sites known east of Istanbul, all the way up to the Sakarya basin.

Accordingly, the present evidence implies that the lake of Iznik constitutes the northern limit of Anatolian Bronze Age cultures, and then there is an enormous territory void of any habitation. Considering the presence of several large Bronze Age mounds around the Iznik lake, the lack of sites around the Sapanca lake, in spite of its very similar setting and located only 50 km. to the north is very difficult to understand.

3.4 Inland Parts of Eastern Thrace

In our surveys, all through the inner parts of Thrace, we have located a relatively small number Early Bronze Age sites, almost all of them being flat without any indication of multi-layered mound formation. The surface evidence of these sites is also strikingly different from those along the Marmara coast, the Ezero type of sherds being overwhelmingly predominant[10]. Moreover, our evidence for the Middle and Late Bronze Age from the inner regions, is even more obscure; there are only a very limited number of cases where we could claim to have recovered clear second millennium B.C. material[11].

However, our recent work at Kanlıgeçit[12] revealed that surface indications are rather misleading. Prior to the excavation, on the surface, Kanlıgeçit looked like any other flat, one period Bronze Age site. There was no apparent indication of mound formation. However, as revealed by the excavations that lasted from 1994 to 1999 the core of the site is a small fortified acropolis, almost an exact replica of west Anatolian Early Bronze Age citadels (Fig. 2). Here, besides the massive fortification system, there were also megarons with stone foundations. However, the stone architecture of Kanlıgeçit is restricted to the uppermost phase only; earlier layers consist of sparsely scattered wattle and daub buildings. The settlement history begins with the Early Bronze Age. without having Late Chalcolithic substratum. In contrast, typical Anatolian Bronze Age sites have their roots in the Chalcolithic period. Thus, due to this uninterrupted development, by the beginning of the Early Bronze Age Anatolian settlements already take the form of a mound.

The cultural sequence at Kanlıgeçit is significant enough to revise our understanding of the Thracian Bronze Age, as it strongly suggests an Anatolian colonization penetrating into eastern Thrace by the end of the third millennium B.C. Whether or not this is an exceptional case, or indicative of a pattern which has not yet became apparent, remains unclear. Accordingly, until more evidence is available, the present level of archaeological record is not enough to make even preliminary assessments concerning the Bronze Age of eastern Thrace.

The Bronze Age cultures of Bulgaria are much better documented than those of eastern Thrace; there the interregional chronology has been established through the extensive excavation of sites such as Ezero, Junatsite, Diyabovo and Galabovo. Moreover, large numbers of minor excavations as

[10] Nevertheless, as in the case of the coastal sites, we are cautious of the fact that the sorting of surface material might be misleading.

[11] For a more detailed assessment of our evidence, see Özdoğan (1993).

[12] Kanlıgeçit is a small, inconspicuous Bronze Age site recovered in 1980 near Asağıpınar, immediately to the south of the provincial center of Kırklareli. Here, stratified above an Ezero layer, a substantial architectural layer, consisting of monumental megaron buildings of stone foundations, yielding typical Anatolian Early Bronze Age III material, was recovered. However, no pottery of this latter horizon was detectable on the surface.

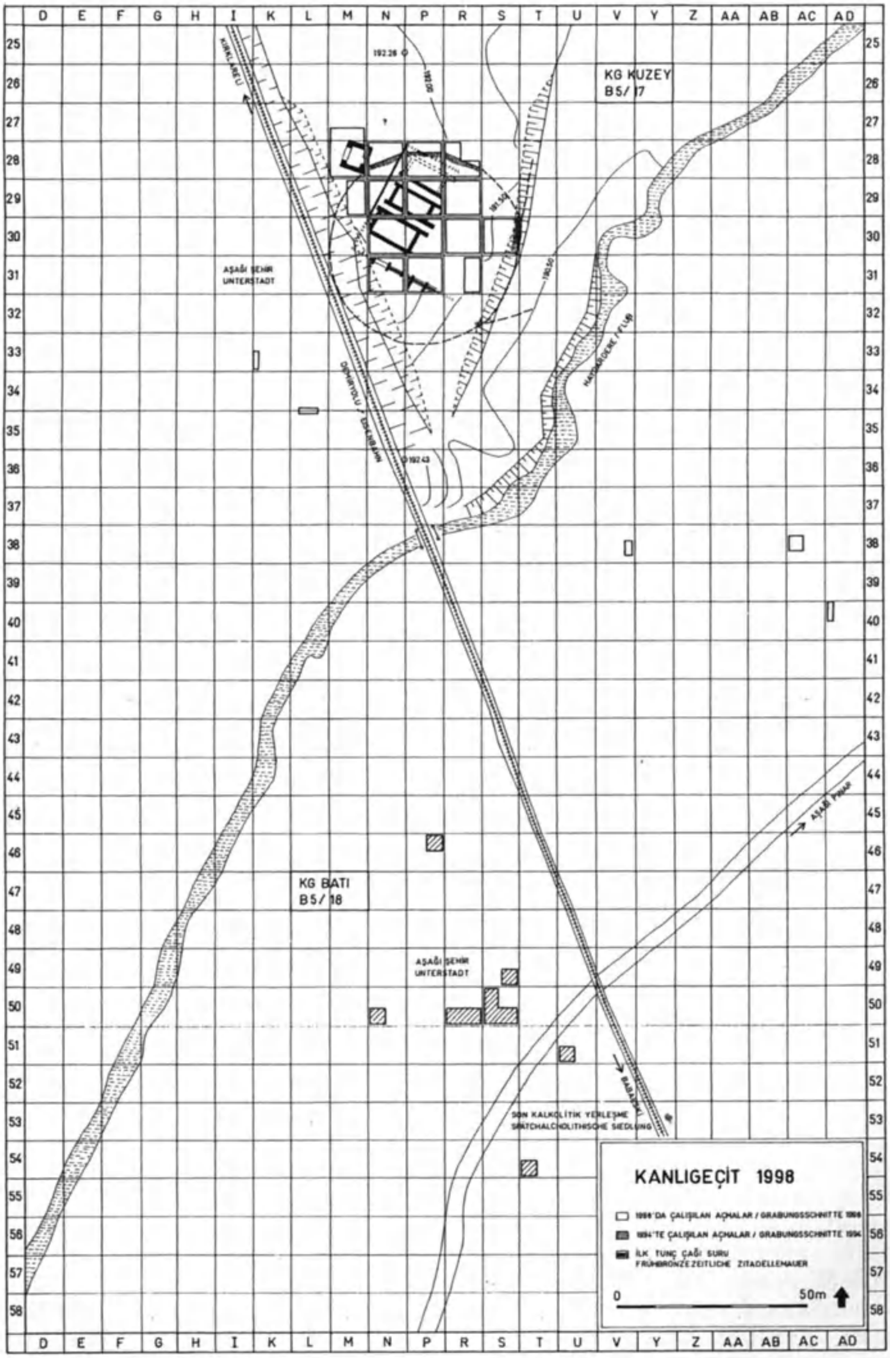

Fig. 2. Early Bronze Age citadel at Kanlıgeçit

well as surface surveys have also contributed to our understanding of the Bulgarian Bronze Age. However, there is no site yet that is comparable to Kanlıgeçit that can be firmly considered as being "Anatolian".

All Bulgarian Bronze Age sites, including mound sites like Junatsite and Ezero or Sveti Krilovo, have no indication of the presence of a complex society. They all lack the monumental architectural remains, as well as the sophisticated artifactual assemblages. Stone architecture, the use of massive defence walls, etc. are all absent from west Thracian Bronze Age sites. The potters wheel, an indicator of urbanization, that came into use on the Anatolian side of the Sea of Marmara by the middle of Early Bronze Age, only appears in Thrace during the Iron Age.

Throughout the Bulgarian Bronze Age, including Thrace, what can be safely considered as imports from Anatolia or from the Aegean are restricted to a few depas and five vessels from Galabovo (Panajatov and Lestakov 1991, Figs. 18–20). Thus, it seems evident that not only was the settlement pattern in Thrace different from the Anatolian one, but the interaction between these two regions were minimal. This makes the evidence of Kanligecit even more interesting.

The traditional tripartite division of Bronze Age into Early, Middle and Late phases used in Anatolia and in the Aegean, seems meaningless in eastern Thrace, and in Bulgaria. In both eastern Thrace and Bulgaria the evidence for most of the second millennium B.C. is also extremely inadequate; possibly indicating a collapse of the social system and the possible domination of the region by pastoral nomadic groups.

3.5
The Pontic Coastal Areas

The coastal areas of the Black Sea are void of Bronze Age settlements. From Bulgaria eastwards, no Bronze Age site has ever been recorded along the coast. Considering the importance given to maritime trade by the Myceneans and Hittites, this is even more strange. However, the recently discovered submerged Bronze Age sites in Bulgaria are strongly suggestive that the Bronze Age coastline of the Black Sea was considerably different from today, and that all coastal settlements might have been submerged. The problem related to sea-level changes will be further elaborated below.

As briefly summarized above, there are a number of discrepancies between Thrace and northwestern Anatolia, the two neighbouring regions that are located on either side of a small land-locked sea. We are conscious of the fact that some of the apparent problems may find answers in cultural history and that others might be due to the lack of intensive research. However, when all the evidence is put together, it seems evident that a solution based only on archaeology is not enough to develop a satisfactory picture and that environmental issues should also be considered to understand the cultural happenings of the Bronze Age. Here, we shall try to draw attention to two such problems, both questions deriving from archaeological evidence, but their solutions seem to lie in environmental issues. Here, it is worth remembering that the writer of this paper is neither a geologist, nor a geomorphologist. We can only connote some hints and anticipate that these will stimulate the interests of environmental scientists.

4
A Major Problem: The Submerged Bronze Age Sites under the Black Sea

Along the Black Sea coast of Bulgaria, a number of submerged Bronze Age sites have been found (see especially Porojanov and Popov 1979; Panajotov 1991; Boer 1994; Georgiev et al. 1994; Lestakov 1994; Draganov 1995). The number of sites recovered during the underwater surveys conducted along the Black Sea is over 12, and as surveys continue, this number is increasing. Most of the submerged sites are in the area of Szopol and Ahtopol in southern Bulgaria, but there are others at Varna; accordingly, it can be stated that these sites mark the Bronze Age coastline. Most of the sites are located between 6 to 10 m below the present level of the Black Sea, but some sites are claimed to be situated at lower depths. Considering that no settlement would ever be founded directly along the shore, and usually the Bronze Age sites are located on small promontories, we can place the Bronze Age level of the Black Sea to at least 12 m below its present level.

The recovery of submerged Bronze Age sites in Bulgaria would explain why no Bronze Age settlements are known of on the Turkish part of the Black Sea coast. The problem is to find an acceptable explanation as to how all coastal sites belonging to the third and second millennia B.C. could be submerged. Reports concerning these sites almost unanimously exclude the possibility of tectonic or epirogenic movements; it is also evident that any agent of tectonic origin would not have had a uniform impact throughout the entire extent of the Black Sea coast. The Bulgarian publications have considered a regression of the Black Sea as a possible explanation for the submergence of these sites. However, we never came across any publication attempting to correlate this regression with the globular sea-level fluctuation curves. To the best of our knowledge, there is no consensus on the sea-level fluctuations during the late Holocene, however, the maximum estimates do not exceed ±3 m (e.g., Masters and Fleming 1983; Kayan 1988b) from the present level. Thus, it remains to be explained how a regression of the Black Sea over a range of 12 m may have happened at that time, when there is no record of such a significant change in worldwide sea levels.

Lowering the level of Black Sea can only be possible in two ways, either the global sea level was as low as the Black Sea level, or the Black Sea was not connected to the global marine system. As the former is not possible, then the other alternative would be to consider the Black Sea as being isolated from the Marmara during the third and second millennia B.C.

5
The Sea of Marmara and the Straits

Any major change in the levels, either of the oceans, or of the other seas, is the consequence of major climatic fluctuations. Accordingly, such changes occur at times of global warming or cooling and have an impact in all littoral areas of the world. The last major marine regression which took place at the time of the last maximum phase of the Würm glaciation is dated to about 18,000 B.C., when the sea level was 100–120 m lower than today. Even though there is some dispute on the exact dates and on the speed of the transgression that followed the Würm maximum, there is a general consensus that the velocity of the rise in sea levels was rather rapid until 5000 B.C., and from that time on there were only some minor fluctuations.

The Black sea and the Sea of Marmara are two interconnected inner seas, linked to the worldwide ocean system by narrow, long and relatively shallow straits. Accordingly, even minor climatic fluctuations, or changes in the world-wide sea levels, provoke exaggerated consequences in the closed basins of the Marmara and Black Seas. Furthermore, at certain occasions this system becomes further complicated by being connected to the Caspian Sea.[13]

The water exchange system between the Black Sea and the Sea of Marmara presents a unique case, as the density of their water masses is significantly different from each other. Large rivers, such as Danube, Dnjepr and Don drain almost all of the surface water of central and eastern Europe into the Black Sea; thus it receives large masses of fresh and cold water. On the other hand, the Sea of Marmara receives highly saline warm water from the Aegean through the Dardanelles. Accordingly, the brackish water of the Black Sea is much lighter than that of Marmara and, at present, the Black Sea has an excess input of water which almost completely fills up the Bosphorus. Actually, as the water discharge of the Black Sea overflows the

[13] For further details of this complicated system, as well as for a full bibliography, see Deuser (1972), Degens and Paluska (1979), Grosswald (1980), Stanley and Blanpied (1980), Özdoğan (1985a), Zubakov (1989), Kaplin et al. (1993).

carrying capacity of this narrow and shallow strait, the present level of the Black Sea is considerably higher than that of Marmara.

This complicated system has some rather complex consequences: under certain conditions it may result in the stratification of water masses, according to their density, and thus prevent vertical circulation of oxygen. At present, the Black Sea is under such conditions; the density stratification of its waters prevents dissolved oxygen reaching lower elevations, resulting in anoxic conditions and the formation of sapropels[14]; analysis of the deep-sea cores indicate that Marmara lived under similar conditions during the last glacial period (Stanley and Blanpied 1980).

Accordingly, even a minute change in the system, either eustatic, or global sea levels, or changes in the water input of the Black Sea from river drainage, have considerable effects on:

1. Whether or not saline waters can flow through the Bosphorus.
2. Marine ecology of Marmara and the Black Sea is very unstable and apt to go through radical changes.
   A simplistic overview of this complicated system has already been published elsewhere (Özdoğan 1985a; see also Meric 1990: 107–111), but it is clear that the lacustrine conditions of the Sea of Marmara ended around 7000 B.C. when saline waters from the Aegean passed the Dardanelles. The connection between the Black Sea and Marmara seems to have been established slightly later, possibly around 5500 B.C.). However, it is evident from the bottom sediments of both the Marmara and the Black Sea that the present conditions were established only by the first millennium B.C. (see especially Deuser 1972; Schrader 1979; Meric 1990; Kaplin et al. 1993) and that between the sixth and first millennia B.C., the environmental conditions of the Marmara and the Black Sea were not stable. It seems that during this period, the level of salinity went through significant alterations and the present level of salinity was finally established only by the first millennium B.C.[15]

In spite of this initial contact between the Black Sea and Marmara, the presence of submerged Bronze Age sites strongly suggests that this connection was somewhat interrupted during the third and second millennia B.C. and that the Black Sea lived through a period of strong regression (see also Orachev 1990). Sometime around the beginning of the first millen-

[14] See diagrams in Özdoğan (1985a, Fig. 5c), Özdoğan (1998a), Stanley and Blanpied (1980, Fig. 2).

[15] This is best expressed by Stanley and Blanpied (1980, p. 541) as "the physical oceanographic conditions presently measured in the Sea of Marmara...were established at ~3.000 B.P.".

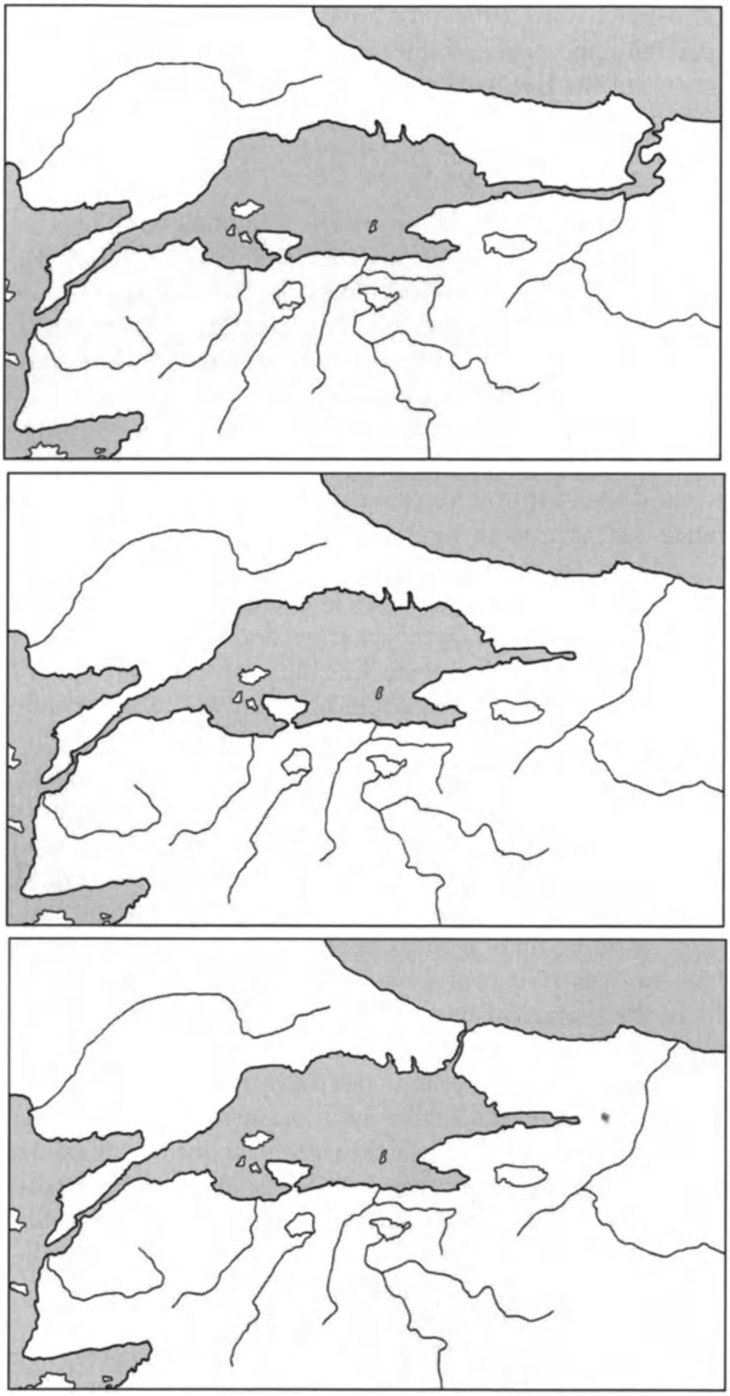

Fig. 3. Possible connections between the Black Sea and the Sea of Marmara

nium B.C. a new connection must have taken place, as indicated by the almost sudden appearance of the so-called Greek colony settlements. We are conscious of the fact that this assumption will be considered to be far fetched by geomorphologists; however, a more convincing explanation should be presented to explain the archaeological evidence of submerged Bronze Age sites in the Black Sea.

Archaeologically, the break between the Anatolian and Thracian assemblages follows the Izmit-Sapanca depression. The fact that Paleolithic deposits were still intact along the Bosphorus also leads to the question when this water channel was formed. Moreover, the topographical features around the Bosphorus seem to be very young (also noted by Darkot 1938) as if no cutting of the valleys took place.

Many years ago an alternative Bosphorus was suggested through this depression by Pfannenstiel (1944) and recent work in the Sapanca basin, as well as around the Gulf of Izmit, have recovered convincing paleontological evidence that, at least during the Pleistocene, prior to the formation of the Sakarya Delta, the discharge of the Black Sea was through this depression. We might surmise that the early Holocene contact between the Black Sea and Marmara was through this channel and during the fourth millennium B.C., at a time when there was less input of water into the Black Sea basin, extensive silting as well as a rapid buildup of the Sakarya delta possibly blocked this channel, in the same manner as the Manych channel between the Caspian and Black Sea was silted. What happened later is rather speculative, but a tectonic movement by the beginning of the first millennium B.C. could have resulted in flooding of the Marmara through the present valley of the Bosphorus over into the Black Sea (Fig. 3).

Here, it is worth mentioning the theory developed by Pitman and Ryan on the cataclysmic filling-up of the Black Sea basin (Okay et al. 1994; Ryan et al. 1997) which foresees the date of about 5000 B.C. for this event. There is no reason to doubt the geological evidence put forward by this group for such an abrupt overflow of water from the Marmara into the Black Sea. Leaving aside the archaeological interpretations suggested by this group, which cannot be considered as serious, it seems more appropriate to put forward a later date for such a cataclysmic overflow, as a transgression due to a global rise in sea levels would have been a slow process. Then, we might wonder, whether the actual forming of the Bosphorus channel happened later than the Bronze Age, when the level of the Black Sea was much lower then today, and an abrupt event, possibly a tectonic movement, activated this channel.

As we have already mentioned above, we are conscious of the fact that we have gone far beyond our field of specialization; however, we can still hope that this paper will challenge natural scientists and help to solve this archaeological problem.

Delta Evolution and Culture – Aspects of Geoarchaeological Research in Miletos and Priene

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Abstract

During the last 5500 or so years, the Latmian Gulf has been silted up by the progradation of the Büyük Menderes (Maiandros) delta. Thus, the ancient sea port cities Miletos and Priene became landlocked. Based on the interpretation of drill cores this paper presents evidence that the area of Miletos consisted of islands when the first settlers arrived ca. 3500–3000 B.C. During the Roman era, strong siltation processes can be proven. When Priene was founded anew around 350 B.C., the eastern embayment at the foot of its promontory had already turned into a lake, whereas the western embayment was more suitable for a harbour site.

1 Introduction

Deltas, lakes and river floodplains are the geological memory of a landscape. These sinks store the sediments, supplied by rivers and produced by erosion and denudation in the source areas of the hinterland. Deltas may serve as excellent geo-archives for the effects of different settlement phases on the natural environment, but also for the consequences of catastrophic floods, sea-level fluctuations, earthquakes and other natural phenomena. Accelerated progradation in historical times due to human impact is known about nearly all Mediterranean deltas. Since coastal regions have often served as major settlement sites, their growth is quite well documented. Good examples from the Aegean coast of Turkey are those of Karamenderes (Scamandros) with Troia as the most famous ancient city, Küçük Menderes (Kaystros) with Ephesos and Büyük Menderes (Maiandros) with Miletos and Priene (cf. Brückner 1986, 1995, 1996, 1997a,b, 1998, 1999, 2000; Kayan 1995; Schröder and Bay 1996; Bay 1999a,b; Kraft et al. 1999, 2001).

The beginning of the evolution of nearly all of these deltas is the same: Since ca. 14,000 B.P., the sea level has been rising at an average speed of 1.5 cm/year (15 m/1000 years), presumably having reached its present position (or close to it) around 6000–5000 B.P. (cf. Kayan 1995). This transgression caused enormous flooding worldwide, especially in flat shelf areas. During its peak, marine embayments extended far inland; in the case of the Büyük Menderes, the so-called Latmian Gulf probably reached up to 50 km to the east, nearly up to Aydın (Brückner 1995; Schröder and Bay 1996; Schröder 1998; Bay 1999a,b). Thereafter, delta evolution in a geomorphological sense started. As the most evident result of the delta growth during the following 5500 or so years, many of the former marine embayments have silted up. The sea ports became useless which led to the decline and final desertion of the cities.

As for the Latmian Gulf, the enormous growth of the Maeander delta is evidenced by (1) the still brackish Bafa Gölü, once the south-eastern part of the gulf with open marine conditions; (2) the total integration of the former islands of Hybanda and Lade into the flood-plain (the latter having even been the site of a naval battle in 494 B.C.); (3) the complete filling up of the harbours of the ancient coastal cities Myous, Priene and Miletos.

2 Progradation of the Maeander Delta According to Literary Evidence

Several authors discussed the historical progradation of the Maeander (Büyük Menderes) delta in space and time. The interpretations of Wiegand and Schrader (1904), Grund (1906), Philippson (1936), Eisma (1978) and Erinç (1978) are based on reports from ancient writers like Herodotus (484–425 B.C.), Strabo (ca. 63 B.C.–ca. A.D. 24) and Pausanias (ca. A.D. 110–after A.D. 180) as well as historical documents from monasteries and travelers' reports. These sources do not, however, allow an unambiguous scenario (Fig. 1).

Schröder (1998: 94) suggests that the city later known as Magnesia on the Maeander may originally have been a harbour city when it was founded in the course of the Ionian colonisation and that the delta front reached the city around 800 B.C. Herodotus (5.36 and 6.8) mentions Myous, Priene and Miletos as harbour cities. (Note that Herodotus refers to the Archaic Priene, the site of which is unknown to date.) In the seventh century B.C., the delta front ran north of Hybanda (modern name: Özbaşı), then probably still an island, since gneiss blocks from a quarry in this area north of Myous were transported to Miletos by ship for the erection of the Archaic city wall (cf. Schröder and Bay 1996: 66). From Herodotus (5.36) we may conclude that Myous still had an open harbour around 500 B.C. According to Grund (1906), the northern branch of the Maeander River was then more active so that the northern part of the Latmian Gulf silted up more rapidly during that time. When Alexander the Great freed the re-

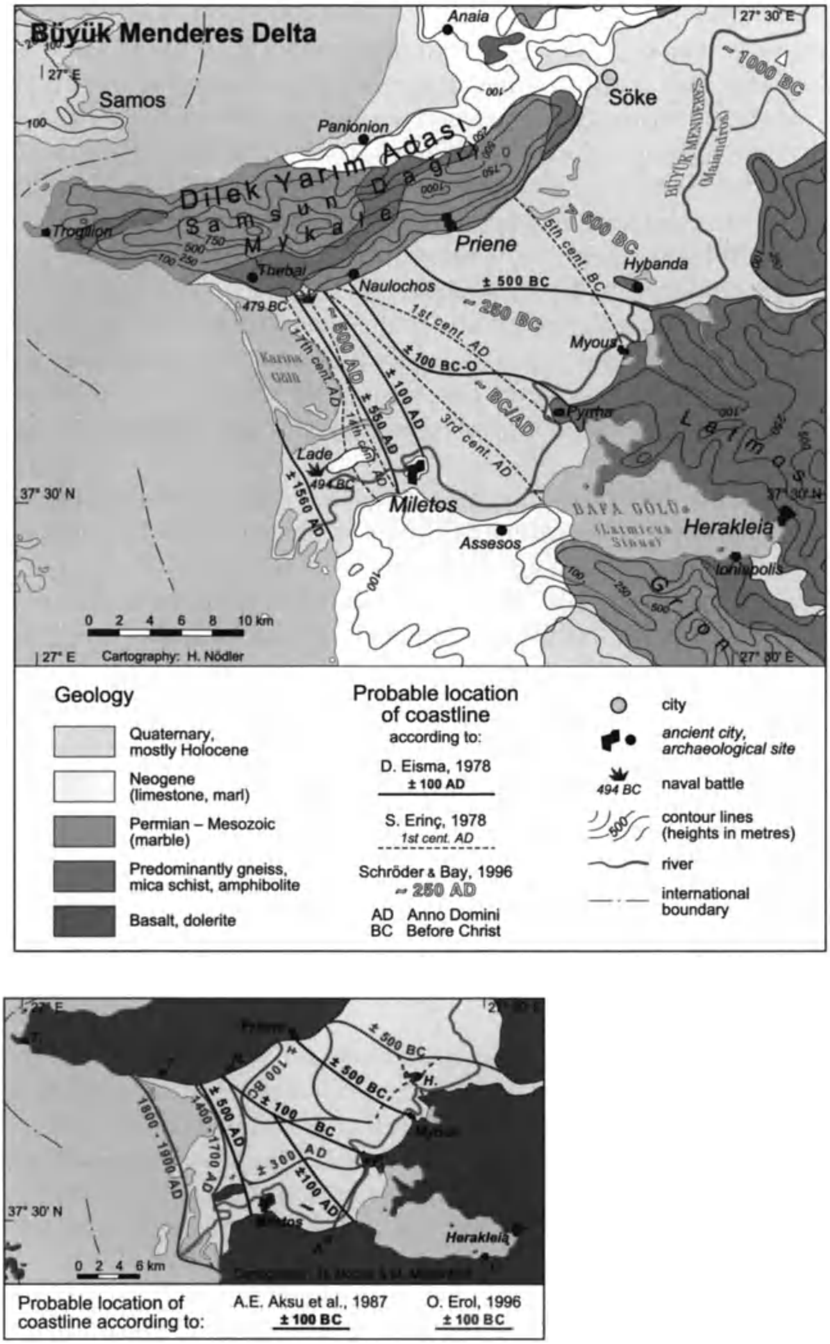

Fig. 1. Scenarios for the progradation of the Büyük Menderes delta in historical times. The area of the alluvial plain and the lakes was once occupied by the so-called Latmian Gulf. Source for the main figure: Brückner (1997a: Fig. 2), supplemented

gion from the Persians in 334 B.C., the harbour of Myous was still of considerable strategic importance (Brinkmann et al. 1991: 9). An Early Hellenistic inscription also testifies to a still well accessible harbour in Myous. Schröder (1998: 96) assumes that the city was deserted approximately 280 B.C.; according to the Eirenias inscription it was 169/150 B.C. (cf. Tuttahs 1998: 157). There are no Roman ruins in Myous. Pausanias (7.10.11) describes a small marine embayment near the former Myous which had been cut off by the Maeander – most likely the present Azap Gölü. In the early first century A.D., Myous was 30 stades ("*stadia*", ca. 5.9 km) inland from the shoreline and the mouth of the river was between Priene and Miletos, about 50 stades (ca. 9.8 km) away from Pyrrha (Strabo 14.1.10). Around A.D. 100 the level of the pavement in the streets in the lower parts of Miletus had to be raised (Eisma 1978: 71); this was probably due to a rise in sea level.

According to Erol (1996), the Büyük Menderes started to accumulate its delta in the centre of the Latmian Gulf; its northward shift after 500 B.C. finally resulted in the filling up of the harbour(s) of the Archaic Priene. The author assumes that when Priene was founded anew in the middle of the fourth century B.C., it was situated at a northern marine embayment, south of which the delta had already developed. When the Büyük Menderes had silted up this embayment, Priene's harbour(s) became landlocked and had to be shifted.

When did the delta progradation create the Lake Bafa, the former Lake of Herakleia? It seems that the delta front reached Pyrrha (at the site of the modern village Sarıkemer) ca. 100 B.C. and the area of the lake around 0 B.C./A.D. According to Philippson (1936: 10), the cutting-off was completed in the fourth century A.D.; according to Erinç (1978: 103), around A.D. 300. Detailed geoarchaeological research by our team, however, led us to the conclusion that this had already happened during the second or third century A.D. (Schultz 1999).

Philippson (1936: 10) assumes a complete silting up of the area around Miletos in the sixth century A.D. Miletos gradually lost its importance as a port. Between A.D. 600 and 700, the former island of Lade was integrated into the delta-plain (Aksu et al. 1987: 233). In A.D. 1560 a Greek sailor reported that the coast was ca. 8 km away from the city (Wiegand 1929, quoted from Eisma 1978: 72). The question of how he had measured the distance (along the river?) remains open.

The scenarios of the historic delta growth shown in Fig. 1 are mostly based on evidence from literature. This is especially true for the ones of Eisma (1978) and Erinç (1978). Aksu et al. (1987) add evidence from sedimentology, Erol (1996) uses the interpretation of aerial photographs as a further source of data, and Schröder and Bay (1996) excerpt information from drillings for water wells, too. It is evident that these sources leave quite some space for different interpretations. This is also true for the latest approach by Tuttahs (1998: 153 ff.). He interprets the filling up of the Latmian Gulf in three phases: (I) the Maeander delta prograded from Söke to Priene along the north-western coast at the foot of Mykale mountains; (II) it turned south from Priene to Miletos; (III) the still open parts in the east and the south of the gulf silted up from Myous to Miletos along the south-eastern coast. The author places the transition from phase I to phase III around 300–250 B.C. Phases II and III run parallel ca. 300 B.C.–0 B.C./A.D.

3 Methods of Geoarchaeology

The procedure presented here is different in that we carried out geoarchaeological research, more or less according to the scheme displayed in Fig. 2. The focus is on fieldwork. Cores are taken with a percussion corer, position and altitude of the cored sites are measured with differential GPS. The laboratory work concentrates on the analysis of the sediment cores. Beside checking the standard parameters, the most vital tool is the identification of the palaeomilieu of deposition (marine, littoral, lagoonal, limnic, fluvial). This is done by the determination of the ostracods, a microfauna which is an especially sensitive indicator of the environment. Dating the cores with artefacts and the radiocarbon method applied on plant remains, charcoal, marine bivalves and gastropods, leads to the establishment of a chronostratigraphy. Supplemented by the input from archaeology and historical sciences, a reconstruction of the palaeogeographic evolution of the study area is achieved.

4 The Palaeogeography of Miletos

From the latest excavations by B. and W.-D. Niemeier, the first settlement dates from the late Chalcolithic period in the second half of the fourth millennium B.C. (Niemeier and Niemeier 1997 and pers. comm.). The Minoan-Mycenaean period started ca. 1900 B.C. when settlers from Crete occupied the site. The Ionian colonisation (ca. 1100–700 B.C.) built their city on the later so-called Milesian Peninsula. Miletos reached its most prosperous time in the Archaic period when it became the metropolis of the Ionian world; it founded 90 colonies in the regions of the Black Sea, the Marmara Sea and the Mediterranean (Akurgal 1993). The city hosted among others the natural philosophers Thales, Anaximander and Anaximenes, the geo-

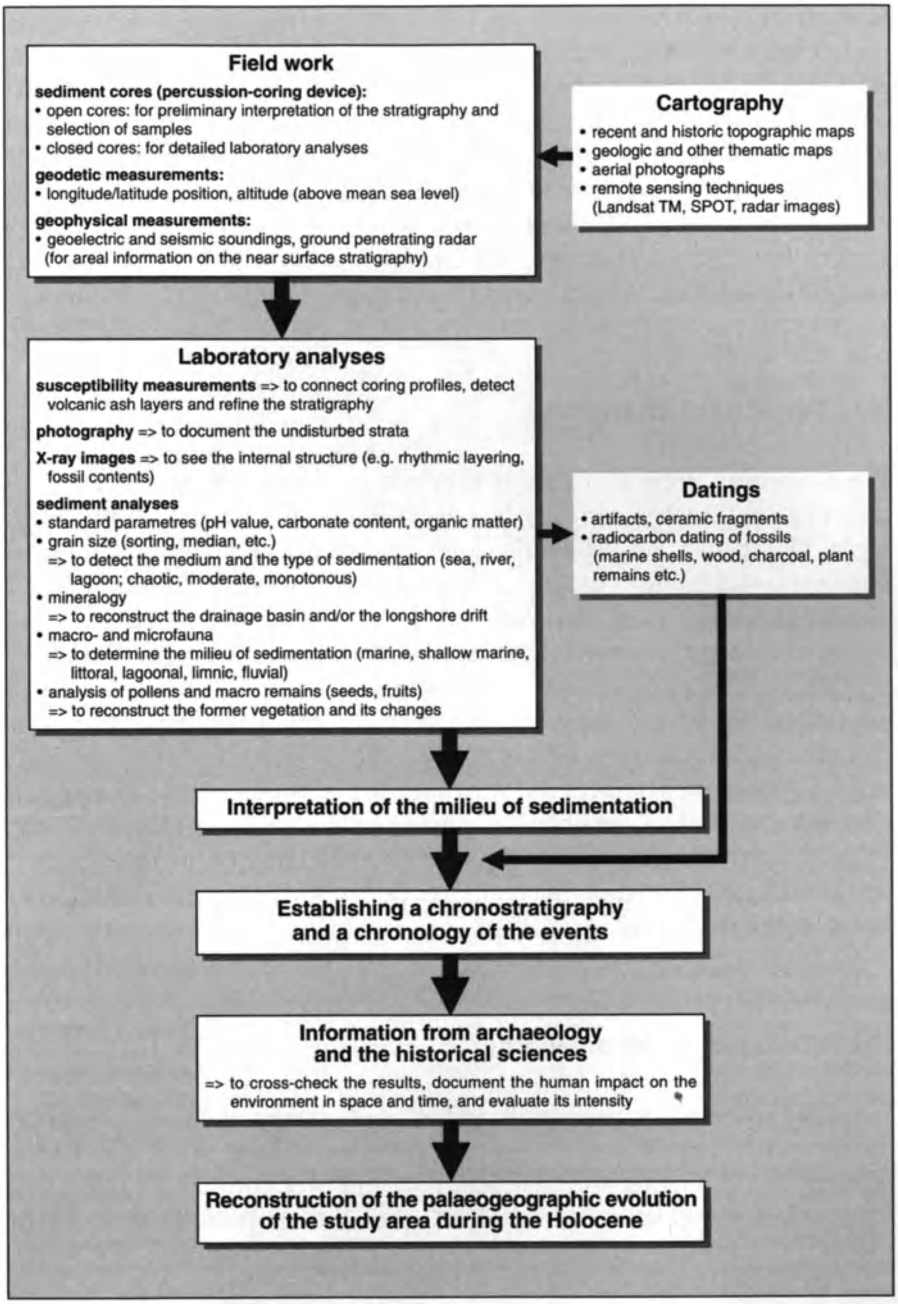

Fig. 2. Methods of geoarchaeology and palaeogeography

grapher Hekataios and the town-planning architect Hippodamos. The Archaic city was strongly fortified with a prominent wall. Ruins of that era are still found on Kalabak Tepe. The naval battle at the island of Lade in 494 B.C. resulted in a devastating defeat and the total destruction of the city by the Persians. It was re-erected soon after this catastrophe in 479 B.C. and a long period of settlement continuity followed.

Our research concentrated on the reconstruction of the palaeogeographic situations at the time of the first occupation, at the beginning of the Minoan-Mycenaean period and during the Roman era.

4.1
The Palaeogeographic Situation in the Fourth and the Second Millennia B.C.

From the sediment cores it is relatively easy to differentiate between sites with and without marine facies. Figure 3 shows the results for the area between Miletos and the island of Lade, displaying the situation at the peak of the Holocene transgression, which was presumably 5000–6000 years ago (Kayan 1995). Figure 4 presents the detailed situation within the area of the later city.

The sediment cores have a similar stratigraphy. The bedrock (Neogene limestone and marls) is truncated by an erosional unconformity caused by the former abrasion platform. This, in turn, is covered by pebbles and sand as evidence of the littoral environment in the course of the Holocene transgression (first transition of the shoreline, from west to east). Sometimes, even boreholes from Lithophagae were discovered in the bedrock as well as on single limestone boulders. The stratum grades into fine sand and silt, deposited during the ongoing transgression which led to an increase in water depth and in distance to the sediment feeding source. Radiocarbon dates show that these environmental conditions with only little sedimentation prevailed for several millennia (e.g. the profile of the Lions' Harbour, cf. Fig. 6 below). The following regression facies is triggered by the progradation of the Büyük Menderes delta. The increase in sedimentation rate and the advance of foreset beds prove the nearness of the delta front (shallow marine silts). The second transition of the shoreline (from east to west) did in some sites lead to a littoral environment with small pebbles or beach sand, in others it is documented by the shift of the deposition milieu from a shallow marine to a lagoonal one. The strata are topped by fluvial deposits of the Büyük Menderes which accumulated whenever the river flooded the delta plain. Near the southern shore of the Latmian Gulf, another sediment source contributing to the silting up was the adjacent slopes where denudation processes started as early as in Neolithic times (Bay 1999a,b; Lohmann 2002). The respective milieus of deposition are

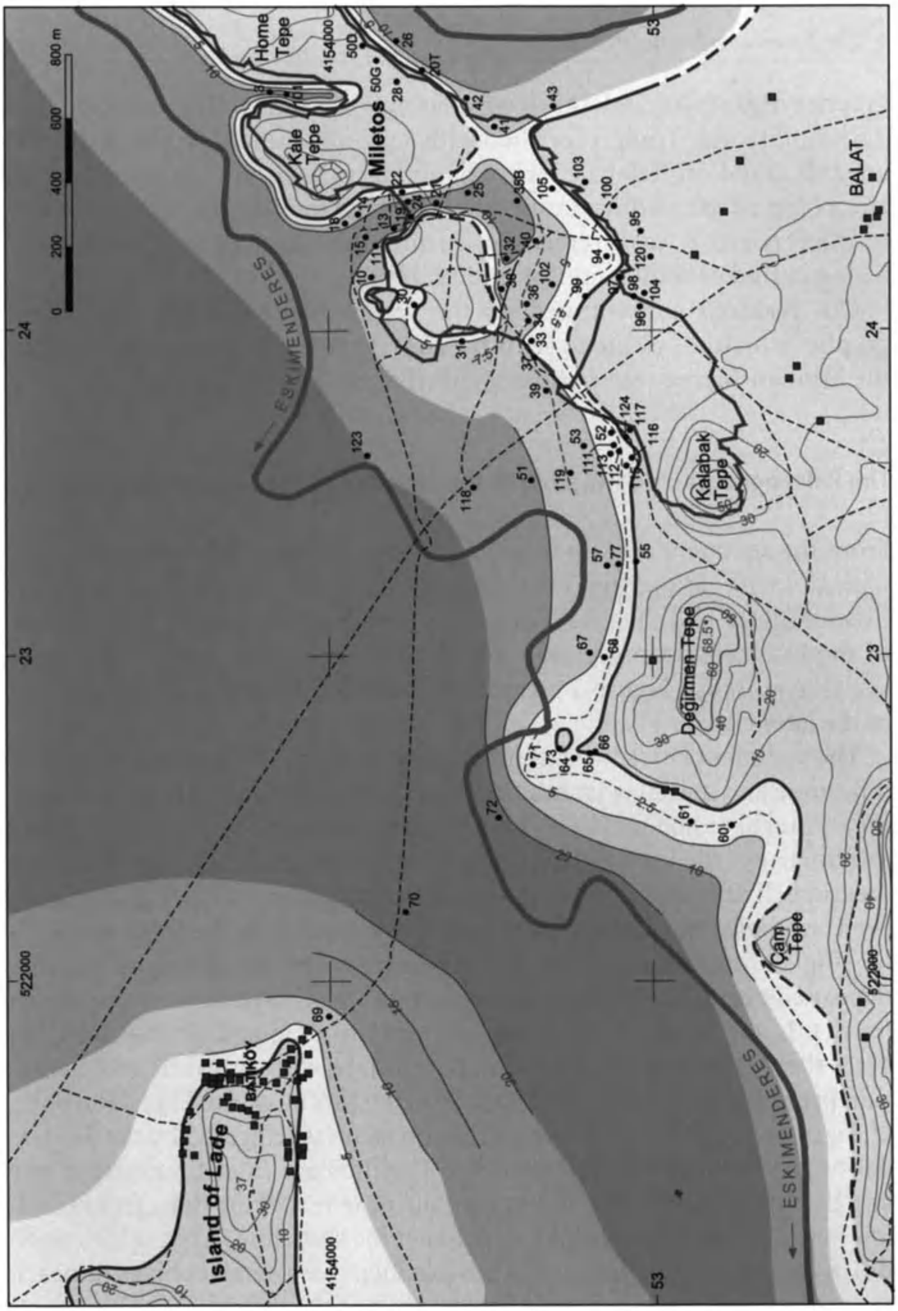

Fig. 3. Land/sea distribution at the peak of the Holocene transgression, which was presumably 5500 years ago. The figure covers the area between the former island of Lade and the later city of Miletos. Reconstruction based (1) on the assumption that sea level had by then reached its present position, and (2) on evidence from drill cores Mil 1 to Mil 124 (for a better legibility not all coring sites are shown). Isobaths (in metres) indicate the depth (below present sea level) of the boundary between bedrock and Holocene marine strata

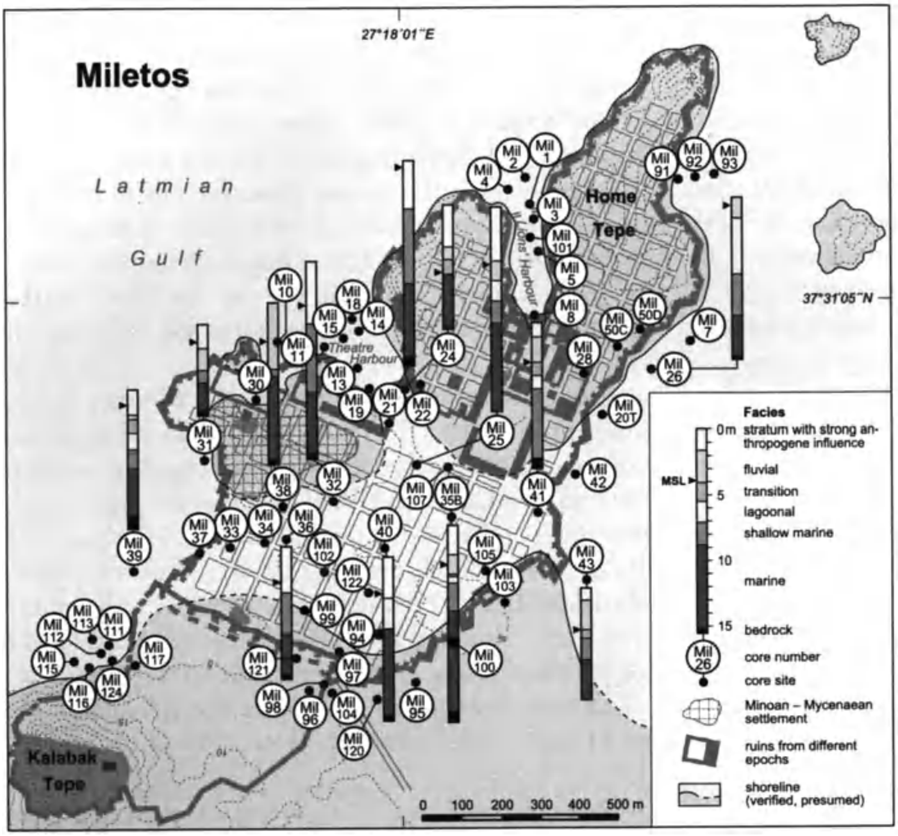

Fig. 4. The palaeogeography of the Milesian Peninsula during the peak of the Holocene transgression. For a better legibility not all stratigraphic columns and cored sites are shown; most of the corings with exclusively terrestrial strata are omitted. *MSL* Present mean sea level. Source: Brückner (1998: Fig. 6b), modified and supplemented

determined by granulometry and the analysis of the microfauna (in our case: ostracods).

The synopsis of our corings (Fig. 4) reveals that at the peak of the Holocene transgression – presumably ca. 6000–5000 years ago – the later so-called Milesian Peninsula consisted of two major islands: one formed by Home Tepe and Kale Tepe, and the other one in the area of the later erected Temple of Athena (near coring site Mil 30, cf. Fig. 4), where, for the last couple of years, B. and W.-D. Niemeier and their team have been unearthing the oldest settlements. When the first settlers arrived in the second half of the fourth millennium B.C., they definitely settled on an island.

It is interesting to note that these earliest finds are now up to ca. 0.90 m below the present sea level; so the excavations can only be done thanks to the installation of a well-point system. There is an ongoing debate whether the sea level had already reached its present position in 5500 B.P. (e.g. Kayan 1995), or whether its present level is the highest in the Holocene (e.g. Flemming and Webb 1986; Morhange et al. 2001). The position of the Chalcolithic finds seems to support the latter interpretation, concluding that the sea level was then at least 2 m deeper than today. However, due to the seismic activity of the region – the lower course of the Maeander is situated in a graben (e.g. Brinkmann 1976) – tectonic action may have caused a later subsidence of the site, displacing it below the present sea level. Earthquakes are known from the area; the last major one destroyed the village of Balat in 1955.

How was the palaeogeography at the beginning of the Minoan-Mycenaean phase of settlement around 1900 B.C.? When did the island topography change to the peninsula? According to ^{14}C datings of charcoal, a grape seed and a shell in living position, the settlement area seems to have been still an island at the beginning of the second millennium B.C. This is at least true for the two dated sites Mil 32 and 36 (Figs. 4, 5; Table 1). However, it cannot be excluded that the island had already been connected with the mainland by a tombolo (sand bar) – although the coring grit is quite dense and such evidence has not yet been found. Future research with geophysical measurements may yield areal information based on the subsurface sediment structures and more ^{14}C dates may supplement the chronostratigraphy.

By the time of the Ionian colonisation starting approx. 1100 B.C., the two main islands were connected with one another and with the adjacent southern flank of the graben by the sedimentation process. As already mentioned, the southern slopes were once more a major sediment feeding source. In his reconstruction of the "Levanto-Mycenaean city wall" Voigtländer (1985: Fig. 10) indicates the presumed shoreline and the peninsula situation of Miletos already during the thirteenth century B.C.

4.2 The Palaeogeographic Situation in Roman Time

Until the Roman era, Miletos was situated on a peninsula, extending into the Latmian Gulf. This topographic setting was an excellent settlement site with deeply incised embayments providing ideal natural conditions for harbours. According to tradition, Miletos had four of them: the Lions' Harbour (where in Hellenistic times two marble lions greeted the incoming ships); the Theatre Harbour at the foot of the Hellenistic-Roman theatre; the third one was most probably near the Temple of Athena; the fourth one is presumed to have been at the eastern flank of the peninsula in a leeward position to the

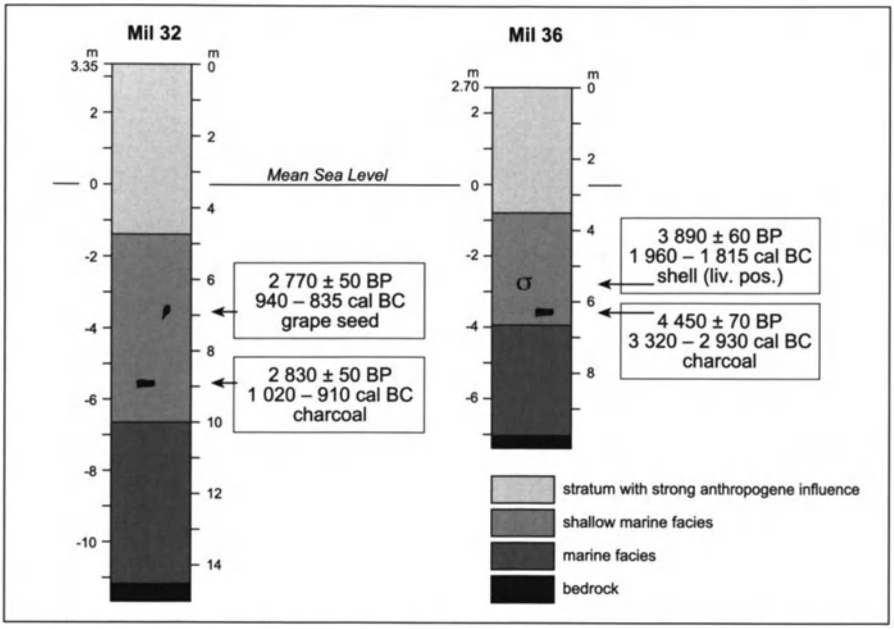

Fig. 5. Stratigraphy and ¹⁴C chronology of the drill cores at sites Mil 32 and Mil 36 between the area of the Minoan-Mycenaean settlement and the southern mainland (cf. Fig. 4)

western winds (our corings east of the Southern Market confirmed a possible harbour site with still relatively deep waters in early Roman times).

In the Lions' Harbour, coring Mil 101 (cf. Fig. 3) reached the maximum depth of the harbour so far: 20.80 m b.s. (= 19.30 m b.s.l.). Coring Mil 3 between the present position of the two marble lions showed the following profile (Fig. 6): weakly developed transgression facies, grading into sandy loamy sediments with a lot of plant remains, probably sea grass (the sediment source were the adjacent hills of Kale Tepe and Home Tepe); from 8.50 m b.s.l. upward are clayey silts to silty clays, indicating the influence of the approaching Maeander delta. In their upper part, they are rich in traces of human activity (ceramic fragments, olive stones, grape seeds). ¹⁴C dates and ceramic fragments prove that the water was still relatively deep in Greek times. The main sedimentation occurred between the first century B.C. and early Byzantine times.

An inscription on the Small Harbour Monument hints to the fact that in Roman Imperial times medium-sized freight ships could still enter the Lions' Harbour, which suggests a water depth of at least 2 m (O. Höckmann, quoted in Tuttahs 1998: 165). In a detailed study concerning the termina-

Table 1. Radiocarbon dates

Sample	Laboratory number	Depth below mean sea level (b.s.l.)	Dated material	Delta ^{13}C (‰)	^{14}C Age	Calibrated and corrected ^{14}C age (cal B.P.) 1 sigma	Calibrated and corrected ^{14}C date (cal B.C./A.D.) 1 sigma
MIL 3/16	UtC 3117[a]	7.30 m b.s.l.	*C. edule*	0.12	2370 ± 60 B.P.	2052–2000 B.P.	102–50 B.C.
MIL 3/25 HK	UtC 3118	9.65 m b.s.l.	Charcoal	–26.3	2380 ± 60 B.P.	2462–2341 B.P.	512–391 B.C.
MIL 3/36 F	UtC 3119	11.65 m b.s.l.	*C. edule*	2.58	5470 ± 70 B.P.	5911–5743 B.P.	3961–3793 B.C.
MIL 7/2 F	UtC 3122	1.80 m b.s.l.	*C. edule*	–4.81	2140 ± 60 B.P.	1793–1630 B.P.	157–320 A.D.
MIL 7/9 HK	UtC 3123	4.95 m b.s.l.	Charcoal	–24.5	2130 ± 50 B.P.	2146–2007 B.P.	196–57 B.C.
MIL 7/13 SG	UtC 3124	6.10 m b.s.l.	Sea grass	–13	2970 ± 50 B.P.	2763–2711 B.P.	813–761 B.C.
MIL 32/4 F	Beta-121051[b]	3.55 m b.s.l.	Grape seed	–25.4	2770 ± 50 B.P.	2890–2785 B.P.	940–835 B.C.
MIL 32/7 HK	Beta-121052	5.55 m b.s.l.	Charcoal	–27.0	2830 ± 50 B.P.	2970–2860 B.P.	1020–910 B.C.
MIL 36/7 F	Beta-121053	2.80 m b.s.l.	Marine shell (liv. pos.)	2.2	3890 ± 60 B.P.	3910–3765 B.P.	1960–1815 B.C.
MIL 36/9 HK	Beta-121054	3.60 m b.s.l.	Charcoal	–27.8	4450 ± 70 B.P.	5270–4880 B.P.	3320–2930 B.C.
MIL 53/7 F	UtC 6056	1.68 m b.s.l.	*C. edule*	0.8	2344 ± 38 B.P.	1986–1895 B.P.	36 B.C.–55 A.D.
MIL 67/7 F	UtC 6055	1.53 m b.s.l.	*C. edule*	–0.5	2216 ± 37 B.P.	1845–1753 B.P.	105–197 A.D.
MIL 69/8 F	UtC 6054	2.88 m b.s.l.	*C. edule*	0.8	2391 ± 36 B.P.	2047–1952 B.P.	97–2 B.C.
MIL 118/12	UtC 10616	2.05 m b.s.l.	Marine shell	1.5	2272 ± 32 B.P.	1912–1837 B.P.	38–113 A.D.
MIL 119/5 Pf	UtC 10618	1.08 m b.s.l.	Wood	–27.3	1837 ± 31 B.P.	1821–1713 B.P.	129–237 A.D.
PRI 2/24	UtC 10214	4.05 m b.s.l.	Peat	–26.5	2549 ± 35 B.P.	2744–2553 B.P.	794–603 B.C.
PRI 4/17	KIA 7661[c]	7.35 m b.s.l.	*C.edule* (articulated)	–0.94	2958 ± 36 B.P.	2751–2714 B.P.	801–764 B.C.
PRI 7/31 H	UtC 10215	6.13 m b.s.l.	Wood	–29.5	3331 ± 35 B.P.	3632–3475 B.P.	1682–1525 B.C.
PRI 8/22 HK	UtC 10224	2.82 m b.s.l.	Charcoal	–24.8	1787 ± 35 B.P.	1732–1630 B.P.	218–320 A.D.
PRI 8/27 HK	UtC 10225	4.47 m b.s.l.	Charcoal	–24.8	2034 ± 43 B.P.	2039–1929 B.P.	89 B.C.–21 A.D.
PRI 11/19 PF	UtC 10226	2.64 m b.s.l.	Plant remains	–30.1	2199 ± 35 B.P.	2308–2133 B.P.	358–183 B.C.
PRI 11/27 PF	UtC 10227	4.89 m b.s.l.	Plant remains	–27.3	2992 ± 36 B.P.	3243–3079 B.P.	1293–1129 B.C.

Marine carbonates are corrected for the average reservoir effect of 402 years. *C. edule* = *Cerastoderma edule* (shallow marine/lagoonal bivalve); [a] UtC: R.J. Van de Graaff laboratorium, Universiteit Utrecht (Dr. K. van der Borg); [b] Beta: Beta Analytic Inc., Miami/Florida (Dr. M.A. Tamers and D.G. Hood); [c] KIA: Leibniz-Labor für Altersbestimmung, Christian-Albrechts-Universität Kiel (Prof. Dr. P.M. Grootes) tion of its use, Tuttahs (1998: 165 ff.) concludes that from A.D. 300–350 on, ship traffic was hindered by the silting up of the Lions' Harbour.

To the east of the Milesian Peninsula, a core was drilled at the presumably early Osmanic bridge (H. Lohmann, pers. comm.; in Wilski's (1906) map noted as "m-a Brücke", i.e. Medieval bridge), now to a great part buried in the alluvium of the Maeander (Fig. 6). The coring operation started at the base of the bridge when the water table was more than 1.25 m below the present sea level. (In summer the freshwater of the river is pumped for the irrigation of the cotton fields while the river mouth is closed to avoid seawater intrusion.) The coring did not reach the bedrock. However, from the radiocarbon stratigraphy it is evident that – as in the Lions' Harbour – the major sedimentation occurred in the Roman era.

It is noteworthy that all corings in the Theatre Harbour (cf. Fig. 4) revealed no ceramic fragments earlier than Roman Imperial times. This fact is strange since all the early settlement sites, starting even from the Chalcolithic foundation, were close by. An explanation might be a dredging of the harbour in Roman times; however, no supporting evidence from literature has yet been found. It is well possible that this action was carried out during the first century A.D. when emperor Nero ordered the construction of the Roman theatre with 15,000 seats, thereby renovating its Hellenistic predecessor. The transport of the heavy limestone and marble weights was best done by ship. Therefore, it made sense to clean the harbour which was obviously already threatened by being silted up. In addition, theatre performances in front of a swampy, stinking harbour would not have been very attractive.

Coring site Mil 53 (cf. Fig. 3) renders another hint for the strong siltation around Miletos in Roman times: The marine stratum, 4.40 m thick, is topped by 3.85 m of alluvium. The shallow marine/fluvial boundary (= foreset/topset contact) at a depth of 1.68 m b.s.l. was dated: 36 cal B.C.– 55 cal A.D. (*Cerastoderma edule*). Soon after that time, Roman tombs were built in this formerly marine area (Parakenings and Kerschner 1991). Their original base level has since been buried by 1–1.2 m of alluvium. North of Değirmen Tepe, 2.1 km further to the west, the lagoonal/fluvial boundary dates from 105–197 cal A.D. (*Cerastoderma edule*; at site Mil 67, 1.53 m b.s.l.). In Roman Imperial times this site changed to a terrestrial environment. Since then, the periodical floodings have accumulated 3.72 m of alluvium.

The coring sites Mil 118 and 119 reveal maximum water depths of 2.05 and 1.08 m, resp., in Roman Imperial times (cf. Fig. 3, Table 1). Even at the foot of the former island of Lade, the siltation in Roman times can be proven: 2.88 m b.s.l., 0.62 m above the shallow marine/lagoonal boundary, a specimen of *Cerastoderma edule* dates from 97–2 cal B.C. (site 69); the lagoonal/fluvial facies transition is at 1.50 m b.s.l.; this is topped by 3 m of alluvium.

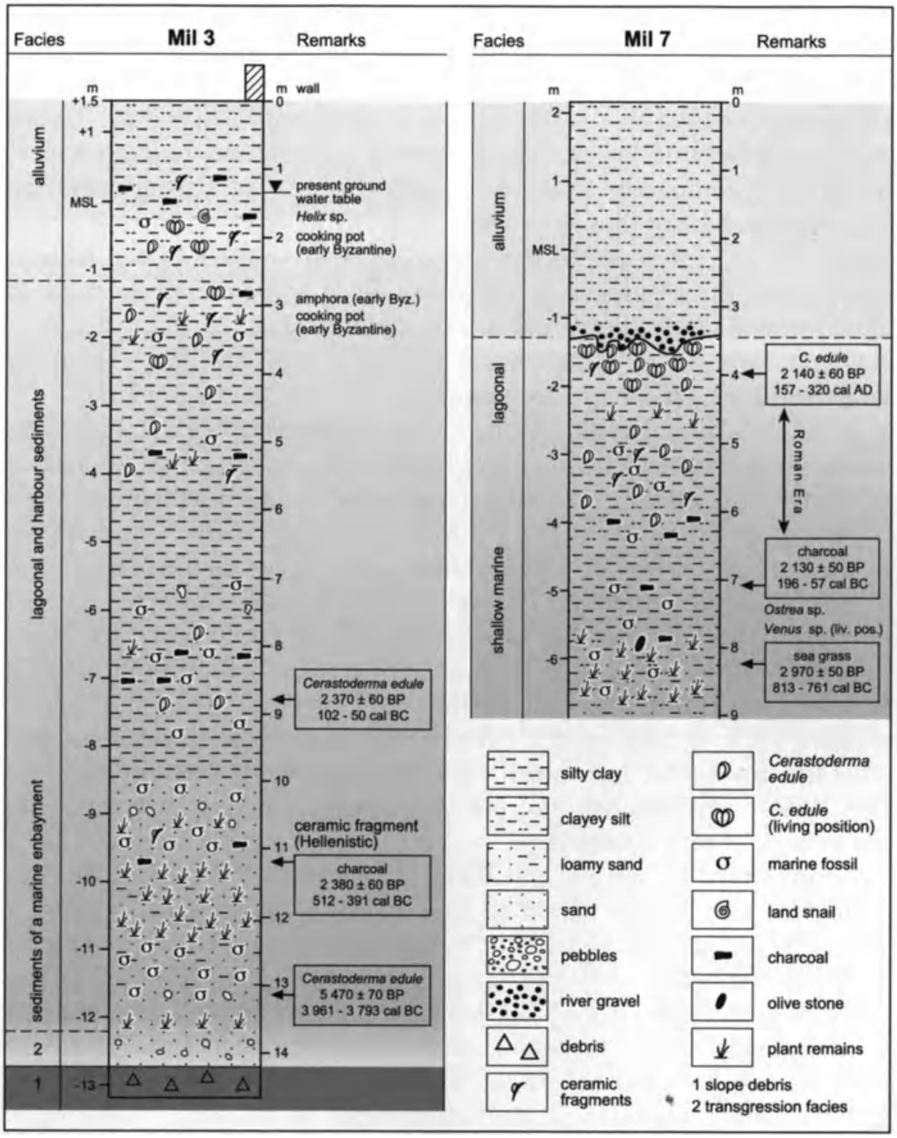

Fig. 6. Stratigraphy and ^{14}C chronology of the drill cores taken in the Lions' Harbour (Mil 3) and at the early Osmanic bridge (Mil 7)

In summarising it can be noted that the strong sedimentation around Miletos in Roman times – and especially in Roman Imperial time – is evident. The chronostratigraphy of the profile in the Lions' Harbour (Fig. 6) leads to the following calculation:

III	12.21 mm/a	580 cm in ca. 475 years	from 75 B.C. to ca. A.D. 400
II	6.27 mm/a	235 cm in 375 years	from 450 B.C. to 75 B.C.
I	0.58 mm/a	200 cm in 3425 years	from 3875 B.C. to 450 B.C.

In Roman time (III) the average sedimentation rate is doubled compared to the centuries in Classical Greek and Hellenistic times (II). Considering the millennia before these two historic periods (I), the rate was even accelerated by 21 and 11 times, respectively. Although already endangered from being silted up, Miletos was, however, still well accessible by ships, otherwise the Romans would have given up the city.

The reasons for the enormous increase in sediment supply are (1) the nearness of the delta front in Miletos during the Roman era so that the transition of the foreset beds causes a strong sedimentation in a relatively short time (much more, of course, than the advance of the bottomset beds); (2) the ecologically unwise land-use in Roman times. There is evidence that the climax vegetation – a light, deciduous oak forest – degraded to the secondary formations of macchia and garrigue; this process had already started with the Ionian colonisation and was accelerated in Greek and Roman times (cf. Brückner 1995, 1996; Wille 1995; see also Bay 1999a,b). The deforestation in the hinterland led to strong erosion features like gullies and badlands. The easily erodible rocks – strongly weathered Palaeozoic mica schists and Neogene sand-, marl- and claystones – were the source areas out of which the delta growth was fed.

5 The Palaeogeography of Priene

The site of the Archaic Priene – first mentioned in the seventh century B.C. – is unknown to date. There is an assumption that the city had been situated at the Latmian Gulf (probably near or under the present town of Söke, according to H. Lohmann, pers. comm.); however, due to the growth of the Maeander delta it lost its function as a sea port city. In the middle of the fourth century B.C., the old city was deserted and the new one founded in a strictly orthogonal pattern on a promontory at the foot of the Mykale mountains (formerly: Samsun Dağı, modern name: Dilek Yarım Adası). This Late Classical to Hellenistic Priene experienced the most economically prosperous period during its first three centuries. The Roman era, starting in 129 B.C., brought a general decline; one reason was the high tribute the city had to pay. During Byzantine times (A.D. 395–1280) when Priene was part of the East Roman Empire, several churches and chapels were erected. In A.D. 1280, the Seljuks conquered Priene and the surrounding area (cf. Akurgal 1993).

From the palaeogeographic point of view, the most interesting question is that of the harbour situation when Priene was refounded. Was it originally a seaport city? Strabo (12.8.17) confirms this; he notes, however, that already in his time (early first century A.D.) the distance to the coast had become 40 stades (ca. 7.8 km). Potential original harbour sites are the two embayments at the foot of the Mykale.

5.1 The Eastern Embayment

To cast more light on the progradation of the delta in the area of Priene, two cores were analysed in detail, especially concerning their ostracod content, and a ^{14}C chronology was established (see also Kammler 2000). One core is from the central floodplain, undisturbed by direct human impact (Pri 4), and the other one from the marginal floodplain out of the eastern embayment near Priene (Pri 11; Fig. 7).

Pri 4 (27°18′54.17″*E*, 37°37′01.40″ N, at the main drainage canal) shows marine facies – well sorted, light to dark grey silty fine sand – up to 10.70 m b.s. (= 7.70 m b.s.l.; the bedrock was not reached). Then the environment turns brackish, the facies change to a grey clayey silt with several specimens of *Cerastoderma edule*. This lagoonal stratum is 1.90 m thick. The top layer starts at 8.80 m b.s. (= 5.80 m b.s.l.). It is a light olive brown clayey or fine sandy silt with terrestrial gastropods in its upper part. An articulated specimen of *Cerastoderma edule* from the lower part of the lagoonal layer gave a ^{14}C age of 801–764 cal B.C. (7.35 m b.s.l.). We can conclude that in the central part of the Latmian Gulf at site Pri 4, the advance of the delta front must have happened as early as approx. 800 B.C.

The facial buildup of site Pri 11 is more complicated: Open marine conditions with the deposition of medium to dark grey silty sand prevailed up to 10.85 m b.s. (= 4.15 m b.s.l.). After a 0.45-m-thick zone of transition, lagoonal facies (grey clayey silt) follows up to 9.65 m b.s. (= 2.95 m b.s.l.). On top of this is a limnic to slightly brackish layer (medium grey clayey silt with some alluvial cone debris and terrestrial gastropods). From 7.05 to 6.30 m b.s. (= 0.35 m b.s.l. to 0.40 m a.s.l.) the layer is a greenish-blackish silty sand. This stratum, containing artefacts and alluvial cone debris in a limnic milieu, represents the cultural layer known from adjacent cores. The

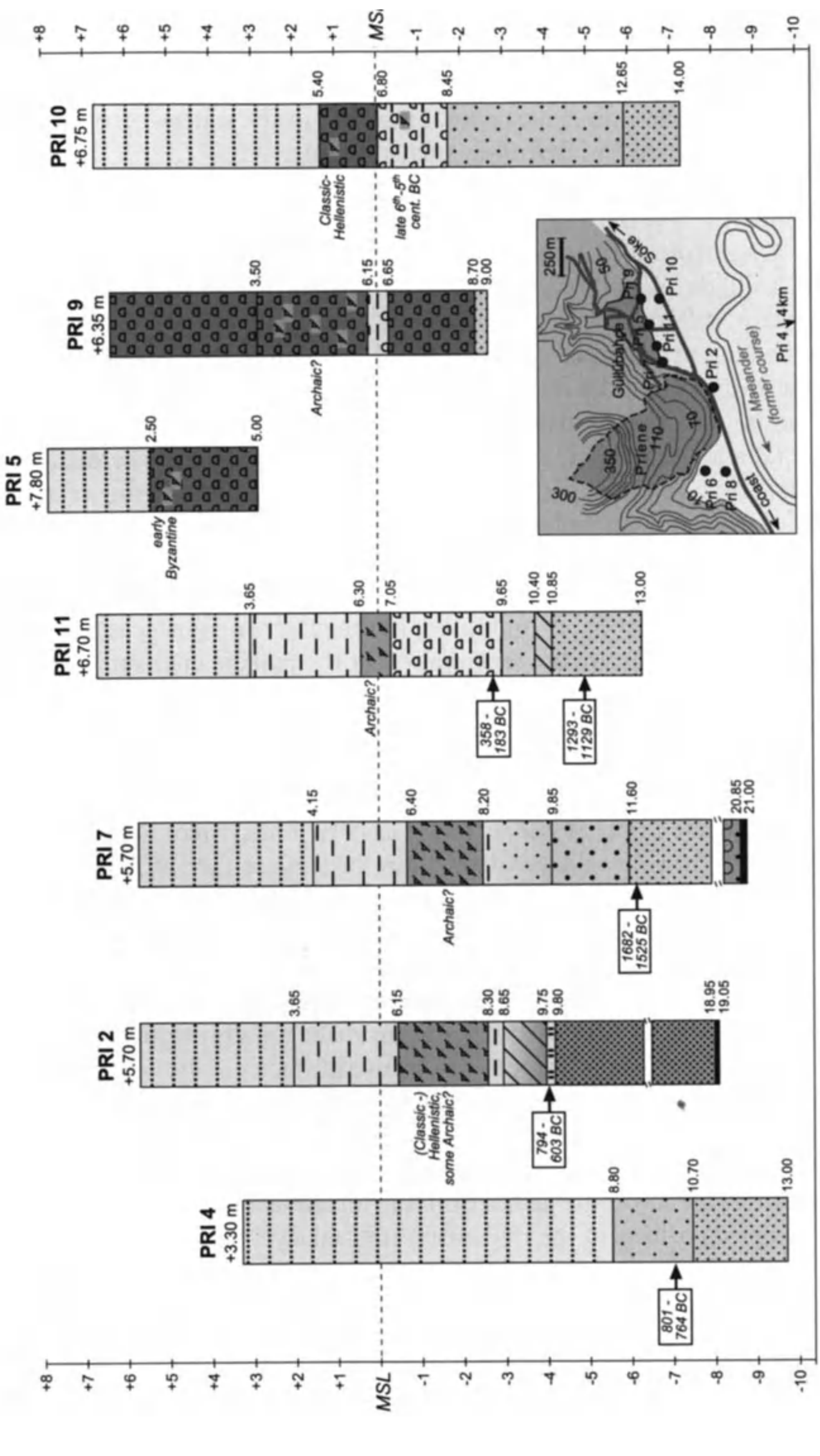

Fig. 7. Position and stratigraphy of drill cores in the eastern embayment of Priene and in the central plain (Pri 4) (legend cf. Fig. 8)

upper 6.30 m are limnic sediments (olive-grey clayey silt) and Maeander alluvium (medium brown sandy silt). ^{14}C dated plant remains render a chronostratigraphy: the age of 1293–1129 B.C. proves marine conditions still in the thirteenth/twelfth century B.C. However, in the fourth/second centuries B.C., the milieu had definitely turned limnic.

A synopsis of the profiles from the eastern embayment is shown in Fig. 7. Concerning the question of the termination of marine conditions in this area, a ^{14}C age from core Pri 2 is of interest: a backswamp peat at 9.75 m b.s. (4.05 m b.s.l.) developed 794–603 B.C. Furthermore, the profiles show a cultural layer at different depths starting in a limnic environment. It is noteworthy that no artefact has yet been found in the definitely marine facies. The determination of the often badly preserved ceramic fragments is difficult. So far, some Hellenistic artefacts were identified unequivocally. It seems that a few fragments date from the Archaic era, but the evidence is still shaky. In the eastern part of this embayment, sediments from an alluvial cone strongly contributed to the filling-up of the embayment.

We conclude that for the eastern embayment of Priene, marine conditions prevailed at least until the thirteenth/twelfth century B.C. The delta progradation most probably took place in the ninth or eighth century B.C. Sediments which indicate the termination of the marine environment are dated to 794–603 cal B.C. (peat from a backswamp, Pri 2) and 801–764 cal B.C. (lagoonal facies with *Cerastoderma edule*, Pri 4). At that time a sand spit or barrier beach must have formed, extending towards the Mykale. Landward of it, the Latmian Gulf turned brackish – in the delta-plain (around site Pri 4) as well as in the eastern embayment near Priene.

The prominent cultural layer dates from the time of the Late Classical – Hellenistic Priene which is evidenced by the definitely determinable artefacts as well as the ^{14}C age of a plant remain, stratigraphically corresponding to the lower part of the cultural layer (358–183 cal B.C., cf. Pri 11). The many ceramic fragments were either washed down from the city during catastrophic rains, or intentionally deposited in order to make a path through the wetlands. This marker horizon is topped by lacustrine facies in the western part, and alluvial cone debris in the eastern part of the eastern embayment. The ceramic fragments in the alluvial cone (e.g. early Byzantine pottery) were washed down from the Mykale. A major contributor to the filling-up of the eastern embayment was the debris from the torrential river east of the city.

The deepest position of the Hellenistic cultural layer is 2.60 m below present sea level (Pri 2). Its base is found within a lacustrine sediment. Therefore, when Priene was founded anew in the Late Classical period, the eastern embayment had already changed to a brackish, or even freshwater lake.

In Hellenistic times the water depth of the lagoon was shallow, all the more since the eustatic position of the sea level was then probably 1–2 m deeper than today (cf. Kayan 1995), and later sediment compaction and tectonic subsidence have to be considered, too. Unless there was a small outlet, ships would have had to be pulled into the lake over a sand bar. Whether or not this natural setting was favourable for a harbour site in Hellenistic times is a question that has to be answered by historians and archaeologists.

5.2 The Western Embayment

Until April 2001, only two sites had been cored in the western embayment (Fig. 8). At site Pri 8 the marine strata, represented by well sorted fine to medium sand with marine shell debris and an articulated specimen of the marine species *Lucinella divaricata*, reaches at least up to 12.70 m b.s. (= 6.90 m b.s.l.). The following layer is a medium to dark grey clayey silt to

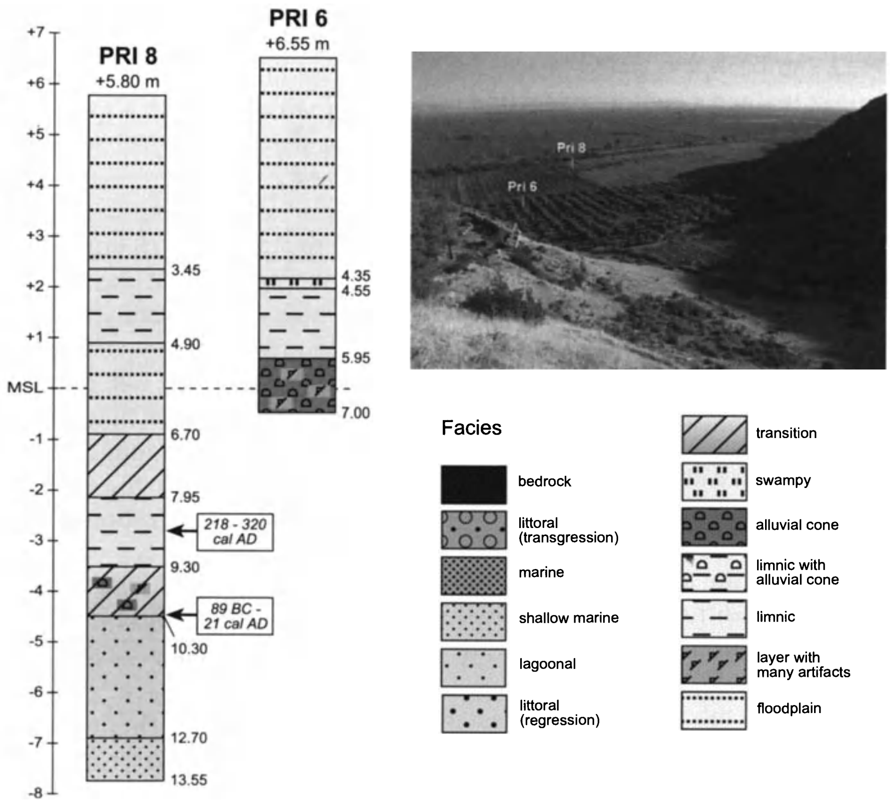

Fig. 8. Position and stratigraphy of drill cores in the western embayment of Priene as of April 2001

silty clay with charcoal and plant remains, reflecting a calm milieu of deposition up to 7.95 m b.s. (= 2.15 m b.s.l.); the section 10.30–7.95 m b.s. is especially rich in organic matter (up to 6.9 % loss on ignition). According to the ostracod fauna, a lagoonal section (12.70–10.30 m b.s.) is followed by a zone of transition (with a few ceramic fragments and alluvial cone debris) and a limnic stratum (9.30–7.95 m b.s.). On top of a 1.25 cm thick transition layer is the river alluvium, homogeneous well sorted medium grey silty fine sand, changing to medium brown clayey silt with some lenses of fine to medium sand in the upper part. Limnic facies is intercalated from 4.90 to 3.45 m b.s. (0.90–2.35 m a.s.l.).

The second core (Pri 6) hit the alluvial cone with angular rocks and cultural debris (ceramic and bone fragments) at a depth of 5.95 m b.s. (= 0.60 m a.s.l.). This massive layer could not be penetrated further than 7 m b.s. (= 0.45 m b.s.l.).

For Pri 8 a ^{14}C chronostratigraphy was established: The charcoal at 10.25 m b.s. (= 4.45 m b.s.l.), most probably originating from *Castanea sativa* (edible chestnut), was dated to 89 B.C.–A.D. 21. The fragment of a carbonised plant stem from Apiaceae (? deposited at a depth of 8.60 m b.s. (= 2.80 m b.s.l) was dated to A.D. 218–320. The sediment of the transition zone contained a complete specimen of a land snail at 9.90 m b.s. as well as some minor pebbles and ceramic fragments, the latter most probably washed in from the alluvial cone of the hinterland.

Based on the arguments discussed in the previous Section 5.1 and on Strabo's (12.8.17) account that the shoreline was 40 stades (ca. 7.8 km) to the west of the city around 0 B.C./A.D., the still-water sediments most likely represent a lagoonal environment behind a sand bar which was further to the west.

As for the western embayment of Priene, the synopsis leads to the following conclusion: Natural conditions for a harbour site were well given in Hellenistic times. Water depth was then several metres more than in the eastern counterpart, and the marine environment persisted longer. Sediments of a lake at ca. 3 m b.s.l. date from the third to early fourth centuries A.D., i.e. the Roman Imperial era. Therefore, the natural environment was well set for a harbour. However, archaeological proof has not yet been found since the area has never been excavated. The western embayment filled with sediments more slowly than the eastern one as it was sheltered from alluviation by the river due to its leeward position behind the promontory of the Priene rock.

For both embayments, the western and the eastern one, the top sediments are alluvium from the Maeander, often mixed with coarser material from the Mykale. The sedimentation occurred whenever the river flooded the alluvial plain or when floods washed material down from the steep mountains.

Further research is needed. A question which has to be answered by the archaeologists and historians is the discussion of the prerequisites of a harbour site in Hellenistic times. If boats only needed to be pulled onshore or over a sandbar into a lagoon, then these conditions were definitely given in the western embayment and even in the eastern one. However, the latter soon became too shallow. Therefore, the western embayment seems to have been favourable for the use as a harbour longer than the eastern.

6 Conclusion

The interpretation of the palaeogeographies of the Büyük Menderes flood- and delta-plain in space and time is based on corings taken with a percussion corer. In this paper, the focus is on the areas of the ancient cities of Miletos and Priene.

During the peak of the Holocene transgression, ca. 5000–6000 years ago (cf. Kayan 1995), the marine embayment of the Latmian Gulf extended far inland. The area of the later city of Miletos was then composed of islands. One of them hosted the earliest settlement dating from the second half of the fourth millennium B.C. When the Minoan settlers arrived around 1900 B.C. this island topography is likely to have persisted; however, hints of an already existing connection with the adjacent mainland by a sandbar (tombolo) cannot be neglected. The Roman time – especially the Roman Imperial era – witnessed strong siltation processes around Miletos.

As for Priene, the most interesting question under palaeogeographic perspective is that of the harbour site(s) when the city was founded anew around 350 B.C. Potential areas are the eastern and western embayments at the foot of the promontory of Priene. The ceramic and ^{14}C stratigraphies led to the conclusion that in Late Classical times the eastern embayment had already changed to a freshwater lake. In the western embayment, however, natural conditions for a harbour site were well given in Hellenistic times. This embayment was filled with sediments more slowly than its eastern counterpart since it was sheltered from alluviation by the river due to the leeward position behind the promontory of the Priene rock.

Acknowledgements

The palaeogeographic research in the Büyük Menderes delta plain is financially supported by the German Research Council (DFG-AZ: Br 877/17–1, -2) which is gratefully acknowledged. I want to thank the Turkish authorities for granting the working permits. Thanks are also due to Prof. Dr. V. von Graeve and Prof. Dr. H. Lohmann, both at Bochum University, Dr. B. and Prof. Dr. W.-D. Niemeier, now at Athens, as well as Prof. Dr. W. Raeck, Frankfurt/Main, who supported our work at Miletos and Priene, respectively. The ceramic fragments were kindly determined by Prof. Lohmann. Microfauna analyses were carried out by Dr. M. Handl, Marburg (for ostracods) and Dr. R.W. Gehrels, Plymouth (for foraminifera). Most radiocarbon dates were provided by Dr. K. van der Borg, Utrecht (AMS-^{14}C). The Ph.D. students and Diploma students of geography, respectively, C. Günther, W. Kammler, M. Müllenhoff, B. Schultz, W. Strate and A. Wullstein, all at Marburg University, and L. Uncu, Ege Üniversitesi, Izmir, assisted during fieldwork. This study is a contribution to the UNESCO IGCP Project 437 "Coastal Environmental Change During Sea-Level Highstands".

CHAPTER 10

Early Bronze Age Metallurgy in the North-East Aegean

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Abstract

The accelerated cultural and technological development in the Aegean in the third millennium B.C. has been interpreted by two mutually exclusive models, namely diffusion of materials, technology, and/or population, on the one hand, and indigenous development triggered by two innovations, namely domestication of the olive tree and especially the discovery and introduction of bronze technology. The second model implicitly assumed the presence of a geological tin source in the Aegean. The fact that such a source has not been found was attributed to possible depletion of a minor occurrence. Extended field studies have resulted in a realistic assessment of the potential of the Troad for ancient miners and smelters. It turns out that lead (and silver), copper and gold were available and produced in the Bronze Age, but tin remains elusive. Geochemical, especially lead isotope studies of ores, slags, and metal artefacts have shown that practically all ore mineralisations in the Troad exhibit only a relatively small variation in their lead isotope ratios. Interestingly, the earlier artefacts of the first half of the third millennium B.C. are mostly consistent with having been derived from regional ores while a large part of the later artefacts dating to the Troia II period are significantly different from all hitherto analysed ores from the Aegean and Anatolia. Although negative, this evidence nevertheless indicates long-distance trade. Therefore, even if a small occurrence of tin should ever be found in the region then it will most likely be isotopically different from most of the bronze artefacts that have been available for analysis. This result makes the model of indigenous development highly unlikely and re-establishes the older ideas of diffusion (trade in its widest sense) of at least copper and tin. For lead and silver objects there are isotopically matching ore deposits in the Troad and in the Aegean, but the separation of lead and silver by cupelleation seem to have been introduced in the Near East earlier than in the Aegean. Finally, the distribution of early bronze artefacts is reviewed and the possible provenance of the tin shortly discussed.

1 Introduction

In the fourth millennium B.C. the Aegean was characterised by the existence of relatively isolated regional groups of the Final Neolithic. Beginning with the third millennium B.C. an unprecedented rise in trade, art and craftsmanship can be observed in the distribution of certain artefact types over the whole region. More specifically metals begin to play a major role in the inventory including the appearance of new metals like tin and bronze, lead, silver and gold. From the sudden increase in the number and size of settlements it has also been inferred that the population increased substantially. Traditionally these major cultural changes have been variably attributed to influence and contact with or even immigration from the eastern Mediterranean (e.g. Evans 1921–1935; Childe 1957; Vermeule 1964; Schachermeyr 1984).

Quite a different explanation for the observed cultural and technological change was presented by Renfrew (1972). He stressed the continuity between the Late Neolithic and the Early Bronze Age in the Aegean and pointed out that metallurgy and fortified settlements had developed earlier in the region. Many sites show signs of metallurgy and the uneven distribution of grave goods and the discovery of metal hoards would indicate social stratification suggesting that a proto-urban level of culture was reached which contrasted with the more egalitarian society that is imagined for the Greek Neolithic. Renfrew proposed that two economic factors may have initiated this development, namely the intensification of farming due to the domestication of the vine and the olive and the discovery of the alloying of copper with tin to make bronze. With a surplus in food production and metals as new commodities a system of redistribution would naturally develop that would result in craft specialisation and intensified trade as well as in the accumulation of wealth that we find in this period. This and the introduction of new weapons such as the dagger would almost certainly lead to more instability and even hostility between rival communities so that it was desirable for everyone to obtain metals which would further accelerate the economic development and lead to a homogenisation of different cultural regions in the Aegean. It has been mentioned that there was something of an "international spirit" at this time that was considered to be primarily the result of the impact of metallurgy.

The idea that the invention of tin bronze as a new material for weapons and tools may have triggered the transformation process in terms of the economy, technology and social organisation of the time did not seem unreasonable. Quite in contrast, it appeared so convincing and self consistent that it soon replaced the earlier models based on influence from the urban civilisations in the eastern Mediterranean and in Mesopotamia that were brandmarked as crudely diffusionist. The problem with this hypothesis is, of course, the lack of any real evidence for local tin sources. Therefore, Renfrew (1967) suggested that tin may have been brought in from a distant source in Italy or Spain or may have been found in a small deposit in the north-east Aegean, where most of the early tin bronzes are found. Such a small deposit may have been worked out in a short time and no trace may be left.

2
Troia and the Development of Metallurgy in the North-East Aegean

Several dozens of Chalcolithic metal artefacts are known from the fifth and fourth millennia Aegean. Many of their typological features point towards the Balkans and it seems that these metal objects might be just a faint echo of the flourishing metallurgical activity of the south-east European Copper Age. Although links between Thessaly and the Balkans based on pottery styles had already been established in the Neolithic, it originally appeared that the Aegean and western Anatolia neither took part in the development of early metal usage in the Balkans nor with that as it was practised in central and eastern Anatolia. This observation then led to the suggestion that the smelting and working of metals should have been independently invented in eastern Anatolia and south-eastern Europe and that only in the Early Bronze Age, with the beginnings of Troia in the early third millennium B.C., this apparent geographical gap of metal usage was filled.

Nowadays, this hypothesis is increasingly questioned because of new finds of copper artefacts from the middle and late Neolithic, particularly at Dikili Tash and Paradeisos in northern Greece, but also in the Kitsos Cave in southern Attica and the Kalithies Cave on Rhodes. According to the present evidence, already in the middle of the fourth millennium B.C. the two areas of metal usage in south-eastern Europe and eastern Anatolia were definitely joined in a common metallurgical tradition that has been termed the *Circumpontic Metallurgical Province* by E. N. Chernykh (1992). It is characterised by the use of arsenical copper and the first appearance of new types of objects like e.g. daggers in the north-east Aegean region. This tradition is represented at Ilipinar (Roodenberg 1995) and continues into the first half of the third millennium B.C. at Beşiktepe and at Thermi on the island of Lesbos (Lamb 1936).

In this period new metals make their first appearance in the Aegean, namely silver (Poliochni azzurro), lead (Beşiktepe, Thermi), tin (Thermi), and tin bronze (Troia, Beşiktepe, Thermi, Poliochni verde). By the end of the Early Bronze Age the north-east Aegean abounds in technologically advanced metal artefacts such as the objects in the rich hoard finds from Troia, but also from Poliochni on the island of Limnos (Bernabo-Brea 1964). Most significant is the regular use of tin bronze that seems to have made its earliest appearance in the archaeological record at this time. The sudden rise of metal usage has frequently been noted, but the views on its origin have differed greatly as already mentioned in the introduction. While the traditional view saw the rise of metallurgy in the Aegean as evidence for foreign influence, or the arrival of foreign people, indigenous causes for this technological change have been proposed during the last two decades. It has even been suggested that the discovery and indigenous development of tin bronze in the north-east Aegean may have triggered the social and cultural changes observed in the Aegean in the Early Bronze Age.

The hypothesis of an indigenous development of metallurgy in the north-east Aegean obviously implies that ore deposits should have been available in that region and, indeed, it has been suggested that there may once have been a small tin deposit somewhere in north-western Anatolia that might soon have been depleted. Archaeometallurgical surveys, conducted during the last two decades by several teams have now identified more than 200 ancient metallurgical sites in the Aegean and in Anatolia. Many mining and smelting sites for copper ores, ranging back into the fourth millennium B.C., have been found, but the search has not yet yielded a single undisputed tin source in the Aegean region. Claims for tin deposits in the Bursa area have been made (Kaptan 1983), but have never been substantiated.

It is possible and intriguing to test the various conflicting hypotheses on the origin of metallurgy in the Aegean with scientific methods. It has long been suspected that archaeological metal objects carry some information on their provenance in their material and that e.g. trace element concentrations can be used as a guide to trace its origin back to the original ore deposit. Such ideas were formulated more than 100 years ago. One early example is Göbel (1842) with an extended title that reads like an abstract. In (the authors') translation it reads: "On the impact of chemistry on the tracing of prehistoric peoples, or results of the chemical investigations of ancient metal objects, especially of those from the Baltic region, to determine the peoples from whom they derive." He drew his conclusions from the geographical distribution of about 120 analysed objects and ascribed them to seemingly well-defined ethnic groups as was normal in those days. It should be remembered that the three period system had been proposed only a few years earlier, by Thomsen in 1836, and that an additional motivation for the analyses was the desire to date metal objects based on their compositions. It was discovered that minor elements were useful in determining the nature of the ore from which the metal came and perhaps even its geographical origin (von Fellenberg 1860–1866; von Bibra 1869).

Very large analytical programs for ancient metal objects were performed along these lines, but their results are still in dispute and the conclusions that can be drawn from them seem unclear. Opinions range from complete rejection to close to acceptance. The metal objects were classified according to their chemical composition and the distribution in time and space of these metal groups was studied. It is obvious that the choice of elements is most important for the formation of these groups and the information that can be gained. For provenance determination only those elements are useful that follow the copper closely in the pyrometallurgical process involved in copper production. From thermodynamic data and experimental studies of modern technology it can de deduced that the concentrations of Au, Ag, Ni, Sb, As, Bi, Co, Pb, and with some restrictions Se and Te should be most indicative of the ore source. Thus, they can be regarded as something like a fingerprint of the ore. Unfortunately this fingerprint is not as unique and indicative as the human one. Many ore deposits have similar trace element concentrations so that in many cases they cannot be differentiated.

It is, therefore, necessary to use additional parameters and lead isotope ratios have proven particularly useful, because they are not altered on the way from ore to metal to any measurable extent. Furthermore, due to the fact that three of the four stable isotopes of lead are produced by radioactive decay of uranium and thorium the lead isotope ratios depend on the geological age of a deposit and its geochemical environment. On its formation the ore minerals are normally effectively separated from these radioactive elements so that no further change of the lead isotope ratios can occur. With the application of lead isotope analysis to copper-based alloys (Gale and Stos-Gale 1982) chemical analysis of ancient metal objects seems to have become unnecessary. Although lead isotope ratios are usually better indicators of provenance there are cases where the trace element pattern may be even more indicative of an ore source than lead isotope ratios. At Feinan, Jordan, for example, the ore deposit is chemically homogeneous, but shows wide variations in its lead isotope ratios (Hauptmann et al. 1992). In addition, lead isotope ratios are strongly correlated so that only a small part of the theoretically possible, three-dimensional space is occupied resulting in a tendency for different ore deposits to overlap. In such a situation it is common sense that a combination of both sets of data – lead isotope ratios and trace element concentrations – will provide better discrimination between different sources. This approach was adopted by the Heidelberg/Mainz group from the very outset (Pernicka et al. 1984).

A further prerequisite for a comparison of artefacts with ore deposits is, of course, a comprehensive knowledge of possible ore sources. During several field studies about 30 sites in the Troad with a potential for early metal production were studied and sampled as well as about 200 more in the Aegean and in Anatolia. The results of the field studies confirmed extensive ancient mining for copper and lead/silver, but despite much effort no tin was found. In the following section the archaeometallurgically most interesting sites are described.

3
Ancient Mining and Smelting Sites of North-West Turkey

The Troad exhibits not only strikingly different landscapes, but also rather complex geological structures resulting in a variety of ore types (cf. Yılmaz, this volume). Occurrences of gold, lead, silver, copper and iron ores are known and many of them have been exploited since prehistoric time. In view of the wealth of archaeological metal objects at Troia itself and on the neighbouring north-eastern Aegean islands of Lesbos and Lemnos, the question about the potential of these occurrences as metal and ore sources have been repeatedly raised by various scholars since Frank Calvert's and Heinrich Schliemann's time. Travellers in the Troad occasionally reported observations on ore occurrences as well as mining and smelting sites, but a more systematic survey was lacking (cf. Cook 1973).

On the other hand, modern geological prospection studies produced a lot of information on metals in Turkey and in particular in north-western Turkey. Essentially these are the reports by Ryan (1960), the MTA Monographs No. 129 (1970) *Arsenic, Mercury, Antimony and Gold in Turkey*, No. 133 (1972) *Lead, Silver and Zinc Deposits of Turkey* and No. 145 (1971) *Türkiye Demir Envanteri*. For many of the sites mentioned therein ancient workings have also been reported. With the aim to locate and identify as many of the ancient metal sources around the Sea of Marmara as possible, archaeometallurgic reconnaissance surveys were undertaken in 1975, 1983 and 1985. During these campaigns, known sites were re-visited and others were described for the first time. This survey was part of a larger project, and details about these archaeometallurgical sites were already published by Gentner et al. (1978), Pernicka et al. (1984), Wagner et al. (1986) and Wagner and Öztunalı (2000). The present contribution briefly summarises archaeometallurgical sites that show signs of ancient workings. The area covered deals not only with the Troad, but is extended to the wider landscapes around the Sea of Marmara, that is Thrace and north-western Anatolia (Fig. 1).

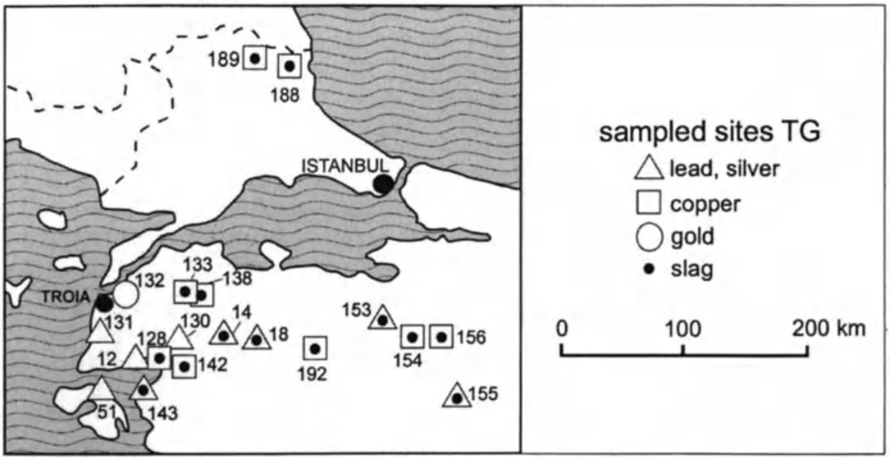

Fig. 1. Archaeometallurgical sites in north-western Turkey (with locality code numbers)

3.1 Gold

3.1.1 *Astyra (TG 132)/Çanakkale Province*

These famous gold mines at the hills Kaletaş and Kartalkay, situated at ca. 300–440 m elevation about 20 km south-east of Çanakkale along the road from Çiftlik to Bayramiç, are commonly identified with those of ancient Astyra and Kremaste. They were discovered in the mid-nineteenth century by F. Calvert and visited by many scholars, among them H. Schliemann and W. Leaf. At Kartalkaya the dacitic tuffs and lavas are crossed by a 15–30 m thick hydrothermal quartz vein which contains finely distributed pyrite and native gold. Started in the nineteenth century by Calvert, but abandoned already in the early twentieth century, the vein has been exploited by an up to 20-m-wide and 80-m-deep open pit (Fig. 2). On its walls there are numerous ancient galleries intersected (Fig. 3). Charcoal which was collected from such a gallery gives a ^{14}C-age of 790–400 B.C. In the surroundings one observes shaft openings and dumps of mining waste, occasionally also ceramic fragments. The nearby remains of a settlement probably represent the site of ancient Astyra.

It is unknown if this gold occurrence could have been or was exploited in the Early Bronze Age. Analyses by Hartmann (1982) show that the gold finds from Poliochni were alloyed with copper, presumably to alter the colour of the original gold-silver alloy. This renders a comparison of the

Fig. 2. Astyra, Kartalkaya, open-pit mine

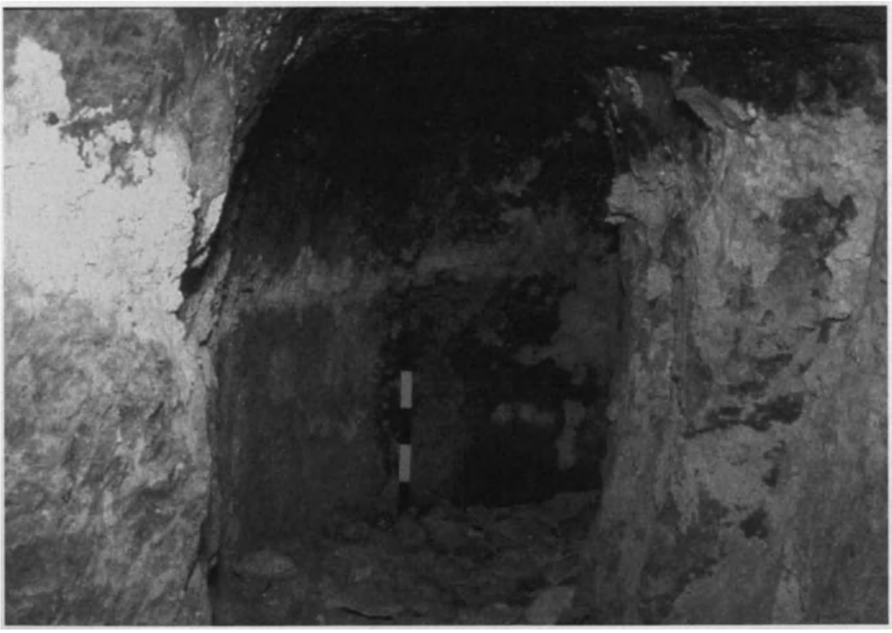

Fig. 3. Astyra, Kartalkaya, ancient (Classical) gallery intersected by modern mining (*scale* 50 cm)

natural occurrence with archaeological artefacts difficult, even if analyses of the Troian gold objects were available. Nevertheless, it would be interesting to know if their composition is comparable to the ones from Poliochni.

3.2
Lead and Silver

3.2.1
Altınoluk (TG 12)/Çanakkale Province

This mining district is situated at Maden Dere ca. 2 km north-west of the village Altınoluk, at ca. 460 m elevation at the southern slope of Kaz Dağ. Within amphibolite schist and marble there are polymetallic ores consisting of galena, sphalerite, pyrite, chalcopyrite, bornite as well as secondary copper minerals. From these ores lead, silver and copper may have been produced. There are numerous remains of modern underground mining activities, essentially from the late nineteenth and early twentieth centuries that unfortunately had more or less completely destroyed traces of earlier workings. Still visible traces of older phases probably stem – according to cross sections of adits (Fig. 4) as well as tool marks and thick sinter crusts

Fig. 4. Altınoluk, ancient (probably Hellenistic) gallery intersected by modern mining (*scale* 50 cm)

on the walls – from the Hellenistic, Byzantine and Osmanic periods. Slags were not found.

3.2.2
Karaaydın (TG 14)/Balıkesir Province

This mining area lies ca. 3 km south-west of the village of Karaaydın, but several slag heaps occur closer to the village. The ore deposit occurs within a marble/schist series and consists of galena, sphalerite, pyrite, chalcopyrite, arsenopyrite as well as secondary iron and copper minerals. The abandoned underground mining activity took place around the turn of the nineteenth/twentieth centuries, but older traces are visible, among them a narrow adit, tool marks and exploitation pockets. At the surface there are filled shaft entrances. The analysis of slags indicate lead and iron production, but silver and copper smelting is also conceivable. Surface finds of ceramics near one slag pile imply Hellenistic and Byzantine activities.

3.2.3
Balya (TG 18)/Balıkesir Province

Balya is one of Turkey's major lead-silver deposits and the traditional mining centre of north-western Anatolia. This district with numerous mining and smelting remains extends over an area of several km^2 at 200–400 m elevation This polymetallic deposit consists of different types of formation phases. Geologically, the deposit is associated with dacite which intruded into limestone and clastite. The ores contain sphalerite, pyrite, tetrahedrite, bournonite, jamesonite, arsenopyrite, chalcopyrite, orpiment and realgar. The deposit carries an oxidation zone with secondary lead, iron and copper minerals, among them commonly malachite and azurite. Apart from lead and silver Balya also produced some gold. Although the copper mineralisation has no economic value for modern exploitation, the situation might have been different in prehistoric periods so that in prehistoric time Balya may have been not only a source for silver and lead, but also for copper and gold. The Balya ore district has numerous traces of mining and smelting from prehistoric to recent periods. There are numerous ancient adits extending to 50 m below the surface. Next to the shafts there are fine-flaked ore dumps, which also contain secondary copper minerals. According to cross sections of the adits and tool marks (Fig. 5), it is possible to distinguish several working phases, probably belonging to prehistoric, classical and Byzantine periods. Ceramic finds at the surface identify Hellenistic, Roman, Byzantine and Osmanic activities. Lead slags are very common, but clear evidence either for mining or smelting of copper ores

Fig. 5. Balya, Melisse gallery, ancient tool marks on adit wall

was not discovered. Wiegand (1904) localised the ancient mining site of Pericharaxis in Balya.

3.2.4 *Argenos (TG 51)/Lesbos Island*

Although it does not belong to Turkey this site is included here for completeness since it may have functioned in the past as metal source for Troia. It is situated on the northern shore of the north-eastern Aegean Greek island of Lesbos below Argenos village and directly opposite Assos on the Turkish mainland. It was visited in 1975 and 1983. The ore mineralisation occurs in steep quartz veins within dacite and consists of galena, sphalerite, chalcopyrite, arsenopyrite, bournonite, hematite, azurite, malachite. There are several entrances to galleries in the cliff (Fig. 6). The mine was abandoned in the early twentieth century. However, inside numerous narrow adits and shafts (Fig. 7) which exhibit tool marks and lamp niches on the walls are intersected. These workings are undoubtedly of considerable, but unknown age. They might have been aimed not only at lead and silver, but also for copper.

Fig. 6. Argenos (Lesbos), cliff with quartz vein and mining traces

Fig. 7. Argenos (Lesbos), waste backfillings on floor of ancient gallery

3.2.5
Avcılar (TG 128)/Balıkesir Province

Remains of mining and smelting occur south-west of the village of Avcılar. The ore mineralisation occurs in a contact zone of limestone next to granodiorite and consists of galena, sphalerite, magnetite, chalcopyrite and pyrite. The mining activities were apparently recent, but had already been abandoned when visited. The slag pile west of the village is left over from copper smelting which probably took place during Hellenistic times as indicated by surface finds of ceramics. Traces of ancient lead/silver production were not observed.

3.2.6
Güre (TG 130)/Balıkesir Province

Near the village of Güre there are several remains of ancient mines and slag piles. The ore mineralisations occur in mica schist as well as in the contact zone between marble and granodiorite. Ore minerals hematite, limonite, pyrite, arsenopyrite, scheelite and magnetite were observed. There are several narrow adits with a rectangular cross section with tool marks on the walls. According to their type, these adits may well be of Hellenistic age. Since these galleries are essentially within secondary iron minerals it is not clear what has been extracted there. The slag pile contains spherules of metallic lead and less frequently of iron. Numerous ceramic fragments of mainly Hellenistic and Roman, but also of Medieval age were observed.

3.2.7
Bergaz (TG 131)/Çanakkale Province

Near the village of Bergaz (new name Gökcebayir) there is a small lead-zinc occurrence in the contact zone between marble and granodiorite. In weakly mineralised, hydrothermal veins magnetite, pyrite, limonite, galena, sphalerite and malachite were observed. There are several shafts of unknown, but probably rather recent age. Slags are not known nearby.

3.2.8
Maden Adası (TG 143)/Balıkesir Province

This small island north of Ayvalık is essentially built up by andesite and is crossed by a north–south trending mineralisation zone. The hydrothermal ore veins contain galena, sphalerite, pyrite, chalcopyrite, chalcosite, bornite, boulangerite, siderite, hematite, limonite and secondary copper minerals. There are numerous underground mines along the zone which were abandoned in the twentieth century. During this mining ancient workings were encountered such as narrow adits with tool marks and small-flaked back-fillings. These workings may represent several phases, but are not yet dated. Apart from lead and silver copper might also have been produced there.

3.2.9
Madenbelenitepe (TG 153)/Bursa Province

This site with several mining and smelting remains is situated near Soğukpinar south of the Uludağ massif. The ore mineralisation occurs in pneumatolytically altered granitic rocks (greisen) and contains galena, sphalerite, arsenopyrite, chalcopyrite, pyrite and fahlore. The existence of the tin minerals stannite and cassiterite, announced by Çağatay et al. 1981, could so far neither mineralogically nor chemically be confirmed by us. Two inclined, narrow and irregular shafts with tool marks were observed. There are several slag piles, which probably stem from lead and copper smelting activities. ^{14}C dating of charcoal from one of these piles indicates Osmanic workings, but older ones are also possible. The claim by Kaptan 1983, that Madenbelenitepe is a likely source for early tin bronze, deserves some scepticism.

3.2.10
Gümüşköy (TG 155)/Kütahya Province

This site with plenty of mining and smelting traces is situated near the village of Gümüşköy. The ore bodies are placed near the contact between andesitic tuffite and metasediments. The polymetallic mineralisation occurs in the silicified tuffites and consists of galena, sphalerite, pyrite, chalcopyrite, antimonite, realgar, orpiment, freibergite, pyargyrite, proustite, native silver, malachite and other secondary copper minerals. Traces of ancient workings are overwhelming. There are large waste and ore dumps as well as lead smelting slags. The mining waste is rich in archaeological objects, such as stone tools and potsherds of various ages. A charcoal sample collected from the backfilling in an ancient gallery at 46 m below the surface gave a late third millennium B.C. ^{14}C-age. Although it is clear that this Bronze Age underground mining, as well as the workings during later periods, aimed primarily at silver and lead, it may well be that at earlier periods copper was also produced.

3.3
Copper

3.3.1
Doğancılar (TG 133)/Çanakkale Province

This place with mining and smelting traces consists of several sites at 450–560 m elevation ca. 7 km north of Doğancılar village near Çan. The ores occur in hydrothermal, silicified veins within a dacitic series. As primary sulphides galena, sphalerite, chalcopyrite and pyrite were identified. The gossan of the deposit contains hematite, limonite and malachite. Filled-in open diggings and a narrow adit were observed. The small-flaked, ancient ore waste contains predominantly malachite fragments. There are also two large piles of copper slags. Although prehistoric activities could not yet be verified, this site has the potential of being an important centre for prehistoric copper production.

3.3.2
Yuvalar (TG 138)/Çanakkale Province

This district with its numerous mining and smelting remains is situated at ca. 220–230 m elevation approx. 2 km north-east of Yuvalar village near Can. The ore mineralisation is within a contact-metamorphism zone between granodiorite and mica-schist. The ore minerals pyrite, chalcopyrite, hematite, limonite and malachite were observed. Open diggings, up to 3 m wide and 2 m deep, and narrow entrances of collapsed adits are visible. The waste dumps contain limonite, malachite and a little sulphide. Due to ceramic finds prehistoric activities seem likely, whereas classical and medieval workings are verified. The slag piles indicate copper smelting. As to the age of the smelting, ^{14}C dating on charcoal and TL dating on a ceramic sherd taken from slag piles point towards second millennium B.C. as well as Roman copper production.

3.3.3
Kozcağız (TG 142)/Balıkesir Province

This site with numerous abandoned workings on both sides of the Havran to Kalkım road is situated near the village of Kozcağız (new name: Fazlica) at elevations between 400 and 600 m. The ore mineralisation occurs in the contact-metamorphism zone between granodiorite and a marble-schist series. It contains magnetite, chalcopyrite, bornite, galena, sphalerite, scheelite, pyrite, limonite, malachite and other secondary copper minerals. One finds numerous open and closed shafts which belong undoubtedly to a rather recent mining phase as well as numerous more ancient filled-in shafts and mine dumps. There is plenty of copper slag encrusted by malachite. Due to common finds of ceramic sherds in the slag piles the copper smelting belongs mainly to the late Roman and early Medieval periods, which is supported by TL dating.

3.3.4
Keleş (TG 154)/Bursa Province

This minor copper deposit is situated at ca. 900 m elevation on Gelemic Yayla north-east of Keleş. The ore mineralisation occurs within the contact-metamorphic zone around a granite intrusion in limestone. It occurs in veinlets and thin lenses. The ore minerals are pyrite, chalcopyrite, galena, molybdenite, limonite, azurite and malachite. Old underground workings – with exploitation pockets and mining waste thickly covered with calcareous sinter – of unknown age were observed. There are piles of copper slags. The smelting activities at these sites are also of unknown age.

3.3.5
Tahtaköprü (TG 156)/Bursa Province

This minor occurrence of copper ores is situated at around 500 m elevation ca. 5 km north-west of the Koçayaylar pass between Tahtaköprü and Domanic. The mineralisation belongs to the contact-metamorphic zone between granite and limestone. It consists of chalcopyrite, bornite, chalcosite, covellite, malachite and other greenish copper minerals. The walls of the quarry intersect several narrow adits and shafts which follow the cupriferous veinlets (Fig. 8). ^{14}C dating of a charcoal fragment, collected from the

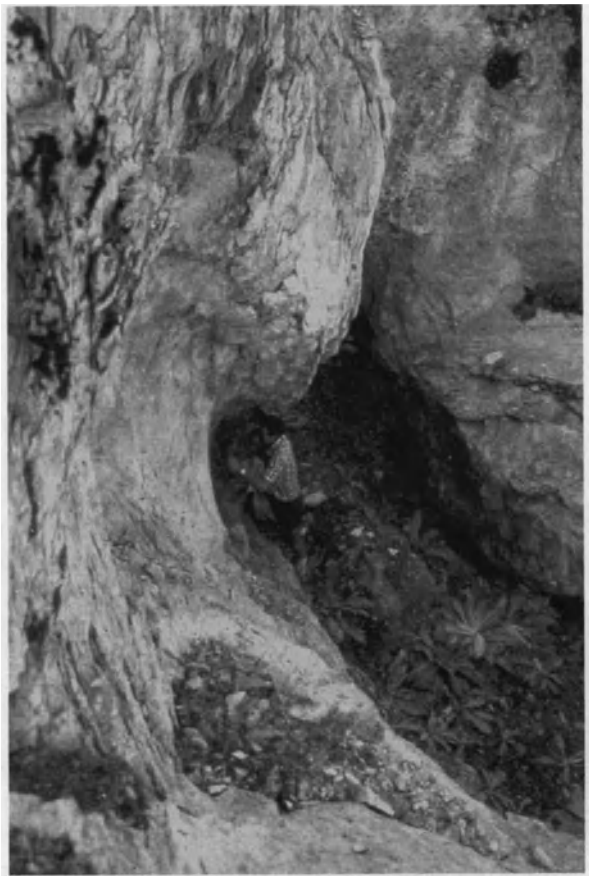

Fig. 8. Tahtaköprü, prehistoric adit intersected by modern open-pit mining

backfilling in such an adit, indicated fifth century mining activities. However, in addition to this late Roman phase prehistoric workings are also likely, due to the narrow and rounded cross sections of the adits. Nearby there is a copper slag pile of unknown age.

3.3.6
Ikiztepe (TG 188)/Kırklareli Province

This copper deposit with numerous mining and smelting traces is named after the 664 m high Ikiztepe hill a few kilometres west of Demirköy. In hornfels, at the contact between marble and granodiorite, a mineralisation with pyrite, chalcopyrite, chalcosite, scheelite, molybdenite, limonite, malachite and other secondary copper minerals has formed. Mining activities were abandoned in the twentieth century, but the remains of older workings are very common, among them open-cast mines from the Osmanic period. An earlier phase of open dig mining with small flaked rock cuttings belongs, according to ^{14}C dating of charcoal, to Roman activities around 240–410 A.D. However, prehistoric workings in this widely extended area also seem likely. Large piles of copper slags are still present. The extensive copper smelting very likely belongs to the Roman period as is also indicated by a TL age of 300 A.D. ± 160 years.

3.3.7
Dereköy (TG 189)/Kırklareli Province

This area near the Bulgarian border a few kilometres north-east of Dereköy village is an old copper production district at 400–700 m elevation with numerous traces of abandoned mining and smelting activities. The ore mineralisation belongs to a porphyry copper type within granodiorite as well as to a skarn type at the contact with diorite. Ore minerals chalcopyrite, pyrite, limonite and malachite among other greenish secondary copper minerals were observed. The youngest, probably Osmanic workings are represented by large open-cast mines. Earlier phases which left open diggings and densely spaced filled shafts stem from Roman activities, as is shown by ceramic finds, and probably also from prehistoric periods. There is a large pile of copper slags (Fig. 9). ^{14}C dating of charcoal collected from the pile yields 210–280 A.D. TL dating of burned furnace clay taken from the pile yielded 630 A.D. ± 140 years and dating of a ceramic sherd found near the pile gave 30 B.C. ± 220 years. These dates confirm Roman and Byzantine copper smelting on a large scale.

Fig. 9. Dereköy, Çatak Tepe, ancient (Roman) copper slag pile

3.3.8
Serçeörenköy (TG 192)/Balıkesir Province

In the southern Cataldag, a mountainous area between Balikesir and Bursa, copper ores and ancient mining remains were found near Serçeörenköy at 800–900 m elevation. The ore mineralisation is connected with the granodiorite intrusion into marble, mica-schist, amphibolite and metabasites. The ore occurs predominantly within the limestones and contains magnetite, pyrrhotite, bornite, chalcopyrite, sphalerite, fahlerz, chalcosite, covellite, limonite, malachite, azurite and some native silver. Several narrow, irregular cross sections of old adits (Fig. 10) are exposed in an abandoned wollastonite quarry as well as numerous filled-in shafts, diggings and waste dumps. The waste dumps consist of small flakes with numerous cm-sized pieces of malachite. This suggests that oxidic copper ores had been mined. Stone tools, among them a pick and several mall fragments, indicate prehistoric activities probably as far back as the Chalcolithic period. Due to finds of pot sherds, Early Bronze Age, Hellenistic and Byzantine workings are also likely. A few slags of unknown age are scattered across the surface.

4
Local Production vs. Import of Metals

4.1
Copper and Tin

There are certainly enough copper occurrences in north-west Anatolia to account for the use of local sources of copper. This copper was apparently

Fig. 10. Serçeören, prehistoric adit intersected by modern open-pit mining

used in the Chalcolithic to make artefacts out of unalloyed copper as well as those made of arsenical copper. Arsenical copper represents an alloy with a long history in Anatolian metallurgy. In fact, it is the hallmark of metallurgy in the fourth millennium B.C. that appears almost simultaneously from the Near East to central Europe (Sangmeister 1971; Schubert 1981). According to Chernykh (1992), this marks a restructuring of cultural relations between Anatolia and Europe that led to the so-called Circumpontic Metallurgical Province. In Turkey, it is represented at sites like Late Chalcolithic Beycesultan, level VIA at Arslantepe-Malatya, where 30 analyses averaged 3.5% As (Caneva et al. 1985), Ikiztepe (Bilgi 1984, 1990) and Ilıpınar (Begemann et al. 1994). The range of arsenic concentrations in arsenical copper is usually large (about 0.5–5%, sometimes even more) which suggests that the composition was not tightly controlled. This, in turn, argues against any deliberate alloying of copper with arsenic and for the use of copper ores rich in arsenic, which may or may not have been specifically selected. The use of this type of copper continued into the Aegean Early Bronze Age as attested by finds from Thermi (Begemann et al. 1992), Poliochni (Pernicka et al. 1990), the 'Kythnos' hoard (Fitton 1989) and, last not least, Beşik-Yassıtepe (Pfeffer 1990).

Isotopically, all ore samples from north-western Anatolia plot within a narrow area that is embedded in a field that is defined by more than 100

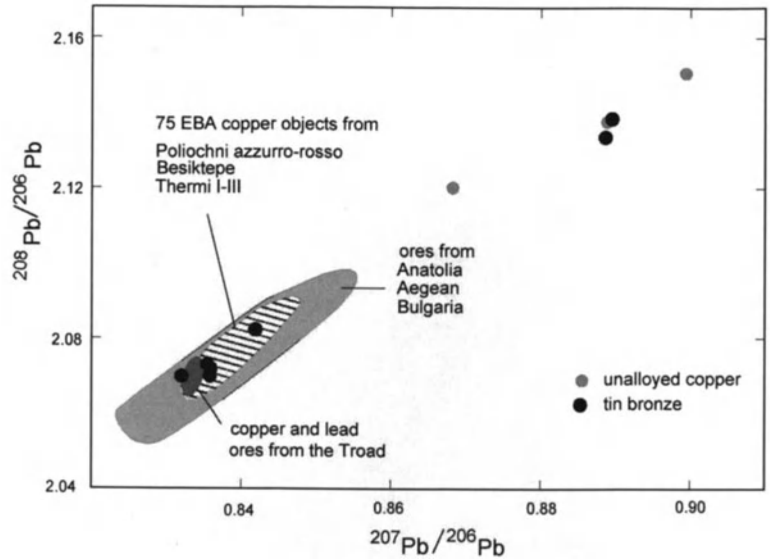

Fig. 11. Lead isotope ratios in ore and slag samples from the Troad (*small ellipse*) compared with copper and lead ores from the Aegean, Bulgaria and Anatolia (*large shaded field*) as well as with copper-based artefacts from the first half of the third millennium B.C. Data are from Pernicka et al. (1990), Stos-Gale (1992), and Wagner et al. (1985)

analyses of Aegean lead and copper ores (Fig. 11). Interestingly, most of the unalloyed copper artefacts and the arsenical coppers match with those regional ores from the Troad including the prehistoric copper mine of Serçeörenköy near Balıkesir (TG 192). This mine is also one of the few copper occurrences in north-western Anatolia with gold concentrations high enough to fit the artefacts of Ilipinar and Thermi. This is important, because gold is one of the elements that are most useful for discussing the provenance of copper, due to its similar behaviour during smelting. However, the arsenic concentration in this mine is low. Since arsenic can only be lost during copper production due to its volatility, one must either assume that arsenic was somehow intentionally added, which appears unlikely, or one has to admit that the ores from Serçeörenköy simply do not provide a perfect match for the arsenical coppers of the region. Unfortunately, there is a general lack of highly arsenical copper ores in north-western Anatolia which aggravates the difficulty for simply stating that local ores were used in the late Chalcolithic and the beginning of the Early Bronze Age.

Although there are a few bronze finds known from the first half of the third millennium B.C. (for a recent compilation see Muhly 1985; to this an Ibex-headed pin and a chain fragment from Beşik-Yassitepe have to be added, see Begemann et al., this volume) real use of the alloy is made only in the Troia II period. Apart from Troia and a metal hoard from an unknown site in the Troad (Bittel 1959), the pattern of the introduction of bronze is particularly well represented at Poliochni on the island of Lemnos. This large proto-urban settlement yielded similarly rich hoard finds like Troia. The excavators identified seven building periods which they designated with colours. The town flourished mostly in the Early Bronze Age which is represented in the consecutive settlement periods 'azzurro', 'verde', 'rosso' and 'giallo' that range from roughly 3000 B.C. to late Troia II, i.e. around 2300 B.C. While there was no bronze object found in the earliest period the number of bronzes increases steadily and reaches almost 60% of the inventory of copper-based artefacts in period 'giallo'. Of the contemporary objects from Troy and the Troad, 31 out of 50 had over 1.0% tin, representing 62% of the analysed material (Esin 1969). Thirty of these had over 4.0% tin, averaging 7.95% tin (Pernicka et al. 1984). The highest concentration of tin at Troia was 13.2%, found in a flat axe now in Istanbul, whereas a dagger from Poliochni 'rosso' had 19.8% tin. There is also an actual tin bangle from Town IVa at Thermi (Lamb 1936), the only object of tin from the Aegean Early Bronze Age an, indeed, the earliest tin object found so far. The number and percentage of bronzes is much smaller at Thermi, but in a hoard dated to the final occupation levels that can also be tentatively dated to the end of the Troia II period, five out of six copper-based artefacts contained more than 1% tin, usually considered as indicative of intentional addition.

Clearly these analytical data document a major shift in metallurgical technology, from arsenical copper to tin bronze. This shift had been to some extent already documented by Schliemann. What lead isotope analysis has now revealed, however, is that this shift coincided with the introduction of new sources of raw material, of tin certainly and, most likely, also of copper (Fig. 12). Many of the bronzes from Troia and the north-east Aegean as well as the tin bangle from Thermi plot in the upper right-hand corner of the lead isotope diagram, clearly apart from the ores from north-western Anatolia and even clearly different from all hitherto analysed copper and lead ores from the Aegean, the Balkans and all of Anatolia.

Since lead isotope ratios are determined, in part, by the geological age of the ore deposit, this means that the lead in these artefacts came from an ore deposit geologically far older than any deposits being exploited before the Troy II period. Far older, in fact, than any ore deposits known from the Balkans, the Aegean or from Anatolia. Local sources for tin can, therefore, be largely ruled out simply on the grounds of geological age of the lead contained in the tin bronzes. This also constitutes a strong argument against a local development of bronze metallurgy in the Troad (including

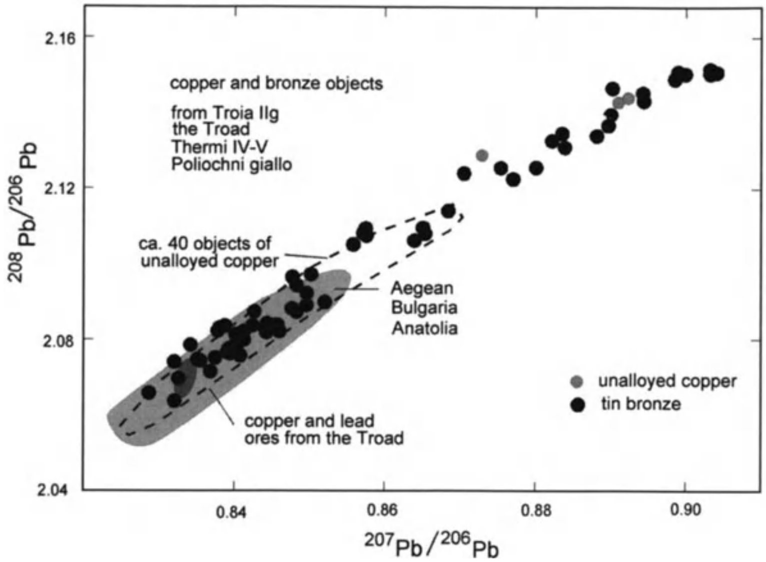

Fig. 12. Lead isotope ratios of Early Bronze Age copper-based objects from various settlements in the north-east Aegean dating to the second half of the third millennium B.C. during the Troy II period, which is known for its prosperity, as indicated by metal hoards among other things. *Full circles* indicate objects with more than 1% tin (tin bronze) and the *dashed line* comprises objects with less than 1% tin. Ore and slag samples are plotted as in Fig. 11. Data are from Pernicka et al. (1990), Stos-Gale (1992), Begemann et al. (1992), and Wagner et al. (1985)

the north-east Aegean). The lead in these artefacts can only have come from Precambrian ore deposits that are 700–900 million years old. Such deposits are unknown in south-eastern Europe as well, but they are to be found in central Asia (the Altai), in north-west India and perhaps also in Afghanistan. The Afghan tin deposits that have been studied to date seem to be quite young, dating to late Jurassic or early Cretaceous times (200–150 million years old) or even to the Oligocene period (30 million years old; Rossovsky et al. 1987), but Afghanistan is geologically a very complex country and older deposits are certainly a geological possibility. It should also be pointed out that the tin deposits of Cornwall and the Erzgebirge are from the Paleozoic period and are thus as old as most of the lead present in the bronzes from the cultural region of Troia. Although they would fit isotopically with part of the 'exotic' artefacts there is no cultural link to suggest that the tin came from there. Indeed, in the Erzgebirge there is still no clear evidence of the exploitation of the tin deposits in prehistoric times (Niederschlag et al., submitted). With the introduction of tin for bronze we seem to have the appearance of new sources of copper as well.

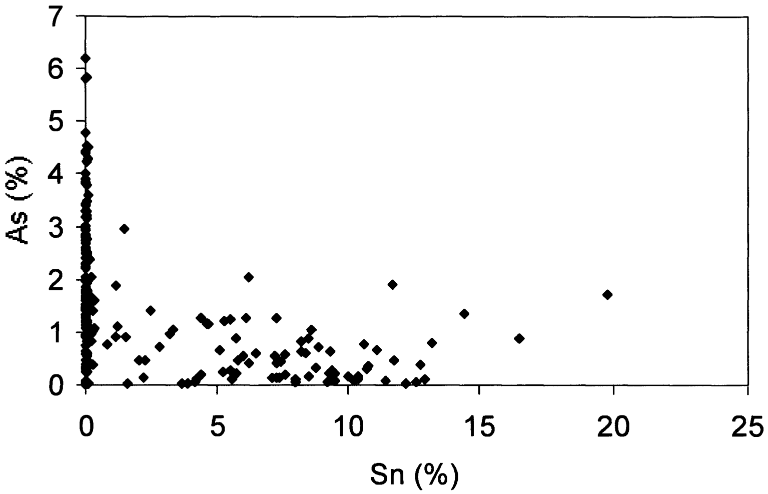

Fig. 13. Tin and arsenic concentrations in Early Bronze Age copper-based artefacts from the north-east Aegean. Tin seems to have only been added to copper containing only relatively low amounts of arsenic

It could be argued that the much older lead identified by lead isotope analysis came into the artefact not from the copper, but from the tin. Tin is, after all, the distinctively new element in the metallurgy of the Troy II period. This is indeed a possibility that deserves careful consideration, but the present state of our knowledge seems to be against such an explanation for two main reasons:

1. Cassiterite is known to contain only very low amounts of lead.
2. Artefacts in the 'exotic' range of the lead isotope diagram include not only bronzes, but also objects of unalloyed copper, where the lead in the artefact can only have come from the copper ore.

   Strangely enough objects made of arsenical copper do not plot in the 'exotic' area of the lead isotope diagram. Tin seems to have been added mainly to that copper having no appreciable amount of arsenic (Fig. 13). This would seem to indicate that arsenical copper constituted the local copper metallurgy of the north-east Aegean and north-western Anatolia; new sources of copper and the extensive use of tin seem to come into this metallurgical zone from some outside source(s) during the Troy II period. It must be admitted, however, that not all the bronzes from Troy and Poliochni plot in the 'exotic' range of the lead isotope diagram. This probably indicates that we are dealing with imported raw materials, copper and tin, not imported bronze (or even imported artefacts), with some of the imported tin being added to copper from local sources.

4.2 Lead and Silver

At first sight the state of affairs looks very different, if one regards only lead and silver that have been used abundantly at Troia, but also on the Cyclades and the Greek mainland. Most of the finds plot within the field defined by argentiferous lead ores from the Aegean (Fig. 14). In addition, Early Bronze Age lead/silver mines have been identified on the Cycladic island of Siphnos (Wagner and Weisgerber 1985), at Laurion in Attica (Spitaels 1984), and at Balya and Gümüşköy in the Troad (see above) so that an indigenous innovation indeed appears to be a plausible explanation (on Thasos Bronze Age mining is possible, but no exact dates are available). Closer examination of the chronology of the analysed objects and the lead isotope fields of individual deposits, especially those with Early Bronze Age mines, shows that the two earliest silver objects of the Aegean, a double spiral pin from Poliochni azzurro and a necklace with silver beads from Naxos do not derive from the mines of Laurion or Siphnos. The same is true for most silver objects from the north-east Aegean including Troia. A more detailed view reveals that argentiferous lead ores from the Cycladic islands of Siphnos and Thasos provide isotopic matches, but at least Thasos can be excluded due to the very low gold and bismuth contents of its lead ores. On

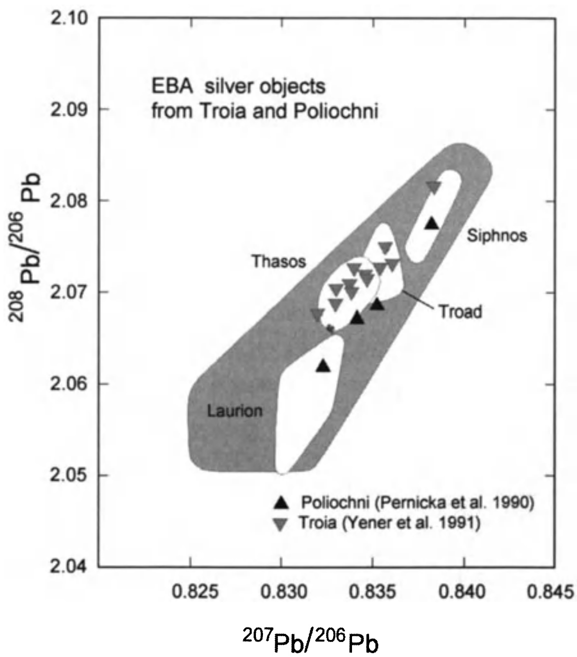

Fig. 14. Lead isotope ratios in Early Bronze Age silver objects from Troia and Poliochni. Ore fields are given for regions where ancient Bronze Age mining is attested (for an overview with relevant literature see Pernicka 1990)

the other hand, there are several lead ore deposits in the Troad that would fit equally well.

Does this suggest that the production of silver was discovered in the Aegean? The distribution of silver objects in the fourth millennium B.C. does not support such an assumption, because with the exception of Beycesultan they mostly derive from south-eastern Anatolia, the Levant, and especially Mesopotamia (Prag 1978; Kohlmeyer 1994). Moreover, the earliest find of litharge, a by-product of silver production derives from Habuba Kabira in present-day Syria (Pernicka et al. 1998). An obvious explanation could be that the knowledge and impetus for silver production came from other regions, but that the technology was readily acquired, because argentiferous lead ores are abundant in the Aegean – in contrast to copper ores.

In summary, it seems that we can design a scenario of the development of metallurgy in the Aegean that is characterised by a cultural and technological orientation towards the north in the fourth and early third millennium B.C. with little indigenous progress that is followed by an influx of new metals and alloys which may have provided a stimulus for local production, at least of lead and silver.

Tin and tin bronze was imported and it is still uncertain from where. General geological considerations that can be deduced from the lead isotope ratios indicate that the source area has to be sought in a geologically ancient terrain, i.e. outside the relatively young mountain ranges that extend from the Alps in central Europe to the Himalayas. Such ancient terrains are known on the Arabian peninsula including the Eastern Desert of Egypt, in central Asia and India. The first two areas are also known for gold and tin deposits (Alimov et al. 1998), but only central Asia boasts the additional occurrence of lapis lazuli, of which there is such a magnificent example in Treasure L from Troia. Furthermore, the remaining three ceremonial axes of the same hoard are made of nephrite and jade, materials that also point towards central Asia so it may be speculated that this region is, at present, the most likely source for Early Bronze Age tin in the eastern Mediterranean.

5
Distribution of Bronze in the Third Millennium B.C.

It has long been known that bronze makes its first appearance in the Near East (Muhly 1985 discusses the evidence from the older literature). Schematically the situation is presented in Fig. 15. It highlights the paradoxical situation that early bronze objects consistently occur in those regions that have no known tin deposits. This enigma has been discussed for

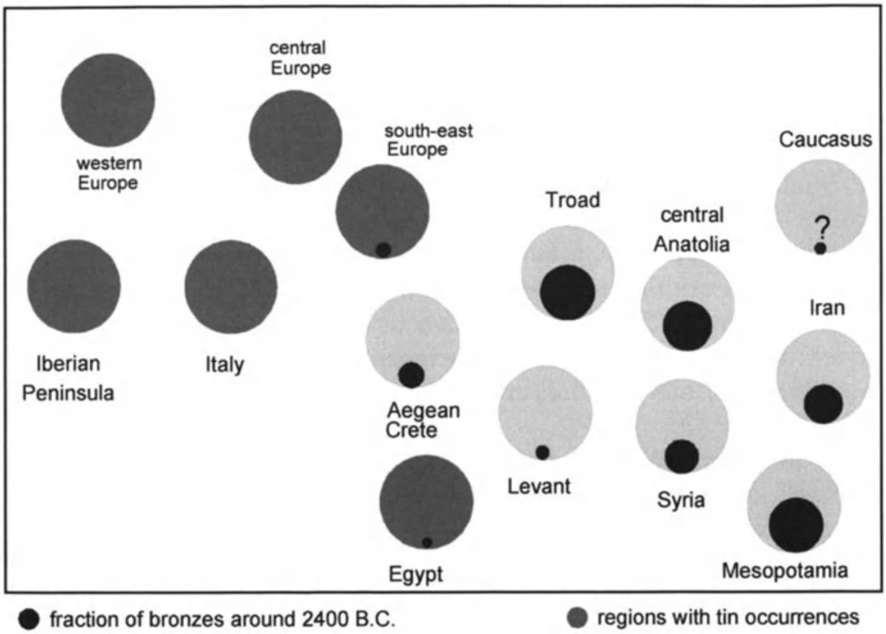

Fig. 15. Schematic regional distribution of bronze artefacts before 2400 B.C. Regions with known tin occurrences and deposits are darker than those without any known tin sources. The approximate fraction of bronze in the metal inventory is indicated by the size of the *inner circle*

more than 100 years (e.g. Baer von 1876) and is still not solved. Most publications on this topic, however, deal only with the provenance of tin. While this is certainly a most important aspect which will be dealt with in the next section, it is also remarkable that the bronze metallurgy was adopted in practically all of the Old World within a comparatively short period. By the middle of the third millennium B.C. bronze-using cultures range from the Indus valley over Iran (Susa), Mesopotamia (Royal cemetery of Ur), Anatolia (Alaça Hüyük, Horoztepe) to the Aegean including Troia and even beyond into the Adriatic Sea, as exemplified by the rich burial of Velika Gruda (Primas 1996). In principle this could be mere coincidence, but it is much more likely that we are dealing with highly stratified societies that were in close contact with each other and probably also exchanged ideas and goods such as metals. At least in Mesopotamia there is also textual evidence for long-distance trade. Only Egypt does not seem to take part in this development, because there are hardly any bronze artefacts from Egypt in the third millennium B.C. Only two vessels from Abydos contained tin (Cowell 1987) and an undefined piece of metal from Tell el-Fara'in in the Nile delta (Pernicka and Schleiter 1997). This is a further enigma as

Egypt is about the only region in the eastern Mediterranean with proven tin deposits near the Red Sea (Muhly 1973, 1993). Apparently, they have not been known or at least not been exploited. Even during the Middle Kingdom there is little bronze. Only in the eighteenth dynasty does the regular use of bronze in Egypt begin. This is corroborated by the chemical composition of green and blue pigments from wall paintings in well dated Egyptian tombs which were made artificially (Egyptian blue). For the colouring copper was used and apparently mostly scrap metal as suggested by other elements that are usually associated with copper metal. Previous to the eighteenth dynasty those pigments frequently contain arsenic besides copper and later, usually tin (Schiegl et al. 1990).

Outside the Aegean, especially in central Europe, a similar development took place a couple of centuries later. In the first phase bronze objects are rare, but in the developed Early Bronze Age bronze is widely distributed (Spindler 1971). However, the new technology not only expanded to the west, but also to the east into the Iranian plateau (Heskel and Lamberg-Karlovsky 1980) and central Asia on the one hand, and the Indus valley on the other (Wheeler 1968). In southern China and Thailand with very rich tin deposits, bronze is introduced in the first half of the second millennium B.C. (Bronson and White 1992). It is not clear if all these developments have a common origin, but it is noteworthy that the spread follows a consistent pattern that at least resembles the spread of the knowledge of bronze by diffusion out of a relatively large core area in south-west Asia. There are of course regional variations, but if multiple totally independent inventions should have occurred then there is no reason that they should not have been made much earlier or later than in the core area.

It has already been mentioned that the lead isotope ratios provide conclusive evidence that most of the tin-rich copper alloys from Troia and its surroundings did not derive from regional ores. Thus, the hypothesis that the discovery of bronze in the Aegean led to the observed culture changes is rendered obsolete and one is led to recur to the older model of a foreign influence or even immigration. Considering the types of objects that were made of bronze it is evident that this material must have been quite expensive and was mainly used for prestige items. It is easily imagined that the social elites of the early urban centers used them to indicate their rank and status and it is also possible that such expensive items were exchanged as presents among them. In this model bronze would not be the trigger of the development, but would come as one of several other precious goods with a social development that clearly originated in southern Mesopotamia. The urban organisation and its lifestyle, at least of the elites, seems to have been so attractive that it was quickly adopted in neighbouring areas that also adopted the prestige symbols.

6
Considerations on the Provenance of Tin

In the history of research many sites have been proposed to have been the source of tin in the Early Bronze Age of the Mediterranean. Some have quickly been proven geologically untenable, others were impossible for archaeological reasons. It is, therefore, not surprising that new reports on the occurrence of tin minerals meet particular attention, especially if they are located in Turkey (e.g. Kaptan 1983). A similar mineralisation as Soğukpınar near Bursa that was already rejected as an ancient tin source by Pernicka et al. (1984) was reported slightly later in the Taurus range (Çağatay et al. 1989). The news of tin occurrence at Sulucadere near Bolkardag was again greeted with great enthusiasm and was immediately related to early Bronze Age tin production (Yener and Özbal 1987). The mineralisation consists of a small ore lens of a few meters length with lead and zinc minerals as the major components together with some fahlore. This accessory phase contains microscopically small ex-solution droplets of stannite, a mineral consisting of copper, tin, iron and sulphur. One ore sample contained 24% lead and only 0.2% tin (Wagner et al. 1989) besides 0.4% silver. This ore would yield only argentiferous lead on smelting and the small tin content surely remained unnoticed in ancient times.

In the same year the first occurrence of cassiterite (tin oxide) in Turkey was reported near Kestel, some 100 km north of Sulucadere in the northern foothills of the Taurus range and in a different geological environment (Çağatay et al. 1989). This seemed to be the final breakthrough in the search for tin (Yener et al. 1989), because it was associated with an ancient mine that could be dated by charcoal finds to the first half of the third millennium B.C. In addition, the Early Bronze Age site of Göltepe with many grinding stones and crucible fragments is very close by. Some crucibles show small vitrified areas in the interior with a thickness of about 0.1 mm. These glassy layers often contain a tiny inclusion of tin oxide of 0.1–3 μm width and up to 50 μm length which have been interpreted as proof of tin smelting (Yener and Vandiver 1993). Despite this almost perfect association some doubts as to the interpretation of a tin mine were formulated (Hall and Steadman 1991; Muhly et al. 1991; Muhly 1993), which were mainly based on the very low tin concentrations that were reported with less than 1.4% tin in all samples (Earl and Özbal 1996).

However, there are more questions associated with this site such as the small grain size of the cassiterite (< 70 μm), which would make it difficult to be recognised and separated from the associated iron ore of a similar colour. Given the type of mineralisation the occurrence of larger grains of cassiterite is unlikely. At Göltepe some powdered stanniferous iron ore was found and it was shown that enrichment of cassiterite by vanning is possible (up to a factor of 12), but unpredictable (Adriaens et al. 1999). Smelting experiments (5 g vanned ore with about 10 % Sn yielded 0.175 g tin metal) showed that tin production is possible from the iron-tin ore. However, at Göltepe the tin contents of untreated powders is similar to heated ones so the smelting experiments do not provide conclusive evidence for tin production at the site.

Archaeological inconsistencies relate to the early dates of Kestel and Göltepe, ca. 2800 B.C., a time when tin bronze just came into usage. Since tin was hardly recognisable in the ore at Kestel and tin could only have been detected by assaying, one wonders how the miners knew what to look for. Moreover, by the Middle Bronze Age (nineteenth to eighteenth centuries) large quantities of tin were imported into the area (Larsen 1982).

Muhly et al. (1991) have noted that the iron ore at Kestel also contains gold and Yener (2000) also reported an average content of 1.31 µg/g. Like tin this is not particularly rich, but it is certainly a significant enrichment over the average of the earth's crust and indeed, the solution may be the assumption that Kestel started as a gold mine. It is not impossible that it may then have produced tin also, but it is difficult to believe the estimate of 115 tons of tin (Yener 2000). It is equally possible that gold was the only product as the vitrified parts in the crucible fragments could also derive from melting gold. Gold frequently occurs together with tin and it would be equally necessary to crush and powder the ore and heat it in small crucibles. The reported tin content could then be accidental. In any case, if tin was produced at Kestel in the Early Bronze Age it must have ended relatively soon and the total output must have been much smaller, maybe a few hundred kilograms, than the above estimate.

A recent study of ancient tin mines in Uzbekistan and Tadjikistan (Alimov et al. 1998) yielded similar estimates, although the tin content at Karnab with a more or less comparable mineralisation as Kestel ranged up to 5.7 % tin. In a nearby settlement the ore powder even contained almost 8 % tin. In addition, the mineralisation is in a clearly visible vein. In Tadjikistan there is a very large tin deposit at Muschiston with stannite ($CuFeSnS_4$) as the major mineral. Accordingly, tin concentrations range up to 80 % in oxidised ore. Both mines date to the era of the second millennium B.C.

This indicates that most probably there was not only one source for tin in the Early Bronze Age, but several. At present, all archaeological and geological evidence points to the east as the most likely direction for the origin of the tin. The reasons are the following: (1) There is still a time gap between the appearance of bronze in the eastern Mediterranean and central and western Europe where the largest tin deposits are located. The spread of bronze technology to the east is much less clear, but it seems evident that in the Indus valley bronze was used in the Akkadian period (about twenty-fourth century). (2) There is no textual evidence for the provenance of tin, but it transpires from various texts that tin came from a great distance both over land and by sea (Moorey 1994). (3) Exotic materials like lapis lazuli and carnelian prove the contact with central Asia, because there are still no other sources of lapis lazuli known than the ones in eastern Afghanistan and possibly the Altai range (Penhallurick 1986). (4) The lead isotope ratios in Early Bronze Age artefacts (Fig. 12) indicate that the lead in the analysed copper and bronze artefacts derives from a geologically ancient (Precambrian) terrain. Such old rocks are neither known in Anatolia nor in the Balkans, or the Aegean and are unlikely to occur there.

On the Composition and Provenance of Metal Finds from Beşiktepe (Troia)

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Abstract

Lead isotopy and trace element contents of most of the copper-based artifacts from Beşiktepe dating to Troia I suggest that the copper derives from western Anatolian ore deposits. Gümüşköy, Serçeörenköy, and Balya, all sites with evidence for prehistoric mining activities going back to the late third millennium B.C., are most conspicuous in this respect. These ore occurrences also qualify as sources for many of the contemporaneous copper objects from Thermi on Lesbos and Poliochni on Lemnos analyzed previously. Exceptions among the Troia I Beşiktepe objects are the two pieces of bronze found among the 22 fragments chemically analyzed, and one piece of unalloyed copper. Notably, none of the copper objects can be traced back to Ergani, neither to its copper ores nor to its native copper. Eleven artifacts recovered from graves at the Beşik-Necropolis, dating to Troia VI, are all bronze. Their trace element abundance patterns are remarkably uniform; silver contents in the bronzes are much lower than in the unalloyed copper dating to Troia I indicating that these bronzes cannot have been manufactured by alloying tin with the kind of copper that is present in the unalloyed copper. Lead isotope data, not available at present, will have to decide whether the characteristics of these bronze pieces are again foreign to all copper ores from Anatolia and the Aegean just as has been observed to be the case for most bronze objects from Poliochni and Thermi.

1 Introduction

Copper-based metal artifacts from Troia and the Troad previously analyzed for their lead isotopic composition and their trace element contents (Pernicka et al. 1984; Stos-Gale et al. 1984) comprise the Troas hoard find of Bittel (1959), a small collection of daggers and needles from Yortan, and a series of implements, daggers, and vessels from Hisarlık, excavated by Schliemann and published in part by Schmidt (1902). They all have in common that their age setting is rather uncertain. This is true for the objects from Troia-Hisarlık, all of which are of uncertain stratigraphy, and it is even worse for the Troad hoard find and the small collection of weapons and implements from Yortan cemetery which actually derive from the art market. Recently, however, metal objects have become available from well-executed and well-documented excavations performed at Beşiktepe from 1982–1986 by M. Korfmann and his team (Korfmann 1984, 1985, 1986, 1988). Therefore, it appeared worthwhile to take up these investigations again. They should be considered complementary to those of the well-stratified and well-dated finds from Poliochni on the island of Lemnos (Pernicka et al. 1990) and Thermi on the island of Lesbos (Begemann et al. 1992, 1995).

Beşiktepe is located about 9 km southwest of Troia, on a steep promontory on the present-day Aegean coastline. The settlement layer dating to Troia I has been estimated by Korfmann to cover 150–300 years, at most (Korfmann and Kromer 1993). Thermoluminescence (TL) dating of pottery sherds from the Troia I layer yielded 2820 ± 80 B.C. (Wagner and Lorenz 1992), which accords well with calibrated radiocarbon dates of 2920–2740 B.C. (Korfmann and Kromer 1993). By comparison, a charred fig from the period "azzurro" at Poliochni dates to 2910–2672 B.C. (calibrated) and pieces of charcoal from about the lowest pebble floor level at Thermi to 3022–2700 B.C. cal. (Begemann et al.1992). These sites, then, are closely contemporaneous, dating to the very beginning of the third millennium B.C.

The early objects excavated at Beşiktepe are almost all rather indistinct-looking small finds whose typological features do not allow their chronological setting to be determined (see Table 1). Instead, their age had to be deduced from associated pottery sherds retrieved from the same excavation levels. Particular attention was paid to eliminate potential late intrusions. Twenty-three of the copper-based artifacts (one of them a copper crucible slag)[1] and three pieces of lead, all classified as dating to Troia I, were sampled, some of them more than once. Of the 26 samples analyzed for their chemical composition 20, including the piece of crucible slag, were selected for the more demanding analysis of the isotopic composition of their lead content.

[1] The excavators identified two of the sampled objects as "slag" (HDM 1021 and 1114). Both objects are rather small (a few hundred milligrams) and broken into a number of pieces. In the case of HDM 1021 the shape of one larger fragment suggests that rather than a slag, the object might be a completely corroded piece of a metal pin. Such a suggestion is corroborated by the low iron content (see below). For the present purpose we have retained the identification of HDM 1114 as "slag", but have classified HDM 1021 as metal. Both classifications are ambiguous, however. Five of the specimens have been assigned probabilities of between 93 and 98% of belonging to Troia I. These are the unalloyed copper pins, or fragments thereof, HDM 1009, 1013, 1108, and 1111 as well as the only arsenical copper in our suite of samples, a needle with double-conical head (HDM 1116; Pfeffer 1990).

Table 1. Metal artifacts from Beşiktepe investigated in the present study. When objects were sampled more than once the first column lists the numbers under which the results are reported

HDM No.		Object	Inv. No.	Period
163		Nail fragment, square cross section	LL 83.27	Chalcolithic
164[a]		Angular piece	R 14.492	Uncertain
165		Pin	S 15.166	Troia I, 3
166		Pin with spherical head	S 15.170	Troia I, 3
167	1124	Nail, square cross section	Q 12.94	Uncertain
168	1122	Pin	R 14.430	Troia I, 8–6
171[a]		Sheet fragments (4)	R 12.69	Hellenistic
172[a]		Rod fragment	R 12.150a	Hellenistic
174[a]		Sheet	S 13.260	Hellenistic
176[a]		Token	S 13.289	Hellenistic
180[a]		–	S 13.429	Hellenistic
183[a]		–	S 13.503	Hellenistic
184[a]		–	S 15.56	Hellenistic
185[a]		–	S 15.70	Hellenistic
187[a]		Sheet	T 10.164	Hellenistic
269[a]		Sheet	R 12–61	Hellenistic/ Byzant.
301		Awl fragment	S 15.260	Hellenistic
302		Awl fragment	S 15.269	Hellenistic
303	1250	Pin	ZI 29.7	Uncertain
304	1109	Pin	S 15.272	Hellenistic
305[a]		–	ZI 28.22	Troia VI
306[a]		–	RS 13.162A	Uncertain
307	1120	Pin	S 13.834	Troia I, 3
308		Fragment	ZI 29.28	Troia VI, grave 46
309[a]		–	S 13 Ost.232	Troia I
310[a]		–	XI 29.5	Troia VI
311		Vessel(?) fragment	YI 29.4	Troia VI, grave 15
312		Fragment	ZI 28.23	Troia VI, grave 49
313	1119	Pin fragments (3)	S 13.682	Hellenistic
314[a]		–	ZI 28.19	Troia VI
315[a]		–	S 13.743	Troia I
316		Wire(?) pieces	YI 29.60	Troia VI, grave 25
317[a]		Vessel handle	S 12 Ost.12	Uncertain
318		Arrow head	S 13.683	Hellenistic
319	1244	Knife	YI 28.7	Troia VI
320[a]		–	ZI 28.18	Troia VI
321		Fragment	YI 28.42	Troia VI, grave 4

Table 1 (continued)

HDM No.		Object	Inv. No.	Period
322[a]		–	S 12.388	Uncertain
323	1121	Pin	R 12.411	Troia I, 8
324		Wire(?) piece	YI 29.50	Troia VI, grave 25
325[a]		–	VI 29.4	Troia VI
326		–	YI 29.14	Uncertain
327		–	YI 29.7	Troia VI
328		–	YI 29.10	Troia VI, grave 15
329[a]		–	S 13.694	Troia I
330	1113	Nail, square cross section	S 12 Ost.23	Hellenistic
331		–	S 12 Ost.84 ?	Uncertain
1009	992	Pin	S 12.550	Troia I, 7
1010	993	Nail fragment, square cross section	S 13.625	Troia I, 7
1013	996	Fragment	S 15.405	Troia I, 8
1015		–	S 13.698 ?	Uncertain
1016		Spherule fragment	M 18.61a	Hellenistic
1017	1000, 1219	Awl fragment	Q 12.376	Troia I, 4
1018	1001, 1218	Awl fragment	Q 12.364	Troia I, 5/4
1020	1003, 1220	Awl fragment	Q 12.466	Troia I, 1
1021	1004	Awl(?) fragment	S 12.572	Troia I
1108	994, 1011	Pin	S 15.409	Troia I, 8
1110		Pin(?)	S 15.330	Hellenistic
1111	997, 1014	Awl(?) fragment	S 15.437	Troia I, 8/7
1112	1012	Fragment	S 15.400	Troia I, 8
1114	991, 1008	Slag(?) crumbs	S 12.591	Troia I
1116	989, 1006	Pin with double-conical head	S 12.818	Troia I, 3
1117	990, 1007	Fragment	S 12.853	Troia I, 2
1118		Vessel fragment	S 13.268	Hellenistic
1123	1002, 1019	Chain link(?) fragment	Q 12.391	Troia I, 4
1125		Pin	R 13.260	Uncertain
1126		Awl fragments (2)	R 13.238	Uncertain
1128		Ibex-headed pin	S 15.731	Troia I, 5
1129		Pin with spherical head	S 15.874	Troia I, 4
1130[a]		Sheet fragment	S 15.634	Hellenistic
1131		Sheet fragment	S 14.190	Hellenistic

Table 1 (continued)

HDM No.	Object	Inv. No.	Period
1132	Fragment	S 13.975b	Troia I, 3
1228	Nail(?)	E 22.6	Hellenistic
1229	Nail	S 12.426	Hellenistic
1236	Arm ring(?) fragment	S 15.478	Troia I, 6
1252	Fragment	VI 29.11	Hellenistic
1257	Anklet	ZI 7.12i (4930)	Troia VI, grave 68
1258	Anklet	ZI 7.12i (4931)	Troia VI, grave 68

[a] Lead objects.

From among the later objects analyzed for their chemical composition, 11 are bronze artifacts from graves at the Beşik-Bay cemetery; they date back to Troia VI, i.e., to the middle of the second millennium B.C. The remaining samples, copper-based as well as the pieces of lead, are mostly from Hellenistic contexts. A list of all objects analyzed is given in Table 1. It contains the respective inventory numbers, what little typological information is available, and the Mainz/Heidelberg HDM laboratory numbers which are used in the text.

2 Chemical Composition and Trace Elements

Chemical analyses were performed by instrumental neutron activation (INAA). Most objects from the Troia I period were heavily corroded so the metal content of the analyzed samples rarely approaches 100 %; more often it is only around 50 % (Table 2). In order to correct for this, and to make the results comparable with analyses of well-preserved clean metal, the concentrations of minor and trace elements are normalized to the sum of all analyzed elements. Strictly speaking, such a normalization procedure implies that, upon corrosion of the metal, the trace elements behaved just like copper and, moreover, the uptake of trace elements from the environment did not increase their concentration in the artifacts to any significant extent. Note that for bronzes the listed tin contents are as measured; they are not normalized to copper. The same holds also for all trace elements in the slags.

Among the artifacts dating to Troia I, a wire loop, which is possibly a chain-link fragment or a piece of a finger ring (HDM 1123), and an ibex-headed pin (HDM 1128) are made of bronze; in addition, a pin with a spher-

Table 2. Chemical composition of copper-based artifacts from Beşiktepe. Copper and tin are listed as measured (in weight percent). All other concentrations are in µg/g, normalized to the sum of the contents of the measured elements. Tin in nonbronzes was less than 0.1 % in all cases

HDM No.	Cu	Sn	As	Sb	Co	Ni	Ag	Au	Fe	Zn	Se
Chalcolithic											
Unalloyed copper											
163	100	–	190	20	33	330	640	15.4	<400	<20	187
Troia I											
Unalloyed copper											
165	27	–	3700	66	<4	370	17,300	1.8	43,000	<260	74
166	47	–	11,200	234	6	570	2360	15.0	4500	<50	94
168[a]	89	–	10,400	370	2	1100	2030	8.5	<800	<50	60
307	99	–	<10	53	1	46	770	18.8	<210	<10	107
323[a]	70	–	6900	950	<1	870	1610	2.4	1680	<50	65
1009	48	–	12,800	750	<1	210	87	1.3	20,600	80	2
1010	39	–	17,500	470	<1	1120	365	1.5	27,000	120	53
1013	28	–	5900	120	37	630	1840	2.3	14,900	290	22
1017[a]	46	–	4900	144	1	770	1200	1.7	7100	70	117
1018[a]	48	–	3900	48	<1	72	880	1.2	2010	160	24
1020[a]	51	–	960	45	67	1200	560	0.5	21,100	140	81
1021	31	-	9800	650	52	2670	80	1.8	13,100	1340	38
1108	87	-	14,400	170	<1	300	520	1.3	<260	<20	92
1111	56	–	10,000	105	18	1060	340	1.1	15,500	30	91
1112	79	–	2520	340	36	230	14	37.0	3000	50	12
1117	52	–	8800	900	6	180	460	1.8	22,500	80	52
1129	100	–	5800	260	<3	350	1290	2.5	11,300	550	103
1132	99	–	9900	400	3	2400	890	<0.5	1320	<40	56
1236	94		10,200	290	14	2790	810	1.1	2220	30	52

Table 2 (continued)

HDM No.	Cu	Sn	As	Sb	Co	Ni	Ag	Au	Fe	Zn	Se
Arsenical copper											
1116	78	–	90,000	490	<1	1030	1780	10.9	<290	<20	70
Bronzes											
1123	49	11.5	3300	1340	38	810	830	82.0	<510	230	123
1128	84	9.2	870	240	28	244	330	37.0	<200	20	124
Crucible slag											
1114[b]	17	–	20,500	310	84	2800	39	0.1	92,000	120	6
Troia VI											
Bronzes											
308	92	6.6	3800	125	190	350	58	7.6	2710	50	43
311[c]	88	10.7	1600	42	100	153	16	3.1	1030	40	67
312	87	9.3	5000	146	91	360	54	10.1	1370	<10	72
316[d]	69	12.8	1830	156	31	84	28	4.7	2200	<30	152
319[a]	94	7.7	1790	75	42	270	30	4.5	680	20	98
321	72	14.1	7300	510	37	116	18	5.9	4600	<40	125
324[d]	69	14.1	2470	220	32	<73	26	6.5	3300	<60	209
327	42	14.6	4100	400	55	220	36	20.0	7600	110	107
328[c]	78	10.5	1930	50	70	90	10	3.6	1800	<30	51
1257[e]	90	10.5	5000	250	590	1410	71	14.3	1340	180	56
1258[e]	85	10.5	5400	290	470	1370	73	13.9	<710	160	66
Hellenistic											
Unalloyed copper											
301	100	–	2400	2400	35	160	1400	15.4	<600	<30	57
302	100	–	1900	370	224	340	296	28.8	<450	<20	38

Table 2 (continued)

HDM No.	Cu	Sn	As	Sb	Co	Ni	Ag	Au	Fe	Zn	Se
304[a]	99	–	3600	4000	<8	235	1440	18.9	<1000	<50	36
330	83	–	810	350	269	<100	102	34.0	<2400	<80	41
1131	65	–	1070	127	310	156	156	23.6	5400	42	16
1228	97	–	1820	113	41	157	223	29.4	2530	20	49
1229	100	–	1490	280	360	275	234	22.6	<900	<50	34
1252	97	–	1200	160	650	320	158	21.9	1240	240	18
Bronzes											
313	68	9.7	540	55	220	190	203	17.6	2360	<15	87
318	79	5.4	1800	363	1800	350	200	30.2	<3000	<110	10
1016	41	1.3	2590	360	30	620	910	3.6	28,100	80	<5
1110	100	9.4	670	140	<1	1470	1680	5.7	<1800	1140	23
1118	63	9.9	380	26	9	27	13	2.9	1100	24	6
Uncertain date											
Unalloyed copper											
167	94	–	3600	3100	2	204	2240	12.4	1280	<70	55
303[a]	100	–	1920	230	24	270	152	18.5	2000	<20	20
331	86	–	360	170	1000	180	155	11.6	1620	<50	30
1125	100	–	2240	360	224	310	263	25.5	2000	210	42
1126	60	–	15,500	244	<1	980	24,200	330.0	<2750	<150	28
Bronzes											
326	75	8.6	830	32	43	<160	11	2.7	2670	<130	80
1015	50	2.8	1960	160	79	3300	1010	3.5	26,500	2100	<4

[a] Because of their poor state of preservation, these objects were sampled and analyzed twice; listed are the averages.
[b] All concentrations as measured.
[c,d,e] Objects are from the same grave, respectively.

ical head (HDM 1116) is made of arsenical copper. All others consist of unalloyed copper. Silver is notable for its constancy; with one exception on the high side[2] and three others on the low side (HDM 1009, 1021, 1112), the total range (330–2360 μg/g) is less than a factor of ten. For all other measured trace elements the concentrations fall into the same ranges as previously observed in roughly contemporaneous objects from the Aegean and western Anatolia (Esin 1969; Pernicka et al. 1984, 1990; Begemann et al. 1992, 1995).

Nevertheless, looking at abundance *ratios* of trace elements reveals significant differences between different sites. At Ilıpınar, for example, independent of chronological period, higher arsenic contents and lower concentrations of antimony combine to make As/Sb ratios very much higher than reported here. Ratios usually are around 1000, or higher, at Ilıpınar (Begemann et al. 1994), but less than 100, and typically only about 35 here (Fig. 1). Similarly, in the Yortan implements (Pernicka et al. 1984), the As/Sb ratios are again distinctly higher than observed here (Fig. 1). The Ag/Au ratios in the Yortan samples, on the other hand, are about ten times lower than found in the Troia I metal analyzed here (Fig. 2). The same is also the case, even more pronouncedly, for the "Troas" samples analyzed previously (Pernicka et al. 1984). It should be noted, however, that all Troas samples with low silver contents are bronzes, not unalloyed copper. Moreover, since they are of uncertain stratigraphy, but generally dated as late Troia II, a comparison with the older Troia I artifacts made from unalloyed copper is perhaps of only limited relevance.

Although it is true that trace element concentrations, as well as their abundance ratios, are affected by the physical-chemical conditions prevailing during the smelting of ores, or on the conditions during casting and working of metal, such potential changes are not expected to have caused the large differences observed for the metal recovered from the different sites. We maintain the differences rather indicate that different ore sources were exploited at Ilıpınar, Yortan, and Beşiktepe, respectively. We shall return to this problem when discussing the lead isotope data.

Not surprisingly, all objects dating to Troia VI are bronzes. After all, this period falls right into the Aegean Late Bronze Age. What we do find surprising, however, is that among the metal pieces from Hellenistic times so many (eight out of thirteen) should still be made of unalloyed copper. Apparently, unalloyed copper had its use side-by-side with bronze, a result

[2] Since the high-silver object (HDM 165) is a badly corroded pin fragment, the significance of the high *normalized* silver content is somewhat ambiguous.

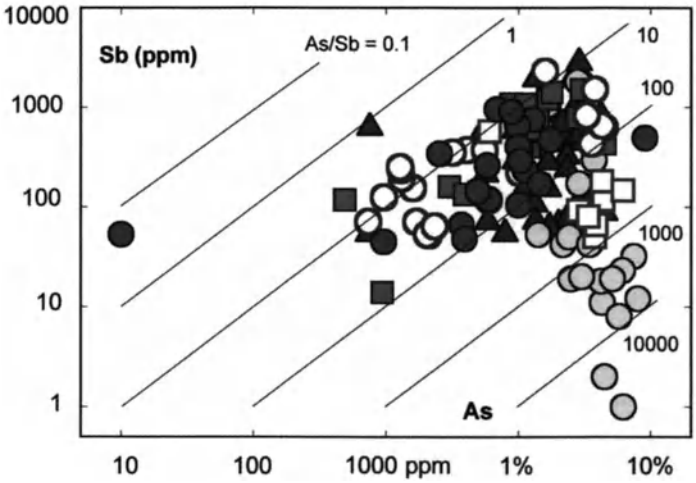

Fig. 1. The concentrations of arsenic (*As*) and antimony (*Sb*) in EBA copper-based metal artifacts (see text) from Beşiktepe, dating to Troia I, are similar to the concentrations in contemporaneous objects from Poliochni on Lemnos and Thermi on Lesbos. Metal from Ilıpınar and the Yortan cemetery, on the other hand, tends to contain more As and less Sb which, together, results in As/Sb abundance ratios which are 10–100 times higher. *Red dots* this paper; *yellow dots* Ilıpınar (Begemann et al. 1994); *blue circles* Troas (Pernicka et al. 1984); *blue triangles* Thermi (Begemann et al. 1992, 1995); *green squares* Poliochni (Pernicka et al. 1990); *red squares* Yortan (Pernicka et al. 1984)

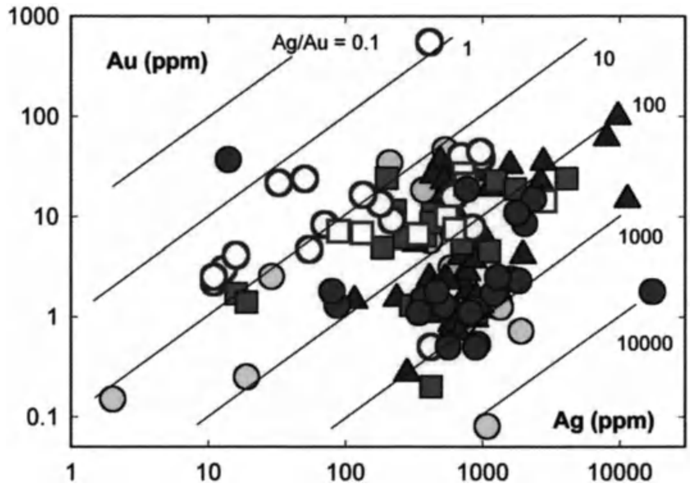

Fig. 2. In a gold vs. silver diagram the Troia I artifacts from Beşiktepe fall again together with the EBA objects from Poliochni and Thermi although for Poliochni, and even more so for Ilıpınar, the grouping of objects is not very tight. *Symbols* are as in Fig. 1

which would, of course, be more interesting if we knew what type of objects we are dealing with which we don't (see Table 1).

The tin content of the bronzes varies considerably, between 1.3 and 14.6 %, similar to what has previously been observed for artifacts from the Aegean and western Anatolia. The low tin concentrations are remarkable in so far as written texts from Ebla und Ur, dating to the second half of the third millennium B.C., prescribe proportions of tin and copper that yield alloys with between 9 and 17 % tin (Limet 1960; Waetzoldt and Bachmann 1984). Since two of the bronzes with a low tin content date to the Hellenistic period when the technical possibilities to rigorously control the tin content did exist, perhaps there was no reason seen why it should be constant in the first place. Of course, remelting "proper" bronzes together with unalloyed copper would also reduce the tin content. For one of the low-tin bronzes (HDM 1015 with 2.8 % Sn) such an explanation is unlikely, however. Of all objects analyzed, this sample is highest by far in nickel content while mixtures, by necessity, must always be intermediate in any of their compositional material features between the putative end members used for mixing.

It is interesting that in the bronzes tin is not correlated with the content of any trace element. Thus, there is no evidence that significant amounts of any of the trace elements in the bronzes have been introduced together with the tin used for alloying; the tin appears to have been rather free from impurities. This accords with analyses of tin ingots from shipwrecks at Uluburun (Kaş), Hishuley Carmel and Kefar Shamir in the eastern Mediterranean (Maddin 1989; Begemann et al. 1999), although these ingots date only to the end of the second millennium B.C., i. e., they are much younger than Troia I and also somewhat younger than Troia VI.

Besides the higher fraction of bronzes among the suites of objects later than Troia I, there are, in addition, more subtle chemical differences, in trace element concentrations as well as in concentration ratios, between the objects dating to Troia I and those from later periods. This is true for both the bronzes and the objects made from unalloyed copper. The general tendency is for the younger objects to be higher in cobalt and gold, but to be lower in silver and arsenic. The differences are most obvious from plots of nickel vs. cobalt (Fig. 3), gold vs. silver (Fig. 4), and antimony vs. arsenic (Fig. 5). Note that "uncertain age" as defined here allows for the possibility that an object so classified belongs to Troia I or, for that matter, to Troia VI. Hence, for this reason alone, it is not surprising to find some overlap of the areas populated by the data for artifacts of uncertain age with those of, say, Troia I. We emphasize, however, that such an agreement of trace element features must not be construed to indicate these artifacts to be Troia I in

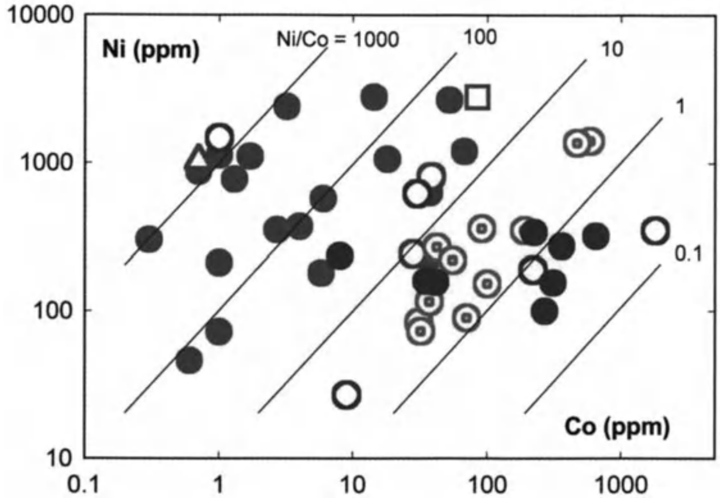

Fig. 3. Nickel and cobalt contents in metal from Beşiktepe are very variable. There is a clear tendency for cobalt contents to be higher in younger objects than in those dating to Troia I. Some of the samples of uncertain age (not shown) plotted (see text) together with the objects from Troia I; this must not be construed to mean that these objects are Troia I in age (see text). *Red* Troia I; *green* Troia VI; *blue* Hellenistic. *Full dots* Unalloyed copper; *open circles* bronze; *triangle* arsenical copper; *square* crucible slag(?)

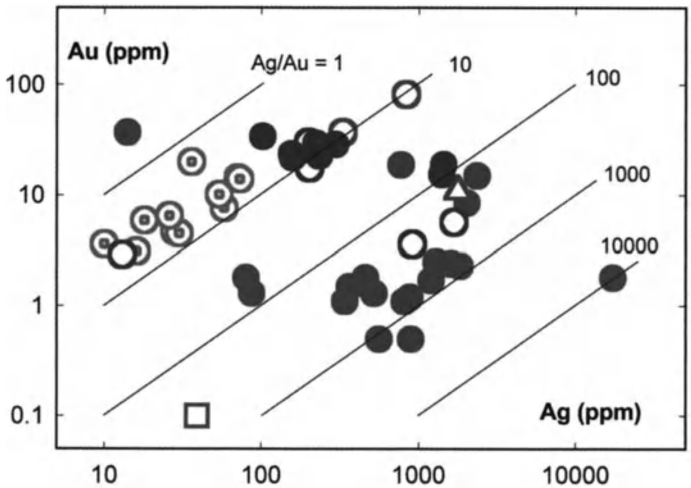

Fig. 4. There is a clear distinction in the trace element abundance pattern between unalloyed copper dating to Troia I and the bronzes from the cemetery dating to Troia VI. The Troia VI grave offerings are remarkable for the constancy of their Ag/Au ratio. Note that the silver content in the Troia VI bronze pieces tends to be very much *lower* than in the unalloyed copper, independent of its age setting. Obviously, this bronze *cannot* have been manufactured by alloying tin with the kind of copper as is present in the unalloyed artifacts. *Symbols* are as in Fig. 3

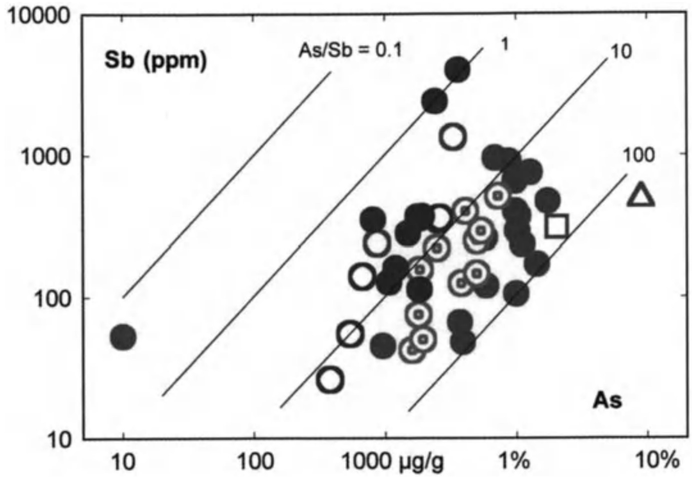

Fig. 5. The tendency for objects from different periods to be distinct in their trace element contents, or trace element abundance ratios, is followed by arsenic and antimony. This is essentially due to arsenic concentrations being lower in later periods. *Symbols* are as in Fig. 3

age; it is equally plausible that the same ore deposits, or deposits with the same trace element characteristics, were exploited over an extended period of time.

The pieces of bronze from Troia VI are remarkable for the uniformity of their trace element abundance patterns. This is true, in particular, for element abundance ratios (nickel/cobalt ≅ 3, silver/gold ≅ 5, and arsenic/antimony ≅ 23) which are all constant to within a factor of two. In Figs. 3, 4, and 5, respectively, this is obvious from the alignment of the data points along lines of constant abundance ratios[3]. Another important result to be noted from Fig. 4 is that the bronze artifacts dating to Troia VI are set apart from almost all coppers by their low silver contents. Thus, this kind of bronze cannot have been manufactured by alloying tin with the

[3] An alignment along lines of constant element abundance *ratios* results if different ore charges contained different amounts of an accessory phase which carried the two elements in a constant ratio. The silver-gold diagram suggests, e.g., that the bronze objects dating to Troia VI received their silver and gold from a carrier phase that varied in amount about tenfold, but contained the two elements in an abundance ratio Ag/Au ≅ 5. The unalloyed copper from Troia I, on the other hand, shows about the same tenfold spread in silver and gold contents as the Troia VI bronze objects but in this instance the Ag/Au abundance ratio in the putative carrier phase of the two elements appears to have been several hundred, rather than five as for the Troia VI bronze.

kind of copper present in our suite of unalloyed copper objects. In that case, the silver content of the bronzes would be equal to that of the copper, or higher if any silver had been introduced together with the tin. Clearly, this is not the case. As mentioned already, the same has also been observed for the "Troas" artifacts reported by Pernicka et al. (1984). Similar reasoning, although not based on silver contents, but on differences in "cluster assignment" and lead isotopy, led us before to conclude that at Poliochni the bronze artifacts and those made of unalloyed copper are also not genetically related (Pernicka et al. 1990). The bronze from Poliochni also cannot have been manufactured by adding tin to the kind of copper excavated there; a conclusion of particular interest because at Poliochni the copper objects and those made from bronze are strictly contemporaneous.

In the Ag–Au diagram of Fig. 4, there is a kind of grouping of eight coppers and three bronzes, with silver contents around 200 μg/g and Ag/Au ratios close to ten [4]. With one exception (HDM 331 which is too low in arsenic) the members of this group also fall close together in the Sb vs. As plot, with abundance ratios As/Sb ≈ 8, and they are fairly constant in Ni content, between 156 and 350 μg/g Ni. All this suggests that these objects might be genetically related as far as the provenance of their metal is concerned. Interestingly, cobalt in these samples is not constant at all, but varies by a factor of 75, between 24 and 1800 μg/g; its abundance is not tied to that of any of the other elements analyzed. What argues rather convincingly against a common origin of the metal in these samples, however, is their lead isotope signature. The differences among the seven samples analyzed for the isotopic composition of their lead are such that a provenance from the same orebody is improbable (see below).

3 Lead Isotopic Composition

Previous analyses for the isotopic composition of lead in copper and copper-based artifacts from western Anatolia and the eastern Aegean had revealed an extremely wide scatter of the lead isotope abundance ratios which to a large extent, but not exclusively, was due to bronze objects (Pernicka et al. 1984, 1990; Stos-Gale et al. 1984; Begemann et al. 1992, 1995; Stos-

[4] Objects in this group are a piece of bronze dating to Troia I (HDM 1128), the Hellenistic coppers HDM 302, 1131, 1228, 1229, 1252 and bronzes HDM 313 and 318, and three objects made of unalloyed copper of uncertain age (HDM 303, 331, 1125). Of these, only HDM 302, 331, 1125, and the three bronzes have been analyzed for the isotopic composition of their lead.

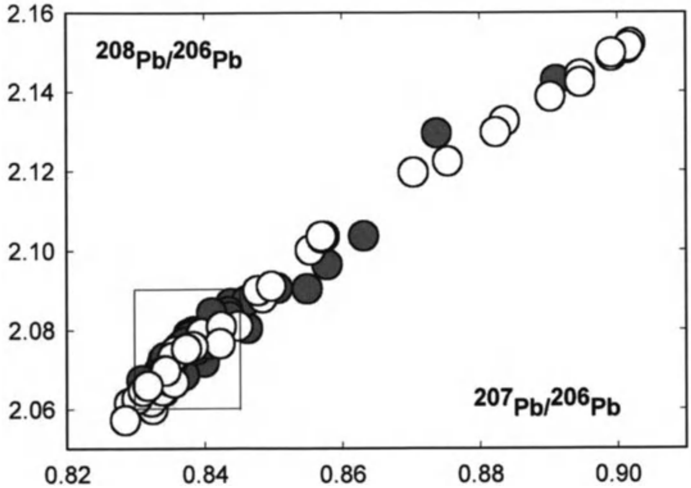

Fig. 6. The isotope abundance ratios of lead traces in copper-based artifacts from the eastern Aegean and western Anatolia cover a wide range which to a large extent, but not exclusively, is due to (tin) bronzes from Poliochni, Thermi and the Troad. In contradistinction the lead in the objects of the present study is much more constant in its isotopic composition; all samples, unalloyed copper as well as bronzes, plot into the small rectangle in the lower left corner of the diagram. *Open circles* Bronze; *gray dots* unalloyed copper

Gale 1992). Moreover, at sites where the relative chronology of the artifacts was known, namely at Thermi on the island of Lesbos and at Poliochni on Lemnos, younger artifacts showed a much wider scatter in abundance ratios than the older ones. At Thermi, e.g., objects with widely varying isotope abundance ratios became prominent only during settlement period V, at Poliochni only during period "giallo"[5].

The present metal does not show such a trend. All samples, those dating to Troia I and Troia VI as well as those from Hellenistic times, fall into the small rectangle in the lower left-hand corner of Fig. 6. There are no gross differences in the isotopic composition of their traces of lead between

[5] At Thermi, from the oldest periods I–III, dating to Troia I, there are just 4 objects out of 49 with high ^{206}Pb-normalized abundance ratios, from Thermi IV 1 out of 10, but from settlement period V there are 3 out of 8 with high ratios. Likewise, among the 11 artifacts from the 2 oldest copper-bearing periods at Poliochni, "azzurro" and "verde" (Bernabo-Brea 1964, 1976), there is not a single one with a high ratio; from the next one, period "rosso", it is 1 out of 22, but from period "giallo" it is 11 out of 54. In the present context we define "high" ^{206}Pb-normalized abundance ratio as such with ^{208}Pb/^{206}Pb >2.10. Although somewhat arbitrary, any other reasonable choice for the separation line will change the numbers, but not the conclusion.

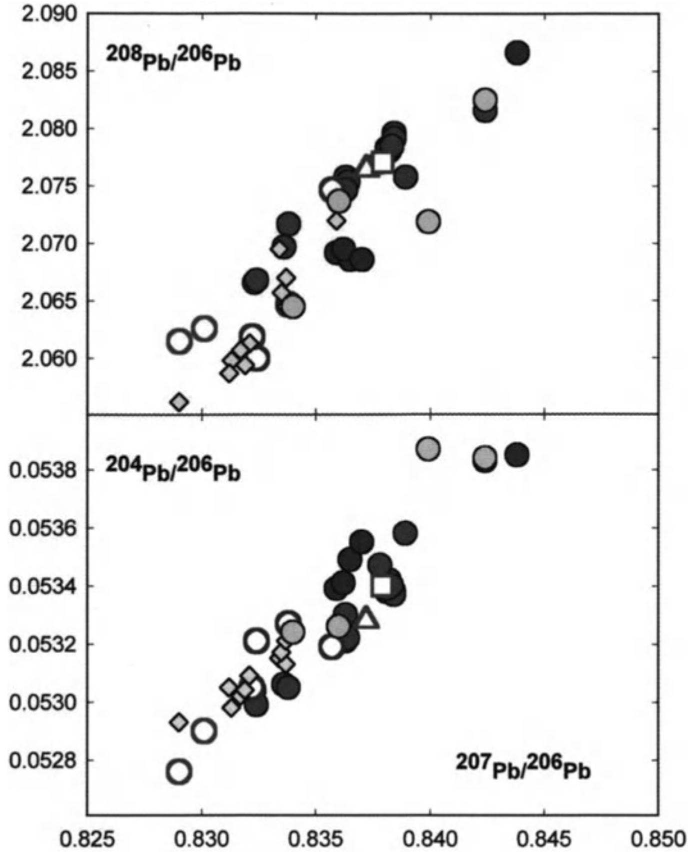

Fig. 7. Lead isotope abundances, normalized to ^{206}Pb, of copper-based artifacts dating to Troia I show some clustering, the most pronounced being at ^{208}Pb/^{206}Pb $\cong$ 2.078, ^{207}Pb/^{206}Pb $\cong$ 0.838 and at ^{208}Pb/^{206}Pb $\cong$ 2.075, ^{207}Pb/^{206}Pb $\cong$ 0.836, respectively. Objects later than Troia I, copper-based as well as lead objects, tend to fall below the Troia I trend line in the *top panel* and above the trend line in the *lower panel*. They form grouplets of their own. Isotopically matching ores are known to exist in western Anatolia for all samples but the two Troia I bronzes (*lower left*) and the three objects in the *upper right* of the *top panel*. For the latter matching ores occur at Murgul near the Black Sea coast in northeastern Turkey. *Symbols* are as in Fig. 3 and Fig. 6. Lead objects are marked *yellow*

bronze objects and such made of unalloyed copper (Fig. 7). Nor are objects of uncertain age grossly different in their lead isotopy from the artifacts dating to Troia I. However, more subtle trends do exist. There is a tendency for bronzes to have lower ^{206}Pb-normalized abundance ratios than unalloyed copper which makes the bronze pieces plot into the lower left of both panels of Fig. 7. In addition, all Hellenistic objects and those of uncertain age, bronzes as well as unalloyed copper, in the upper panel of Fig. 7, tend to plot below the trend line defined by the lead in Troia I objects and, in the lower panel of Fig. 7, to plot above the corresponding trend line defined by the Troia I objects.

Most of the artifacts from Troia I – ten made of unalloyed copper, the severely corroded sample tentatively classified as crucible slag (HDM 1114) and the arsenical copper needle (HDM 1116) – have very similar lead isotope abundances. They form two very tight groups(HDM 168, 323, 1009, 1013, 1017, 1111, 1114, 1117, and HDM 166, 1018, 1021, 1116, respectively) which are actually so close to one another that the copper in all these objects might well derive from a single ore deposit (Table 3). One sample of "uncertain" age, the unalloyed copper HDM 1126, and the low-tin bronze HDM 1016 (1.3 % Sn), belong to this (lower) group also. Interestingly, this particular bronze is set apart from the other bronze pieces not only by its low tin content, but together with another bronze fragment (HDM 1110) and one of uncertain age (HDM 1015), by its trace element abundance pattern as well. The silver/gold ratio in these bronzes is around 300, similar to what is characteristic of unalloyed copper dating to Troia I, while in all other bronze objects the ratio is typically below ten (Fig. 4). Similarly, in the Ni vs. Co diagram two of these bronze pieces again plot together with unalloyed Troia I copper, separate from the Troia VI and Hellenistic bronzes (Fig. 3).

Table 3. Isotope abundance ratios of lead in metal objects from Beşiktepe. Uncertainties, on the 95% confidence level, are 0.1% for all isotope abundance ratios

HDM No.	Pb µg/g	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$
Troia I				
Unalloyed copper				
165	120	2.0697	0.8336	0.05306
166	5400	2.0758	0.8363	0.05321
168[a]	2080	2.0783	0.8381	0.05338
307[a]	240	2.0816	0.8424	0.05383
323[a]	6050	2.0796	0.8384	0.05338
1009	>12,000	2.0792	0.8384	0.05337
1013	>23,000	2.0781	0.8382	0.05342
1017	>14,000	2.0782	0.8381	0.05339
1018	200	2.0754	0.8364	0.05322
1020	40	2.0666	0.8323	0.05304
1021	12,200	2.0747	0.8363	0.05330
1108	>25,000	2.0717	0.8338	0.05305
1111	7700	2.0785	0.8383	0.05340
1112	120	2.0758	0.8389	0.05358

Table 3 (continued)

HDM No.	Pb µg/g	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$
1117	80	2.0771	0.8378	0.05347
1132	13,700	2.0668	0.8324	0.05299
Arsenical copper				
1116	n.d.	2.0765	0.8372	0.05328
Bronzes				
1123	3900	2.0615	0.8290	0.05276
1128	3250	2.0626	0.8301	0.05290
Crucible slag				
1114	38,700	2.0771	0.8379	0.05340
Hellenistic				
Unalloyed copper				
301	590	2.0866	0.8438	0.05385
302	440	2.0692	0.8359	0.05339
304	75	2.0686	0.8365	0.05349
330[a]	230	2.0695	0.8362	0.05341
1131	110	2.0686	0.8370	0.05355
Bronzes				
313[a]	120	2.0600	0.8324	0.05321
318	50,000	2.0619	0.8322	0.05305
1016	600	2.0747	0.8357	0.05319
1118	60	2.0647	0.8338	0.05327
Lead				
171	n.d.	2.0607	0.8317	0.05302
172	n.d.	2.0695	0.8334	0.05315
174	n.d.	2.0562	0.8290	0.05293
176	n.d.	2.0720	0.8359	0.05327
180	n.d.	2.0598	0.8313	0.05298
183	n.d.	2.0587	0.8312	0.05305
184	n.d.	2.0670	0.8337	0.05313
185	n.d.	2.0657	0.8335	0.05317
187	n.d.	2.0645	0.8337	0.05321
1130	n.d.	2.0594	0.8319	0.05304
Uncertain date				
Unalloyed copper				
167[a]	170	2.0825	0.8424	0.05384
331	90	2.0719	0.8399	0.05387
1125	50	2.0645	0.8340	0.05324
1126	590	2.0737	0.8360	0.05326
Lead				
164	n.d.	2.0613	0.8321	0.05309

[a] Because of their poor state of preservation, these objects were sampled and analyzed twice. In all cases, the isotope abundance ratios agreed to within the stated uncertainties; listed are the averages.

Smaller grouplets of objects where the lead isotope abundance ratios agree within experimental uncertainties are HDM 302, 304, 330, 1131 and several pairs of objects for which the isotopic compositions are virtually identical (HDM 167 and 307, HDM 165 and 1108, HDM 1020 and 1132, HDM 1118 and 1125); all but HDM 1125 are unalloyed copper.

4
Provenance of Copper-Based Artifacts

Although western Anatolia is not, and probably never was, a major source of copper for the Aegean and its surrounding shores, there are nevertheless a number of copper deposits in the vicinity of Troia which, at some time in the past, may have served to fill local demand (Ryan 1960; de Jesus 1980). Many of these occurrences were visited some 15 years ago during field campaigns organized by G. A. Wagner and Ö. Öztunalı (Gentner et al. 1978; Pernicka et al. 1984; Wagner et al. 1986). Copper ores were found at about 20 sites. In most instances, however, the occurrences were so small, or copper ores were only so subordinate, that these ore bodies are unlikely ever to have been exploited, even in antiquity when very much smaller occurrences than today would have been of economic interest. Based on criteria such as the presence of ancient slag, of prehistoric stone tools and potsherds, or the winning techniques employed, Wagner and Öztunalı (2000), in their recent compilation, list six sites in northwest Anatolia where evidence exists for prehistoric copper mining and/or smelting activities[6]. They also suggest as potential sites for ancient copper production Balya (Balıkesir Province) and Gümüşköy (Kütahya Province) although both are major lead-silver deposits. While clear evidence for mining or smelting of *copper* ores was not discovered at either site, the authors argue that the striking visibility of oxidic copper ores close to the surface would hardly have gone unnoticed by chalcolithic metallurgists and, moreover, that at Balya secondary copper minerals in the old mining waste are a common feature.

Lead isotope analyses were performed on copper slags and copper ores or galenas (PbS) from the same sites as the slags. For easy reference the

[6] The sites in question are Doğancilar (TG 133) and Yuvalar (TG 138) in Çanakkale Province, Kozçağiz (TG 142) and Serçeörenköy (TG 192) in Balıkesir Province, Keles (TG 154) and Tahtaköprü (TG 156) in Bursa Province. Three more sites with copper slags or copper ores, but without evidence for ancient mining activities, are Avcılar (TG 128) and Halılar(TG 144) in Balıkesir Province and Camyurt (TG 136, Çanakkale Province). Detailed descriptions of the sites as well as lead isotope abundance ratios have been reported in part in Wagner et al. (1986).

data are compiled in Table 4, together with results of some other ore and slag samples relevant for the present discussion[7].

Generally speaking, ores and slags fall together with the artifacts in the same region of the lead isotope diagrams. In detail, the lead from Gümüşköy matches that in the group of 12 objects from period Troia I discussed above. Thus, the lead isotope abundance ratios suggest the copper in these objects to have been derived from Gümüşköy. This result must be qualified, however. First, because the ore sample analyzed was a galena (PbS), not a copper ore. Although more often than not copper ores and lead ores from the same mines agree in their lead isotopy, there are also exceptions (Table 4, see also Fig. 29 in Wagner et al. 1989). Moreover, it must be remembered that an assignment based on material features of an artifact to a specific ore deposit is not unique: there is always the possibility that other deposits might exist which fit the relevant artifact features equally well. In the present instance these are the deposits at Bakır Daği (TG 282) in Central Anatolia, Kayseri Province and at Kürtün-Cayırcukur (TG 207) in North Anatolia some 50 km southwest of Trabzon (Fig. 8). Both are also listed by Wagner and Öztunalı (2000) as sites with archaeometallurgical remains and evidence for early copper production. Still, Gümüşköy is our favorite source site, not only because of its relative proximity to Troia, but also because at Gümüşköy calibrated ^{14}C dates of a piece of mining timber (Demirok 1982) and a piece of charcoal from the backfill in an old mine (Wagner and Öztunalı 2000) attest to mining activities in the late third millennium B.C.

Of the smaller lead isotope grouplets of artifacts the one with four members (HDM 302, 304, 330, 1131) has corresponding ores and/or slags at Avcılar, Camyurt, Alihoca, Menteşe, and Tekmezar (Table 4). The first two sites geographically are close to Troia, but evidence at these locations for copper production in antiquity is weak or nonexistent (Pernicka et al. 1984; Wagner and Öztunalı 2000). Alihoca in the Bolkardağ district in the central Taurus in South Anatolia, Menteşe in Central Anatolia, and Tekmezar, ca. 10 km inland from the central Black Sea coast are considered more promising in this respect (Wagner and Öztunalı 2000) but nothing more definitive can be said at the present time.

[7] For determining the provenance of copper metal via its lead isotope fingerprint copper *slags* are to be preferred over copper *ores* because slags not only contain the lead from the copper ores themselves, which can be very small, but also all extraneous lead as may have been introduced from sources like flux or gangue. Thus, the lead in slags and the lead in the metal are identical in their isotopic composition and this may well be quite distinct from the ore lead. In contradistinction, *trace elements* in slags, concentrations as well as their abundance patterns, are of only limited value for provenance studies.

Table 4. Lead isotope abundance ratios in Anatolian copper and lead ores and slags which have matching compositions among the Beşiktepe artifacts. Prehistoric mining and/or smelting activities are reported for all sites except at Avcılar and Camyurt. (Wagner and Öztunalı 2000)

	TG No.		$\frac{^{208}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{204}Pb}{^{206}Pb}$	Ref.
Alihoca	287 A	Cu ore	2.0717	0.8375	0.05382	(unpubl.)
Alihoca	287 B	Cu ore	2.0719	0.8354	0.05353	(unpubl.)
Alihoca	287 F	Cu ore	2.0261	0.8139	0.05179	(unpubl.)
Alihoca	287 B-Cu	native Cu	2.0760	0.8405	0.05404	(unpubl.)
Alihoca	287 C.1	Pb slag	2.0542	0.8265	0.05266	(unpubl.)
Alihoca	287 E.1	Pb slag	2.0537	0.8258	0.05262	(unpubl.)
Avcılar	128 B-2	Galena	2.0656	0.8337	0.05323	Wagner et al. (1985)
Avcılar	128 C-8.1	Cu slag	2.0691	0.8352	0.05336	Wagner et al. (1986)
Bakır Dağı	282 B.1	Cu ore	2.0761	0.8379	0.05339	(unpubl.)
Bakır Dağı	282 C.1	Cu ore	2.0711	0.8362	0.05328	(unpubl.)
Bakır Dağı	282 B.2	Cu slag	2.0764	0.8378	0.05341	(unpubl.)
Balya	18 A	Galena	2.0722	0.8348	0.05318	(unpubl.)
Balya	18 C	Galena	2.0711	0.8344	0.05314	Wagner et al. (1985)
Balya	18 D-1	Galena	2.0694	0.8340	0.05316	Wagner et al. (1985)
Balya	18 D-2	Galena	2.0695	0.8340	0.05316	Wagner et al. (1985)
Balya	18 D-3	Galena	2.0693	0.8340	0.05317	Wagner et al. (1985)
Balya	18 E	Galena	2.0711	0.8347	0.05319	Wagner et al. (1985)
Balya	18 A-SCH	Pb slag	2.0705	0.8342	0.05315	(unpubl.)
Balya	18 H-SCH	Pb slag	2.0691	0.8335	0.05311	(unpubl.)
Balya	18 H-SP	Speiss	2.0704	0.8342	0.05316	(unpubl.)
Camyurt	136	Cu slag	2.0681	0.8355	0.05336	Wagner et al. (1986)
Doğancılar	133 E	Galena	2.0641	0.8333	0.05331	Wagner et al. (1985)
Doğancılar	133 B-2	Cu slag	2.0641	0.8333	0.05319	Wagner et al. (1986)

Table 4 (continued)

	TG No.		$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{204}Pb/^{206}Pb$	Ref.
Gümüşköy	155 C	Galena	2.0761	0.8373	0.05335	Wagner et al. (1985)
Kozcağız	142 H-1	Galena	2.0721	0.8350	0.05328	Wagner et al. (1985)
Kozcağız	142 D-4	Cu slag	2.0668	0.8335	0.05317	Wagner et al. (1986)
Kürtün Çayırçukur	207-A	Cu ore	2.0786	0.8398	0.05371	Wagner et al. (1989)
Kürtün Çayırçukur	207-G1	Cu ore	2.0744	0.8374	0.05349	Wagner et al. (1989)
Kürtün Çayırçukur	207-C	Cu slag	2.0854	0.8442	0.05408	Wagner et al. (1989)
Mamlis	221 A	Cu/Pb ore	2.0611	0.8284	0.05279	Wagner et al. (1989)
Mamlis	221 B	Pb slag	2.0622	0.8287	0.05276	Wagner et al. (1989)
Menteşe	281.1	Cu ore	2.0701	0.8371	0.05343	(unpubl.)
Serçeören Köy	192–4	Cu ore	2.0723	0.8349	0.05314	(unpubl.)
Serçeören Köy	192–5	Cu ore	2.0704	0.8345	0.05314	(unpubl.)
Serçeören Köy	192–6	Cu ore	2.0699	0.8342	0.05317	(unpubl.)
Serçeören Köy	192–7	Cu ore	2.0700	0.8346	0.05318	(unpubl.)
Serçeören Köy	192–8	Cu ore	2.0705	0.8345	0.05317	(unpubl.)
Serçeören Köy	192–9	Cu ore	2.0700	0.8346	0.05320	(unpubl.)
Serçeören Köy	192–10	Cu ore	2.0715	0.8342	0.05315	(unpubl.)
Serçeören Köy	192–11	Cu ore	2.0710	0.8347	0.05318	(unpubl.)
Serçeören Köy	192–12	Cu ore	2.0715	0.8347	0.05317	(unpubl.)
Serçeören Köy	192 A-1	Cu slag	2.0710	0.8340	0.05318	(unpubl.)
Serçeören Köy	192 A-2	Cu slag	2.0707	0.8346	0.05316	(unpubl.)
Serçeören Köy	192 B	Cu slag	2.0693	0.8340	0.05312	(unpubl.)
Serçeören Köy-Demir	192–2	Cu ore	2.0704	0.8346	0.05319	Wagner et al. (1986)
Serçeören Köy-Demir	192–3	Cu ore	2.0695	0.8344	0.05318	Wagner et al. (1986)
Tahtaköprü	156	Cu ore	2.0637	0.8321	0.05314	Wagner et al. (1986)
Tekmezar	202–A	Cu ore	2.0731	0.8378	0.05354	Wagner et al. (1989)
Tekmezar	202–A1	Cu slag	2.0731	0.8374	0.05344	Wagner et al. (1989)

For an explanation of the wide range in isotope abundance ratios in the Cu ores from Alihoca see, e.g., Wagner et al. (1986).

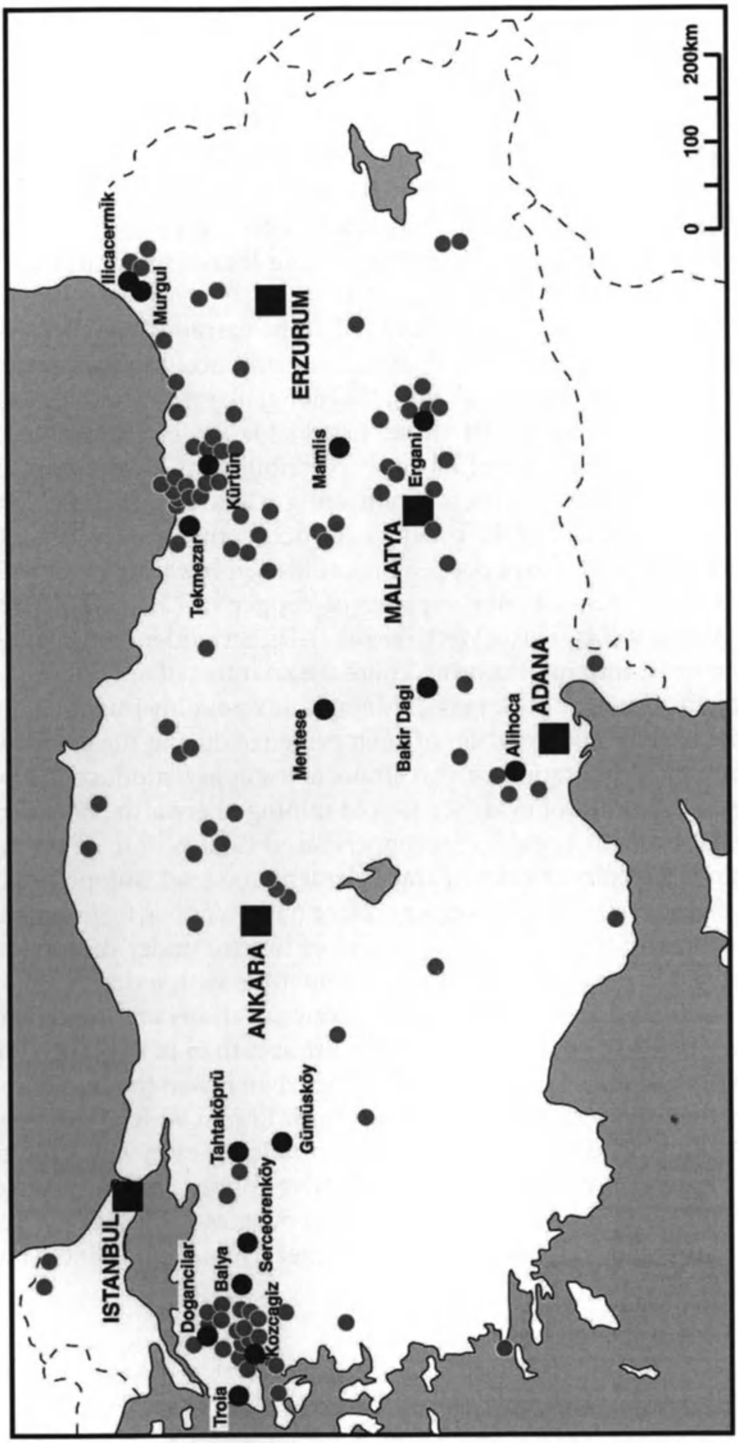

Fig. 8. Prehistoric copper/lead mines in Anatolia with lead isotopic fingerprints as they occur in copper-based artifacts from Beşiktepe dating to Troia I. These mines (*black dots*) qualify as sources of the Beşiktepe copper during the first half of the third millennium B.C. The total coverage of Anatolia during the various surveys is indicated by *gray dots*

Of the four pairs of objects for which the members of each pair have the same lead isotopy, three have corresponding ores and/or slags in western Anatolia, at sites listed by Wagner and Öztunalı (2000) to show evidence for prehistoric exploitation[8]. For the fourth pair (HDM 167, 307) matching copper ores and/or copper slags exist at Ilıcaçermik, Kayabaşı Köyü, and Murgul, all located in northeastern Anatolia near the Black Sea coast (Wagner et al. 1989). Of these, Murgul in particular has been shown to have been operational as early as in the second half of the fourth millennium B.C. (Lutz et al. 1994; Wagner and Öztunalı 2000).

The two pieces of bronze from Troia I fall at the extreme lower left end of the distribution (Fig. 7). Isotopically matching ores occur in East Anatolia, at Ergani Maden (Seeliger et al. 1985; Wagner et al. 1986) and at nearby Mamlis (Wagner et al. 1989). Of these, Ergani Maden is a particularly intriguing possibility. Because of its easy accessibility, its location on the upper Tigris at the trade route connecting Central Anatolia with Mesopotamia, and because of the conspicuous occurrence at the surface of colorful oxidic ores and native copper Ergani Maden has frequently been suggested to have been a major supplier of copper in Chalcolithic and Bronze Age Anatolia (Birgi 1950; Wertime 1964). Direct evidence in support of this conjecture is missing, however. There are no traces of old mining reported at Ergani (Seeliger et al. 1985), although this possibly might be due to the destruction and obliteration of such evidence during the extensive modern open-pit exploitation of this important copper producer. However, besides the absence of evidence for old mining, there also is no compelling evidence for the presence in copper-based Chalcolithic or Bronze Age artifacts of the combination of trace element and lead isotope signatures as are characteristic of the copper ores, or native copper, from Ergani. Indeed, this is again true for the two pieces of bronze under discussion. While their lead isotopic composition is compatible with a derivation of the copper from Ergani the trace element concentrations are not: cobalt contents are more than 50 times lower in the bronzes than in the ores while silver is 100 times higher in the pieces of bronze than it is in the ores. Judging from the two samples of native copper from Ergani which have been analyzed (Pernicka et al. 1997, Table A3a) the situation is even worse for local native copper. These two specimens of native copper contain arsenic, antimony, cobalt, nickel, silver and gold all in concentrations of 25 µg/g or less which is too low by large factors, of up to several hundred, to fit the two

[8] For HDM 165, 1108 isotopically matching copper ores exist at Serçeörenköy and matching lead ores at Balya, for HDM 1020, 1132 at Tahtaköprü, and for HDM 1118, 1125 there are matching copper slags at Doğancılar and at Kozçağız (Fig. 8).

Troia I bronze objects. Arguing that these trace elements in the bronze were somehow introduced from some extraneous source cannot be refuted, but accepting this explanation goes, of course, to the heart of the whole method of matching material features of artifacts with those of ores; it would make all such provenance studies futile.

Actually, arguments like the present ones, including chemical data of Maddin quoted by Muhly (1989), would appear to have resulted in a change of opinion on the possible role of Ergani as a source of copper in prehistoric Anatolia. Muhly (1989) summarizes the discussion following his presentation at the Heidelberg 1987 "Old World Archaeometallurgy" Symposium that "it was the consensus of opinion that Ergani Maden has been greatly overrated as a source of copper, or even *the* source of copper for the metal industries of prehistoric Anatolia."

5 Lead Artifacts

The trace element contents of the lead objects reveal nothing unusual (Table 5). Antimony, with a mean concentration of 600 µg/g, is about ten times more abundant than is arsenic with a mean content of 72 µg/g. Silver concentrations, 200 µm/g on average, are remarkably constant. For Troia VI and Hellenistic lead such low values are expected because, by this time, essentially all the lead would have been desilvered by cupellation since, indeed, the production of lead was not aimed at the lead itself, but rather at the silver it contained. Note, however, that the three samples dating to Troia I have low silver contents also.

In the isotope abundance diagram (Fig. 7, yellow diamonds) lead objects lie in the lower left part, at low ^{206}Pb-normalized abundance ratios, with some overlap of their compositions with those of the lead in copper-based artifacts of Hellenistic age. Five of the samples (HDM 164, 171, 180, 183, 1130) are indistinguishable from one another in their isotopic composition. They agree with lead ores from Laurion (Barnes et al. 1974; Gale et al. 1980; Stos-Gale et al. 1986), the vast lead deposit across the Aegean in southeast Attica which is known to have been exploited more or less continuously from the beginning of the third millennium B.C. to the beginning of last century (Spitaels 1984). Also compatible with a provenance from Laurion are the isotopic fingerprints of two of the bronze objects (HDM 313 and 318). The implications of this result are not quite clear because so far no traces of copper slag have been reported from Laurion. Hence, although copper ores do occur at Laurion their potential role as a source of copper in antiquity remains uncertain.

Table 5. Trace elements in pieces of lead from Beşiktepe. Concentrations are listed in µg/g. Copper in all cases was below 0.1% except in HDM 322 where the upper limit is 0.2%

HDM No.	Sn	As	Sb	Ag	Au	Bi
Troia I						
309	<540	4	–	172	<0.02	–
315	<620	63	1160	257	0.31	–
329	<550	34	337	174	0.92	–
Troia VI						
305	<340	21	–	392	0.11	–
310	<3000	<60	–	<150	<0.30	–
314	<340	6	343	388	78.00	–
320	<370	11	371	372	0.09	–
325	<310	433	1240	230	0.69	–
Hellenistic						
171	–	22	573	168	0.20	–
172	–	224	2200	216	0.36	231
174	–	4	42	50	0.96	57
176	–	24	145	174	0.26	11
180	–	128	954	123	<0.02	2
183	–	73	739	178	<0.03	–
184	–	110	417	174	0.23	–
185	–	12	261	162	0.36	–
Uncertain						
164	–	10	115	128	0.06	151
269	–	25	618	172	0.27	34
306	<690	207	–	250	0.33	–
317	<470	5	180	178	0.10	–
322	<1000	36	540	106	0.19	–

Four other specimens (HDM 172, 184, 185, 187) also form a tight isotope cluster. For them, corresponding ores exist at Balya and a few small ore occurrences in northwestern Anatolia (Avcilar and Adası Maden in Balıkesir Province; Dagoba, Doğancılar, and Kuştepe in Çanakkale Province [Wagner et al. 1985]). Among these, Wagner and Öztunalı (2000) report evidence for ancient mining activities aimed at lead only at Balya, however. Other, geographically more removed, but nevertheless potentially interesting source regions for this kind of lead, are Thasos and also the Kassandra ore district, west of Stration, in the northwest of the Chalkidike peninsula (Chalkias et al. 1988; Gale et al. 1988). On Chalkidike there is again no evidence for old mining activities, but on Thasos such activities are well documented (Speidel 1929; Gialoglou et al. 1988; Pernicka and Wagner 1988, Fig. 264). Moreover, the concentrations of arsenic, antimony, and gold in lead metal recovered from slags on Thasos agree fairly well with those in the lead from Beşiktepe[9].

6
Summary and Conclusions

The lead isotope fingerprints of almost all copper-based Troia I artifacts from Beşiktepe are compatible with a derivation of the copper from ore deposits in western Anatolia. The same had been found earlier for many of the contemporaneous objects from settlement phases I–III at Thermi on the island of Lesbos (Stos-Gale 1992; Begemann et al. 1992, 1995) and for objects from periods "azzurro" and "verde" at Poliochni on Lemnos (Pernicka et al. 1990). In detail, the isotopic composition most frequently encountered at Beşiktepe is also found in 17 out of a total of 37 objects analyzed from Thermi and in 6 (out of 11) objects from Poliochni. Thus, Gümüşköy, the ore deposit we find most plausible to have been the source of this copper may well have been a mayor supplier of copper to Troia and the eastern Aegean during the first half of the third millennium B.C. Serçeörenköy-Balya, present with two cases of matching isotopy among Beşik-Yassıtepe copper pieces, occur with four more samples among the artifacts from Thermi and with one more from Poliochni. Since there are small, but systematic differences between artifacts from the three archaeological sites in their trace element contents it would appear that the metal recovered at the three sites derived from different locations within the large ore deposits of Gümüşköy, Serçeörenköy and Balya, possibly because of slight differences in age of the objects from the relevant periods at Beşiktepe, Poliochni, and Thermi. Chemical data presently available on ores from the three deposits are not comprehensive enough to indicate the range in trace element concentrations one might reasonably expect. It is, of course, also possible that several different ore deposits were exploited in western Anatolia with very similar lead isotope signatures, but different trace element contents.

Most authors writing on the subject of early Aegean metallurgy stress the difference between the initial phase, equivalent to Troia I, and "developed Troia II" (Renfrew 1967; Branigan 1974; de Jesus 1980; Yakar 1984). They all note the typological similarities across the Aegean during the later phase which did not exist earlier, suggesting a marked increase of contacts owing to the advances in regular seafaring and the extent of the trade of metals, among other commodities. Renfrew (1972) sees the appearance

[9] Silver in the metal spherules from these lead slags is about ten times higher than in the Beşiktepe metal. However, such a difference between original lead and desilvered lead is, of course, to be expected.

during this period of an "international spirit", and dramatic expressions like "Metallschock" (Schachermeyr 1984) and "metallurgy explosion" (Branigan 1974) have been used to describe the sudden increase in the number of metal finds. We note that these conclusions, based on typology, are in accord with the material science data: while during Troia I the lead isotopic composition and the trace element contents of copper-based artifacts at Beşiktepe, Poliochni, and Thermi are compatible with a derivation of this copper from western Anatolian sources, during Troia II a different kind of copper reached the Aegean, either as copper ingots or as finished objects (Pernicka et al. 1984, 1990; Begemann et al. 1992) which came to be used side-by-side, but never completely replaced the copper from the old source(s). The provenience of this new metal is still somewhat enigmatic because there is no plausible source among the studied ore deposits in southeastern Europe, the Aegean, and Anatolia. The contemporaneous appearance of such metal also at Kastri on the island of Syros (Stos-Gale et al. 1984) perhaps suggests the influx of foreign metal (and people?) into the Aegean. The most likely direction from where it came seems to be the east.

Lest there be any misinterpretation, we reemphasize that our data, as all such data, do not allow a definitive positive assignment; they only tell us whether or not certain assignments are possible. According to our ore data bank, for many of the artifacts under discussion there are isotopically matching copper ores and copper slags from many more places in the Mediterranean and the Aegean, from Sardinia, Cyprus, Crete, Kea, Siphnos and Thasos, as well as from Afghanistan, Bulgaria, Jordan, and Serbia. Occam's Razor[10], however, makes it prudent first to look for local sources, in particular if evidence exists that these were actually exploited at the times in question.

Problems with definitive conclusions do not exist if the conclusions are in the negative. Therefore, it is worth repeating that none of the copper-based Early Bronze Age artifacts from the eastern Aegean and the vicinity of Troia can be traced to Ergani. Evidence for an important seminal role of Ergani in the development of copper-based metallurgy remains elusive.

Concerning the 11 bronze objects from the Troia VI cemetery we reemphasize that these objects are notable for their uniform trace element abundance patterns (lead isotope data do not exist). The "extensive evidence of the presence of exotic materials among the small finds from the cemetery" (Basedow 2000) is not reflected in a diversity of chemical compositions. Typologically, adornments like the two bronze anklets from grave No. 68 (HDM 1257 and 1258), in particular, are exceedingly rare in the

[10] William of Occam, ca. 1280–1349. "*Entia non sunt multiplicanda praeter necessitatem*". Quoted from Encyclopaedia Brittanica.

Aegean having their closest parallels in samples from the Caucasus and from northern Germany. Still, chemically they are only notable for the perfect agreement in the concentrations of tin and all trace elements, making it virtually certain that they were manufactured together. However, there is nothing that would set this pair of artifacts apart from the other bronzes from the cemetery, except perhaps that nickel and cobalt concentrations are somewhat high. The constancy of the composition of all 11 bronze objects argues for a single, presumably local source of the metal in these artifacts. Since the trace elements in the Beşiktepe bronzes are dominated by the contributions originating with the copper, not with the tin used for alloying, the local source of metal pertains only to the copper. Because of the absence of any tin deposits in western Anatolia, tin would have to have been imported and the alloying to have been performed locally, or alloy ingots to have been imported.

Acknowledgements. We acknowledge Prof. M. Korfmann for generously making the objects available for sampling, Messrs. R. Becks, A. Pfeffer and Dr. P. Jablonka for their tedious work identifying and backtracing the artifacts, and Mmes. R. Löhr, U. Schwan and C. Sudek for their able help in the laboratory. Discussions with Prof. G. A. Wagner on Anatolian ore deposits are very much appreciated.

CHAPTER 12

Provenance of the White Marble Building Stones in the Monuments of Ancient Troia

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Abstract

This paper presents the first results of archaeometrical research on marble building material of Troia. The material for the monuments could have been shipped from various areas since deposits of marble are widespread in Asia Minor. In order to clarify the provenance, systematic sampling and investigation of marble from the Biga peninsula and other Anatolian deposits were carried out. In addition to the field studies, mineralogical, isotope geochemical and cathodoluminescence analyses were applied. Comparison between the building stones and those from ancient quarries of the Biga peninsula and around the Marmara Sea provide evidence for the origin of the main building stones, but some stones were derived from Aegean islands or from the Attic mainland.

1 Introduction

At the time when Homer lived (eighth century B.C.), most of the abandoned sites such as Troia were re-settled by Greeks from Asia Minor. It was the beginning of the Greek period, Ilion (Troia VIII, shortly before 700–85 B.C.). From the beginning of the third century B.C. in particular, Troia was widely known as the "Holy City of Ilion". This period is characterised by the building of the sanctuary dedicated to Cybele to the south-west of Troia, and of a temple to Athena inside the citadel. In 85 B.C., the site was completely destroyed by the Romans.

Later, Ilion or Ilium (Roman Period, Troia IX, 85 B.C.–ca. A.D. 500) received generous patronage from Rome until the third century A.D. The Temple of Athena was rebuilt, it was developed especially under the rule of emperor Augustus. The preserved ruins of the monument include: (1) long sections of the massive foundations supporting the porticoes and surrounding walls of the 9500 m^2 rectangular sacred precinct; (2) altars and an assembly-hall, (3) the Odeion, a small, roofed theatre from the period of Augustus, but rebuilt under Hadrian. Not far from here, there is (4) a mosaic-floored presumably sport and bath complex; and (5) a large theatre situated in a natural hollow to the north-east of the temple hill (Korfmann and Mannsperger 1998).

These phases of construction left their fingerprints on the buildings and monuments of Troia. The building material could have been shipped from various quarries since the marble from which the monuments and buildings could have been constructed have widespread deposits in Asia Minor. So far, no clear provenance of the building material has been provided; in this paper we present the first results of our investigation. In order to clarify the provenance, systematic sampling and investigation of marble from the Biga peninsula and other Anatolian deposits were carried out. The first step in the attempt to determine the origin of the marbles was the identification and characterisation of the marble materials. A comparison of mineralogical and geochemical characteristics of the Troian marble monuments with those of local and regional marble quarries allows a distinction between local (surrounding area of Biga peninsula) and imported marble from Asia Minor or other ancient marble production centres, e.g. Aegean islands or Attic mainland.

Several scientific methods were applied in order to distinguish antique marble quarries. No single technique allows a clear characterisation of white marble. Therefore, a multi-disciplinary approach is more promising. For a basic grouping of samples, macroscopic features like colour and smell and microscopic properties like texture, grain size analysis and staining techniques were used. Furthermore, the determination of minor and trace elements was carried out with chemical techniques like XRF (X-ray fluorescence) and ICP-MS (inductive coupled plasma mass spectrometry), the $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios were measured with a mass spectrometer. Finally, for the fine division of samples that were still ambiguous cathodoluminescence and Sr isotope analyses were used.

2 Material and Short Geological Overview

For the investigation, more than 300 geological samples were taken from Anatolian marble quarries, especially in the Biga peninsula and around the Marmara Sea – near Troia (Fig. 1). Western Turkey is made up of several continental fragments with independent Paleozoic and Mesozoic geological histories that had assembled by the Early Tertiary, following the closure of the intervening Tethyan oceanic basins (Okay et al. 1996). The first three zones are (1) the Strandja, (2) the İstanbul, and (3) the Sakarya zones including the Armutlu-Ovacık zone, which show Laurasian affinities and are classically referred to as the Pontides. They are separated by the Izmir-

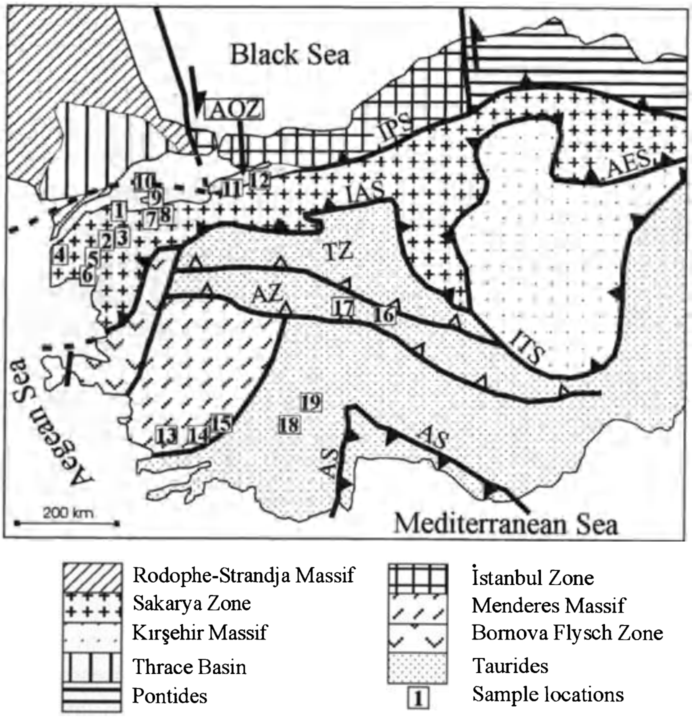

Fig. 1. Simplified tectonic map of Turkey after Okay and Tüysüz (1999), Stampfli (2000), Robertson and Pickett (2000) and Yılmaz et al. (2000) with sampling locations. *IAS* Izmir-Ankara Suture, *AS* Antalya Suture, *AES* Ankara-Erzincan-Suture, *ITS* Inner-Tauride-Suture, *IPS* Intra-Pontide-Suture, *SEAS* South-east-Anatolian-Suture, *AOZ* Armutlu-Ovacık Zone, *AZ* Afyon Zone, *TZ* Tasvanli Zone. Sampled marble locations: *1* Karabiga, *2* Ayazma, *3* Yenice, *4* Bergaz, *5* Serhat, *6* Altınoluk, *7* Manyas, *8* Mustafa Kemalpaşa, *9* Bandırma, *10* Marmara, *11* Orhangazi, *12* Iznik, *13* Milas, *14* Yatağan, *15* Muğla, *16* Afyon, *17* Uşak, *18* Babadağ, *19* Denizli

Ankara-Erzincan suture from the (4) Kırşehir Massif, (5) Menderes Massif, and (6) the Anatolide-Tauride block in South Turkey (Okay et al. 1996). In this study results are presented of marbles from the Sakarya Zone, Menderes Massif, Kırşehir Massif, and Tauride block.

The Paleozoic continental basement of the Sakarya zone consists of granitic and metamorphic rocks (Okay et al 1996). The metamorphism was at high-grade-amphibolite facies to granulite facies with local anatexis. This zone had a complex thermo-tectonic history, with Mid-Carboniferous (Hercynian), Late Triassic, and Oligo-Miocene (Alpine) thermal events. The basement of the Biga peninsula (see Fig. 1 in Satır and Zöldföldi, this Vol.) between Edremit bay and the Sea of Marmara is represented by calc schist, metaquartzite, schists, serpentinites, and marble. They are well exposed in the tectonic window of the Kazdağ ranges. Several marble locations of this area were sampled (italic numbers in parenthesis are shown in Fig. 1): *Karabiga (1)*, *Ayazma (2)*, *Yeniçe (3)*, *Bergaz (4)*, *Serhat (5)* and *Altınoluk (6)*.

The Paleozoic basement is tectonically overlain by the Karakaya Complex (Okay et al. 1996), which consists in some regions, such as *Manyas (7)*, *Mustafa Kemalpaşa (8)*, *Bandırma (9)*, and on the island of *Marmara (10)* of Permo-Triassic carbonates (Okay et al. 1991, 1996). They are several hundred metres thick and have undergone high-pressure greenschist-facies metamorphism.

The basement of the Armutlu-Ovacık zone, near Iznik lake, consists of metalava, graphite-schist and metaclastics interbedded with recrystallised limestones (Gönçüoğlu and Erendil 1990). These are overlain by a Permo-Triassic marble sequence; of which *Orhangazi (11)* was also sampled. This unit passes upward into white, recrystallised, cherty limestones (Gönçüoğlu and Erendil 1990), termed *Iznik (12)* in this study.

The next unit, the Menderes Massif, is a large metamorphic terrain. It is mainly composed of gneissic granites, migmatites, mica-schists and marble succession. In several previous studies the gneissic granites and amphibolite-grade micaschists were described as the Precambrian core (Dürr 1975; Şengör et al 1984; Satır and Friedrichsen 1986; Hetzel et al. 1998), and the metapelites with marble lenses and emery-bearing massive marbles have been defined as the Paleozoic-Mesozoic cover series of the Menderes Massif (Şengör and Yilmaz 1981). In the Tire region, the Menderes Massif is represented by a thick metasedimentary sequence including marble intercalations of Triassic-Jurassic age (Güngör and Erdoğan 2001). The Mesozoic sequence of the southern Menderes Massif mainly consists of massive platform-type neritic marbles. The uppermost part of the Mesozoic sequence is characterised, from bottom to top, by emery-bearing marbles, rudist-bearing marbles, reddish pelagic marbles and flysch-like rocks. This sequence has been metamorphosed to greenschist-facies conditions (Satır and Taubald 2001; Özer et al. 2001). Recent quarries sampled in this region are *Milas (13)*, *Yatağan (14)*, *Muğla (15)*.

In addition, some marble samples were taken from the Anatolide-Tauride block. Permo-Carboniferous clastic rocks, limestones and minor tuffs are the lowest formations exposed in the Afyon zone; they progress up to Lower Triassic shallow-water clastics and dolomites, which are succeeded by Middle-Triassic platform carbonates, overlain by pelagic micrites, radiolarian cherts and siliceous shales (Okay et al. 1996). The Afyon zone has undergone low-grade greenschist-facies regional metamorphism (Özçan et al. 1988). Samples from *Afyon (16)* and *Uşak (17)* represent marbles from this zone. Samples from *Babadağ (18)* and *Denizli (19)* represent the Anatolide-Tauride block south of the Afyon zone.

In addition 35 samples were taken from Troian monuments, like the Athena Temple (PBA1–6) dated at 280 B.C., Athena Temple Porticoes (PBA7–10) dated at 230 B.C., the "Sanctuary" of the Roman Altar (PBA11–13) and the Blue Marble Building of the Bath (PBA14–16) dated to the third century B.C., the North Building Threshold of the Sanctuary (PBA17–18) and the seats of the Bouleuterion (PBA19–21) dated to the second century B.C., the "Children of Claudius Inscription" (PBA22) dated at 53 A.D., an architectural element (PBA23–25) and columns (PBA26–29) of the Odeion dated from early second century A.D., and the Nymphaeum base moulding (PBA30–31), also the base moulding (PBA32–33) of the Bath dated from the late second century B.C.

3 Methods

In this study, we have focused on all possible features of marbles which may be useful in the distinction of their different types. Since there may be slight differences in the facies of the various marbles, macroscopic, microscopic, and chemical compositional properties were studied in detail. A rough separation of originating areas is based on macroscopic features: colour and smell are distinctive properties for the initial grouping. A more detailed classification is possible using microscopic features such as texture, grain size and staining technique with the aid of the polarising microscope. A fine clustering of samples was possible based on instrumental studies, which included X-ray diffraction (XRD), X-ray fluorescence (XRF; Knacke-Loy 1994), inductively coupled plasma mass spectrometry (ICP-MS; full details of the procedure are given by Jenner et al. 1990), O, C, and Sr isotope geochemistry, and cathodoluminescence imaging.

The extraction of CO_2 and stable isotope measurements were performed using an on-line automated carbonate extraction system coupled to a Finnigan MAT 252 mass spectrometer. The GasBench uses a continuous flow technique to provide gas samples to the mass spectrometer from carbonates. The CO_2 is prepared with phosphoric acid (103–105%) in a sealed, He-flushed sample bottle. After reaction and equilibration an automated syringe is used to extract the sample He-CO_2 mixture and transfer it via a gas chromatograph to separate CO_2 from other trace gases to the mass spectrometer. Reproducibility for both carbon and oxygen was ± 0.2‰. The results are reported in terms of the standard notation relative to PDB standard calcite as $\delta^{13}C$ and $\delta^{18}O$.

The whole-rock powders selected for Sr isotope analysis were dissolved for 24 h in 1 ml 2.5 N ultra-pure HCl at 80 °C. For isotope analysis, strontium was isolated on quartz columns by conventional ion exchange chromatography with a 5 ml resin bed of Bio Rad AG 50W-X12, 200–400 mesh. All isotopic measurements were made on a Finnigan MAT 262 mass spectrometer. Sr was loaded with a Ta-Hf activator on pre-conditioned W filaments and was measured in single-filament mode. The $^{87}Sr/^{86}Sr$ isotope ratios were normalised to $^{86}Sr/^{88}Sr = 0.1194$ for mass fractionation. Analysis of 28 separate loads of National Bureau of Standards (NBS) 987 Sr standard during the course of this study (01/2000–10/2001) gave a $^{87}Sr/^{86}Sr$ of 0.710259 ± 0.000012 ($\pm$ errors are 2σ of the mean). Total procedural blanks (chemistry and loading) were < 300 pg Sr.

Cathodoluminescence imaging was performed on polished thin sections of marble with the Nuclide ELM-3 instrument at the Department of Environmental Geology, Eötvös Loránd University, Budapest. The microscope was a monocular Olympus Pos, with an Olympus D Achromat 4× objective. A high sensitivity cold cathode CL-microscope was used. Experiments were carried out between 10 and 30 keV accelerating voltage and 0.60 $\mu A/mm^2$ beam current density. Colour slides were taken with Kodak 400 and 800 ASA colour transparency film.

4 Results

4.1 Mineral Composition

4.1.1 *Anatolian Marbles*

Based on the thin section observation with alizarin, XRD, and microprobe investigation, the marble is predominantly calcitic in most quarries. Apart from dolomite, many accessory minerals can be observed, such as feldspar, muscovite, quartz, epidote, phlogopite, graphite, apatite, perovskite, rutile, gypsum and opaque minerals (Table 1). Their abundance rarely exceeds 5 %, the probability of their microscopic observation, therefore, strongly depends on the random choice of the material used to make the thin sections. In the majority of the hitherto analysed Anatolian marbles, however, there is minor variation in the accessory minerals. First, we can make up two groups based on the dolomite amount of the samples. (1) The deposits of Marmara (2–8 wt%), Bandırma (up to 6 wt%), Altınoluk (5–12 wt%), Muğla (up to 4 wt%), Milas (<1 wt%) belong to the first group, (2) the

Table 1. Mineral composition of marble used as construction material in Troy

	Anatolian marble quarries										Troian marbles					
	Marmara	Orhangazi	Bandırma	Karabiga	Ayazma	Altınoluk	Muğla	Milas	Afyon	Babadağ	Athena Temple	Athena Temple Porticoes	Bouleuterion	Odeion	Bath Nymph. base	Bath moulding
Calcite	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dolomite	+	+	+			+	+	+			+		+	+	+	
Apatite	×	×	×	×	×	×	×	×		×	×		×	×	×	×
Barite								×								
Quartz	+	+			+	+			+	+	+	+		+		
Muscovite			+							+	+	+	+			
Phlogopite	×		×		×	×						×	×			
Diopsiode						×										
Epidote				×					×							
Titanite	×					×										
Perovskite						×	×									
Rutile	×					×										
Sphalerite								×								
Magnetite						×						×				
Pyrite	+		+				+		×	+	+	+	+			
Kyanite												×			×	
Gypsum							+									
Feldspar												×				
Chlorite						+	+									
Clay min.					+							+				

+ Determined by XRD and × determined by electron microprobe.

second group of the samples lacks dolomite, such as Karabiga, Ayazma, Afyon, Babadağ, Orhangazi.

In some cases, a lot of minerals are present, like the marbles from Marmara (dolomite, apatite, phlogopite, titanite, rutile, pyrite), Altınoluk (dolomite, apatite, quartz, phlogopite, diopside, titanite, perovskite, rutile, magnetite, talk-chlorite) and Muğla (dolomite, apatite, perovskite, pyrite, gypsum, talk-chlorite), but others are poor in accessory minerals, such as Afyon (apatite, epidote, pyrite), Babadağ (apatite, quartz, muscovite, pyrite), Karabiga (apatite, epidote) and Ayazma (apatite, phlogopite, clay minerals).

4.1.2 *Troian Marbles*

Samples from the Athena Temple (PBA 1–6) are mineralogically characterised by presence and amount of calcite, dolomite (up to 3 wt%), apatite, quartz, muscovite and pyrite (Table 1).

Two groups of building material from the Athena Temple Porticoes can be recognised. First, the samples PBA 7–8 with the mineral association calcite, dolomite, quartz, muscovite, phlogopite, magnetite, pyrite, clay minerals; second calcite, quartz, muscovite, phlogopite, magnetite, pyrite, aluminium silicates (probably kyanite), feldspar and clay minerals in the samples PBA9 and PBA10. Calcite, dolomite, apatite, muscovite, phlogopite and pyrite are found in the samples of Bouleuterion (PBA19–21), and calcite, dolomite, apatite, quartz in the case of Odeion (PBA23–29). The marble of the Bath and Nymphaeum base (PBA30–31) is characterised by dolomite, apatite and aluminium silicates, probably kyanite.

Generally, the accessory minerals do not serve to distinguish between the marbles. However, in some cases, the mineral compositions can be helpful for provenance analysis, such as the presence of aluminium silicates (e.g. kyanite). Troian marble samples (Athena Temple Porticoes, PBA9–10 and the Bath Nymphaeum base, PBA30–31) contain kyanite, which is not known in the Anatolian marbles investigated in this study.

4.2 Texture

4.2.1 *Anatolian Marbles*

Textural differences are observed in the studied samples. The rock samples from (1) Milas, Muğla (Fig. 2C) belonging to the Menderes Massif, (2) Baba-

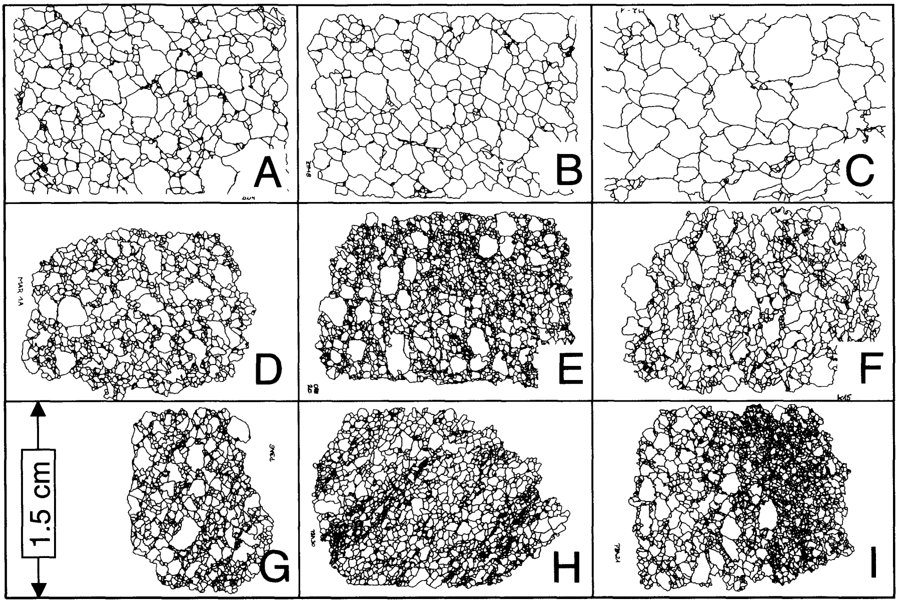

Fig. 2. Grain boundaries, drawn after the thin sections from Anatolian marbles. **A** Babadağ, **B** Uşak, **C** Muğla, **D** Marmara, **E** Orhangazi, **F** Altınoluk, **G** PBA6, **H** PBA30, **I** PBA21

dağ (Fig. 2A), Afyon, Uşak (Fig. 2B) belonging to the Anatolide-Tauride block and (3) Kemalpaşa, and Serhat (N Kazdağ) belonging to the Sakarya zone display a well-developed homeoblastic texture. They show simple calcite mosaic, the grains are separated by linear or gently sutured boundaries (Fig. 2). The texture of the marbles from (4) Marmara (Fig. 2D), Orhangazi (Fig. 2E), Ayazma (Fig. 2F) and Altınoluk is predominantly heteroblastic. All samples belong to the Sakarya and Armutlu-Ovacık, that is to the Pontides. This type is characterised by large abraded calcite relics in a fine matrix, produced by shearing and recrystallisation (Fig. 2).

4.2.2
Troian Marbles

The investigated architectural fragments from Troia always display a heteroblastic texture, large abraded calcite relics in a fine matrix (Fig. 2G). Therefore, it is most likely that the origin of the Troian building material is the Pontides area. In some cases, such as samples from the Athena Temple Porticoes (PBA9–10) and Bath-Nymphaean Base (PBA30–31) the dolomite grain form occurs in stripes (Fig. 2H,I).

4.3
Maximum Grain Size

4.3.1
Anatolian Marbles

The size of the calcite grains and especially the maximum grain size (MGS) turned out to be a most helpful criterion to distinguish between marbles originating from different districts. In Fig. 3 the ranges of the MGS in the marble samples are shown. Although the MGS does not allow us to distinguish each of the deposits from all the other ones, it is clear that occasionally the MGS could be used as a direct discriminating factor, e.g. to distinguish Muğla (3.2–5.6 mm) from Milas (2.4–3.0 mm) and Babadağ (2.5–2.9 mm), or to separate Pentelikon (0.8–1.5 mm) from all other quarries,

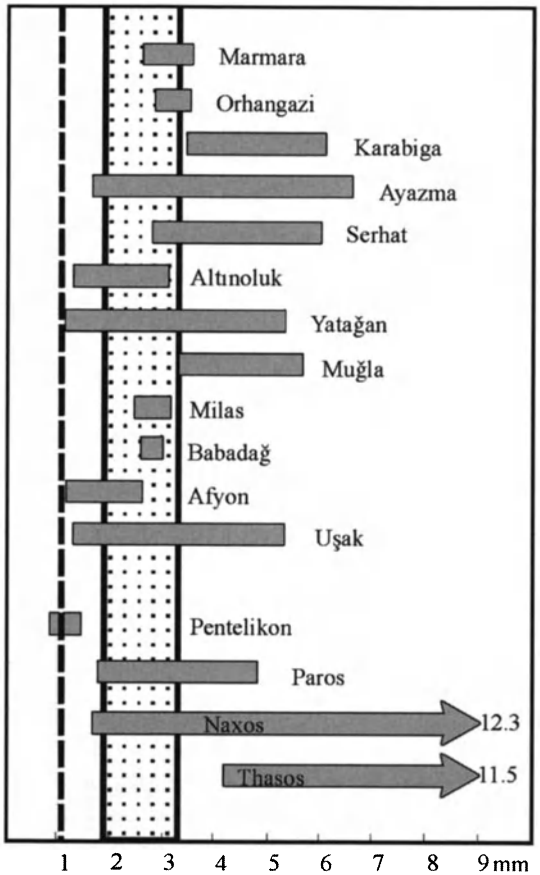

Fig. 3. Range of the maximum grain size (MGS) for the investigated quarry districts. The *dotted field* shows the MGS of the Troian samples (PBA1–8 and PBA11–34), except the samples PBA9–10 of Athena Temple Porticoes (*dashed line*)

except Altınoluk (1.2–3.0 mm), Yatağan (1.1–5.3 mm), Afyon (1.0–2.6 mm) and Uşak (1.0–5.3 mm; Fig. 3).

4.3.2
Troian Marbles

The samples from Troian monuments are characterised by an MGS of 2.0–3.2 mm (Fig. 3, dotted field), so the possible provenance areas are Marmara, Orhangazi, Ayazma, Altınoluk, Yatağan, Milas, Babadağ, Afyon, Uşak from Asia Minor and Paros and Naxos from Greece, except for the samples of the Athena Temple Porticoes (PBA9–10), which contains grains less than 1.2 mm (Fig. 3, dashed line). This value is common for marbles from Pentelikon (Lepsius 1890; Moens et al. 1987).

4.4
Cathodoluminescence

4.4.1
Anatolian Marbles

The different colours of luminescence depend on impurities hosted in the crystal or on lattice defects. In carbonates the principal activator is manganese (generating orange luminescence). Spectral analysis of luminescence in calcitic white marbles indicates that less than 5 µg/g manganese still produces weak, but visible, luminescence (Barbin et al. 1991). The main quencher of luminescence is iron. White marble samples can be subdivided into three major families based upon their dominant colour. (1) Calcitic marbles have a dominant orange colour (Afyon, Babadağ;, Milas, Kemalpaşa and Serhat), or on the contrary, (2) a blue luminescence (like Marmara, Orhangazi and Ayazma) and (3) marbles with dolomite content (Altınoluk) show a dominant red luminescence. Furthermore, unique features of cathodomicrofacies are distinct for each area.

4.4.2
Troian Marbles

The Troian samples also have different cathodoluminescence-features: some of them have a light orange colour, such as the fragments from the Athena Temple Portico and Bouleuterion. Others have a blue luminescence, like elements from the Bath, but two of them, samples from the Nymphaeum base moulding of the Bath, show some red, because of the presence of dolomite.

4.5 Chemical Analysis

The concentration of major and minor elements was determined by XRF and ICP-MS analysis in marble samples collected in the recent quarries of West-Anatolia, which until now had not been investigated in the case of Troian marbles. So we will discuss only the chemical element concentration of Anatolian marble samples. Ranges in concentration are large for several elements and separated ranges are observed in some cases: while marble from Muğla has a significantly higher Fe_2O_3 concentration (0.2–0.6 wt%, measured by XRF), the samples from Afyon have a typically low MgO concentration (0.04–0.1 wt%). Marbles from Altınoluk and Muğla have an extremely high Cr content (Altınoluk: up to 258 μg/g and Muğla: up to 110 μg/g), but in Bergaz and Babadağ there are marbles with a high Zn content (Bergaz: up to 60 μg/g and Babadağ up to 30 μg/g) (Zöldföldi and Satır 2001a,b). The limestones from which the various marbles were formed were deposited at different geological times and in different environments, therefore, their trace element pattern may reflect this source environment. The rare earth element (REE) distribution undergoes a minor change during metamorphism. Usually, the REE are normalised by chondrite in order to correct for the Oddo-Harkins effect. We have applied REE normalisation to post-archaic Australian shale (PAAS)-clays, as it is much more enriched in REE and reflects the sedimentary environment better (Fig. 4). There is a clear differentiation from marbles of Yatağan and Afyon. Some overlapping also occurs between Altınoluk and Muğla, but there are differences in sequences of clusters, since marbles from Serhat and Babadağ are indistinguishable.

4.6 Isotope Geochemistry

4.6.1 *Anatolian Marbles*

$^{18}O/^{16}O$ and $^{13}C/^{12}C$ analyses of marbles play an increasingly important role in solving archaeological problems of relationship and provenance. Differences in age, sedimentary facies, metamorphic temperature and fluid-rock history result in different isotopic ratios of the marbles (Faure 1986; Herz 1988). The controlling processes involved are (1) origin of the calcareous sediment, either as a chemical precipitate or a complex of organic shell fragments or a mixture of both, (2) composition of cements formed during diagenesis, (3) the isotopic composition of water associated with carbonate

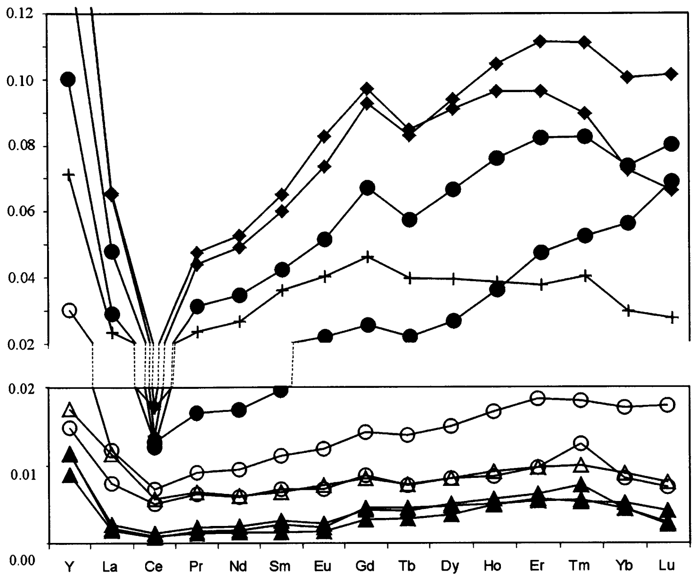

Fig. 4. Trace element patterns of Anatolian marbles. *Open circles* Serhat, *full circles* Altınoluk, *full triangles* Afyon, *open triangles* Babadağ, *full diamonds* Yatağan, *crosses* Muğla

minerals during their formation and thereafter, (4) temperature of metamorphism which converted the limestone into marble and the extent of reactions and fractionation with adjacent rocks and pore waters, and (5) later weathering history. In this way, marble from a given region formed at a particular time with its own geological history may develop unique isotopic characteristics. Useful geochemical discrimination may be possible if the protolith was deposited and underwent diagenesis in a uniform environment, and isotopic equilibrium was attained and maintained during formation and subsequent metamorphism, and if the marble unit is homogenous – preferably almost pure carbonate – and thick.

The isotopic data of Anatolian marbles are summarised in a $\delta^{13}C$–$\delta^{18}O$ plot (Fig. 5a). Marbles from Bergaz ($\delta^{18}O$ = –11.2 to –10.4‰ and $\delta^{13}C$ = 2.3 to 4.0‰), Karabiga ($\delta^{18}O$ = –10.4 to –5.1‰ and $\delta^{13}C$ = 2.7 to 4.2‰) and Mustafa Kemalpaşa ($\delta^{18}O$ = –2.5 to –1.0‰ and $\delta^{13}C$ = 3.6 to 5.3‰) can be clearly separated, while Serhat ($\delta^{18}O$=–10.7 to –1.1‰ and $\delta^{13}C$=1.5 to 3.‰), Ayazma ($\delta^{18}O$ = –3.4 to –0.9‰ and $\delta^{13}C$ = 2.0 to 2.6‰) and Altınoluk ($\delta^{18}O$ = –10.8 to 0.2‰ and $\delta^{13}C$ = 1.1 to 3.2‰), like Marmara ($\delta^{18}O$ = –3.5 to –0.8‰) and Orhangazi ($\delta^{18}O$ = –1.5 to –5.6‰ and $\delta^{13}C$ = 2.5 to 4.3‰) overlap in the plot. An interesting feature of marbles from Serhat, Altınoluk is their elongated distribution due to the restricted $^{13}C/^{12}C$ ratios and the

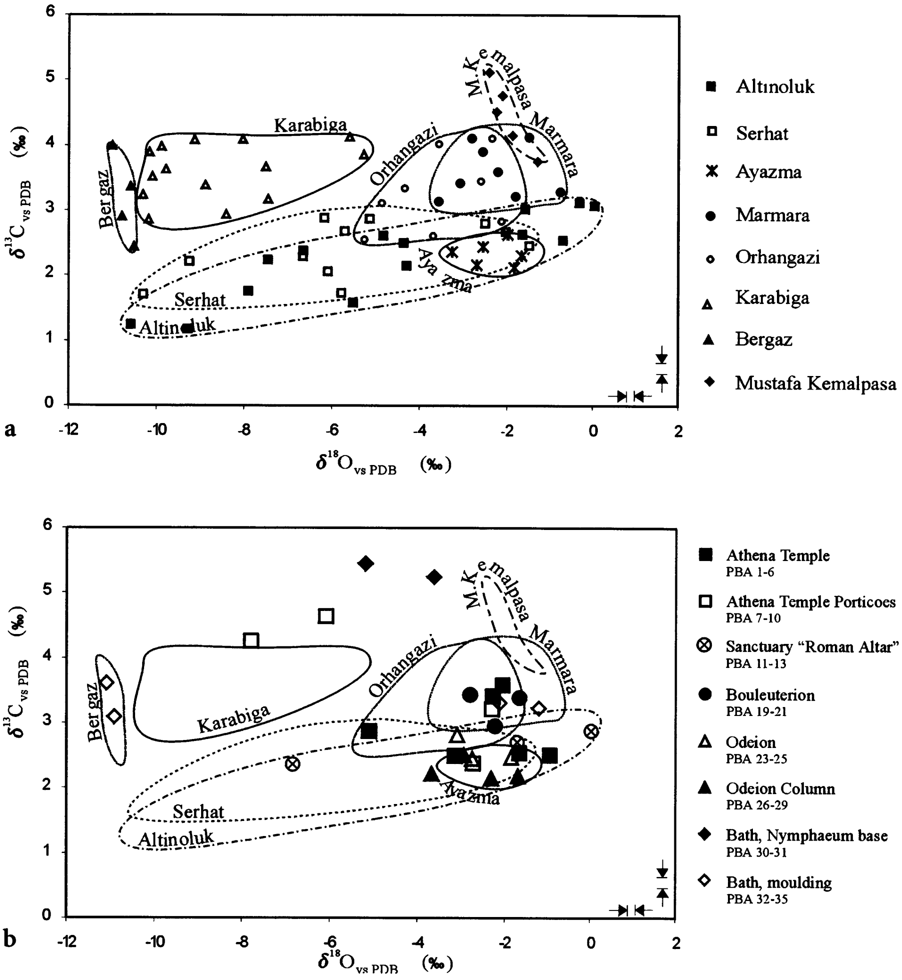

Fig. 5. a Carbon versus oxygen isotopic compositions [$\delta^{13}C$ and $\delta^{18}O$ in parts per thousand relative to Peedee formation belemnite (PDB)] of the marble quarries in West Anatolia. **b** Data set of carbon-oxygen isotopic compositions of the Troian marble samples

large spread in $^{18}O/^{16}O$ ratios. This comes from the lack of isotopic equilibrium with aqueous fluids or weathering. Exchange with metamorphic pore fluids, and equilibration with other country rock can also introduce high variations in $\delta^{18}O$ values (0.5–1.8‰), but only moderate to low variations in $\delta^{13}C$ values (0.2‰, Herz 1988).

4.6.2
Troian Marbles

Carbon and oxygen isotope ratios of marbles from Troian architectural fragments were also determined. Most of the samples fall into well-defined groups. The material of the Athena Temple shows an isotopic composition ($\delta^{18}O = -5.09$ to -0.94‰ and $\delta^{13}C = 2.50$ to 3.59‰) similar to those from Marmara Island and Orhangazi, but the quarries Serhat and Altınoluk cannot be excluded. The samples from the Athena Temple Porticoes can be grouped into two clusters on the basis of their isotopic composition. One of these two groups ($\delta^{18}O = -2.29$ to -2.73‰ and $\delta^{13}C = 2.38$ to 3.22‰) is similar to those of the Athena Temple (Fig. 5b). The other group has higher C-isotope ratios ($\delta^{13}C = 4.26$ to 4.64‰), and lower O-isotope ratios ($\delta^{18}O = -6.08$ to -7.80‰). After comparing these values with data from several publications (Craig and Craig 1972; Herz 1988, 1998; Lapuente et al. 2000), the conclusion may be that these fragments originated from Pentelikon in Greece ($\delta^{13}C = 2.2$ to 4.7‰ and $\delta^{18}O = -3.4$ to -9.7‰). The architectural fragments of the Roman Altar ($\delta^{18}O = 0.21$ to -6.70% and $\delta^{13}C = 2.38$ to 2.84‰) and Odeion ($\delta^{18}O = -1.85$ to -3.08% and $\delta^{13}C = 2.48$ to 2.82‰) have an isotopic composition similar to Marmara, Altınoluk and maybe Serhat. The material of the Bouleuterion ($\delta^{18}O = -1.65$ to -2.79‰ and $\delta^{13}C = 2.95$ to 3.43‰) appears to be related to the quarries of Marmara or Orhangazi. The samples from the Bath have three major groups with respect to their isotopic compositions. The provenance of the first group ($\delta^{18}O = -1.20$ to -2.12‰ and $\delta^{13}C = 3.23$ to 3.31‰) might be Marmara, Orhangazi or Altınoluk. The second ($\delta^{18}O = -10.92$ to -11.20‰ and $\delta^{13}C = 3.09$ to 3.60‰) may stem from Bergaz, and the third ($\delta^{18}O = -3.62$ to -5.19‰), with high C-isotope ratios ($\delta^{13}C = 5.25$–5.45‰) had to be derived from Paros ($\delta^{13}C = 3.4$–5.8‰ and $\delta^{18}O = -4.3$ to -1.5‰); compare with Craig and Craig (1972), Herz (1988, 1998), Lapuente et al. (2000).

4.7
Strontium Isotopic Composition

4.7.1
Anatolian Marbles

The O- and C-isotope values of the investigated source areas overlap. To further constrain the origin of the marbles the $^{87}Sr/^{86}Sr$ isotope composition of Anatolian and Troian samples were measured.

In a given chemical system the isotopic ratio of $^{87}Sr/^{86}Sr$ is determined by four parameters: (1) the isotopic abundance at the time of calcite formation, (2) the Rb/Sr ratio of the system, (3) the decay constant of ^{87}Rb to

^{87}Sr, and (4) the time elapsed since the formation of calcite. Local differences in the Rb/Sr will, with time, result in local differences in the abundance of ^{87}Sr. Mixing of material during recrystallisation will tend to homogenise these local variations (Gast 1960; White 1997).

One interesting and useful feature of this system arises from the long residence time of Sr in sea-water and its ready substitution into calcium carbonate. Because of its long residence time, the $^{87}Sr/^{86}Sr$ ratio of seawater is homogeneous at any given time. The $^{87}Sr/^{86}Sr$ ratio of seawater is controlled by the relative input of Sr from the continents and ridge-crest hydrothermal activity. The ratio of these will vary with mean spreading rate, erosion rates, and plate geometry. The variation of $^{87}Sr/^{86}Sr$ in seawater through the Phanerozoic was determined from the analysis of carbonate and phosphate fossils (Peterman et al. 1970; Palmer and Elderfield 1985, Hess et al. 1986), so that ages can be determined simply by determining the $^{87}Sr/^{86}Sr$ ratio of marine carbonate precipitated from seawater and comparing these values to the published Sr-evolution curves.

The $^{87}Sr/^{86}Sr$ ratios of Anatolian and Troian marbles are illustrated versus $\delta^{13}C$ in Fig. 6. Unfortunately, we could not analyse more than three samples for each recent marble quarry. Therefore, we can only present the

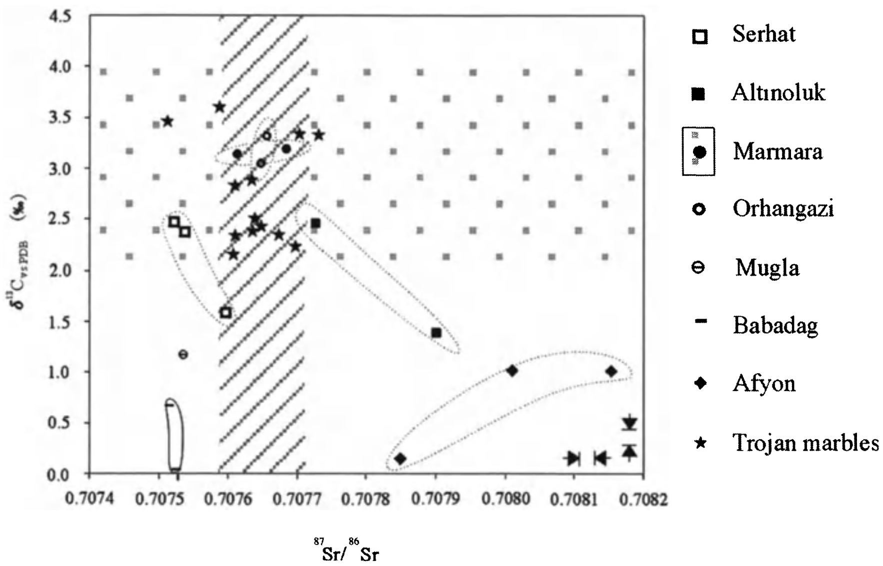

Fig. 6. $^{87}Sr/^{86}Sr$ isotopic composition versus $\delta^{13}C$ values of samples from the marble quarries in West Anatolia and Troian marble samples. The *hatched field* shows the $^{87}Sr/^{86}Sr$ ratios characteristic for the areas from Marmara and Orhangazi. The *dotted field* represents the already published $\delta^{13}C$ values of the marbles from Marmara. (Craig and Craig 1972; Herz 1988, 1998; Moens et al. 1992; Lapuente et al. 2000)

first results of $^{87}Sr/^{86}Sr$ ratios in Anatolia, but in the future we will aspire to obtain more analyses. The already existing strontium isotopic data of quarries like Marmara and Orhangazi (0.70762–0.70768 and 0.70765–0.70766, respectively), Serhat (0.70752–0.70759), Altınoluk (0.70773– 0.70790), Babadağ (0.70752–0.70753), Afyon (0.70785–0.70815) and Muğla (0.70754) help to distinguish these groups, but we cannot distinguish the samples from Marmara and Orhangazi. The rocks from Altınoluk and Serhat have undergone contact metamorphose, while those of Marmara and Orhangazi were affected by regional metamorphose.

4.7.2 *Troian Marbles*

$^{87}Sr/^{86}Sr$ ratios of building materials from Troia vary from 0.70680 to 0.70771. Some of them unambiguously referred to the deposits at Marmara and/or Orhangazi, such as the samples from Athena Temple (PBA1–2) and the moulding of the Bath (PBA 32). However, we have a homogeneous group, including most of the Troian samples, which have similar $^{87}Sr/^{86}Sr$ ratios (0.70760–0.70772), as samples from the quarries of Marmara and Orhangazi, but lower $\delta^{13}C$ values than the samples from these recent quarries. On the other hand, the archaeological samples have higher $^{87}Sr/^{86}Sr$ ratios than the marbles from Serhat, but lower $^{87}Sr/^{86}Sr$ ratios than the quarries from Altınoluk. It is certain though that the Troian marbles cannot be derived from the deposits of Afyon, Muğla or Babadağ.

5 Conclusions

As the data from various analyses presented above show, the grouping of samples from Anatolian marbles (taken from recent quarries) and Troian marbles (samples of archaeological objects) is possible if a combined technique based on macroscopic, microscopic, chemical analysis data, and isotope geochemistry is used.

A summary of our results is shown in Fig. 7. In *phase I* the marble samples from various quarries and Troian monuments were grouped on the strength of their texture. In *phase II* the cathodoluminescence properties, like colour and homogeneity were considered. With respect to MGS, in *phase III* further grouping of the marble samples was possible. The next phase, *phase IV*, represents the discrimination based on the stable isotope geochemistry. Finally, for the definite division of marble samples that were still ambiguous, Sr isotope ratios were used in *phase V*. In Fig. 7 one can

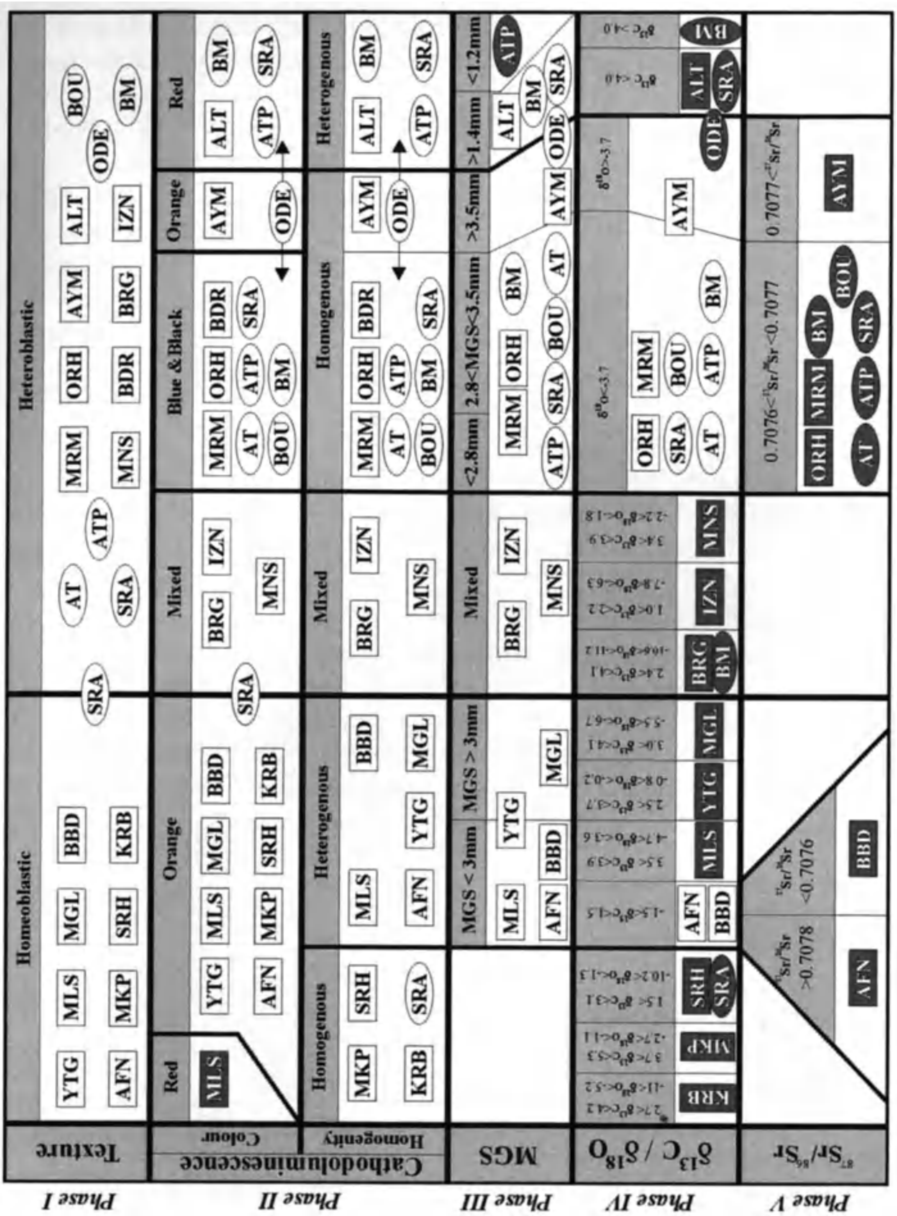

Fig. 7. Decision tree for grouping of the Anatolian and Troian marbles. Anatolian marbles in *rectangles*: *YTG* Yatağan; *MLS* Milas; *MGL* Muğla; *BBD* Babadağ; *AFN* Afyon; *MKP* Mustafa Kemalpaşa; *SRH* Serhat; *KRB* Karabiga; *MRM* Marmara; *ORH* Orhangazi; *AYM* Ayazma; *ALT* Altınoluk; *MNS* Manyas; *BDR* Bandirma; *BRG* Bergaz; *IZN* Iznik. Troian marbles in *ovals*: *AT* Athena Temple; *ATP* Athena Temple Porticoes; *SRA* "Sanctuary" of Roman Altar; *BOU* Bouleuterion; *ODE* Odeion; *BM* Bath moulding

follow the similarity and discrepancy of the above mentioned properties of Troian archaeological samples (in the oval) and of the marble samples from Anatolian quarries (in the rectangle).

Based on microscopic investigation and stable isotopic geochemistry, the material used for construction of the Athena Temple (AT in Fig. 7) dated at 280 B.C. could have come from the Marmara and/or Orhangazi area. Some samples of the Temple (PBA1–2) can be clearly referred to Marmara and/or Orhangazi, based on their $^{87}Sr/^{86}Sr$ ratios, but the rest of them also fall into the $^{87}Sr/^{86}Sr$ ranges of Marmara and/or Orhangazi. More specific reference to provenance cannot be made presently, because the geological samples from these areas, Marmara and Orhangazi are indistinguishable. Future trace element analyses may help to constrain the provenance further. The investigation of the Athena Temple Porticoes (ATP in Fig. 7) dated at 230 B.C. shows that, in part, the same building material was used for the Athena Temple (new shipping from the same quarries or recycling). However, a new group of material, most certainly from Pentelikon, Greece, was also found. According to the stable isotopic geochemistry, the "Sanctuary" of the Roman Altar (SRA in Fig. 7), dated from the third century B.C., was built of marble from Serhat or Altınoluk, but Marmara and/or Orhangazi cannot be excluded. The building material of Bouleuterion (BOU in Fig. 7) dating from the second century B.C. derived from Marmara; this has been proved based on microscope, cathodoluminescence investigation, stable isotope geochemistry, and Sr isotope ratios. Concerning the next construction period (Troia IX) fragments of several architectural elements and columns of Odeion (ODE in Fig. 7) were investigated. Based on microscopic investigation and isotopic geochemical constrains, we conclude that the marble for this construction phase came from Marmara/Orhangazi, Serhat, Ayazma, or Altınoluk. A more exact provenance can be provided by studies of Sr isotopic ratios. The fragments of the Bath moulding (BM in Fig. 7) dating from the late second century B.C. can be sharply separated into three groups. One of them stems from Marmara and/or Orhangazi, the second from Bergaz, while the third one shows affinity to Paros (Greece) on the basis of stable isotope geochemistry and cathodoluminescence features (Barbin et al. 1992). This complex provenance pattern demonstrates that this architectural feature was constructed from material from various shipments (including marble from Greece) or, more probably, partly from recycled material already present at Troia.

In summary, we conclude that the majority of marbles used for construction of the Troian architectural elements is derived from the Marmara and/or Orhangazi areas, with minor percentages of other north-west Anatolian and Greek shipments at various historical periods.

Acknowledgements. This work was supported by the Graduate College 442 of the Deutsche Forschungsgemeinschaft, called "*Anatolien und seine Nachbarn*" at the University of Tübingen. Troian samples are the courtesy of M. Korfmann, B. Rose and "Troia Projekt". Some Anatolian marble samples were provided by E. Yüzer (Technical University of Istanbul). We thank G. Bartholomä, M. Schumann, B. Steinhilber, G. Stoscheck and E. Reiter for their help in sample preparation. This paper benefited greatly from discussions with I. Dunkl, I. Györösi, W. Siebel, B. Székely, H. Taubald and T. Vennemann. We also thank A. Mindszenty and Z. Lantos for their help in cathodoluminescence investigation and M. Tóth for help in the XRD analysis.

CHAPTER 13

Provenance Studies of Pottery and Granite Columns in Troia

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Abstract

The Bronze Age pottery of Troia has been characterised with geochemical and mineralogical methods in order to constrain the provenance of imported pottery wares. Determination of the chemical composition of pottery and local sediments enabled the establishment of several groups for the local Troian pottery production. Chemical and isotopic compositions indicate that Mycenaean pottery had been imported.

The geological, geochemical, isotopic and mineralogical characteristics of the Kestanbol Intrusion near Ezine is documented in the second part. The use of this igneous rock as construction material all around the Mediterranean Sea in ancient times underlines its importance for archaeological investigations.

1 Introduction

The questions "where did it come from, and how did it get there?" are fundamental in archaeology. The meaning of the exchange of goods is important for cultural interactions. The development of civilisations is without doubt not static, but is to be defined and critically questioned in each single case. With the help of mineralogical, petrological, chemical and isotopic methods, archaeological sites can be examined systematically and conclusions can be drawn concerning their origin and distribution. Provenance determination of pottery, used in the prehistoric period, and of granite, used in the architecture, provides the archaeologist with fundamental information regarding trade and economic development. Moreover, it is important for historical research and for conservation purposes of the artworks.

Two previous studies on Troian Bronze Age pottery and on Kestanbol quartz-monzonite, also known as "Marmor Troadense" at the University of Tübingen, have already been published, hence only a brief overview will be given here. Pottery, one of the most interesting goods, is subject to exchange with neighbouring cultures and can provide important information on trade routes and transport pathways.

During Greek and Roman times, "Marmor Troadense" or "granito violetto" was the trade name for a popular igneous rock derived from a small site in north-western Anatolia. Columns, fabricated in quarries 20 km west of the town Ezine and 40 km south of ancient Troia, were shipped to human settlements located all over the Mediterranean Sea. Remnants can be encountered in local sites (Troia, Ephesus), but also in remote areas (southern France, Tunisia, Israel; Lazzarini 1988; Williams-Thorpe and Henty 2000). The important questions are: why was this small intrusion selected for the construction of cultural monuments all over the Mediterranean Sea? Why was an intrusion chosen whose shipping harbour was located more than 10 km from the quarries?

2
Research Area

The first step in the attempt to determine the provenance of Troian pottery was the identification and geochemical characterisation of the raw materials used by local pottery workshops in the Troad. There is no evidence and, indeed, no convincing reason to assume that such materials were traded over long distances during the past. A comparison of mineralogical and geochemical characteristics of the Troian pottery with those of local sources of clay, therefore, allows for a distinction between locally produced and imported pottery. As sources of the pottery, the rock types of the Biga Peninsula are very important.

The geology of the Biga Peninsula (Fig. 1) is described in several publications, such as Bingöl et al. (1975), Şengör and Yılmaz (1981), Okay et al. (1991, 1996), and Okay and Satır (2000a, b). The oldest rocks are metamorphic Paleozoic continental basement rocks and granitoids that have been isotopically dated as Devonian and mid-Carboniferous (Okay et al 1996; Okay and Satır 2000a,b). The development of sediments, which can be taken into consideration for pottery production, started during the Tertiary on the Biga Peninsula. The oldest Tertiary deposits are neritic limestones, formed during the Middle Eocene. They are overlain by Miocene turbiditic series, starting with andesites and andesitic tuffs. These rocks were tectonically uplifted and eroded during the Oligocene. During the Late Oligocene, the calc-alkaline magmatism started, which was continuous until the Middle Miocene (Ercan et al. 1995, 1997, 1998). These Miocene volcanics yield dates of 21–16 Ma by the K/Ar whole rock method (Borsi et al. 1972; Ercan et al. 1986) and show a trend from calc-alkaline dacites towards alkaline shoshonites (Birkle 1992). Isolated abundances of alkali olivine basalt on the Biga Peninsula result from Late Miocene volcanic activity at about 9.7 Ma (Borsi et al. 1972; Ercan et al. 1995). The Kestanbol in-

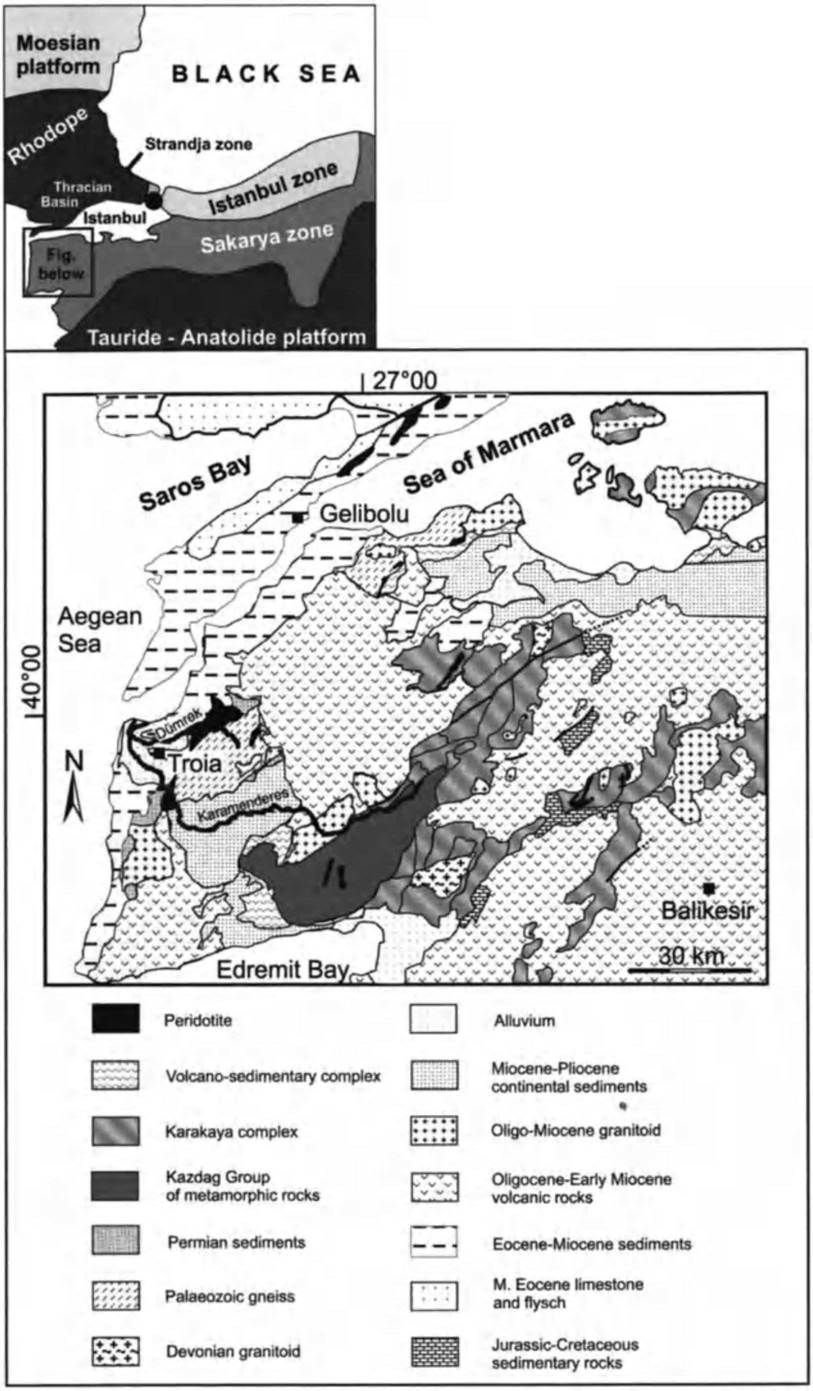

Fig. 1. Simple geological map of the Biga Peninsula. (After Okay et al. 1991, 1996)

trusion near Ezine and the Evciler intrusion, near Bayramic, represent the largest granitoid intrusion on the Biga Peninsula in north-western Anatolia. Rb-Sr biotite cooling ages from Kestanbol and Evciler intrusions are 21 and 25 Ma, respectively, and imply a minimum age of the intrusion and not the time of crystallisation. The Upper Miocene is characterised by deposits of fluvial and shallow marine sediments. During the Pliocene, partly fluvial, but also limnic, lacustrine deposits were formed. During the Quaternary, alkali-basaltic volcanism occurred, which had a smaller area extent than the Tertiary volcanism, and is characterised by alkali-olivine basalts. The lowered sea level during the glacial stages of the Pleistocene caused increasing erosion of the easily erodible Neogene sediments. Valleys became deeper and wider. However, during the interglacial stages, marine-estuarine sedimentation advanced into the mouths of the deepened river valleys (Kayan 1991). It is apparent from this short overview that the geology of the Biga Peninsula is very complex.

Troia is located at the junction of two rivers, Dümrek (Simoeis) and Karamenderes (Scamander). The sediments of these provide two possible clay sources for the ancient pottery production.

3
Analytical Methods

Thin sections were prepared for petrographic analysis. The coarse mineral grains, rock, and shell fragments were identified using a polarising microscope. For the determination of minor and trace element concentrations XRF (X-ray fluorescence) and INAA (Instrumental Neutron Activation Analysis) were used. The chemical composition of pottery shards and sediment samples from the immediate surroundings of Troia and other potential sources of raw material on the Biga Peninsula was determined using XRF analysis (Knacke-Loy 1994). The concentrations of 25 minor and trace elements on 90 selected samples comprising pottery shards and sediments were determined using instrumental neutron activation analysis (INAA). The samples were grouped according to their trace element composition using methods of numerical taxonomy (Sneath and Sokal 1973), namely the average-linkage cluster analysis (ALCA). The isotopic analyses were determined using a thermal ionisation mass spectrometer (Finnegan MAT 262). The isotopic compositions of the elements neodymium, strontium and lead were determined. Nd and Sm concentrations were measured with the isotope dilution method (Knacke-Loy et al. 1995b). A detailed description of the analytical procedures is outlined in Hegner et al. (1995).

4
Results and Discussion

4.1
Provenance Studies of Troian Bronze Age Pottery

Seven types of different temper associations can be distinguished. The comparison of characteristic inclusions of coarse-grained rock fragments in pottery shards with the rock types occurring on the Biga Peninsula indicates that all rock fragments identified do occur on the Biga Peninsula. The typical temper association of Troian pottery is: quartz, plagioclase, orthoclase, biotite, muscovite, green hornblende, minor or no calcite, shell fragments, gneiss, mica schist, altered intermediate volcanics, and grog.

Another group of shards (black-brown polished ware, Troia I) contains almost exclusively fragments of a plutonic rock. These fragments are similar in composition to the quartz-monzonite intrusion 25 km south of Troia (Birkle and Satır 1994, 1995). A third group of shards (early Aegean scored ware, Troia I) shows a striking macroscopically observable feature: they contain large dark grains of rock fragments. This component is made up of metamorphosed ultramafic rock fragments with chromite mineralisation. They are responsible for the very high contents of Mg, Cr, and Ni detected in these shards. Also included in the pottery of this type are fragments of fine-grained carbonate rocks and chlorite schists. It is probable that these inclusions have been collected by pre-historic potters in the river beds draining the weathering products of metamorphosed ultramafic rocks, which are common on the Biga Peninsula (Okay et al. 1991; Öngen 1992; Okay and Satır 2000a). Petrographic analysis and determination of major element concentrations help to identify samples. Additional trace element characterisation is generally only necessary for fine-grained wares. The trace elements (Ti, Mn, P, Ba, Cr, Ni, Zn, Zr, Rb, Sr, V, Nb) allow an initial chemical classification of the pottery samples. While Na, K, Ba always show large variations, other elements like Mg, Cr, and Ni prove to be very distinctive. The Cr and MgO contents reflect the amount of mafic components in the sediments used for pottery production. The following five groups can be distinguished: (1) high-Al clays, from the area of Çan; (2) sandy sediments, river Scamander; (3) clay, river Scamander; (4) clay, village Akköy; (5) clay, river Simoeis. The grouping of the samples according to their trace element composition using multivariate statistical procedures is described in detail by Harbottle (1976) and Mommsen et al. (1988). The trace element pattern of the pottery from Troia is very similar. Therefore, the cluster analysis, on an otherwise reasonable level of chemical similarity, puts all these samples into the same group. As will be shown in the next section, the same pottery groups can also be clearly distinguished by their isotopic composition.

The idea of using isotope analysis for this purpose is based on three assumptions: (1) since the isotopic composition was successfully used to determine the provenance of basin sediments, it was reasonable to assume that this method could also be suitable for pottery; (2) the isotopic composition does not change or only very little, during refining and burning of the clay; (3) the isotopic ratios are not affected by burial in the soil for several thousand years. Figure 2, from Knacke-Loy (1994), shows an example of this study for using isotope analysis. The field "Troad" includes sediment samples from the Karamenderes plain, the Dümrek plain and Neogene continental sediments around the village of Akköy, together with pottery of Troia II and Troia VI as well as modern pottery from Akköy. Nevertheless, their isotopic composition is distinct with respect to the other regions investigated. The field "Argolid" comprises shards from Mycenae and Tiryns together with Mycenaean shards found in Troia.

The field Aharköy encloses two shards found at Aharköy. Although the chemical composition of these samples and those from Troia is nearly identical, the isotopic ratio of $^{143}Nd/^{144}Nd$ discriminates the two groups.

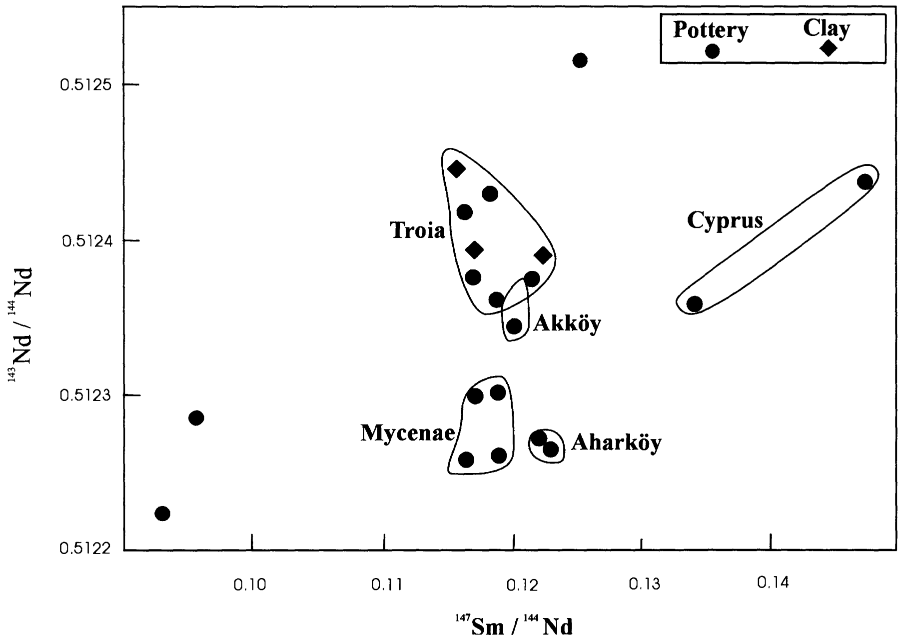

Fig. 2. $^{143}Nd/^{144}Nd$ versus $^{147}Sm/^{144}Nd$ ratios of Troian bronze age pottery and sediments from the eastern Mediterranean area. (After Knacke-Loy 1994)

The overlap with the field of Argolid is of minor importance, because the groups differ in their chemical composition and through geological circumstances as well as their $^{206}Pb/^{204}Pb$ ratio (Knacke-Loy et al. 1995b). The other three data points represent imports found in layers of Troia I of as yet unknown origin.

Four groups of local Troian pottery could be differentiated on the basis of their chemical composition. One of the reasons for the existence of groups of different chemical composition among the local pottery is that the prehistoric potters obviously used two chemically and mineralogically distinct clay deposits for pottery production. One type is represented by the sediments deposited by the river Dümrek (Simoeis), the other consists of sediments deposited in the flood-plain of the river Karamenderes (Scamander). In all cases investigated, the isotopic analysis of neodymium, strontium and lead provided a fingerprint that permitted the unequivocal assignment of the samples, pottery shards or clay, to their place of origin. Despite their different chemical compositions, all original Troian pottery shards analysed have the same neodymium isotope composition ($^{143}Nd/^{144}Nd$ of 0.5111236–0.51242). The analysed clay samples from the surroundings of Troia have a similar isotopic composition ($^{143}Nd/^{144}Nd$ of 0.51226–0.51230). In some cases where trace element analysis did not lead to an unequivocal provenance determination, (Troia, Mycenae, Tiryns, Cyprus) the place of production could be identified by applying the isotopic "fingerprint". A painted fragment of a vessel, which so far was regarded to be an import from Greece, thus could be identified as a Troian imitation of Mycenaean pottery. This proves that this high quality pottery ware had been produced in the Troad also. But Mycenaean imports from Argolid could also be identified among the shards of Mycenaean ware in Troia by means of the analysis of chemical and isotopic compositions. One of the shards found in Troia originates with high probability in Central Cyprus, as its trace element composition suggests.

4.2
Construction Material from the Kestanbol Intrusion, "Marmor Troadense" at Archaeological Sites

Geochemical and isotopic data have been obtained for the Kestanbol intrusion. It consists of a homogeneous quartz-monzonite body with a surface extension of 100 km^2. The quartz-monzonite consists of phenocrysts of reddish/violet orthoclase interbedded in a coarse-grained matrix with white plagioclase. Mineral phases include hornblende, biotite, quartz, magnetite, sphene, apatite, and zircon. Big megacrysts of orthoclase crystals up to 1.5 cm in size form the largest components of the plutonic rock.

The reddish/violet colour of the orthoclases gives the rock its optical qualities (Birkle 1992; Birkle and Satır 1994, 1995).

A biotite cooling age for Kestanbol intrusion was determined by the Rb-Sr method. The corresponding initial $^{87}Sr/^{86}Sr$-value is 0.7088. The SiO_2 content ranges between 62 and 65%, indicating an intermediate to acid composition for the quartz-monzonite. The total alkaline content (K_2O+Na_2O) varies between 7.7 and 8.5%. The Ni (13–28 µg/g) and Cr (17–31 µg/g) contents are very low, also the Zr (206–249 µg/g) content is relatively low. High Ba content can be explained by the incorporation of Ba in abundant K-bearing feldspars. The geochemical values for different localities of the intrusion are very similar, indicating a very homogeneous body with little differentiation of the magma during crystallisation (Birkle 1992).

The $\delta^{18}O$-values of +7.4–8.2‰ for the Kestanbol intrusion are normal for I-type granites. High $^{87}Rb/^{86}Sr$-ratios for separated biotite minerals allow the calculation of an isochron age 21±2 Ma for the Kestanbol Intrusion. This date represents a biotite cooling age, thus the minimum age of the intrusion and not the time of crystallisation. We assume a shallow emplacement of the intrusion with a short crystallisation period of less than 1 or 2 Ma. Therefore, the cooling age and the crystallisation age should be similar. The initial value for $^{87}Sr/^{86}Sr$ is 0.7088 indicating involvement of crystal components (Birkle and Satır 1994, 1995).

Various small ancient mines along the contact of the intrusion with Permian marble indicate its significance as an ore supplier. The skarn deposit provided ores such as lead, copper and zinc, which are abundant in the minerals sphalerite, galenite, bornite, chalcopyrite, chrysocoll and malachite. Perhaps gold and silver were also mined.

The quartz-monzonite is not only optically appealing, but also has very good geotechnical properties favouring its use as a decorative construction material. This potential was also recognised in Greek and Roman times. Ancient quarries are located near the villages Koçali and Uluköy, in the central and south-western part of the intrusion.

Even today, traces of working processes can be observed on the quarry walls, and abandoned columns of enormous dimensions with a length of up to 12 m can also be seen. The reasons for the abandonment of nearly finished columns are unknown. The nearest site where the finished columns were installed as a part of a building is the ancient site of Troia, about 50 km north of the quarries. Another place in Turkey where columns of quartz-monzonite from the Kestanbol intrusion can be observed is Ephesus. The columns were transported, mainly by ship, to other cultural centres around the Mediterranean Sea (Lazzarini et al. 1980a,b; Lazzarini 1988). Quartz-monzonite is a typical, outstanding, but not a very common rock type within the group of igneous rocks. The macroscopic rock classification of the ancient columns could be enough to prove their origin from Kestanbol. Better proof would be chemical or petrographic analysis from column samples all over the Mediterranean area.

Acknowledgements. The authors wish to thank T. Vennemann for the critical review of this paper.

CHAPTER 14

On the Origin of Coarse Wares of Troia VII

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Abstract

Following the warlike destruction of the town, the VIIb phase in Troia is mainly characterized by a change of ceramics. The new vessels are hand-made and as such, clearly different from the well-established Troian wheel-manufactured ceramic traditions. These so-called Knobbed and "Barbarian" wares were considered by most researchers as an indication of the arrival of a new ethnic group at Troia. The origin of this ceramic tradition was sought in southeastern Europe where similar pottery is abundant. Nevertheless, due to the relatively large amount at Troia, it has always been assumed that this pottery was locally produced. This chapter combines two approaches: archaeological (functional analysis of vessels within their contexts) and geochemical (trace element and isotope analysis), in an attempt to identify the origin and function of the pottery in Troia. Preliminary results show that at least part of the pottery was indeed imported, although it is not yet possible to narrow down the region of origin. Future geochemical studies may well achieve this aim.

1 Introduction

One of the most intriguing puzzles concerning the end of the Bronze Age in northwestern Anatolia is connected with the presumed immigration of Thracian "barbarians" in the period following the destruction in Troia, traditionally connected with the Trojan War. This migration was mentioned by Herodotos: "By what the Macedonians say, these Phrygians were called Briges as long as they dwelt in Europe, where they were neighbors of the Macedonians; but when they changed their home to Asia they changed their name also and were called Phrygians." (Herodotos VII, 73; Loeb Classical Library edition, translated by A.D. Godley; cf. also commentary in Asheri 1990: 153–154); according to the ancient author, the phenomenon was associated with a culture change and assimilation of the migrants to the new conditions, reflected by changing their ethnic name. The picture of the migrating northerners regained sharp contours when the excavations in Troia revealed two new types of pottery, namely the Knobbed and "Barbarian" wares in the levels of the seventh settlement.

The early excavators of the citadel – Schliemann and Dörpfeld – were already aware of the presence of this pottery and provided a description of it (Schliemann 1881: 660–663; Schmidt 1902a: 300–303). The first proper archaeological definition of the ware was, however, provided by the Cincinnati team (Blegen et al. 1958: 158–159). Of the names given by Blegen – Knobbed and Coarse wares, respectively (Blegen et al. 1958: 158) – the first became widely accepted as referring to the German equivalent "*Buckelkeramik*" introduced by Heinrich Schliemann (Schliemann 1881: 660–663; see also Schmidt 1902a: 300–303). The name "Coarse ware" has been abandoned as being not precise enough and replaced by the denominative "Barbarian" ware, especially in Greece (cf. Catling and Catling 1981; Karageorghis 1986; Whitbread 1992). Eventually, it was proposed to replace it with "Handmade Burnished Ware" to avoid ideological connotations (French and Rutter 1977; Deger-Jalkotzy 1983; Pilides 1994: 9, n. 1). As the latter name is not precise enough (in the case of Cyprus, it seems that it has been used to describe both Coarse and Knobbed wares ; cf. Pilides 1994), we will use the terms "Knobbed" and "Barbarian" ceramic in this article.

It was also Blegen who made a first attempt to identify the origin of these wares and pointed out their immense archaeological importance based on three facts:

1. The appearance of "Barbarian" and, subsequently, Knobbed wares in Troia follow the destruction, most probably of a warlike character, which the town suffered at the end of the VIIa period (Blegen et al. 1958: 143).
2. The wares represent a complete class of hand-made pottery, which appeared suddenly in a town with a 1000-year-old tradition of the use of the potter's wheel. In fact, Blegen stressed the inferior quality of those vessels compared to the earlier assemblages in Troia (Blegen et al. 1958: 143).
3. The claimed inferiority in quality of the pottery corresponded, according to Blegen, with the inferior quality of the architecture and spatial organization of the Troian citadel in the period following the destruction. Within the city walls, still standing after the catastrophe, the inner space of the citadel had been organized in a completely different way: in place of free-standing single-unit buildings, multi-chambered houses appeared, crammed in irregular blocks, and wide streets were replaced with crooked lanes (Blegen et al. 1958: 141).

   Blegen commented on the appearance of the "Barbarian" and Knobbed wares: "... we are dealing not with commodities which found their way to Troia in course of ordinary trade, but rather with products that continued to be made by a migrating people after they had established themselves in their new home." (Blegen et al. 1958: 144). This strongly confirmed the opinion formulated already at the beginning of the century by Schmidt (1902a: 303).

2 Characteristics of the Pottery

2.1 Chronology

Blegen noted that "Barbarian"-type vessels first appeared in the levels immediately following the destruction of Troia VIIa, and continued through the entire VIIb period. The vessels decorated with knobs did not date earlier than the second phase of the VIIb settlement (Blegen et al. 1958: 142–144). There is, however, no overall destruction horizon dividing the VIIb settlement into two phases and very often the division into $VIIb_1$ and $VIIb_2$ has been based on pottery. For Blegen, the very appearance of the knobbed sherds in a deposit automatically classified it as $VIIb_2$ (Blegen et al. 1958: 142–144). However, some houses were destroyed by fire during and at the end of Troia $VIIb_1$ (Mountjoy 1999b: 321–324, 332–334).

To establish an numeric chronology the most effective way seems to be to link the Troian pottery sequence to the Aegean, where numeric dates are better established, though not free from discussion. The terminus *post quem* for the Knobbed and "Barbarian" wares can be defined by the finds of Mycenaean pottery at Troia. After many widely different dating schemes (Fig. 1), the Troia chronology of the final phase of the Late Bronze Age has recently been revised by Penelope Mountjoy (1997: esp. 292; 1999a: esp. Table 1, p. 298); the numeric dates she proposes are quite similar to the original dating of Blegen and the Cincinnati team [Blegen et al. 1958: 8–10 (for VIIa) and 142–8 (for VIIb)]. According to this system, the beginning of Troia $VIIb_1$ – and the appearance of the "Barbarian" ware – can be placed around the time of the destruction of the Mycenaean palaces ca. 1200 B.C., whereas the beginning of $VIIb_2$ and the appearance of the Knobbed ware can be – very approximately – dated to the beginning of LH III C middle.

The terminus *ante quem* is much more austere. In Troia Knobbed ware extends into the Dark Ages, for which no Mycenaean material is available for dating. Most recent excavations have shown that the Knobbed ware also occurs together with protogeometric pottery (Korfmann 2000: 30–32; cf. also unpublished report for the year 2000 by Marta Guzowska) which, according to Catling's typology, should be dated between 1025 and 950 B.C.

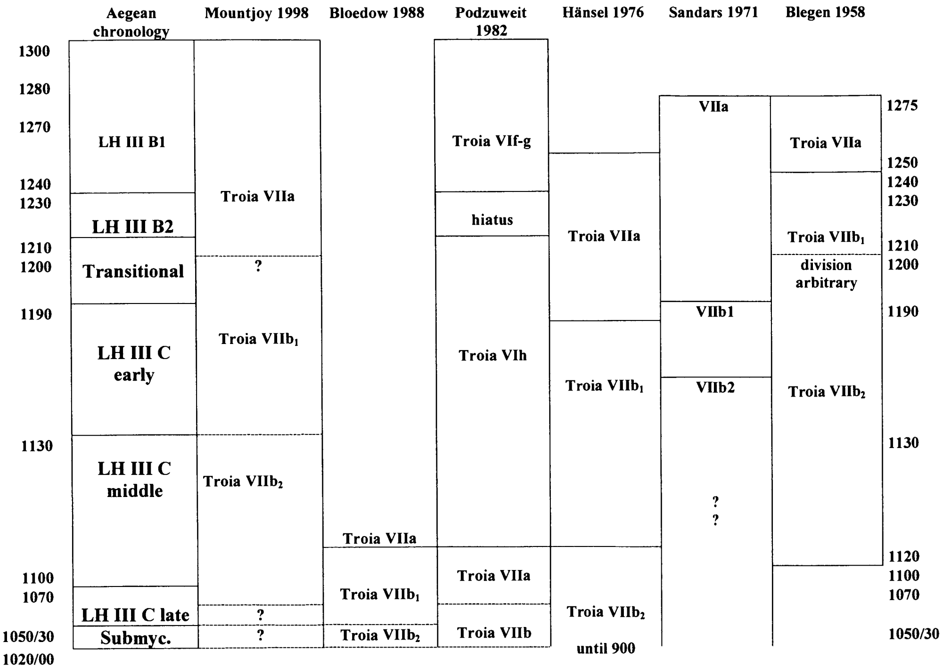

Fig. 1. Dating schemes for the numeric dating of the seventh settlement in Troia

(Catling 1998: 176; for the typology of the protogeometric pottery in Troia cf. Lenz et al. 1998).

2.2
Appearance in the Citadel and Relative Abundance

The wares appear in Troia in the whole area of the citadel and the lower town, yet the amounts are difficult to estimate, because sherds without the characteristic decoration can hardly be identified unambiguously. A comparison of numbers given by Blegen (Blegen et al. 1958: 182–302) with those resulting from the recent excavation (Koppenhöfer 1997: Table 1, p. 306) shows large discrepancies. While according to Blegen the amount of Knobbed ware varies between one quarter and one third of the ceramic inventory in a given deposit, recent excavations suggest a much smaller percentage. A detailed analysis of the recently excavated deposits is necessary to establish the exact abundance of the wares in question. Important, however, is the fact that Knobbed ware does indeed appear in Troia in relatively large, though not precisely defined amounts.

3
Methods Employed in Previous Research

After this brief introduction let us return to the key question: can the appearance of "Barbarian" and Knobbed ware in Troia be indicative of the appearance of new population groups? The methodological approach which led to this deduction in previous research has been the following:

1. Both Knobbed and "Barbarian" ware are technologically inferior to the contemporary Troian pottery;
2. Both appear in large quantities in the two subsequent phases following the VIIa destruction;
3. They could not be attractive commodities for the Troian market (too ugly), nor could they be acquired through trade (quantities too large). This prompted the conclusion that the wares were brought to Troia and later produced locally by the migrating hoards of "Barbarians" who settled peacefully (sic!) among the Troians, but preserved the pottery traditions of their homeland. In other words: the appearance of Knobbed ware is an indicator of the ethnic change in Troia in the $VIIb_2$ period.

This conclusion presented in the publication by Blegen has never been questioned. Instead, the following research concentrated on identification of the source of this migration. This was undertaken in the traditional way, using stylistic analogy as a main tool (cf. e.g., Dimitrov 1971, esp. pp. 75–78; Koppenhöfer 1997, esp. p. 337).

Parallels which have been searched both for the decoration and the shape of the vessels, indicated clearly a connection with the eastern Balkans. The origins of the "Barbarian" ware can be most convincingly traced to the Pontic area, comprising the Noua-Sabatinovka culture in the north transformed into the Coslogeni group in the south (Hänsel 1976: 73–76, pl. 8. 3–9, also p. 231; Koppenhöfer 1997: 334–337). The most exact parallels for the Knobbed ware could be found in the Babadag group, developed from the Coslogeni culture in southeast Romania (Morintz 1964; Hänsel 1976: 120–134, pl. 14–17, also pp. 230–236). Other sources of typological parallels can be found in the Chatalka culture, the Maritza-Tundsha area, the Black Sea coast of Bulgaria, e.g., the Pshenichevo Group (Dimitrov 1968, 1971; Chichikova 1968; Stefanovich 1974; Hänsel 1976: 191–227, pl. 21, 23, 24–7, 28, also pp. 232–233; Koppenhöfer 1997: 337–341), the area of Macedonia (represented mainly by the site of Kastanas, Hochstetter 1984: 373–375) and the island of Thasos (Κουκουλη-Χρυσανθακη 1970: 19; 1982, 135).

The "Barbarian" ware has also been identified in several locations on the Greek mainland (e.g., in Korakou, Rutter 1975; Aigeira, Deger-Jalkotzy

1977; Menelaion, Catling and Catling 1981 and in smaller quantities in Athens, Perati, Delphi, Mycenae, Lefkandi and Tiryns: cf. Rutter 1975 and Pilides 1994, 11–37, who collect and discuss the data and quote further references) as well as in Cyprus (Pilides 1994). At least part of this material has been identified as locally produced (Whitbread 1992; Pilides 1992, 179; 1994, 73–74). However, the appearance of this ware in the eastern Mediterranean forms a separate set of problems, beyond the scope of this paper.

This methodology, though perfect to serve the purposes of creating a typology and relative chronology, proves very unsatisfactory when we want to answer the following questions:

- is the presence of pots of Knobbed and "Barbarian" styles in Troia really an indicator of migration?
- if migration existed, what was its size?
- what kind of relations existed between the local population and the newcomers?

In fact, such questions can hardly ever be satisfactorily answered based on one type of archaeological evidence only, namely pottery. The full analysis of the problem requires a combination of research on the architecture, dietary customs, anthropological remains and the like (cf. the most recent models on the archaeological identification of migration, Burmeister 2000; Anthony 1990, 1997, 2000). However, even in the limited field of pottery studies, not enough attention has been placed on the relevance of the applied methodology.

The parallels employed in search of the origins of the "Barbarian" and Knobbed wares were drawn without differentiation of the type of context – materials from settlements, burials and others (like fountain or cave deposits) were treated alike as long as reliable dating could be provided without any attempt to reconstruct the role of the particular shapes within functional assemblages. It must be admitted though that research on functional analogies between Troian and Thracian wares has been practically impossible, due to the poor state of publication of most of the Thracian sites and lack of access to the complete pottery assemblages. The theory of migration of northern peoples in Troia was based on the external similarity of selected pots from the Troian citadel and from scattered sites in the eastern Balkans, and supported by Greek written sources (Herodotos).

4
Knobbed Ware in Functional Pottery Assemblages in the Troian Citadel

A step towards the identification of the cultural phenomenon behind the appearance of the "Barbarian" and Knobbed wares in Troia may be a functional analysis of those vessels within the pottery assemblages of the seventh phase of the citadel. This is possible due to the fact that Knobbed ware appears virtually in every house within the citadel, alongside locally produced wheel-made ceramics.

For the purpose of comparison two houses published by Blegen with good stratigraphy of the VIIb period have been selected: Houses 768 and 769 (Blegen et al. 1958: 203–212). In both houses the comparison of the shapes of Knobbed ware pots with existing contemporary vessels executed in traditional Troian styles, like Tan and Grey Minyan, gave surprising results: both types of pottery are functionally similar (Fig. 2; because of limited space only the case of House 768 is illustrated here). The two sets of pottery form two distinct yet complete functional assemblages. Shapes represented by Knobbed Ware, on the one hand, and the Grey Minyan and Tan, on the other, are not identical, probably because they were created to serve different types of food. Nevertheless, one can eat, drink, and serve food using wheel-made *or* hand-made vessels. Each of those sets can be completed with coarse household pots, executed either in "Barbarian" ware, or ordinary coarse ware techniques. The conclusion is self-evident: in the Troian citadel the function of Knobbed vessels must have been analogous to that of wheel-made pots of old Troian tradition.

This observation may change the understanding of the role the Knobbed ware played in Troia. The vessels executed in this technique have not been used, as most of the excavators have suggested, as coarse ware of inferior quality. They rather served as fine tableware. Consequently, the general opinion about the technical inferiority of the Knobbed ware, an opinion that derived from the traditional view of a linear development of pottery production from hand-constructed vessels to the use of the potter's wheel, has to be questioned. The situation in Troia VIIb seems to be exceptional. The sudden appearance of *hand-made* ware in a town where the *wheel-made* ceramic tradition is well established does not necessarily indicate a decline of the local technology of pottery, especially since wheel-made pottery continues to be produced. In fact, the production of a hand-made vessel with a carefully burnished surface, complicated shape and elaborate decoration, like knobs, incisions or stamp marks is much more laborious than the production of a standardized wheel-made pot without decoration. Neither does the lower firing temperature of the Knobbed ware prove inferior technology. It is rather a sign of a different organization of pottery production, possibly not limited to specialized workshops equipped with kilns, but performed in households with firing carried out in simple ovens (for the organization of the production of wheel-made and hand-made ceramic within one site (cf. e.g., Kyriatzi et al. 1997).

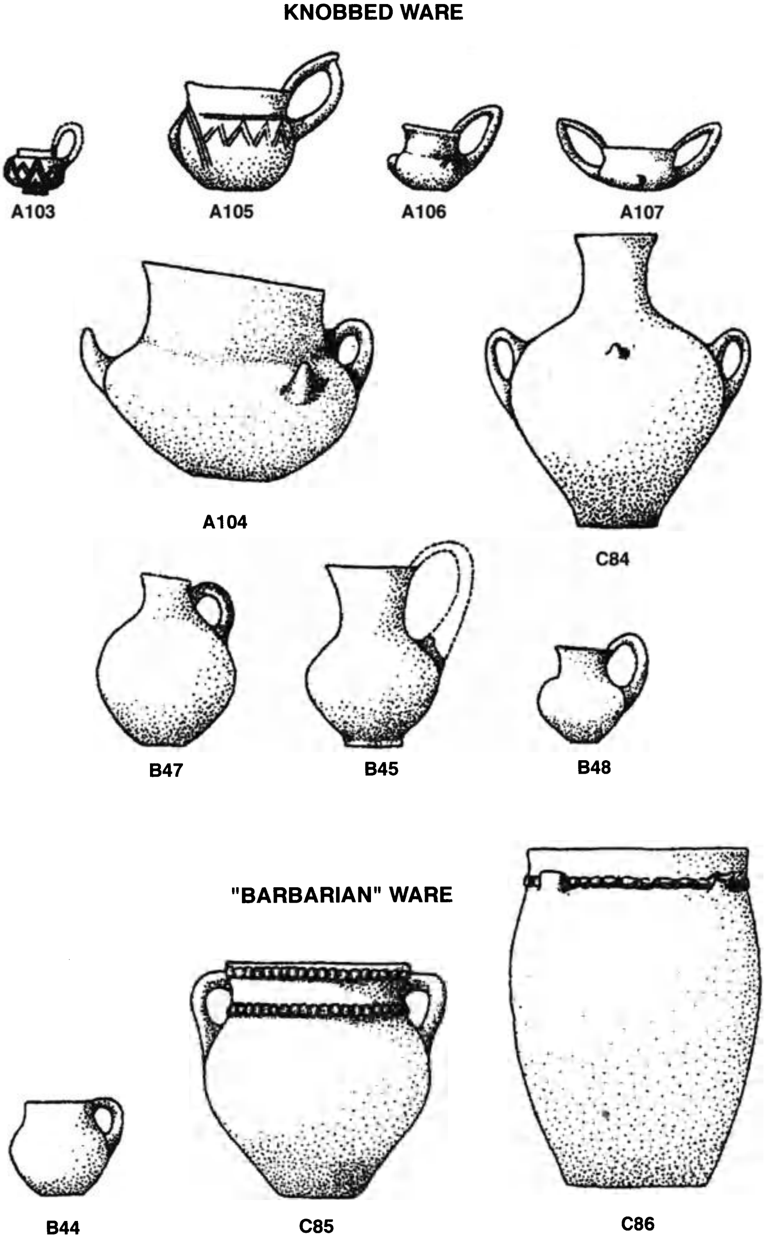

Fig. 2. Pottery assemblages from House 768 in Troia

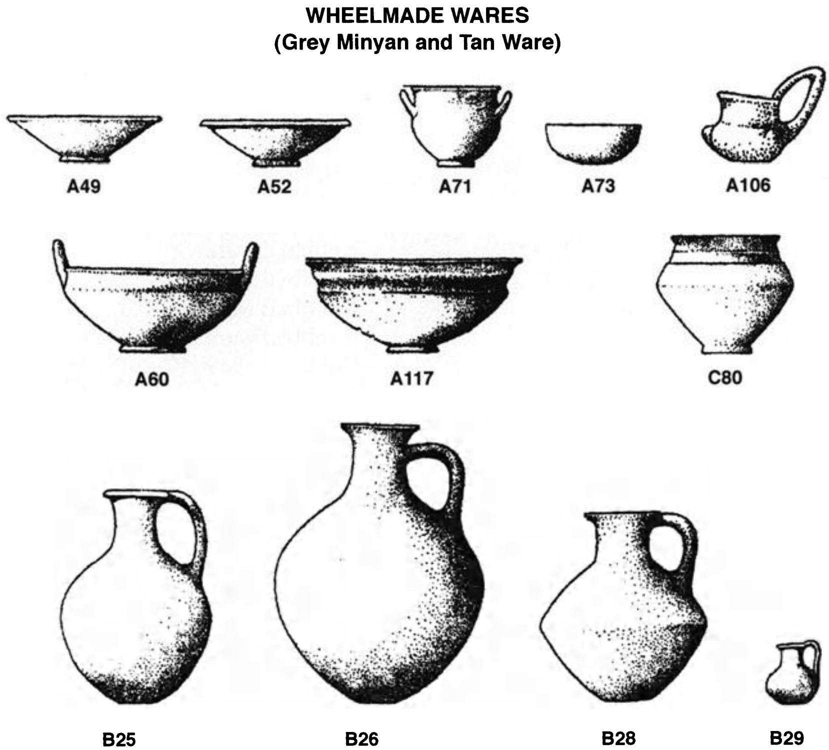

Fig. 2 (continued) Shape A106 executed in Grey Minyan ware is a Troian imitation of a Knobbed ware pot – a phenomenon reverse to that described in the text

5 Knobbed Ware – Import or Local product? Geochemical Analyses

Forty-three ceramic sherds, excavated in Troia, were analyzed using instrumental neutron activation analysis (INAA, Table 1). Of this assemblage, 22 sherds belong to the category of the Knobbed ware, 4 to the "Barbarian" ware (only sherds with preserved decoration of finger imprints were selected), and the remaining 17 comprise the traditional Troian wheelmade pottery groups: Grey Minyan, Tan, and Plain ware (for definitions see Blegen et al. 1953: 35–38; 1958: 21–23). As comparative material, 236 samples from southern Bulgaria were analysed. The material is chronologically and typologically comparable to the Troian Knobbed ware and comes from sites where this type of pottery occurs frequently (Chichikova 1968; Dimitrov 1968; Hänsel 1976: 191–227, pl. 21, 23, 24–27, 28, also pp. 232–233). A detailed description and analytical results of these samples will be published separately (Kuleff et al., forthcoming).

Table 1. Concordances of the Troian excavation numbers and Freiberg Laboratory numbers of the analyzed pottery. Description of the analyzed sherds and cluster assignment. Asterisks indicate multiple sherds from the same excavation unit

Freiberg lab no.	Troia excavation no.	Type of ware	Clusters no.
FG010016	D7.128.39	Knobbed ware	Cluster 1
FG002129	B7.34.301-305	Grey Minyan	
FG010011	D10.29.3	Knobbed ware	Cluster 2
FG010013	D7.128.37	Knobbed ware	
FG010014	D7.82.27	Knobbed ware	
FG010015	D7.85.3	Knobbed ware	
FG010017	D8.236	Knobbed ware	
FG010018	D8.361	Knobbed ware	
FG010019	D8.362*	Knobbed ware	
FG010020	D8.362**	Knobbed ware	
FG010021	D8.362***	Knobbed ware	
FG010022	E9.158.1	Knobbed ware	
FG010023	K3.1	Knobbed ware	
FG010024	K3.1.3	Knobbed ware	
FG010025	z7.1	Knobbed ware	
FG010026	z7.18	Knobbed ware	
FG002095	D8.362.301	Knobbed ware	
FG002096	D8.362.302	Knobbed ware	
FG002097	D10.29.9	Knobbed ware	
FG002098	E9.3.6	Knobbed ware	
FG002099	E9.158.1	Knobbed ware	
FG002100	K3.6.8	Knobbed ware	
FG002101	D7/8.960.6	"Barbarian" ware	
FG002102	D8.973.49	"Barbarian" ware	
FG002103	I17.971.4	"Barbarian" ware	
FG002104	I17.971.6	"Barbarian" ware	
FG002128	B7.37.301-305	Grey Minyan	
FG002131	I17.616.305	Tan ware	
FG002122	A7.1276.306-310	Tan ware	Cluster 3
FG002124	A7.1276.301-305	Grey Minyan	
FG002125	B7.34.306-309	Tan ware	
FG002126	I17.616.301.304	Grey Minyan	
FG002127	B7.37.306-308	Tan ware	
FG002130	I17.612.301-305	Grey Minyan	
FG002132	I17.616.305	Tan ware	
FG002135	K/L16/17.663*	Grey Minyan	
FG002137	K/L16/17.672	Grey Minyan	
FG002138	K/L16/17.617*	Grey Minyan	
FG002139	K/L16/17.617**	Tan ware	
FG002140.	K/L16/17.663**	Plain ware	
FG010012	D7.128.36	Knobbed ware	Outliers
FG002123	I17.618.301-305	Grey Minyan	
FG002141	K/L16/17.663***	Tan ware	
FG002142.	K/L16/17.672	Plain ware	

The analytical method used in this investigation has been thoroughly described by Knacke-Loy et al. (1995b) and Kuleff and Pernicka (2002). After mechanical cleaning of the surface of the sherds with corundum drills, the samples were powdered in an agate mill. About 0.12–0.15 g of the powder was sealed in polyethylene capsules and irradiated with pile neutrons in the TRIGA reactor at the Institute for Nuclear Chemistry at Mainz University for 12 h. The neutron flux was 1.10^{12} cm^{-2} s^{-1}. Two gamma-spectrometric measurements were performed using HP Ge detectors with an energy resolution of 1.8 keV and an efficiency of 38 % at the 1332.5 keV peak of ^{60}Co and a multichannel pulse height analyzer. The first measurement was performed after a cooling time of 1 week and permits the determination of As, Ba, K, La, Lu, Na, Sb, Sm, U, and Yb. The second measurement was carried out after a cooling time of 30 days to determine Ce, Co, Cr, Cs, Eu, Fe, Hf, Nd, Rb, Sc, Ta, Tb and Th. The analytical data were grouped by cluster analysis using the program package of BNL (Sayre 1988) using the concentrations of all elements determined except for As, K, Na, Nd and Sb. Besides a few exceptions only two major clusters were formed. It turned out that all samples except for two Knobbed and "Barbarian" ware belonged to one of the two major clusters while the other contained only samples of Grey Minyan, Tan and Plain ware. Mean values of the trace element concentrations in the two clusters are given in Table 2 together with their relative standard deviations.

Although the distinction seems rather clear and both clusters are relatively tight, one sherd each of Tan and Grey ware were nevertheless grouped together with the Knobbed and "Barbarian" wares. Figure 3 shows

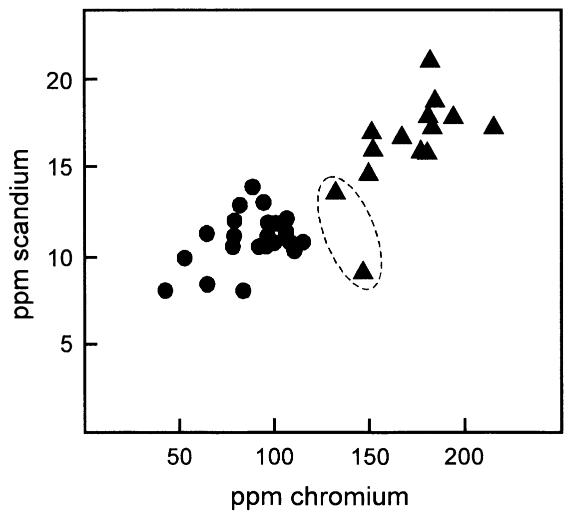

Fig. 3. Plot of chromium versus scandium concentrations in Troian Knobbed ware (*filled circles*) and wheel-made Troian Tan and Grey Minyan wares (*triangles*). The positions of the two samples of Tan and Gray Minyan ware clustered with the Knobbed ware are indicated

Table 2. Mean chemical composition of the clusters (mg/kg)

Element	Cluster 2 ($n = 26$) Knobbed ware		Cluster 3 ($n = 14$) local pottery	
	Mean ± SD	RSD	Mean ± SD	RSD
As	20.6 ± 10.0	48.7	25.9 ± 15.2	58.5
Ba	831 ± 248	29.9	644 ± 245	38.0
Ce	60.9 ± 10.4	17.0	59.5 ± 7.5	12.6
Co	11.4 ± 2.0	17.5	18.2 ± 4.8	26.4
Cr	88.3 ± 25.7	29.1	169 ± 42.8	25.3
Cs	5.9 ± 1.4	23.7	8.1 ± 2.0	24.7
Eu	1.09 ± 0.15	13.8	1.19 ± 0.12	9.9
Fe (%)	2.99 ± 0.37	12.4	4.04 ± 0.51	12.6
Hf	5.1 ± 1.0	19.6	4.2 ± 1.1	26.2
K (%)	2.49 ± 1.02	41.0	2.43 ± 0.93	38.3
La	29.4 ± 4.9	16.7	27.0 ± 5.6	20.7
Lu	0.304 ± 0.063	20.7	0.319 ± 0.056	17.6
Na (%)	1.09 ± 0.39	35.8	0.65 ± 0.21	32.3
Nd	27.3 ± 7.6	27.8	33.5 ± 9.0	26.9
Rb	96.2 ± 16.7	17.4	110.0 ± 23.3	21.2
Sb	0.98 ± 0.77	78.6	1.37 ± 0.35	25.5
Sc	11.0 ± 1.6	14.5	16.7 ± 1.9	11.4
Sm	4.5 ± 0.8	17.8	4.7 ± 1.0	21.3
Ta	0.99 ± 0.15	15.2	0.98 ± 0.11	11.2
Tb	0.63 ± 0.10	16.3	0.66 ± 0.11	16.6
Th	14.2 ± 3.0	21.1	12.6 ± 3.2	25.4
U	3.09 ± 0.80	25.9	2.98 ± 0.96	32.2
Yb	2.22 ± 0.37	16.7	2.03 ± 0.46	22.7

that these two sherds plot between the two major clusters, suggesting that some overlap may occur.

In order to address the question of locally produced or imported pottery the trace element pattern of the two groups in Table 2 was compared with the chemical profile of the local pottery and sediments from the Troian plain that were reported by Knacke-Loy et al. (1995b). Figure 4a illustrates the result of a comparison between the cluster containing the presumed local pottery from Troia (Grey, Tan, and Plain wares) with clay samples of the Karamenderes basin. The assumption that these wares were locally produced is mainly based on the fact that in Troia VI together they make up the majority of the pottery inventory of the site.

The similarity in the chemical composition between these two groups is satisfactory, but not very good: 8 out of 23 elements are slightly outside the 95% confidence limits. It has to be noted that they are all below the *lower* confidence limit of the signature of local pottery and sediments. Since

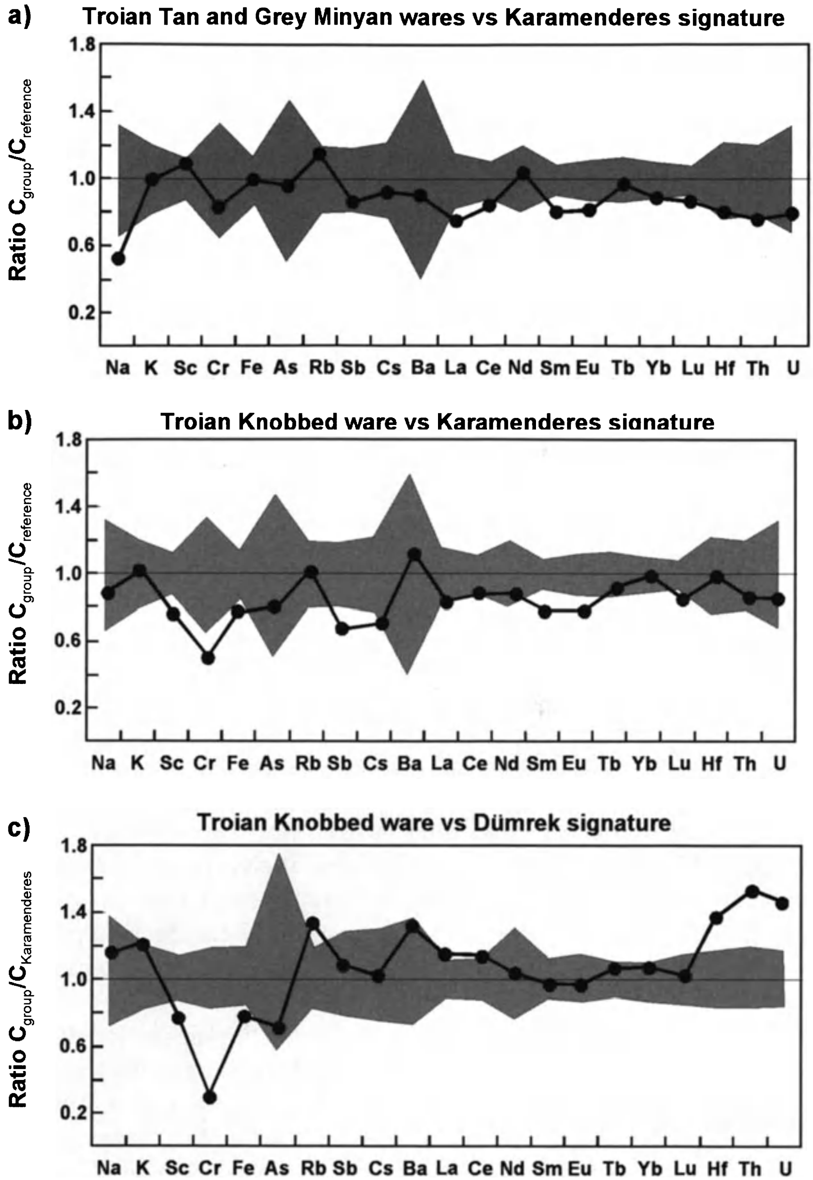

Fig. 4. **a** Comparison of the trace element pattern of Tan and Grey Minyan wares from Troia (cluster 3 in Table 2) and local pottery and clay samples from the Karamenderes drainage system by Knacke-Loy et al. (1995b). **b** Comparison of the trace element pattern Knobbed and "Barbarian" wares from Troia (cluster 2 in Table 2) and local pottery and clay samples from the Karamenderes drainage system by Knacke-Loy et al. (1995b). **c** Comparison of the trace element pattern Knobbed and "Barbarian" wares from Troia (cluster 2 in Table 2) and local pottery and clay samples from the Dümrek drainage system by Knacke-Loy et al. (1995b)

most of them are geochemically immobile like the rare earth elements, we suspect that the clay of these samples may have been diluted by temper in the order of about 10 % by weight. One could account for this by increasing all concentrations of the pottery samples in this cluster by 10 %. In this case only Ba, Cr, K, Rb, and Ta would be outside the 95 % confidence interval. However, this hypothesis needs confirmation by a larger sample of pottery sherds and sediment samples. Nevertheless, one can safely conclude that the Grey Minyan and Tan Ware from Troia were produced using local clay from the Karamenderes drainage system. Incidentally, Knacke-Loy et al. (1995b) defined four local clay groups, two of which can be associated with the sediments of the Dümrek stream north of Troia. However, there was no satisfactory chemical fit between these sediments and the presumed local pottery of the suite analyzed in this study.

If the same procedure is applied to the group of Knobbed Ware then the results are negative for all Troian clay sources reported by Knacke-Loy et al. (1995b). This is illustrated in Fig. 4b,c, where the difference in the chemical composition of Knobbed ware from Troia and the two major Troian pottery and sediment signatures can be seen. This would suggest that the Knobbed ware found at Troia *was not* made from local clays. This is a surprising result, because so far it has been assumed by most scholars that the amount of this ware found in Troia is too large to have been imported in total.

Although the study of Troian sediments by Knacke-Loy et al. (1995b) was concise, it was by no means exhaustive. Therefore, it is not possible to exclude at present that clays (or temper) with other trace element patterns may exist in the Troad. For this reason we also analyzed Sr and Nd isotope ratios in three samples of Knobbed ware. Isotope analysis has proven to be a valuable tool in provenance studies of pottery, because isotope ratios seem to be much less variable in a given region than the trace element patterns.

The procedure for sample preparation included the separation of Sr and the light rare-earth elements by ion exchange chromatography with a 5 ml resin bed of Bio Rad AG 50W-X12, 200–400 mesh in quartz columns. Nd was separated from other rare-earth elements on quartz columns using 1.7 ml Teflon powder coated with HDEHP, di(2-ethylhexyl)orthophosphoric acid, as cation exchange medium. All isotopic measurements were made by thermal ionization mass spectrometry on a Finnigan MAT 262 mass spectrometer at Tübingen University. Sr was loaded with a Ta-HF activator on pre-conditioned W filaments and was measured in single-filament mode. Nd was loaded as phosphate on pre-conditioned Re filaments and measurements were performed in a Re double filament configuration. The $^{87}Sr/^{86}Sr$ isotope ratios were normalized to $^{87}Sr/^{88}Sr = 0.1194$ and the

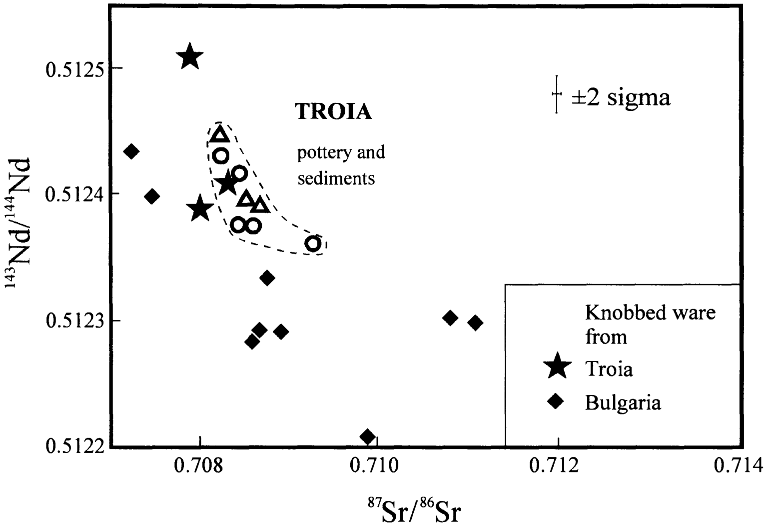

Fig. 5. Strontium and neodymium isotope ratios in samples of Knobbed ware from Troia and southern Bulgaria in relation to local pottery and sediments from Troia

$^{143}Nd/^{144}Nd$ isotope ratios to $^{146}Nd/^{144}Nd = 0.7219$. Analyses of 26 separate loads of Ames metal (Geological Survey of Canada, Roddick et al. 1992) during the course of this study (01–07/2001) gave a $^{143}Nd/^{144}Nd$ ratio of 0.512119±0.00011 (2σ of the mean) and within the same period the NBS 987 Sr standard yielded a $^{87}Sr/^{86}Sr$ isotope value of 0.710259±0.00014 ($n=15$). Total procedural blanks (chemistry and loading) were <200 pg for Sr and <50 pg for Nd.

The results are given in Table 3 and in Fig. 5. It is obvious that for at least one sherd of Knobbed ware the isotope analyses are at variance with the trace element results in that they are consistent with sediments and pottery from Troia. However, all geochemical analyses of this kind provide only conclusive evidence when the raw material in question is different from the archaeological sample studied. In the case of matching geochemical characteristics it is always possible that another source exists with overlapping values. One sherd of Knobbed ware, however, is only marginally compati-

Table 3. Isotope ratios of strontium and neodymium in Knobbed ware from Troia

Sample no.	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$
FG-002096	0.708322 ± 10	0.512407 ± 17
FG-002098	0.708006 ± 10	0.512390 ± 17
FG-002099	0.707928 ± 10	0.512514 ± 09

ble with the presently analyzed Troian sediments and another is chemically and isotopically significantly different from any sediment or pottery from Troia so far analyzed so that one can safely conclude that it was imported. Since this can only be regarded as a pilot study, it is at present, impossible to speculate from which region it may have been imported. Chemically similar pottery has been found in southern Bulgaria in the area of Stara Zagora (Kuleff et al., forthcoming), but the isotopic composition is different and variable. As yet, no comparative data exist from Turkish Thrace or from northwestern Anatolia.

6 Conclusions

The chemical examination of the Knobbed vessels at present suggests that at least part of the Troian material was directly imported instead of having been locally produced as previously presumed. Yet, the fact that in Troia the Knobbed vessels are present in almost every house and that they form full utilitarian assemblages completed with the "Barbarian" coarse wares is an indication that the whole sphere of house activity connected with the use of ceramic vessels had been organized to fit the needs of new population groups.

These results seem to contradict each other. In fact, however, a similar situation has been observed in different archaeological contexts. An interesting parallel may be found in eastern Prussia in the seventh to thirteenth centuries A.D. In the area inhabited by Prussian ethnic groups, as proven by historical sources, Slavic pottery types predominate in all hitherto excavated settlements (e.g., Czarny Las, Boze 1, Ruska Wies), while typical Prussian pottery represents a minor group (Nowakiewicz and Wróblewski 2002). It has not yet been investigated whether the Slavic pottery was imported or locally produced. It is noticeable, however, that it represents a full assemblage of shapes, not only a limited repertoire. The reason for this is unknown, but the changes in the material culture of eastern Prussia in the seventh century are also manifested in the disappearance of cemeteries and the introduction of new settlement forms. These phenomena are, however, not connected with any ethnic change according to written sources.

According to the present state of knowledge, the infiltration of foreign groups in Troia in the VIIb phase cannot be excluded. Therefore, we propose the following scenario: Troia, pauperized after two subsequent destructions at the end of the VI and VIIa settlements (Guzowska 2000), may have been subjected to slow infiltration from the north. At the beginning of the process, the number of the newcomers were probably rather small. As such they were hardly detectable in the archaeological context due to the so-called Versailles effect, when the material culture of the destination place is eagerly adopted by the immigrants coming from less developed areas (Wiener 1984: 17). Possibly, the only trace left is the introduction of pots of "Barbarian" ware, used for limited household purposes, while as tableware local Grey and Tan ware was used. With time, when the number of newcomers grew, the desire to mark ethnicity or origin in order to distinguish themselves from the local population may also have grown. An additional factor may have been the gender structure of the immigrant groups, as often shown in ethnological studies. Such causes can only in exceptional cases be recognized in an archaeological context.

This is only one of several possible scenarios. Other reconstructions may link the appearance of the new pottery types with the new social structure in Troia after a series of destructions at the end of the Bronze Age. The increasing demand for the new style ceramic ware may thus be the result of the development of a new hierarchy within the same ethnic group. This scenario would better fit the observation that the Knobbed ware from Troia cannot typologically be related to any specific Bulgarian group. It rather represents a conglomerate of shapes and decorative forms found in southeastern Europe (cf. Bouzek 1985: 195; Hänsel 1976: 234 who, however, interprets this phenomenon differently).

In Troia, located at the traditional crossover between Europe and Asia, the possible mixing of immigrants with the local groups could be responsible for the extreme complexity of the archaeological record, which may be disentangled in the course of future research.

Acknowledgments. We thank Mr. Reitter of the Institute of Geochemistry at the University of Tübingen for technical help with the isotope analyses. We are also grateful to Mr. Tomasz Nowakiewicz and Dr. Wojciech Wroblewski, the Director of the Galindian Expedition, Institute of Archaeology, Warsaw University, for providing the parallel with Early Mediaeval Prussia.

Chapter 15

Environmental Aspects of Economic Changes in Troia

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Abstract

Based on the animal bone finds from the excavations at Troia and Kumtepe the development of subsistence economy in the Troad is outlined. Stable proportions between the domestic animals developed during the final fourth millennium B.C. at Kumtepe and were gradually modified in response to population development through the prehistoric and historic periods of Troia. A marked deviation from the basic pattern only occurs during period Troia IV. A climatic deterioration is made responsible for this shift. The dependence of faunal spectra and species proportions on environmental versus socio-economic factors is discussed.

1 Introduction

Subsistence economies of ancient societies were complex systems, determined by so many factors both on the human and the environmental side that archaeology will never be able to identify all their components in detail. Nevertheless, scientific approaches to the related problems have developed a set of methods which help to understand basic traits of ancient subsistence systems. How rudimentary this understanding remains is indicated by the fact that the term "environmental determinism" can still be used to de-qualify certain approaches which stress the influence of natural conditions on human behaviour. While there is little doubt that the environment was critical for the subsistence of palaeolithic hunters and gatherers, the reluctance to accept its influence increases with the complexity of the societies dealt with in younger periods.

The settlement of Troia started just after 3000 B.C. According to the structure of the settlement, the population living there at this time may already be considered a complex society. During the sequence of archaeological phases, complexity increased from the fortified village of the Early Bronze Age to a medium-sized centre of political power and economic wealth during the Late Bronze Age, and after a hiatus of a few hundred years, to a major religious and tourist site in the classical period. Can we dare to ask whether the natural environment had an influence on the subsistence economy of the inhabitants? This question will be dealt with here on a basic level of evaluation of the faunal remains.

2 Development of Faunal Spectra at Kumtepe and Troia

Species composition of animal bone refuse from the meals of ancient populations is the most basic parameter for the animal sector of subsistence economy. Figure 1 shows the changes in frequency of the most important species during the main periods of settlement at Troia. Although modified and made more precise during the American excavations of the 1930s and the recent research since the late 1980s, the phasing of settlements at Troia has basically remained the same since the work of Schliemann and Dörpfeld in the last century. Periods I–III belong to the Early Bronze Age and are now referred to as the Maritime Troia Culture. Periods IV and V are transitional periods. Periods VI and VII represent the Late Bronze Age when the largest and most developed prehistoric settlement existed at Troia between about 1600 and 1050 B.C. Period VIII is the Hellenistic city

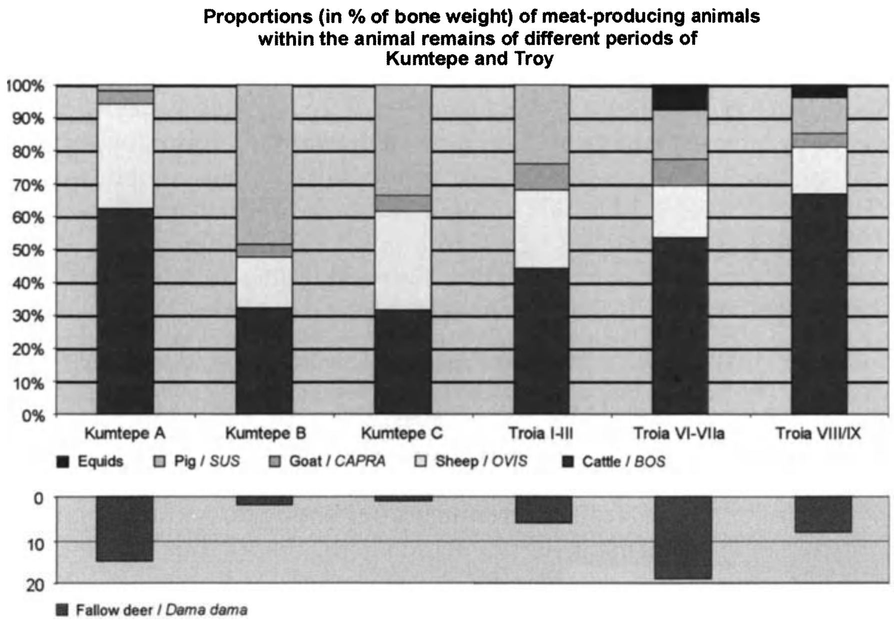

Fig. 1. Development of faunal spectra of the major phases of Kumtepe and Troia from the Late Neolithic to the Roman period

rebuilt at the ancient site on the order of Alexander the Great and period IX is the Roman Ilion.

In addition to bar diagrams for the main periods of Troia, Fig. 1 also contains such bars for three periods of the neighbouring site of Kumtepe, which preceded Troia and overlapped with its beginning. Kumtepe is located about 5 km northwest of Troia on the other side of the former Skamander embayment. When it was founded in the fifth millennium B.C., it was situated on a narrow peninsula between the open Aegean and this embayment close to its shore and not far from the Dardanelles. The river has since filled the embayment with its gravel and the coastline has prograded to a position some 2 km north of Kumtepe. The chronology of phase A of Kumtepe is not completely clear and will be discussed later. Nevertheless, this settlement ended sometime in the late fifth or early fourth millennium B.C. After a hiatus the settlement of phase B began in the late fourth and lasted into the third millennium B.C. Phase C is its continuation parallel to period I of Troia.

Although the location of Kumtepe on a peninsula separated it from the higher hinterland, its general environmental situation is very similar to that of Troia. The central area of the whole Troad consists of low hills and plateaux dissected by broad valleys. Originally, deep soils must have covered the soft lime- and sandstone of the geological underground. Under climatic conditions similar to the present the whole area would have been covered with lowland Mediterranean broad-leaved forest. Depressions with springs and small freshwater swamps as well as marshy areas close to the shorelines were within the reach of both settlements. Between the sites lay the Skamander bay as a southward extension of the Dardanelles. The mouth of the Skamander or Karamenderes River was still several kilometres south of Troia when its first settlement was founded. The delta slowly prograded north with time, and in the classical period it had already passed the headland on which Troia is situated (cf. Kayan et al., Kraft et al., this Vol.).

The settlement of Kumtepe was smaller than Troia and it is assumed that it represents a rural village. Its economy depended on agriculture (Riehl 2000) and animal husbandry, but wild resources in the form of collected fruits and molluscs as well as some fishing and hunting also contributed to the subsistence of the inhabitants. The faunal remains from the excavations of 1993 and 1994 were analysed by Margarethe Uerpmann. The Kumtepe diagrams in Fig. 1 are based on her results. As in the case of Troia, bone weight was used for species quantification.

One should expect that especially the subsistence economy of phase A would represent a fairly natural interaction between man and environment. However, the faunal spectrum of Kumtepe A does not really meet the expectations based on the outlined reconstruction of the environment. The very low representation of pigs especially is not in accordance with an oak-dominated vegetation, nor does the dominance of cattle agree with the general picture of a Mediterranean village economy. These expectations are met to a much larger extent by the faunal spectrum of Kumtepe B. The dominance of pig bones there reflects the extensive use of the surrounding forests and wetlands as forage areas for this species. Cattle and the small ruminants will also have grazed in the forests, but their preference are the open parts where grass forms a strong undergrowth. These animals actually transform forests into more open habitats by selective feeding on tree-shoots, thus suppressing natural rejuvenation of the forest. The shift of the faunal spectrum from Kumtepe B to C towards less pigs and more small ruminants might reflect such changes to the surrounding vegetation.

The combined faunal spectrum of Troia I–III is quite similar to that of Kumtepe C, which chronologically overlaps Troia I. A similar basic adaptation to the local conditions may therefore be assumed for the first settlers of Troia as well. The increase in cattle visible in Fig. 1 between Kumtepe C and Troia I–III may, in this case, not reflect environmental circumstances, but rather depend on the human side of the whole system. Body size of domestic animals is a factor which, to an important extent, determines their choice for being slaughtered. Before refrigeration was invented butchered carcasses needed to be consumed before decay made them useless. A small village community will only have culled a piece of cattle if enough consumers could be expected to get through the meat in a few days. This may only have been the case on certain occasions, festivities for example. Larger communities, where rapid consumption was no problem, may have had a preference for larger carcasses in order to optimise the relation between meat yield and the investment of labour during its procurement. Of course, this also requires a distribution system crossing the borders between small family units. It is obvious that such factors only create tendencies and are not compulsory. Nevertheless, they will create visible results if the involved time span is long enough.

In this context, it must be asked whether a combined faunal diagram for the periods Troia I–III is meaningful at all. The time involved lasted for almost three quarters of a millennium. Can the animal sector of a subsistence economy be stable over such a long period? The bone finds of individual archaeological units do indicate variability. However, archaeological units are not consumption units, at least not in the case of the Troia excavations. They have to be combined in order to reflect longer time spans and in order to eliminate the inherent variability of small statistical units. Table 1 documents the two major units which are the numerical basis of the bar diagram for Troia I–III in Fig. 1.

Table 1. Numeric representation of major species in different units of periods Troia I–III

Species	Period Troia I from C3 and D3				Periods Troia II + III from E4/5			
	NISP[a]	NISP (%)	WISP[b]	WISP (%)	NISP	NISP (%)	WISP	WISP (%)
Cattle, *Bos*	1907	23.4	24,516	43.6	983	22.7	12781	43.9
Sheep, *Ovis*	419	5.1	4066	7.2	254	5.9	2630	9.0
Goat, *Capra*	137	1.7	1400	2.5	55	1.3	456	1.6
Sheep or goat	3762	46.2	12,774	22.7	1965	45.4	6437	22.1
Sheep and goat	4318	53.1	18,240	32.4	2274	52.5	9523	32.7
Pig, *Sus*	1896	23.3	13,411	23.8	1060	24.5	6752	23.2
Others	16	0.2	84	0.1	15	0.3	38	0.1
Domesticates	8137	100.0	56,251	100.0	4332	100.0	29,094	100.0
Fallow deer, *Dama dama*	92	46.0	1184	36.8	220	89.4	2345	84.4
Wild boar, *Sus scrofa*	48	24.0	876	27.2	10	4.1	139	5.0
Others	60	30.0	1161	36.0	16	6.5	294	10.6
Wild animals	200	100.0	3221	100.0	246	100.0	2778	100.0
Wild animals as % of total		2.4		5.4		5.4		8.7
Totals	8337		59,472		4578		31,872	

[a] NISP, number of identified specimens.
[b] WISP, weight of identified specimens in grams.

Numerically, these are large enough statistical units. While there is some variability in the fragment counts, the relative bone weights of the domesticates are quite similar between the two complexes. This is remarkable because the finds for period I are mainly from the base of the "Schliemann Graben" and therefore represent early parts of this period. A thick package of layers separates these finds from the "pinnacle" in square E 4/5 which yielded the bone finds analysed mainly by J. Weinstock as samples for periods II and III. The future evaluation of intermediate bone complexes may show more variability, but the high degree of conformity between the beginning and the end of what is called the "Maritime Troia Culture" (Korfmann 1996) indicates some stability of subsistence economy during this period.

The next stable period of subsistence economy is indicated by the bone finds of periods VI and VIIa. A total of more than 25,000 bones with a weight of some 270 kg is the basis for the respective bar diagram in Fig. 1. Compared to the earlier periods there is a further increase in cattle, which can be explained along the same lines of argumentation as above. The size of the Troia VI settlement indicates a major increase in the population. The appearance of the horse and donkey in period VI has probably nothing to do with the environment either, but reflects the general spread of the domestic horse in the Near East during the first half of the second millennium B.C. Environmental reasons may partly be responsible for the higher proportion of fallow deer, because parts of the plateaux east of Troia, which had been used for agriculture and grazing in the earlier periods, were possibly given up when the river plain prograded north and arable land became available there closer to the settlement.

However, there are also indications that hunting in Troia VI/VIIa had a strong social component. Species like wild goat could not be hunted in the immediate vicinity of Troia, because the surroundings of the site are too flat for wild goats. Today, this animal has completely disappeared from northwest Turkey. The next possible habitat for this species are the mountains in the southeast of the Biga Peninsula. Probably the Troians had to travel southeast for more than a day in order to reach the area where wild goats may have occurred in the past. Such hunting expeditions cannot have been subsistence activities, because they yielded much less nutritional value than was spent in order to go to the mountains and back. The appropriation of this kind of venison should rather be seen as a luxury connected to the existence of some kind of nobility in Troia. The situation with red deer – which is a rare animal for the early periods of Troia – may have been similar. Today, the red deer is an occasional inhabitant of the forested areas east of Troia at altitudes of more than 400 m above sea level. While the few red deer bones in earlier contexts might be from occasional animals wandering into the lowlands, the more regular finds from period VI/VIIa might indicate special efforts to obtain this animal in its distant natural habitat.

Fallow deer bones are found at even higher frequencies in the sanctuary area of Troia. Starting in Troia VI, it seems to have been a favourite animal for offerings. Some of its bone finds from the settlement area – both in Troia VI/VIIa and during the classical times of Troia VIII/IX – might also be related to the cultic role of the fallow deer. In any case, the high frequency of this animal in the later periods is more likely an effect of social or cultural peculiarities than of environmental developments (cf. Fabiš, this Vol.).

The faunal spectrum for the classical period (Troia VIII/IX) is based on a large amount of data collected to a large extent by Marian Fabiš, who continues to analyse faunal remains from these periods. Although the overall species proportions will probably not change much with future additions of new data, one has to be aware that there is variation in faunal composition depending on the area within the ancient city (Fabiš 1999).

The bar diagram for the classical periods indicates a continuation of the development visible in Fig. 1 which is in accordance with the interpretations given above: the remains of cattle increase further with the continuing growth of Troia's population, and a slight shift towards more sheep and goats in relation to pigs might indicate some further degradation of the vegetation in the nearer surroundings of the city.

Although not represented in Fig. 1, it should be mentioned that faunal remains from the Byzantine settlements at Troia (M. Uerpmann, in prep.) are still within the same scheme. The proportion of cattle decreases in this period in accordance with the smaller population of the latest phase of settlement at Troia, while the relation between pigs and small ruminants (sheep and goats) continues to develop towards slightly higher proportions of the latter.

On the whole, a very stable subsistence economy, which is in balance with the natural environment, seems to have existed from the beginning of the third millennium B.C. to the middle of the first millennium A.D. and, including the Byzantine period, even into the beginning of the second millennium A.D. Obviously the environment provided the frame, and socioeconomic conditions determined the details. Apparently, the stability of the environmental framework was sufficient to allow for the visible increase in cattle-keeping through time. The growth of the floodplain, which provided additional grazing for cattle, may have buffered the environmental effects of this shift. One might therefore conclude that the environment determined the baselines of the subsistence of the ancient Troians while details corresponded to the time-specific requirements of the human population.

However, the impression of long-term stability disappears when looking at the transitional periods not represented in Fig. 1. It is of special interest to deal with period Troia IV in particular. As this period did not leave impressive architectural remains at the site, the amount of excavated materials is much more limited than that from the major periods. Faunal samples are correspondingly small, and a lack of uniformity makes it difficult to lump them together into larger units. Figure 2 gives a more detailed overview of the transitional time between periods Troia II and Troia VI. It is obvious at first sight that period IV deviates strongly from the regular pattern.

Period IV is best represented in the newly excavated material by the finds from the southern prolongation of the "Schliemann Graben" in squares D7 and D8. A smaller sample is also available from square A5/6. Faunal remains from these areas were mainly analysed by Margarethe Uerpmann and Demet Etkin, respectively. In addition, the animal bone sample collected for period IV during Blegen's excavations was re-analysed. These samples – plotted in the centre of Fig. 2 – are not at all uniform.

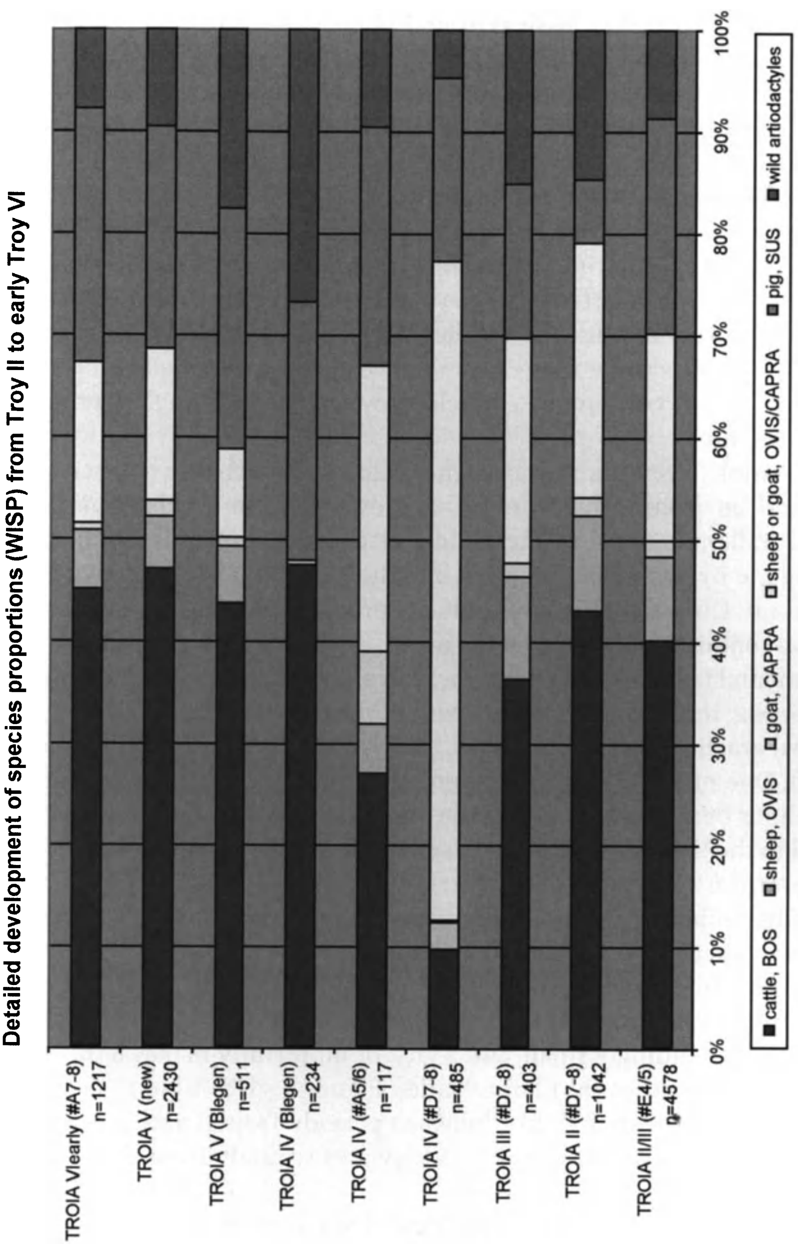

Fig. 2. Details of the development of faunal spectra from phase Troia II to Troia VII

Uniformity was stressed above for the faunal samples of periods I–III. It is again demonstrated in Fig. 2 by the samples of periods II and III from square D7/8, which are not included in Fig. 1, contrary to those from square E4/5, which are part of the respective bar-diagram (cf. also Table 1). While the bone finds contained in Fig. 1 for the periods I–III are all from the core area of the ancient settlement, those from square D7–8 are from outside the fortification walls of the respective periods. The similarity of these faunal samples to those from inside indicates a uniform subsistence, not only through time, but also throughout the settlement. The most important deviation of the samples from outside the wall is a higher proportion of game animals. There are samples from these squares with even higher amounts of deer bones, but their stratigraphic position is not clear enough to be presented here. They might belong to a context of Troia IV where the American excavations of the 1930s found many bones of fallow deer (Blegen et al. 1951). A sample of these bones is still kept in the collections of the Archaeological Museum in Çanakkale. The high percentage of fallow deer is obvious, but the value of this sample is limited, because there is an obvious lack of sheep and goat bones, which might be due to selection by the excavators. The Blegen sample of Troia V bones is included in Fig. 2 as well, and also indicates a certain under-representation of finds of the small ruminants. These samples were restudied because of the general rarity of faunal remains from these periods.

A lack of uniformity may be one of the characteristics of Troia IV faunal remains. In addition to high percentages of wild animals in some samples, we observed accumulations of many bones of young pigs, indicating premature slaughtering. These are signs of instability of the respective subsistence systems. On the archaeological side these observations go along with destruction and thick burning layers (Korfmann 1994). Within the basic interpretation scheme of the faunal remains the samples of Troia IV bones from square D7/8 are characterised by a low percentage of cattle, indicating small consumer units, and – at this extent – probably some environmental deterioration as well. If the environmental conditions had remained the same as during periods I–III, the proportions between small ruminants and pigs should not have been affected by a decrease in the size of consumer units. The increase of sheep and goats versus pigs probably reflects dry climatic conditions. The samples of Troia V – although small – indicate the return of "normal" conditions. The earliest units of Troia VI in Fig. 2 are still similar to Troia V. The equids had not yet been incorporated into the animal economy, and the proportions between cattle and smaller animals indicate smaller units of consumers than during the fully established period VI (cf. Fig. 1). On the whole, the strongest deviation from the expected pattern occurred during period Troia IV.

3
Climate, Faunal Spectra, and Subsistence Patterns

Climatic interpretations of changes in faunal proportions at archaeological sites have become unpopular. This is quite understandable with regard to the many other factors which cause shifts in the spectra of animals consumed by man. It is only against the uniformity of the fauna throughout the millennia of occupation of Troia and because of the chronology and general appearance of Troia IV that such an interpretation needs to be considered here. More or less catastrophic changes are indicated at many sites throughout the Near East at about the same time. Evidence for an abrupt climatic change towards increased aridity at about 2200 B.C. has been summarised by Weiss (1997). However, it remains difficult to separate anthropogenic deterioration of the environment from changes due to climatic shifts. Overgrazing, for example, causes changes of the vegetation which are similar to the effects of desiccation. It seems unlikely, though, that over-exploitation of the environment could cause simultaneous events over large areas, but even such scenarios can be imagined. Various local cycles based on the interaction of slow processes, like population growth, and threshold events, such as a bad harvest, may have culminated and domino effects could have caused a response on a regional scale. In addition to real effects, the interdisciplinarity of palaeo-environmental and archaeological research can result in complex forms of circular argumentation based on the exchange of ideas rather than results between the different fields.

Unexpected help in the separation of climatic and anthropogenic causes for environmental and historical changes in the Near and Middle East came from the study of deep-sea sediments in the northern Atlantic (Bond et al. 1997, 1999). These studies revealed a roughly millennial cycle of iceberg activity, which indicates a correlated climatic cycle independent of human interference. As outlined by Bernd Kromer (pers. comm.), this cycle correlates closely with the production of radiocarbon in the upper atmosphere and, thus, with solar activity. Based on Bond (1999) and additional data provided by Kromer, the "Bond-Events" (BE) can roughly be tabulated according to the figures presented in Table 2.

Correlation of these climatic cycles with palaeobiological processes became obvious when radiocarbon dates for the occurrence of Holocene wild horses in central and southeastern Europe concentrated within BE 4 (H.-P. Uerpmann, in prep.). This event also correlates, on the one hand, with the *'Rotmoos'* and *'Piora'* glacier advances and other indicators of climatic change in the Alps (Haas et al. 1998) and, on the other hand, with a strong phase of desiccation in southeast Arabia (Burns et al. 1998), to mention just the most divergent effects. The arid phase in southeast Arabia put an

Table 2. Approximate duration of periods of increased iceberg activity in the northern Atlantic ("Bond Events") according to core VM 29–191. (Bond et al. 1997, 1999)

Bond Event no.	From ca.	To ca.
0 (Little Ice Age)	1300 A.D.	1800 A.D.
1	200 A.D.	850 A.D.
2	1200 B.C.	650 B.C.
3	2550 B.C.	1950 B.C.
4	4000 B.C.	3500 B.C.
5	6500 B.C.	5450 B.C.
6	7600 B.C.	7150 B.C.
7	8400 B.C.	8050 B.C.
8	9150 B.C.	8750 B.C.

end to Neolithic herd nomadism in the interior of that area (Uerpmann et al. 2000).

In southeast Europe and Anatolia, the earlier two thirds of the fourth millennium B.C. (mostly BE 4) did not leave many archaeological traces. In the Troad, a phase of soil formation interrupts the sequence of settlement layers between the phases Kumtepe A and Kumtepe B. According to Pustovoytov (pers. comm.), this soil – which is well developed in the layers of the Höyük itself and thus marks a settlement hiatus – is a 'chernozem' or steppe soil. The desiccation – also assumed by other authors for this period – is thus corroborated for the Troad by direct pedological evidence. Its effect on the population is indicated by the lack of building activity at Kumtepe during this time and by the discontinuity of many archaeological traits from Kumtepe A to Kumtepe B.

It seems worthwhile to reconsider the atypical faunal spectrum for Kumtepe A (see above and Fig. 1) in this context. Only bone finds from below the dark soil were evaluated for this spectrum. As soils form from up to down below an existing surface, the affected layers must already have been there before the conditions of soil formation came into effect. The layers below the soil must therefore be considerably older than the phase of soil formation. Within these layers there were burials which yielded radiocarbon dates of around 4800 B.C. (Gabriel 2000), which is a *terminus ante quem* for the syn-sedimentary contents of this horizon. Thus, the evaluated bone finds may have originated during the time range of BE 5. More steppe-like conditions would have caused an environment richer in grasses – favouring cattle and sheep – and poorer in oaks, mushrooms and bulbous plants, which might be responsible for the minute proportion of pigs.

Coming back to Troia, it should be realised that all the periods outlined above as phases of economic stability, i.e. Kumtepe B–Troia III, Troia V and

VI, Troia VIII and most of IX, and even the Byzantine settlement in the eleventh century A.D., fall into phases *between* Bond Events. BE 3 as the first event to affect the ancient city itself, occurred in the second half of the third millennium B.C. Troia IV – discussed for its deviating animal economy above – is situated around the peak of this event. A climatic background to the observed changes in subsistence patterns, and to the related archaeological observations and historical changes, thus becomes quite probable. Troia VIIa, at the beginning of BE 2, has indications of demographic stress, although its animal economy is still similar to Troia VI. The final destruction of prehistoric Troia – potentially the Homeric Troian War – is fully within BE 2. The end of the classical city of Ilion was at the peak of BE 1. Neither the Troian War – if it really took place – nor the end of Ilion can be directly related to the subsistence economy of the site. However, from the observations described above it may be generalised that there was an increased risk of collapse for agricultural subsistence systems during periods of high glacial activity in the northern hemisphere.

4
Conclusions

Although some correlation between climatic development and early history is too obvious to be neglected, historical conclusions can only be drawn very cautiously. Neither were all facets of human existence affected in the same way, nor were "Bond Event" or "non-Bond Event" the only two conditions of the Holocene palaeoclimate. It might turn out that within the Bond Events particularly, the periods of sharply decreasing iceberg activity were correlated to draught in the temperate regions of Europe and the Near East. More reliable observations will only be possible after renewed efforts in precision dating of all sorts of climatic indicators from archaeological sites. The results described here are only a hint to the potential of intensified research into the relations between human history and the fluctuations of the Holocene climate. They are not meant to be a 'new' explanatory model for economic changes during pre- or early historic periods. Climate changes may cause adaptations of human behaviour, but do not explain them.

Acknowledgements. Particular thanks are due to Bernd Kromer for drawing my attention to the work of Bond and coworkers in the northern Atlantic and for his views on the wider problems connected to it, as well as for his dating of numerous samples from Troia and from my other projects related to the animal sector of early human economy. Among the members of the archaeobiological Troia team, I would like to thank Marian Fabiš and Margarethe Uerpmann for providing unpublished data of animal remains from parts of the site which were studied under their responsibility.

CHAPTER 16

Troia and Fallow Deer

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Abstract

Current archaeological excavations at Troia yield a large amount of archaeofaunal material. Skeletal remains of wild animals are most frequently represented by fallow deer. Common fallow deer and Mesopotamian fallow deer differ in several characteristics like the shape of the antlers and area of natural distribution. Troia VIII archaeofaunal remains contain 23.5 % of fallow deer bones (according to numbers of fragments) and the elements represent all the main body parts of the animal. The shape of the antlers proves the presence of common fallow deer, *Dama dama*, in the Troad. Chronological comparison of measurements of selected skeletal elements indicates that there was no significant difference in body size between Troia VIII and Troia I fallow deer populations. Similarly, comparison of body size between contemporary fallow deer populations from sites in different geographical areas (Kastanas, northern Greece; Demircihüyük, north-central Anatolia; and Troia, northwest Turkey) proves that the body size of the deer was almost identical throughout a large geographical area. A partial reconstruction of the environment in the Troad is done on the basis of fallow deer environmental and food requirements. Finally, an attempt is made to evaluate the position of fallow deer in the life of the ancient inhabitants of Troia and to describe the importance of this animal as derived from ecofacts and artefacts in combination with the archaeological context.

1 Introduction

Every season the archaeological excavation at Troia yields a large quantity of archaeofaunal materials. Among them, remains of the main domestic animals – like sheep, goat, cattle and pig – strongly dominate. A much smaller portion of the animal bone assemblage represents the skeletal remains of wild species. Of these, the most frequently identified are bones of fallow deer (*Dama dama*) and it does not matter if the osteological material is from Bronze Age or younger layers. A fairly large assemblage of fallow deer skeletal elements allows me to study this species more in depth than the rest of the wild animals identified at the site. The core assemblage used in this study belongs to the Hellenistic Troia VIII period, but fallow deer remains of the Bronze Age period will also be involved.

According to zoological classification, the fallow deer belongs to the family: Cervidae, subfamily: Cervinae, and genus: *Dama*, containing the species: *Dama dama* (Linnaeus 1758), generally called common or European fallow deer, and *Dama mesopotamica* (Brooke 1875), named Persian or Mesopotamian fallow deer. Before providing information about the Troia fallow deer some basic information on the biology of this species (mainly according to Kratochvíl 1966; Bakoš and Hell 1999; Becker 1999) will be presented:

1. *Withers height*	90–100 cm
2. *Body weight*	Male 80–100 kg; female 30–50 kg
3. *Body conformity*	Caudal part of body is higher then the cranial one
4. *Colour*	a) *Summer coat*: yellowish-red-brown, dark stripe along the back, white abdomen and bottom of the tail, several parallel longitudinal rows of white spots on both sides of the body b) *Winter coat*: grey-brown without the white spots (besides this basic coloration a strong variability in colour does exist)
5. *Antlers*	Present only in males, smooth surface, shallow marks of blood vessels, the brow-tine springs from the beam above the burr, above the following trez-tine the beam is palmate with several tines on the edge of the palm
6. *Habitat*	Warm park-like broad-leaved or mixed woods with open spaces at lower altitudes (below 600–800 m above sea level). Optimum population density approximately 20–30 ind./100 ha (some sources give ranges of 3–50 individuals).
7. *Social behaviour*	Herds separate by sex, mixed during the rutting season
8. *Food*	Food requirements put fallow deer between roe deer (selective concentrate consumer) and mouflon (volume grass consumer). Fallow deer consume a wide range of plants: grass, acorns, beechnuts, chestnuts, leaves and twigs of various bushes and trees, cultivated plants in fields and gardens
9. *Rutting season*	September–February
10. *Gravidity*	Approx. 230 days
11. *Progeny*	1(2) calf (calves) born around June

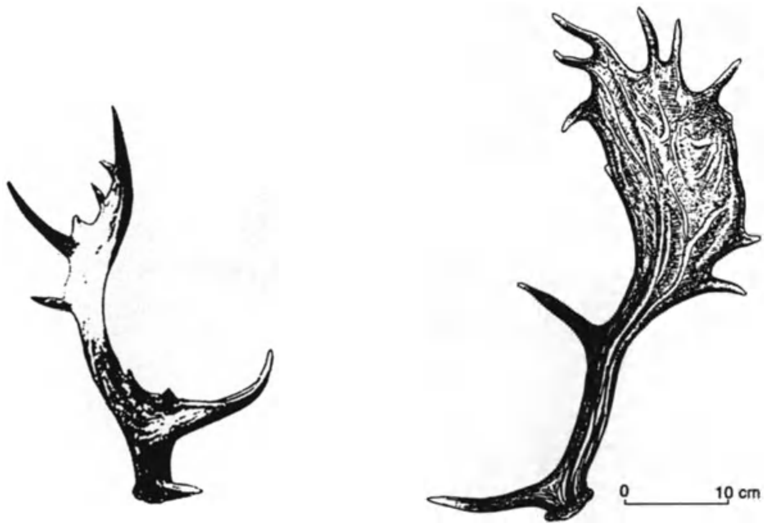

Fig. 1. Antlers of Mesopotamian fallow deer (*left*) and common fallow deer (*right*)

The common fallow deer and Mesopotamian fallow deer differ in several basic characteristics which are worth emphasising. First, there is body size – the Mesopotamian fallow deer is bigger and stronger than the common fallow deer. The second difference is in the shape and conformation of the antlers. The brow tine of the common fallow deer antler springs from the beam above the burr, then follows a fairly long section of the beam without a tine. The section ends with the trez tine above which the beam is widely palmated. The terminal and hind edges of the palmated section bear several tines of various size. The antler of the Mesopotamian fallow deer typically has a small brow tine localised directly above the burr and a stronger and larger trez tine rising very close above the brow tine. The beam above the trez tine is palmate, but not as wide as in the common fallow deer (Fig. 1).

The third difference is in the area of their ancient geographical distribution. Figure 2 indicates the maximum geographical distribution of the common fallow deer (black area in the map) during the early and middle Holocene according to Becker (1999; European area) and Uerpmann (1987; Asian area). Apart from regions of southeastern Europe, it also covers the western part of Asia Minor. The area of the ancient natural distribution of the Mesopotamian fallow deer was southeasterly from the range of the common fallow deer (shaded area in Fig. 2 and beyond).

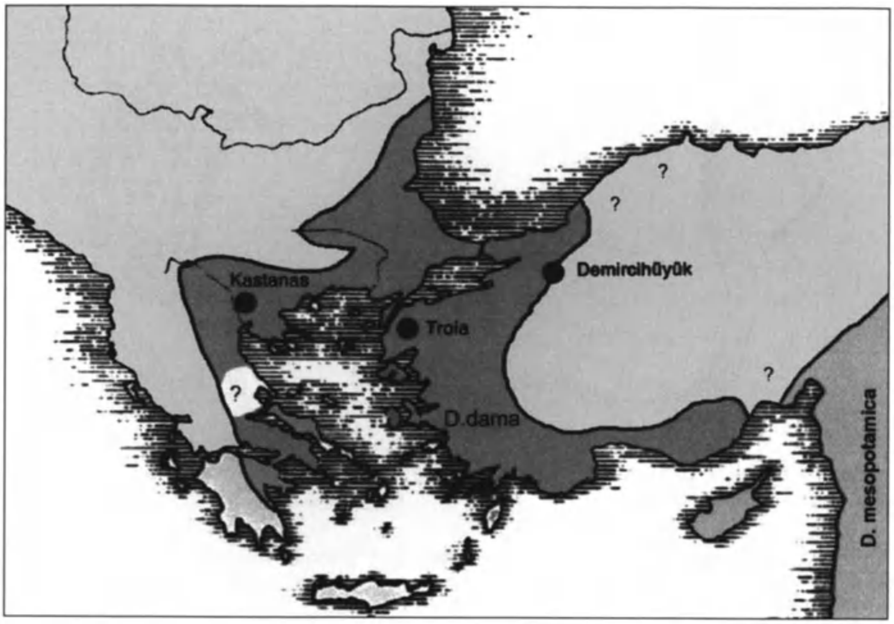

Fig. 2. Map of the ancient distribution of common fallow deer (*black area*) and Mesopotamian fallow deer (*shaded area* of Asia Minor and further east). (Adopted from Uerpmann 1987; Becker 1999)

2 Fallow Deer Remains from Troia

As has already been mentioned, the fallow deer has a strong position among the archaeofaunal remains of Troia. Analyses of the animal bones at Troia, I focus primarily on post-Bronze-Age material, most of it excavated in the area of the sanctuary. Here, the Hellenistic period, Troia VIII, has yielded the largest quantity of animal remains. Of more than 10,000 identified specimens, the 2570 fallow deer bones reach 23.5% according to their number, which is 27.2 kg in weight (26.4%). The total percentage of Troia VIII wild animals, according to the number of identified specimens (NISP), is 30.2%. These figures clearly document the position of fallow deer among the Troia VIII wild animal remains (Table 1).

Analysis of the skeletal element distribution provides the information that the evaluated fallow deer bone assemblage contains elements from all parts of the deer skeleton (Table 2).

To get an overview we put the skeletal elements into groups representing the main body parts: skull together with antlers, backbone and ribs, and fore- and hindlegs. Percentages of the skeletal elements for each of

Table 1. Species list for Troia VIII (mainly sanctuary contexts)

Taxa	NISP	NISP (%)	WISP (g)	WISP (%)
Cattle, *Bos*	2042	18.7	38,057.7	36.9
Sheep, *Ovis*	522	4.8	4025.4	3.9
Goat, *Capra*	177	1.6	1417.3	1.4
Sheep/Goat, *Ovis/Capra*	3392	31.1	12,803.0	12.4
Pig, *Sus*	1131	10.4	7342.8	7.1
Horse, *Caballus*	48	0.4	1546.9	1.5
Donkey, *Asinus*	48	0.4	1322.2	1.3
Unidentified domestic equids	79	0.7	1583.0	1.5
Dog, *Canis*	74	0.7	419.7	0.4
Fowl, *Gallus*	4	0.0	3.1	0.0
Duck, *Anas*	2	0.0	5.1	0.0
Domestic animals	7519	68.9	68,526.2	66.5
Aurochs or cattle	52	0.5	2706.6	2.6
Wild or domestic sheep	4	0.0	70.0	0.1
Wild or domestic sheep or goat	1	0.0	12.0	0.0
Sheep/goat or roe deer	9	0.1	14.0	0.0
Unidentified small ruminants	2	0.0	4.4	0.0
Wild boar or pig	32	0.3	470.1	0.5
Wolf or dog	1	0.0	2.0	0.0
Canidae indet.	2	0.0	4.8	0.0
Domestic or wild animals	103	0.9	3283.9	3.2
Beaver, *Castor fiber*	1	0.0	0.9	0.0
Rodents indet., small	104	1.0	1.8	0.0
Hare, *Lepus capensis*	38	0.3	67.8	0.1
Wolf, *Canis lupus*	2	0.0	23.4	0.0
Fox, *Vulpes vulpes*	8	0.1	26.2	0.0
Bear, *Ursus arctos*	1	0.0	1.0	0.0
Carnivora indet., small	4	0.0	5.3	0.0
Carnivora indet., large	24	0.2	251.7	0.2
Wild boar, *Sus scrofa*	64	0.6	1059.7	1.0
Fallow deer, *Dama dama*	2570	23.5	27,196.1	26.4
Red deer, *Cervus elaphus*	64	0.6	1195.4	1.2
Roe deer, *Capreolus capreolus*	41	0.4	315.4	0.3
Cervidae indet.	14	0.1	55.6	0.1
Aurochs, *Bos primigenius*	10	0.1	522.0	0.5
Wild sheep, *Ovis orientalis*	1	0.0	20.0	0.0
Aves indet.	193	1.8	143.6	0.1
Amphibia indet.	52	0.5	3.4	0.0
Testudinae indet.	71	0.7	205.6	0.2
Reptilia indet.	4	0.0	0.7	0.0
Tuna, *Thunnus* sp.	6	0.1	55.7	0.1
Pisces indet.	25	0.2	50.9	0.0
Wild animals	3297	30.2	31,202.2	30.3
Identified total	10919	100.0	103,012.3	100.0
Identified bones	10919	79.2	103,012.3	92.7
Unidentified bones	2861	20.8	8083.3	7.3
Sample total	13780		111,095.6	

Table 2. Skeletal element distribution of fallow deer from Troia VIII

Element:	NISP	NISP (%)	WISP (g)	WISP (%)
Antler	10	0.4	71.0	0.3
Cranium + antler	20	0.8	940.8	3.5
Neurocranium fragment (a)	44	1.7	229.6	0.8
Neurocranium fragment (b)	28	1.1	276.8	1.0
Neuro-/splanchnocranium fragment	2	0.1	6.4	0.0
Splanchnocranium fragment (a)	4	0.2	7.1	0.0
Splanchnocranium fragment (b)	20	0.8	172.3	0.6
Loose upper teeth	44	1.7	166.9	0.6
Mandibula fragment (a)	84	3.3	773.3	2.8
Mandibula fragment (b)	4	0.2	35.8	0.1
Loose lower teeth	18	0.7	47.7	0.2
Scapula	154	6.0	1292.0	4.8
Humerus	146	5.7	2338.6	8.6
Radius	156	6.1	2178.0	8.0
Ulna	58	2.3	470.5	1.7
Ossa carpi	13	0.5	37.3	0.1
Ossa carpalia	8	0.3	23.1	0.1
Metacarpus III+IV	115	4.5	1094.4	4.0
Phalanx 1, anterior	18	0.7	106.6	0.4
Phalanx 2, anterior	11	0.4	43.1	0.2
Pelvis (fragment)	139	5.4	1277.5	4.7
Pelvis (acetabulum)	20	0.8	428.2	1.6
Femur	208	8.1	3240.2	11.9
Patella	13	0.5	109.3	0.4
Tibia	258	10.0	3870.4	14.2
Os malleolare	5	0.2	8.2	0.0
Astragalus	58	2.3	801.7	2.9
Calcaneus	72	2.8	1221.2	4.5
Os tarsale	1	0.0	1.4	0.0
Os centrotarsale	26	1.0	199.8	0.7
Metatarsus III + IV	129	5.0	1531.7	5.6
Phalanx 1, posterior	31	1.2	195.9	0.7
Phalanx 2, posterior	20	0.8	84.9	0.3
Phalanx 3, posterior	2	0.1	0.6	0.0
indet. Metapodium	2	0.1	5.4	0.0
Phalanx 1 anterior or posterior	13	0.5	48.6	0.2
Phalanx 2 anterior or posterior	7	0.3	22.9	0.1
Phalanx 3 anterior or posterior	22	0.9	67.8	0.2
Atlas	38	1.5	506.4	1.9
Epistropheus	22	0.9	279.9	1.0
Vertebra cervicales	86	3.3	785.8	2.9
Vertebra thoracales	91	3.5	470.4	1.7
Vertebra lumbares	144	5.6	877.0	3.2
Sacrum	17	0.7	193.7	0.7
Costa	188	7.3	653.6	2.4
Cartilago costae	1	0.0	2.3	0.0
Total	2570		27196.1	

these groups are as follows: skull and antlers 10.8%, backbone and ribs 22.8%, foreleg 26.4%, and hindleg 39.9%. The percentages are different, but the most important observation is that each of the body parts is represented by a fair number of its skeletal elements. The presence of skeletal elements from the whole deer skeleton clearly indicates that the animals being successfully hunted in the area around the site were usually brought to the site complete and butchered there, otherwise parts of the body would be underrepresented or missing (mainly the distal parts of the extremities).

Antlers were usually heavily fragmented. Nevertheless, there were some examples preserved to such an extent that we were able to identify them as being that of *Dama dama*, the common fallow deer.

3 Discussion

As we have a fairly large series of measurements from Troia VIII fallow deer bones, we decided to compare the size of fallow deer living and being hunted in the Troad during the period Troia VIII (second half of first millennium B.C.) with those from the Early Bronze Age (Troia I, first half of third millennium B.C.). The aim of this comparison was to look for a possible change in fallow deer body size in the Troad through time. For this purpose, we chose the skeletal elements which provided the most numerous measurements. Measurements were taken according to the definitions by von den Driesch (1976).

Because there are not many measurements for Early Bronze Age fallow deer from Troia (I am grateful to Hans-Peter Uerpmann who kindly agreed to use them for this study), we decided to add contemporary measurements from Beşiktepe – a site located ca. 7 km west-southwest of Troia (von den Driesch 1999). As the sites are located so close to each other, we expect that their fallow deer remains represent the same geographical type of this species. The selected skeletal elements include parts of the front and hind extremities and their most frequently represented measurements. Table 3 and Figs. 3 and 4 demonstrate the results of the comparisons.

As can be seen from Table 3 and both diagrams, fallow deer populations of the Troad region did not experience significant changes in their body size during the 2000 years which separate the compared bone finds. On the contrary, they were almost identical.

We also made a similar comparison between fallow deer of the Troad and other sites in southeastern Europe and Anatolia in order to determine potential differences in body size. For this comparison, we used measurements of selected skeletal elements of fallow deer found in Kastanas/ Greece and Demircihüyük in north-central Anatolia (values are taken from

Table 3. Comparison of measurements of selected skeletal elements of fallow deer from Troia I and VIII

Skeletal elements measurements		Troia I				Troia VIII			
		n	Min.	Max.	x	*n*	Min.	Max.	x
Scapula	*SLC*	4	23.0	26.0	24.6	13	20.2	26.0	22.3
	BG	3	31.5	33.0	32.3	24	24.3	32.4	28.4
Humerus	*BT*	13	30.0	41.0	36.5	27	32.7	39.8	35.5
Radius	*Bp*	9	39.5	44.0	42.0	25	34.7	44.6	39.4
Metacarpus	*Bd*	9	28.0	32.0	30.6	20	27.3	34.0	30.5
Tibia	*Bd*	15	31.5	37.0	34.3	48	25.1	38.9	35.0
Talus	*GLl*	12	35.4	42.7	39.5	33	35.3	42.1	40.0
	BC	12	21.4	27.5	24.9	43	22.7	26.9	25.1
Calcaneus	*GL*	5	84.0	94.5	89.8	23	77.2	92.4	85.5
	GB	5	26.5	30.0	28.5	35	23.0	33.3	26.7
Metatarsus	*Bd*	6	27.0	33.0	31.3	15	28.0	33.6	31.3

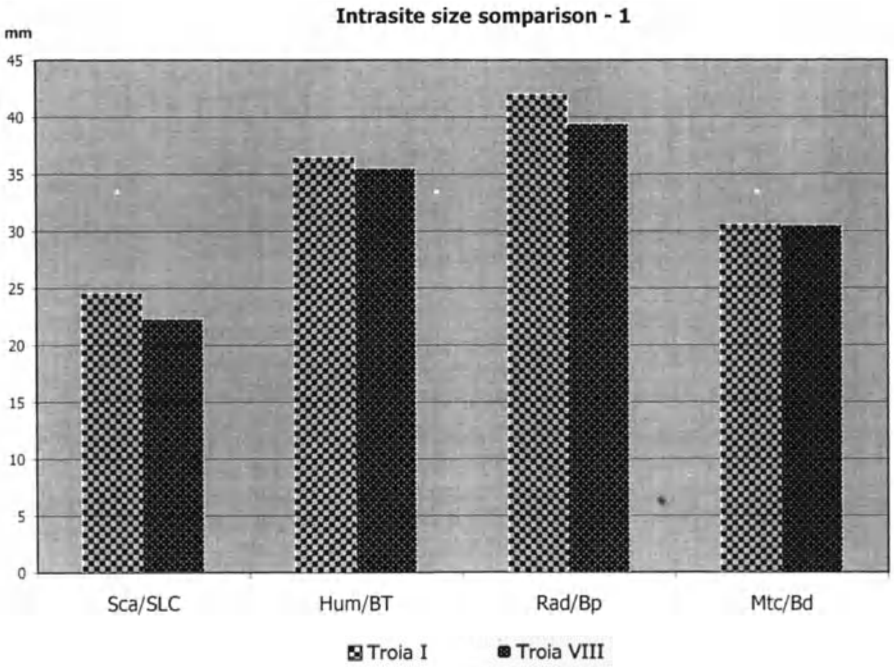

Fig. 3. Comparison of selected measurements (for full details see Table 3) of Troia I and VIII fallow deer scapula, humerus, radius, and metacarpus

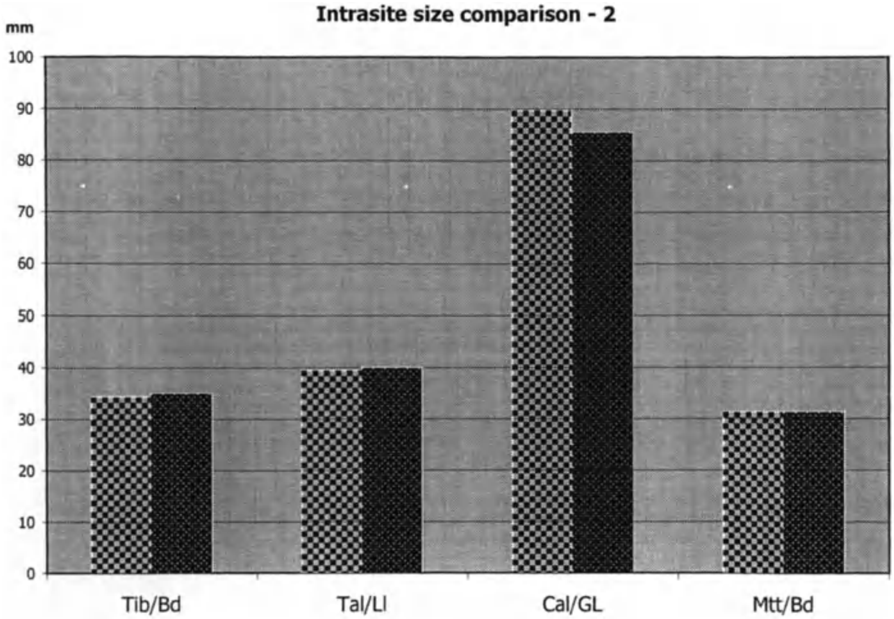

Fig. 4. Comparison of selected measurements (for full details see Table 3) of Troia I and VIII fallow deer tibia, talus, calcaneus, and metatarsus

Becker 1986: 127, Table 52). Locations of the compared sites (Troad, Kastanas, and Demircihüyük) are indicated in Fig. 2.

Selected skeletal elements and their particular measurements are: humerus (BT, *breadth of the trochlea*), radius (Bp, *breadth proximal*), metacarpus (Bd, *breadth distal*), and calcaneus (GL, *greatest length*). Results of the comparison are given in Table 4 and Fig. 5.

It is obvious that there are no significant intersite differences in the mean values of the compared bone measurements. The only exception is the *greatest length* of the calcaneus from Kastanas, giving the highest mean values for this bone. A possible explanation may be a difference in the female to male ratio of this particular skeletal element at Kastanas. Nevertheless, the results of this comparison indicate that the Trojan fallow deer population was very similar to that of the contemporary fallow deer in southeastern Europe on the one side, but also to those living on the northern edge of central Anatolia on the other.

Another interesting question was whether we could reconstruct the ancient environmental conditions of the Troad on the basis of fallow deer food requirements. As was mentioned in the brief biological characterisation of the species, fallow deer require open woodland with enough grass between bushes and trees at low altitudes. It likes acorns and other tree

Table 4. Comparison of measurements of selected skeletal elements of fallow deer from different geographical areas

Skeletal element (measurements)		Troad (this study; von den Driesch 1999)				Kastanas (Becker 1986, Table 52)				Demirci Hüyük (Becker 1986, Table 52)			
		n	Min.	Max.	x	*n*	Min.	Max.	x	*n*	Min.	Max.	x
Humerus	(*BT*)	40	30.0	41.0	36.0	99	32.0	40.3	36.5	27	34.0	42.5	37.7
Radius	(*Bp*)	34	34.7	44.6	40.5	78	36.3	44.2	40.3	19	36.0	45.0	40.5
Metacarpus	(*Bd*)	29	27.3	34.0	30.6	90	27.2	33.4	30.7	15	28.0	33.5	30.5
Calcaneus	(*GL*)	28	77.2	94.5	86.8	82	82.7	98.8	89.9	9	78.5	90.0	82.8

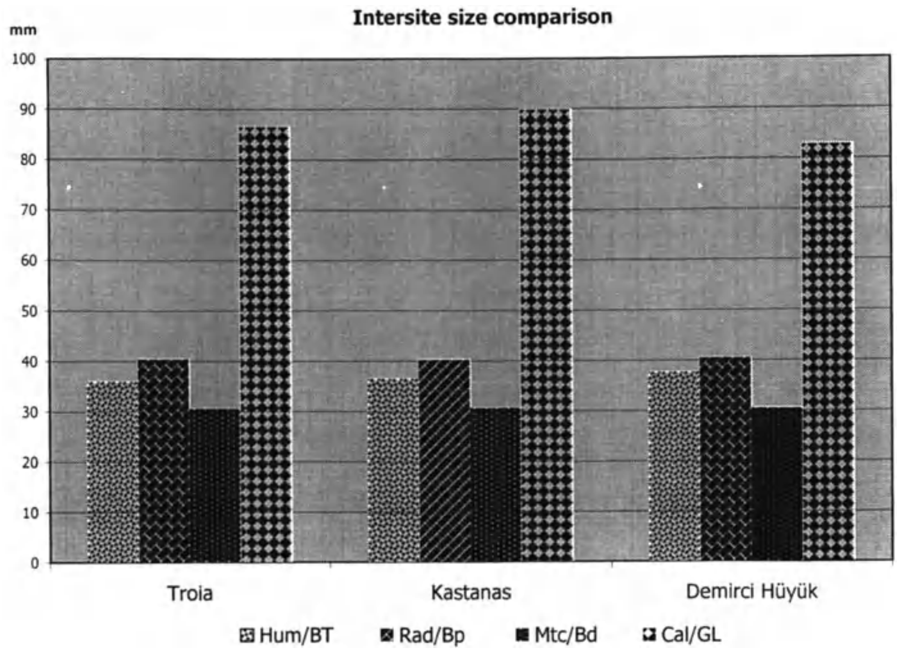

Fig. 5. Comparison of selected measurements (for full details see Table 4) of Troad, Kastanas, and Demircihüyük fallow deer humerus, radius, metacarpus, and calcaneus

fruits. Having such a high percentage of fallow deer bones in our Trojan archaeofaunal remains strongly indicates that this species had good living conditions in the area. Indeed, the general conditions in the Troad – low altitude, warm climate, woods with open spaces, and varied vegetation with grasses and bushes – meet the requirements of fallow deer. Oak trees providing acorns were also proved by archaeobotanical research among the plant remains from Troia. Riehl (1999) provides a thorough list of plant species identified in Troia and the surroundings, and we hoped this list would be useful for verifying that living conditions were really good for fallow deer in the area of our interest. However, this approach had to fail. Studies of grasses and other plant species eaten by fallow deer in England, Germany, Poland, and Hungary (Jaczewski 1983) indicate that this species is fairly adaptable to the vegetation present in the respective areas. The species structure of plants serving as food for fallow deer differed according to the conditions in the particular regions. Therefore, no detailed reconstruction of the palaeo-vegetation in the Troad is possible on the basis of fallow deer food requirements. However, this does not mean that it was difficult for fallow deer to find appropriate pasture and food to live successfully in the surroundings of Troia. On the contrary, the large amount of skeletal remains, as mentioned above, indicates that the Trojan environment was very suitable for the deer.

If we accept this environmental picture and a high frequency of fallow deer in the Troad, then it is not difficult to understand the strong interest of ancient people in this species. Wherever fallow deer existed in the past – not only in Troia – these animals were an important part of life for ancient man . First, they were a source of meat and skin – this use of fallow deer is obvious from butchery marks and cuts left on many of the bones in Troia. Deer bones and antlers were also an appropriate raw material for the manufacture of tools and other items for different purposes.

Hunting for fallow deer can be understood as a pleasure activity of the local nobility. A scene on a contemporary sarcophagus (Sevinç et al. 2001) from the area of Can east of Troia, showing the hunt for a wild boar and two fallow deer, is good evidence for these kinds of activities. Fallow deer also entered the spiritual world of ancient man. They became a part of cult and religion: The numerous finds of fallow deer bones in the area of the sanctuary of Troia VIII prove that this species had been used in sacrificial ceremonies linked with ancient gods. From other sites, not only from Troia, there are, for instance, representations of Artemis with fallow deer. A golden rhyton in the form of a deer head with antlers typical of *Dama dama* from Panagurište in Bulgaria (Zeuner 1963, Fig. 20:14) is another example of links between fallow deer and ancient religious or cult activities. A close relationship between ancient man and fallow deer, and a deep veneration of this creature, also found its reflection in representations of this species on coins. (Zeleia from the Troad for example).

4
Conclusions

Thanks to a fairly large amount of fallow deer bones among the archaeofaunal remains from Troia, it was possible to reconstruct some biological features of the species. This pilot study confirms the existence of the common fallow deer (*Dama dama*), in the northwestern part of Anatolia, which supports our present knowledge about the ancient natural distribution of the two known fallow deer species. A study of skeleton-related size characteristics indicates that fallow deer did not experience significant changes in its body size from Troia I through Troia VIII time periods. In addition, no significant differences in body size were found between fallow deer populations living in widely separated parts of the natural distribution area in the past. All this confirms a genetic stability of the species as well as good living conditions in the inhabited environment. Our attempt to elucidate the Trojan environment, based mainly on the environmental requirements of the fallow deer, resulted in the following picture: light broad-leaved or mixed forests must have surrounded the site, with enough open spaces and a dominance of oak trees.

The value of fallow deer for ancient human communities inhabiting the Troad region may not be explained merely to be that of a simple protein supplier – although this value must not be excluded. Indeed, the importance of this creature was much wider. The fallow deer entered religion and the cult dimension of human life, as is proved directly by finds of its skeletal remains in religious contexts, i.e. the sanctuary of Ilion. Hunting for this species also seems to have been a favoured pleasure activity of ancient man – we suppose that mainly members of the local nobility were active in this way. Fallow deer bones were used in manufacturing tools and implements of various purposes – these finds represent a part of the artefact assemblage collected at Troia. A general importance of the species for the daily life of the ancient inhabitants of the Troad is finally documented also by two- and three-dimensional representations of fallow deer. Some of these come from Troia itself, but others – like the coin of Zeleia – were found at other locations in the Troad.

Acknowledgements. Here, I would like to express my thanks to Prof. Manfred Korfmann of Tübingen University, director of the excavation, for his kind permission to participate in the Troia Project. Many thanks also go to Prof. Charles Brian Rose of Cincinnati University, head of the group of classical archaeologists who allowed me to analyse post-Bronze Age archaeofaunal remains excavated by his team and for his excellent collaboration in all aspects of this research. I am also grateful to Prof. Hans-Peter Uerpmann of Tübingen University, who got me involved with the Troia Project and whose useful comments and remarks are of great value for me in every step of my work at Troia. I also extend my thanks to Dr. Gebhard Bieg for providing professional photos and for his help with the photo-documentation necessary for this presentation. Finally, I am grateful to the members of the organising committee of the Symposium and the Heidelberger Akademie der Wissenschaften, the Gesellschaft für Naturwissenschaftliche Archäologie, and the Troia-Projekt der Eberhard-Karls-Universität Tübingen for creating excellent conditions for the participants of the International Symposium "Landscape Troia between Earth History and Culture".

CHAPTER 17

Troian Bird Remains – Environment and Hunting

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Abstract

A rich bird fauna was recovered from the excavations at Troia. Many of the identified species require particular ecological niches and, therefore, provide information about environmental conditions. The majority of the Troian birds require an aquatic habitat, thus reflecting the delta condition of the Skamander river-mouth in the plain below the site. Other species prefer an open steppe-like landscape. Their presence indicates the human influence on the environment, i.e., the clearing of the indigenous forests. Only a small portion of the bird remains are from woodland species.

1 Introduction

Since the first excavations in Troia faunal remains have been examined. Animal bones were studied during the excavations of Heinrich Schliemann by Rudolf Virchow and Christoph Gottfried Giebel (Virchow 1879: 62–63). Only a short species list was published which included some birds: bean goose (*Anser fabilis*), greylag goose (*Anser anser*), mute swan (*Cygnus olor*) and a small raptor (Accicpitridae).

During the excavations of Carl W. Blegen (1939–39), more animal bones were excavated, but with regard to birds the only species lists were published by Nils Gustav Gejvall (Gejvall 1938, 1939). Again, waterfowl dominate the studied samples.

The recent excavations by Manfred Korfmann have yielded a large complex of animal remains. They are being studied under the directorship of Hans-Peter Uerpmann by archaeozoologists of the archaeozoology laboratory of the Institute for Pre- and Protohistory and Medieval Archaeology (Universität Tübingen, Germany) and of the Department for Physiology and Anatomy of Farm Animals (Agricultural University in Nitra, Slovakia). A number of publications deal with various aspects of the faunal remains (e.g., Uerpmann et al. 1992; Uerpmann and Uerpmann 2000; Uerpmann, this Vol.). The present author has studied the bird remains which were separated from the bone finds before 1995 (Krönneck 1996). The list reproduced in Table 1 gives an overview of the identified bird bones for the main chronological units of Troia.

For the identification of the bird remains from Troia the comparative collections of the Archaeozoology Laboratory and the Zoological Institute in Tübingen were used, as well as the collection of the former Biologisch-Archeologisch Instituut of the Rijksuniversiteit in Groningen (NL), in order to determine the genera and species of the birds represented among the bone finds. Data on the habitats of the birds were collected from the respective literature. Data on the geology and climate of the Troad were mainly taken from Kraft et al. (1982), Meyer and Aksoy (1986), and Pustovoytov (1999). With the help of these data and based on descriptions of the landscape in the nineteenth century (Virchow 1880), the potential habitats for the birds could be located.

2 Avian Ecology in the Ancient Troad

Birds are very mobile animals, therefore, it is difficult to say exactly where they lived. However, man will not travel far to hunt, especially if it is only for food and not for pleasure. From ethnological investigations, it is known that farmers tend to use the area around their settlement which can be reached within one hour's walk (Higgs and Vita-Vinzi 1972). In the Troad, this distance includes the lower plateau, the floodplains of Karamenderes and Dümrek with their deltas, and marginally the bay and coast in the north and west of Troia. In this area, the habitats of the hunted birds should be supposed.

Of the many birds identified, only three species allow a direct identification of their habitats: these are the flamingo (*Phoenicopterus ruber*), the great bustard (*Otis tarda*), and the Chukar partridge (*Alectoris chukar*).

Flamingos need shallow water rich in micro-organisms. These are usually in brackish or saline environments, lakes, lagoons or shallow embayments. The great bustard needs an open steppe-like landscape. Higher vegetation or swampy underground are not tolerated. In the Troad such conditions were probably only found in secondary habitats, because the natural vegetation to be expected there is deciduous Mediterranean forest. The Chukar partridge also likes steppe or rocky slopes with sparse vegetation. Steppe will have been rare in the Troad, but the steep slopes of the lower plateau towards the Dümrek valley are partly rocky and sparsely vegetated. This is also a man-made habitat. The slopes are too steep for agriculture, but in the vicinity of the settlement their original woody vegetation would soon have been cleared for building material and fuel. Sheep and goats would have reduced the vegetation further and erosion then created conditions where only sparse plant-

Table 1. Overview of the bird remains from Troia. (After Krönneck 1996)

	Troia I–III	Troia VI–VII	Troia VIII–IX	Other phases or not stratified	Total	
Podiceps cristatus	1				1	Great crested grebe
Ardea cinerea		1		1	2	Grey heron
Ciconia sp.		2		1	3	Stork
Platalea leucordia		1	1	1	3	Spoonbill
Phoenicopterus ruber		1	1	4	6	Greater flamingo
Anatidae indet.	1	4	3	3	11	Unidenti-fied ducks or geese
Anserinae indet.		1	2	5	8	Unidenti-fied geese
Cygnus sp.	4	1	3	1	9	Swan
Cygnus olor	2		1	1	4	Mute swan
Cygnus cygnus				10	10	Whistling swan
Anser sp.	4	3	6	4	17	Grey geese
Anser albifrons				4	4	White-fronted goose
Branta sp.			1	31	32	Black and white geese
Anatinae indet.	10	17	8		35	Unidenti fied ducks
Tadorna sp.	1	1		29	31	Shelducks
Anas sp.	11	14	8		33	Dabbling ducks
Anas querquedula			2	1	3	Garganey
Anas penelope					0	Wigeon
Anas clypeata	1			23	24	Shoveler
Anas plathyrhynchos	2	13	3		18	Mallard
Anas crecca			1		1	Teal
Anas acuta	3				3	Pintail
Accipitridae indet.	1	1			2	Unidenti fied raptors
Vultures	1	1			2	Vultures
Aquila sp.	1	2	1	4	8	Eagles
Accipiter sp.				1	1	Hawks
Buteo sp.	2				2	Buzzards
Falco sp.		1			1	Falcons
Phasianidae indet.			1	1	2	Partridges

Table 1 (continued)

	Troia I–III	Troia VI–VII	Troia VIII–IX	Other phases or not stratified	Total	
Perdix perdix				1	1	Grey partridge
Alectoris chukar			4		4	Chukar partridge
Coturnix coturnix				1	1	Quail
Fulica atra	1			1	2	Coot
Grus grus			1		1	Common crane
Otis tarda	1	1	1	4	7	Great bustard
Charadriidae indet.				1	1	Unidentified plovers
Scolopacidae indet.				1	1	Unidenti fied sandpipers etc.
Columbidae indet.			6	4	10	Unidentified doves
Streptopelia turtur			2		2	Turtle dove
Columba oenas	1		4	1	6	Stock dove
Columba palumbus		2			2	Wood pigeon
Asio sp.	1				1	Eared owls
Bubo bubo			1		1	Eagle owl
Corvus corone		2			2	Carrion crow
Corvus corax		1	1		2	Raven
Total	49	70	62	135	316	Total

cover could grow. Although a final interpretation will only be possible after all the bird remains from Troia have been studied, it may be indicative that the finds of the Chukar partridge are all from late contexts.

The other birds can be grouped according to their environmental preferences (see Fig. 1). Most of the species found in Troia have habitats in or near the water, and only small groups prefer open vegetation or woods. They are listed according to their preferred habitat in Table 2.

Birds which find their food in water can stay there all the time, like the great crested grebe (*Podiceps cristatus*), others may leave it for feeding, like geese (*Anser* sp.) or grey herons (*Ardea cinerea*). Those sleeping and feed-

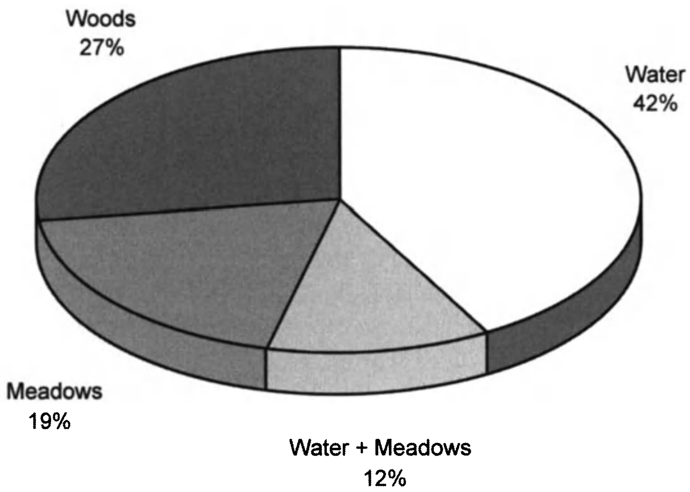

Fig. 1. Distribution of bird species per habitats

Table 2. Troian bird species grouped according to habitat preferences

Water	Water + meadows	Meadows + open vegetation	Woods + parkland
Podiceps cristatus	*Cygnus cygnus*	*Perdix perdix*	*Grus grus*
Platalea leucordia	*Ardea cinerea*	*Alectoris chukar*	*Streptopelia turtur*
Phoenicopteris ruber	*Anser albifrons*	*Coturnix coturnix*	*Columba oenas*
Cygnus olor	*Anas querquedula*	*Otis tarda*	*Columba palumbus*
Anas penelope	–	–	*Bubo bubo*
Anas clypeata	–	–	*Corvus corone*
Anas plathyrhinchos	–	–	*Corvus corax*
Anas crecca	–	–	–
Anas acuta	–	–	–
Fulica atra	–	–	–

ing at the water are not very specific. They can use lakes, rivers or a bay as well as pools, bogs or marshes. Geese want larger bodies of water to sleep near, herons prefer riverine forests for nesting. In the Troad such habitats are widespread in the floodplain and the delta of the two rivers.

Apart from the steep slopes mentioned above, open landscapes in the Troad are mainly fields and meadows. Of the birds listed in this group, only the great bustard (*Otis tarda*) prefers large areas without higher vegetation, whereas the others need a diversified open environment with some shrubs or high-growing herbs. These habitats would mainly have been on the lower plateau and its slopes, but probably also in drier areas of the floodplain. It should be remarked that the great bustard was already present during the period Troia I. At that time, the delta of the Karamenderes was still south of the settlement and degradation of the surrounding forests should not have been too advanced. The presence of the great bustard indicates, nevertheless, that areas with open vegetation existed in the vicinity of Troia.

The species listed as preferring woods do not need real forests. They can all live in parkland with small woods, riverine forests, or even in single trees. Most of them penetrate open areas and cultivated fields.

3
Conclusions

According to Van Zeist and Bottema (1991), the natural vegetation of the Troad was a deciduous forest. At the beginning of the Troia settlement, this forest was partly reduced by man into macchia, fields and grassland. This is shown by palaeo-botanical investigations (Riehl 1999a, b). The clearings may already have been large enough to explain the presence of the great bustard found among Troia I material. The environment did not change much after this time, perhaps it was sometimes drier or wetter, but there was no forest again. The lower plateau and its slopes were a more or less open landscape. The moister and more fertile soils there were cultivated and the drier and more rocky areas were grasslands or bore a sparse shrub vegetation. Single trees or woods were spread throughout the area. The floodplains were crossed by river channels with sandbanks, bogs, pools and small lakes. Riverine forests grew on stabilised banks and all other types of wetland vegetation will have developed according to the dynamics of the rivers. Lagoons may have formed at the mouth of the rivers where salt-marshes may have completed the diversity of the habitats where most of the bird remains found at Troia must have originated. Figure 2 shows a reconstruction of natural habitats in the area around Troia based mainly on maps and descriptions of the nineteenth century. Although the coastline has moved several kilometres north since the time of Troia I, the general distribution of habitats would have been similar in the past.

The high number of waterfowl bones found in Troia indicates that the various habitats of floodplain and delta were the main hunting grounds of the former inhabitants of Troia. Hunting techniques in those times were quite effective, as can be taken from the ancient literature (Pollard 1977; Bucholz 1990) or from pictorial evidence best represented by early Egyptian

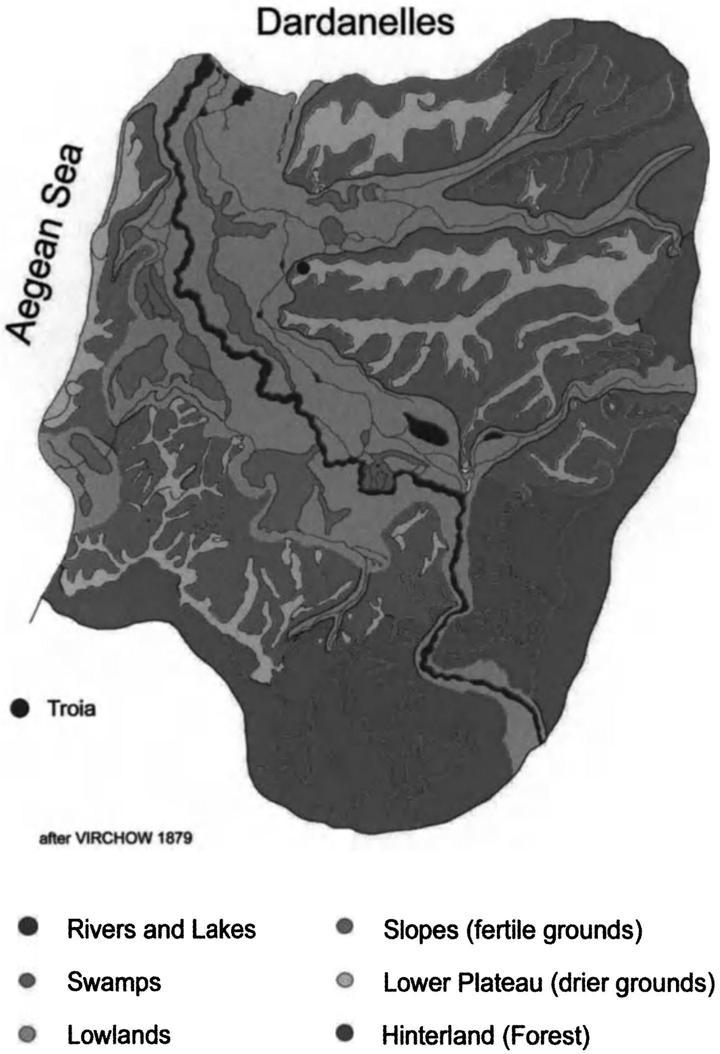

Fig. 2. Reconstructed distribution of natural habitats in the area around Troia

depictions (Boessneck 1988). Traps or nets which were certainly also used in Troia to catch birds were made of organic materials which cannot survive in the layers of Troia. Only under waterlogged conditions – perhaps during future investigations in the floodplain – they might be found.

Birds were never a major source of meat at Troia, but were always a rich complement to the human diet. The excavated bird remains add an important facet to the reconstruction of pre- and protohistoric life in the Troad and to our understanding of the natural conditions around the ancient city.

Proposal for an Effective Protection Concept for the Troad – A Strategy for the Preservation of an Important Ecological Building Block in the International System of Bird Migration

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Abstract

The European Nature Heritage Fund (Euronatur) is committed to the conservation of threatened natural and cultural landscapes and biodiversity. The Troad is quite remarkable from an ecological perspective. It has played an important role as a stopover point for numerous birds within the international migratory bird system. This function of the wetlands around Troia is extremely affected by land usage. In co-operation with the Turkish Authorities and with the support of DaimlerChrysler AG, the European Nature Heritage Fund (Euronatur) conceptualized the first steps towards the goals of the Troia National Park. Nature-friendly tourism, sustainable agricultural and comprehensive ecological education are the aims.

Prologue

The Troad is an important ecological building block within the international migratory bird system. Designating the Troia National Park was an important landmark decision in preserving this region. However, up to now, the implementation of protection strategies is lacking. The remaining natural areas are in jeopardy due to the increased usage of the land that threatens the function of the Troad as a resting place for migratory birds. Also, the agricultural use of the Karamenderes plain is becoming more widespread and intensified. What needs to be done is to conceptualize and implement a protection and management plan for the National Park. The destruction of the remaining natural areas must be stopped immediately and the cultural landscape zones be sustainably developed. It is important to introduce ecological farming methods and to develop efficient marketing strategies for the regional and ecological products.

1 Introduction

1.1 Mission of the European Nature Heritage Funds

The European Nature Heritage Fund (Euronatur) is not predominately active in research, but is committed to the conservation of threatened natural and cultural landscapes and biodiversity. Based on scientific fundamentals, protection and regional development concepts are conceived and implemented. Euronatur is active in approximately 50 European regions and outside Europe as well. Euronatur's fundamental goal is bird migration. The environmental changes in the past decades have had dramatic effects on migratory birds. This is directly connected to the depletion of wetlands. It is quite clear that in order to preserve migratory birds it is not only necessary to protect their breeding areas, but it is vitally important to protect their winter and resting areas.

1.2 The Troad: Land of Homer

The Troad is not only remarkable from an archaeological standpoint, but from an ecological perspective as well. It has played an important role throughout history as part of the trade network between north and south, as well as west and east. Today the Land of Homer is still an intricate part of the international migratory bird system. The mouth of the Dardanelles, where Europe and Asia meet, is a vital stopover point for numerous migratory birds.

The Troad belongs to the Marmara Region and is part of the crossover area between the Mediterranean and Black Seas, as well as Asia and Europe. It is here that elements of the Balkans, Mediterranean and Inner Anatolia unite, creating a rich flora and fauna.

Since the designation of the Troia National Park in 1996, the natural and cultural heritage of the Troad has been protected. Nevertheless, many areas of this fascinating landscape are still being intensely used. Only in some areas have vital ecological habitats been less affected. The purpose of this proposal is to accentuate the ecological values, their threats and the vital approaches necessary to facilitate their protection.

2
Biodiversity: Within an Archaeological Focus

2.1
The Migratory Routes Within the Eurasian – African Migratory Bird System

Within the Eurasian–African migratory bird system there are two main routes – the western and the eastern. The migratory route over Italy and Sicily to North Africa plays a minor role within the migratory system. Millions of migratory birds connect the continents of Europe, Asia and Africa. The Troad is a vital part of the eastern migratory route due to its extensive wetlands which are important resting places for numerous bird species. The function of these wetlands is extremely affected by land use. It is proven that in the past numerous cranes (*Grus grus*) rested in the Troad. Recent polls indicate that in the past few years cranes have not been seen here during migration periods.

2.2
The Troad: Summary

The Troad is characterized by the plains of the Karamenderes (Scamander) and Dümrek Rivers that share a common delta and the bordering hilly terrain. In an ecological landscape analysis vital natural areas were identified and ecologically evaluated (Herrn 2000): Lifelines of the Troad are the Karamenderes and Dümrek Rivers, the irrigation canals used as secondary biotopes, the areas in between land and sea with an extensive undisturbed coastline, and the oak scrub and oak groves.

2.3
The Common Delta of the Karamenderes and Dümrek Rivers

The Karamenderes is a vital lifeline of the Troad. Although in the 1950s dikes were built along, its shores it still remains a habitat for many endangered animal species and plants. Willows and tamarisk line the shores of the Karamenderes. The little crake (*Porzana parva*) is found here, as well as the squacco heron (*Ardeola ralloides*), the night heron *(Nycticorax nycticorax*), the little egret (*Egretta garzetta*), and the heron (*Ardea cinera*). The little ringed plover (*Charadrius dubius*) lives along the sandbanks of the river. Green and wood sandpipers (*Tringa ochropus* and *Tringa glareaola*) rest here during spring migration to their northern breeding areas. The observation of sand martins (*Riparia riparia*) along the river leads to the conclusion that there are breeding colonies in isolated areas.

The delta of the Karamenderes and Dümrek Rivers consists of numerous tributaries and large sandbeds that are surrounded by reeds and rush of various kinds.

2.4 Irrigation Canals: Vital Secondary Biotopes

Today, only a few areas of the Karamenderes plains are not used for agricultural purposes. In the last 5 years, the swamps and wetlands have been drained extensively. A complex canal system is used to irrigate the corn and vegetable fields. The main canals, which are not reinforced, are vital secondary biotopes and are the final retreats for many aquatic animal species. Here, the squacco heron, the pond terrapin (*Emys orbicularis*), and the white stork (*Ciconia ciconia*) find their habitats.

2.5 Between Land and Sea

Most of the Troad coastline is a nonconstruction area. Here, the high-quality dune vegetation is still intact. On the steep slopes Mediterranean scrub grows adjacent to the narrow dunes. Here, the woodchat shrike (*Lanius senator*), the lesser grey shrike (*Lanius minor*), the hoopoe (*Upupa epops*), the bee-eater (*Merops apiaster*), and the black-eared wheatear (*Oenanthe hispanica*) find their habitat. The coastline is an important passage area for small bird species. It is assumed that in this context the Donkey and Hare Islands (Eşekadası and Tavanadası) play an important role.

2.6 The Dardanelles and Aegean

The straits of the Dardanelles separate Europe and Asia by a few kilometers. The narrowest part of the straits is only a little more than 1 km wide. For many birds on their eastern migratory journey the Dardanelles provide an important stepping-stone during their yearly migration. Bird species that predominately rely on gliding have difficulties crossing wide bodies of water where there are no upward thermal currents. For these birds the narrow straits are essential and the subsequent retreat areas of the Troad, especially the wetlands, are most important resting places.

There are still various aquatic mammals like the common dolphin (*Delphinus delphis*), the bottle-nose dolphin (*Tursiops truncatus*) and the striped dolphin (*Stenella coeruleoalba*) found in the Aegean and the Dardanelles. The severely endangered monk seal (*Monachus monachus*), which lived here in large numbers during Homer's time, has vanished. The shearwater (*Puffinus puffinus*), a typical bird species found in the Dardanelles, can be seen in large flocks flying restlessly along the Dardanelles.

2.7
Oak Scrub and Oak Groves

Remains of oak scrub and groves can still be found in the area of the Hasan Paşa Tower. However, the Troian oak (*Quercus trojana*) is rarely seen. The hoopoe, the woodchat shrike and the bee-eater are typical bird species that live in the oak groves. The green lizard (*Lacerta viridis*) is also quite common here. The remains of the oak scrub and groves urgently need to be protected from further destruction.

3
Responsibility for an Important Natural and Cultural Heritage

3.1
Troia National Park: Laws and Reality

In the Troad, the Turkish Government has designated a historical national park encompassing 13,648 ha. This was a landmark decision to preserve the cultural and ecological riches of the region. Compared with international measures, the Troad as a National Park is not the ideal category of a protected area. National parks should predominantly contribute to the undisturbed natural development process without the interference of man (Europarc and IUCN 1999). Approximately 75 % of the Troad National Park has been used for agricultural purposes for some 8000 years.

In 1998 UNESCO declared the archaeological riches of Troia a World Cultural Heritage. With this status comes a high degree of responsibility for the archaeological sites as well as the remaining natural treasures. It is the goal within the alliance of scientists, conservationists, public and private sectors to preserve Troia and its surroundings for future generations through the application of sustainable methods.

As early as the 1970s, a preliminary master plan for the protection of the Troad was conceptualized, but protection was violated in many circumstances. Contrary to the national park status, streets and harbors are still being constructed and agriculture has been intensified. There is neither a national park administration, nor are there park rangers to monitor the park. Directly on the border of the national park a dam has been built on the Karamenderes River which will drastically restrict the water supply to this lifeline of the Troad.

3.2 Construction and Intense Use Threatens the Biodiversity of Troia National Park

The designation of the national park has not yet protected the remaining natural areas effectively. The Karamenderes River will be blocked directly on the national park border by a dam at Araplar Bogazı. This will dramatically affect the hydrological system of the Karamenderes River and it is more than likely that agricultural irrigation of the plains will be intensified. The canals that are not reinforced will be substituted by elevated cement waterways throughout the plains. It is feared that the nonreinforced irrigation canals will cease to exist and that their optimization will lead to further intensified land use. The analysis of aerial and satellite pictures confirms that the delta of the Karamenderes and Dümrek Rivers has recently been decimated by agricultural use. Intense urbanization projects have negatively affected the coastal areas even after the designation of the national park. The harbor near Yeniköy, whose function is still not clear, is a serious disturbance.

The agriculture in the plains is not sustainable. Vegetables, corn and cotton are grown predominantly. Harvesting takes place three to four times a year and chemical fertilizers and pesticides are used. Wooded areas on the plains and slopes that complicate modern mechanical agricultural methods are being removed.

4 A Comprehensive Protection Plan for the Troad

4.1 Trojan Peace with Nature

Troia – a symbol of war, confrontation and dispute – should now become a place of peace with nature. In cooperation with the Turkish authorities and with the support of DaimlerChrysler AG, the European Nature Heritage Fund (Euronatur) conceptualized the first steps towards the goals of the Troia National Park. Nature-friendly tourism, sustainable agricultural and comprehensive ecological education are the aims. Top priority is the approval and implementation of an ecological master plan for the preservation of the remaining retreats for animals and plants in the Troad. If successful – assuredly the crane will once again appear in the Troad to rest during its migratory journey.

4.2
Troia National Park: A Protection and Management Concept

There are two vital factors necessary to preserve the biodiversity of the Troad: the remaining retreats must be protected from further destruction, and use of the cultural landscapes must be ecological and sustainable. It is not intended to ban agriculture in the National Park, but to prevent any further destruction of the sensitive remaining natural areas. The development of a zoning concept – including comprehensive and verifiable goals with regard to the protection of the natural areas – is an imperative part of the master plan. In addition, it is necessary that the protected areas be linked by biotope-connecting measures. The focus of this initiative and its strategies were worked-out and discussed in a workshop in December 2000 in Troia (Euronatur 2000). The participants included an international team, Turkish authorities and regional representatives.

4.3
The Next Step and Future Prospects

In March 2001 the Turkish Department of Forestry commissioned a concept of the management plan for the Troia National Park. The completion of this plan is expected by autumn 2001, and its implementation is to begin immediately thereafter. For this purpose, a park administration and well-trained park rangers are essential.

The natural areas of the Troad cannot withstand any additional destruction if we want this region to fulfill its function as a resting area within the international migratory system. It is imperative that land use be conducted in environment- and nature-friendly ways. For this purpose, it is essential that ecological agricultural methods be implemented and the marketing of organic products be developed. The Troad as a tourist attraction is an ideal environment for the development of an alliance of agriculture, nature conservation, tourism and gastronomy. These benefits should be consequently utilized for the sustainable development of the Troad.

CHAPTER 19

Rural Plenty: The Result of Hard Work – Rich Middle Bronze Age Plant Remains from Agios Mamas, Chalkidike

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Abstract

More than 800 samples of plant remains from a Bronze Age settlement at Agios Mamas in Chalkidike were analysed. They reveal the kind of stock kept in this settlement and give information about the agriculture of the settlement and the techniques involved in the processing and storage of the stock. Important cultivated plants are compared to finds from other sites in the area. On the whole, it is obvious that extensive labour had to be invested into agriculture and the processing of the crops. However, apparently, the result was a stable subsistence economy.

1 Introduction

Agios Mamas is an old capital of Chalkidike, just as suitably situated next to the sea as to the land routes, midway between the Kassandra and Sithonia peninsulas. Even nowadays, the place has an important and well-known annual fair in the first days of September. In the arable land of Agios Mamas, but nearer to the modern village Nea Olynth than to old Agios Mamas, there is a huge Bronze Age settlement site, a toumba. This toumba has been called Agios Mamas since Heurtleys times (Heurtley 1939 fig. p. XXII [C1]; p. 1–8ff.). In the 1990s, new excavations managed by J. Aslanis, Archaeological Museum, Thessaloniki, and B. Hänsel, Free University Berlin, took place. Two sections were cut into the settlement hill, section "A" on top, and section "M" in the middle of the slope. A third section, "B", was established later to connect both A and M.

During the campaigns in this area, I took a large number of samples for an analysis of the plant remains. Each of them is based on a bucket-full of settlement debris. They were washed and floated at the site and analysed in Kiel. This work is now finished and the findings from 826 samples are kept in the Museum at Thessaloniki. The processing at the site, a simple gravity separation in lots of water, concentrates the charred plant remains or their skeletons in a sieve (0.3 mm) and eliminates all other soil components like sand or stones, all potsherds and metal artefacts. Clay and mould pass through the sieve together with the water. The contents of the sieve, free from artefacts and any pieces one might specify as "soil", may be named charcoal and as such can be exported and imported without any problems. An export and import certificate is easy to obtain.

In principle, the site is Bronze Age. Mighty layers of debris cover the Neolithic layers at the base. Settlement stops in the last Late Helladic period III C. However, the site still remained very attractive to people in later times, a little Byzantine chapel and some burials around give witness thereof.

For the archaeobotanist, it is very fortunate that the excavations in the deeper section M uncovered middle Bronze Age buildings, completely burnt down. In houses and annexes, crops in store were charred by the conflagration. Nothing survived the fire undamaged, so the site was levelled and covered with new clay. These stocks show us the whole middle Bronze Age agricultural economy which was barely known up to now. We found emmer, einkorn, and barley, linseed, bitter vetch, broad bean, grass pea, and lentils. In Table 1, eight analyses give examples of the Agios Mamas plant remains. In each, another crop is represented. In Table 2, the thousand-grain-weights show by their number that pulses are more in stock than linseed and cereals. However, the question whether the cultivation of pulses was more important than growing cereals cannot thoroughly be answered. It seems so, however.

2 Archaeobotanical Observations

Among the cereals, barley *Hordeum vulgare vulgare*, emmer *Triticum dicoccon*, and einkorn (or small spelt) *T. monococcum* were cultivated. Free-threshing wheats *T. aestivum*/*T. durum* and spelt *T. spelta* did not yet exist. In the Agios Mamas plant remains, there is a single barley grain that looks like naked barley *Hordeum vulgare nudum*. Naked barley had no importance at Agios Mamas, in contrast to many sites in central-southeast Europe (Kroll 1991). Oats, *Avena* species, do occur, but they are surely weeds. Charred kernels are rare, but twisted pieces of the lower awn parts are common. Oats and some other grasses have such awns, so we call them awns, similar to those of oats. Rye *Secale cereale* was found only in Byzantine layers. Rye and naked wheat *T. aestivum* were typical crops at that time (Kroll 1999). Broomcorn millet *Panicum miliaceum* occurred mainly in late Bronze Age layers of section A. Three quarters of the samples with more than ten millet finds come from section A. In total, there are 17 such samples. In the upper layers of the toumba, millet is quite regular, but in principle, these zones are poor in plant remains. In the middle Bronze Age

Table 1. Toumba of Agios Mamas, Chalkidike. Rich collections of plant remains from undisturbed settlement layers of the pre-minyan middle Bronze Age. Numbers are percentages of the weight +: 0.1 – 1 %. r: < 0.1 %. Nomenclature follows Zander

Find – no section M	1630	2113	2039	2053	1580	2039	2093	1606	
Hordeum v. vulgare	**73**	2	22	10	3	1	r		Barley
Hordeum, rachis fragment			r						
Triticum dicoccon		**93**	14	+		+			Emmer
T. dicoccon, glumes	r	3	+	r		r	r		
Triticum monococcum	+	+	**65**	+		6			Einkorn
T. monococcum, glumes		r	2	+		r			
Cerealia indet.				7					Cereals indet.
Linum usitatissimum	+			**78**	r		r		Linseed
Vicia ervilia	+		11	2	**97**	+	+	+	Bitter vetch
Vicia faba	9	r	3	2		**89**	+		Broad bean
Lathyrus sativus	3	r			+	+	**99**		Grass pea
Lens culinaris	14				r	r	+	**99**	Lentil
Vitis vinifera		r	+	+	r	r	r		Grape vine
Ficus carica	r	r		r			r		Fig tree
Quercus						1	r	+	Oak tree (acorns)
Malva			r	r		r			Mallow
cf. *Apium*	r								Celery
Lolium temulentum		r	+			r		r	Darnel
Chenopodium			r	r		r			Goosefoot
Galium spurium	r	r		r					False cleavers
Euphorbia			r	r					Spurge
Heliotropium europaeum			r			r			Heliotrope
Sherardia arvensis			r			r			Field madder

Table 1 (continued)

Find – no section M	1630	2113	2039	2053	1580	2039	2093	1606	
Lithospermum arvense		r			r				Corn gromwell
Adonis					r				Pheasant's eye
Asperula arvensis								r	Woodruff
Avena, awns				r					Oat, awn
Camelina sativa				r					Gold-of-pleasure
Fumaria								r	Fumitory
Lolium, small-seeded				r					Ryegrass
Poaceae	r	r	r			r			Grass family
Lamiaceae			r						Mint family
Apiaceae				r					Parsley family
Boraginaceae								r	Borage family
Cyperaceae						r			Sedge family
Asteraceae							r		Daisy family
Sum of weights (mg)	5271	60,673	8627	3075	96,215	30,924	57,690	9757	
Sum of finds (*n*)	491	10,547	940	1575	10,369	640	3696	1629	

Table 2. Toumba of Agios Mamas, Chalkidike. Average thousand-grain-weights of rich sample of the Middle Bronze Age. (Kastanas: Kroll 1983)

Taxon	Agios Mamas		Kastanas		Trivial name
	TGW[a]	*n*[b]	TGW	*n*	
Hordeum v. vulgare	10.70	4	9.83	1	Barley
Triticum dicoccon	8.93	4	–	–	Emmer
Triticum monococcum	9.33	4	7.69	1	Einkorn
Linum usitatissimum	1.34	3	–	–	Linseed/flax
Vicia ervilia	8.97	8	11.50	7	Bitter vetch
Vicia faba	69.93	7	–	–	Broad bean
Lathyrus sativus	14.70	9	–	–	Grass pea
Lens culinaris	6.14	9	–	–	Lentil

[a] TGW, thousand-grain-weight.
[b] n, Number of weights, corresponds to the number of rich samples.

stocks, there is no broomcorn millet yet. Italian millet *Setaria italica* is completely missing. In Kastanas, *Setaria italica* is more common in the Iron than in the Bronze Age (Kroll 1983). The cereals from Agios Mamas, einkorn, emmer, and barley, are the old sacred ones, handed down through the millennia. Like rice nowadays, they are more suitable for broth, gruel, porridge, and as an ingredient in many other dishes than for baking bread. We do not know whether the numerous Bronze Age cupola furnaces in the burnt layer contradict this assumption – a problem still to be solved in the future.

As oil crops, we have only flax or linseed, *Linum usitatissimum*. Double name indicates double use. Flax is connected to the fibre used for linen, linseed shows the use of seeds for vegetable fat or as a base for oil extraction, whether hot or cold. Linseed oil dries like lacquer, an oil not only very useful in nutrition, but also for numerous purposes in the household and crafts. Linneus named the plant *usitatissimus*, most useful. This sounds a bit overdone nowadays, but it is an honest praise. In our case, the seed staple in a house implies the use of linseed for nutrition, either as intact seeds or ground or crushed for many dishes, prepared at the fire or in the furnace. However, this does not mean that making linen is unimportant, on the contrary. The regularity of linseeds in the Agios Mamas plant material indicates a rural linen production. As a common rule, charred linseeds are seldom found, because the high oil content causes the seed to burst when charring. If, like here, we find linseeds in every second sample, this must be called a high density. Linseeds are present all over the settlement. This is the fact when linen is produced. The fabrication of linen is older than making cloth from wool. Wool sheep substituted the older hair sheep during the Bronze Age, nobody knows when and where. In principle, there is no difference in spinning and weaving of wool or flax. Tools and actions are the same.

Gold-of-pleasure *Camelina sativa*, a considerable Iron Age oilseed-crop, is not missing here and is still what it will be after the Iron Age, an important weed. An extraordinary discovery in Kastanas layer 14b, a great jug filled with seeds of gold-of-pleasure, shows that gold-of-pleasure was an important cultivated plant in late Bronze Age Kastanas. In Agios Mamas we did not have similar luck. Even in the younger layers, gold-of-pleasure is rare. Only 13 samples contain its seeds, a single sample has more than ten seeds. The limitation of finding the seeds is the same as for linseed, but the fragments are so typical that, with some experience, they can be recognised easily. A unique seed surface aids the determination, for the form of the seed is common in the cruciferous family it belongs to. The crop is healthy, hardy, resistant, modest, certain, reliable, productive, and so on, characteristics which are very important in close crop rotations. Modern plant breeders have renewed interest in gold-of-pleasure as a newly discovered alternative in growing oil seeds. However, as so often, new options are old ones renamed.

Poppy *Papaver somniferum*, is the only old cultivated plant native to western Europe. Poppy is also not yet present in the Macedonian Middle Bronze Age. In the upper Late Bronze Age layers poppy is quite common: 43 samples have poppy seeds, 36 of them come from section A. It is possible to extract oil from poppy seeds, but more plausible is the use of the ripe seeds for cooking and baking and the occasional dispensing of immature opium poppy capsules as a simple medication.

It should be noted that vine grapes and figs occur regularly. In contrast, we never found olive stones. Up to the middle of the twentieth century, no olive trees were cultivated on Chalkidike. There are Byzantine plant remains which correspond to the Middle Age economy of central Europe, with much rye and bread wheat, but even in these finds, olive stones are missing (Kroll 1999). The majority of researchers cannot imagine a Mediterranean household economy without olive oil. However, it is so: vegetable fat may be linseed oil and could be substituted by animal fat. Think of greenish mutton suet! Many inventions changed daily life so dramatically that we cannot imagine how it was before. A meal in the Mediterranean without tomatoes? Without paprika? Inconceivable! These New World introductions were generally not accepted before the second half of the twentieth century. This may elucidate the postulation of the missing olive at Agios Mamas.

For us, grape vine, olive oil, and cereals are the main products of Mediterranean agriculture. However, these three are (at least) four (Sarpaki 1992). Originally, the term *cereals* combines all products of the arable land which are sown again year after year, in contrast to long-lasting plantations like vineyards or olive groves. Apart from the cereals (in the sense of the edible grasses including millets, maize, and rice), the agricultural annuals also include the pulses, the fibre and oil plants, and industrial plants like sugar beet. Linseed, gold-of-pleasure, poppy, hemp (today cotton), sunflowers, and safflower are the main fibre and oil plants. The pulses are so important that they should be mentioned as a proper group besides the cereals. In Agios Mamas, we found bitter vetch, broad bean, grass pea and lentil. In our days, the American and Asian *Phaseolus*-beans and the soybean must be added. The importance of pulses in the prehistoric household economy cannot be overestimated. They are the true daily bread in the fullest sense of the word, because they make simple meals complete in a nutritional sense. Sufficient nutrition for the poorer people, based on cheap and simple storage of staples, is the precondition for stratified class societies. Of course, wine will become vinegar; oil goes rancid, cereals and pulses get musty in the course of time, but with a little effort one can retard or avoid these calculable problems.

Our four pulses are very different. Bitter vetch and lentil have some amazing characteristics. The broad bean *Vicia faba* is an imposing plant which is quite resistant if sown in early spring when the soil is still moist from winter rain. It has large pods with broad seeds. In early times, only the variety *minor* with smaller seeds was known ("Celtic bean"). Today, we also know these little brown seeds as horse beans. The big white cultivars seem to appear late, they are found in the Byzantine layers of Agios Mamas (Kroll and Neef 1997, 546).

The English name of *Lathyrus sativus*, the grass pea, is an artificial name, based on the long grassy stipules. In German, the plant is called *Platterbse*, flat pea. Only the French have a proper word for it: *gesse*. The only generally known species of *Lathyrus* is the sweet pea *L. odoratus*. The Germans call the plant *Edelwicke*, noble vetch. In principle, all species of the genus *Vicia* are vetches, the species of the genus *Lathyrus* are vetchlings. The grass pea as well as the garden pea need a support for climbing, either cereal stalks or mechanical aids. Thick in the field, they support each other. Nevertheless, sweet pea and grass pea are strong, large plants, similar to garden peas with beautiful flowers. The flowers of the grass pea are often bright blue. The seeds are said to be poisonous or at least harmful to man. However, if prepared and processed carefully and consumed moderately, this will not be a problem.

The young plants of bitter vetch *Vicia ervilia* and lentil *Lens culinaris* are absurdly small and very similar to each other. Very slowly the seedlings grow stronger. The reddish, narrow primary leaves and the thin stalks can easily be missed and neglected. The flowers are tiny, the plants stay humble and tend to lie on the ground. Pods are small with only a few seeds. One has to take care of these plants, frequent weeding is necessary. The best climate for them has little rain in summer: a dry summer stops weed-growth while the seeds are ripening. Nevertheless, bitter vetch and lentil were both highly esteemed and cultivated separately. Up to the present, lentils were popular everywhere, but in the richer parts of Europe they are no longer cultivated. This is left to those parts of the world where workmen's wages are low.

Bitter vetch is regarded as an obsolete fodder crop in Europe today and as a peculiarity of southeastern Europe and the Near East. However, this is a recent view: if there are lentils, bitter vetch may also be present at any time: in the early Neolithic culture of the "Linienbandkeramik" as well as in the urn-field period of the Late Bronze Age and in Roman or Medieval times. Sometimes, bitter vetch is not a proper cultivar like in Agios Mamas, but a weedy addition to lentils or to common vetch. Among lentils or common vetch, it will remain undetected and is difficult to remove. The pureness and frequency of bitter vetch (Tables 1, 2) at Agios Mamas leave no doubt about the importance of this plant in daily life at the site during the Middle Bronze Age.

Ripe pulses – in contrast to cereals – are not cut, they are torn out and threshed. Apparently, the yield is stored in the house. Remarkably, finds of pulses in and around the houses are twice as frequent as finds of cereals (Table 2). Perhaps the cereals were stored in a different way to the pulses. The findings of Agios Mamas confirm the importance of the pulses and their autonomous value. Bitter vetch, lentil, grass pea, and broad bean were sown separately, stored separately, and probably prepared separately when cooking daily meals and common dishes. The garden pea *Pisum sativum*, is not missing in Agios Mamas, but is very rare and totally unimportant, more likely to be a weedy component in cereals than a crop or garden plant. Chickpeas *Cicer arietinum* at Agios Mamas occur only in Byzantine period rye finds (Kroll 1999). In the Middle Ages, the chickpea was a common crop.

Dishes made from pulses were either long-boiled stews – if the single ingredients are still visible – or they were gruels. The ingredients may have been the same. The Bronze Age was an era of boiled meals with some stewed meat and broken marrow bones. These dishes were prepared in a pot or a portable cooker ("pyraunos"), in a furnace or anywhere else. Big pieces of grilled meat, indicated by bones with roasting marks, T-bone steaks, are typical Iron Age meals (Kroll 1993, 182). Middle Bronze Age dishes in Agios Mamas were simple, nourishing, and home-made style ("in the epos, women don't eat meat" – Wickert-Micknat 1982).

Pips of grapes and figs are regularly found in Agios Mamas samples. They are so frequent that one may assume that vine products – fresh or dried grapes, juice, wine, and vinegar – belonged to daily life. Wine was an everyday beverage in Bronze and Iron Age Agios Mamas. Fig pips may be so abundant because they survived time even uncharred, and a single fruit contains an innumerable seeds. Charred figs – as known from other places – were not found in Agios Mamas. Fresh and dried figs were popular refreshments between cooked meals.

Other important plants are the oaks with their fruits, the acorns. At tell-sites, the finds of acorns indicate their use as human food. In this situation, acorns can neither be interpreted as fodder for hogs – they lived in the surroundings of the site – nor as windfalls from standing trees. The preparation of acorns is complicated because one has to get rid of the bitter tannin. We may consider this primitive, but this is our poor imagination. Not only do the ingredients make the meal, but also their combination and careful preparation.

Weeds were scarce like everywhere in the Neolithic and Early to Middle Bronze Age. *Galium spurium*, *Sherardia arvensis*, *Lithospermum arvense*, *Asperula arvensis* and *Adonis* all indicate a well-developed, long-lasting agriculture on fertile soils. Darnel *Lolium temulentum* is first among the weeds, but this should not be overestimated. Weeds were rare in Bronze Age Agios Mamas and darnel is by chance the most common of them. This is due to the cereal-like size of its grains and its regular occurrence in Mediterranean cornfields. Finds of darnel are very constant, but few in number and weight. Darnel seems to have been under control. There are no hints of disastrous episodes of mass propagation of this dangerous weed in the Middle Bronze Age (see Kroll 1983). Within the einkorn stocks (Table 1, no. 2039) – the host which corresponds best to the needs of darnel when bread wheat and rye are absent – the proportion of darnel is highest, ranging between 1 per mill and 1%.

3
Conclusions

The stocks of Agios Mamas do not indicate any problems in agriculture. The impression is that everything was at its best, in contrast to the Late Bronze Age. Farming was hard work, but well established, the harvest being more than enough, without the necessity of additional food-gathering. Simple products fulfilled the fundamental needs. Together with the wine of the region, life may have been quite enjoyable at Agios Mamas.

Chapter 20

Regional Palaeodemographic Aspects of Troia and Its Ecosystem

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Abstract

Human remains of Troia are rare and do not represent the population of each chronological layer properly. Despite this basic problem, much palaeoecological information can be deduced from the human skeletons excavated up to now. Attention is given to the infant and child burials of Troia and Beşik-Tepe, which reflect burial rites as well as ecological living conditions.

1 Introduction

Humans, being part of an ecosystem, show multiple interactions with all environmental parameters. This means that not only are humans exposed to external conditions, but also the shape and size of their habitats. We can imagine from the large number of faculties that this is a huge interactive and interdisciplinary complex, which contributes to questions of reconstructing ancient ecosystems. Anthropological research is one field along with archaeology, botany, zoology, geology, geography, mineralogy, and several others that tries to shed light on ancient populations within a holistic approach.

Troia will be one of the promising projects that is hoped to fulfil such expectations of interdisciplinary research. It will be shown to what degree anthropology contributes to this huge aim. The previously available basic data, derived interpretations, and expectations for future anthropological research in Troia will be presented.

2 What Is Palaeodemography?

Palaeodemography promises to contribute significantly to our knowledge of past peoples. The palaeodemographic approach in anthropology is based on information contained in human remains, mainly skeletal material. Since bones are organic human tissues, their growth and development, including size and shape, are governed by the calcium metabolism in the human body. This, in turn, is dependant on internal conditions of the individual, such as the endocrine system, physical activities, food intake etc. and also on external ecological conditions, which contribute to shape the body. Ecological conditions contribute not only in long-term evolutionary aspects, but in the modulation of the biological capacity according to climate, nutrition and other geographical determinants.

Our aim is to extract as much information as possible from hidden biological traits. These traits represent a direct mirror of living conditions, which reflect climatic, dietary, hygienic, and working conditions, as well as health risks and several other settings. Therefore, biological traits are regarded as precious testimonies of past living conditions.

On the other hand, this organic material is exposed to all diagenetic influences through time. This may lead to a reduction of the information basis, whose selective process is unknown to us. In addition, we are limited in the detection of processes that leave traces on skeletal remains. Especially hard to decipher are short-term influences, leading to severe alterations of the human body, such as infectious disease or trauma to the soft tissue, which are not prone to detection. Mortality in these cases may result so quickly that the skeletal material remains unaltered.

3
History of Anthropological Research in Troia

A lot has been written about people who are said to have lived in the settlement of Troia. Particular attention has been paid to specific persons in the literature of Homer's Epics. Even the famous anatomist Rudolf Virchow contributed to the search for "Homers heroes" in the late nineteenth century:

> "Very few landscapes in the world are assumed to be provided with as many high mountains and far visible artificial hills as Troia and the surrounding area. Nowhere else will old epics designate the specific mounds as the tombs of the most famous heroes; nowhere else is the tradition more unanimous and nowhere else the expectation of finding the remains or at least the grave goods of a famous personage in these grave mounds seemed more entitled. However, the labour of excavations, as hard as it has been considering the enormous size of some of these mounds, delivered hardly any results, especially nothing of the skeletons or remains of human bodies were uncovered."
>
> (Virchow 1882, transl. by the author)

The aim of the former excavations represents the scientific interests at that time very well:

(1) the search for human remains which were treated as grave goods,
(2) the interest in specific individuals rather than in populations, and
(3) the aim to verify details of the old epics, which throughout the Roman period and the Middle Ages developed to be regarded as more or less documentary reports.

In addition, this reveals that early excavations were disappointing in terms of anthropological research. Not only were the "famous grave mounds" not found, in general, very few burials were excavated, even under the assumption that Troia was a small, but important citadel.

Thus, Virchow's anthropological report was limited to a few human skulls and long bones uncovered by Schliemann. Consistent with the understanding of science in those days, the manuscript was filled with detailed morphological descriptions on the individual level. This demonstrates the typological view, which, since the 1960s, has given way to a genetic concept on the population level. From that time, frequencies of genetic traits were at the centre of interest, including the genetic variability of a population. With this, anthropologists started to dissociate from the interpretation of a few morphological traits, which show very little out of the range of gene activity, as genetic distance.

The number of represented individuals, which were available to Virchow, was very small and not suitable for interpretations on a population level at all. Thus, the first human remains analysed could not contribute much to the reconstruction of ancient living conditions in Troia.

The tradition of anthropological research was continued by Lawrence Angel, half a century ago. Besides his work on the human remains of Troia, excavated during the campaigns of Carl W. Blegen 1932–1938, Angel was among the first to push the new field of palaeodemography. His reflections about reconstructions of the population of ancient Troia are considered a scientific landmark (Angel 1951). From this starting-point, the concept of population reconstructions in an ecological context developed (Grupe 1985).

However, the number of individuals represented did not improve significantly during the excavations of Carl Blegen. Altogether, Angel had no more than 86 individuals from the whole settlement periods of Troia I up to the Osman Period at his disposal (Angel 1951). The significance of this sample is best shown by the concluding remarks of L. Angel:

"The small size of the sample allows no certainty in such a spiral scheme of relationship, but it implies very much more than can be considered even a fairly good guess at the complexity of human genetics in the ancient Near East ... and thus finally all these conclusions stress gradations, change, and continuity in any attempt to examine the human biology of any stretch of time or space." (Angel 1951, 32).

Angel's report was based on the remains of 86 individuals, including intramural settlement burials from several layers and a partial burial complex within the Troia settlement, which might have been used as a cemetery during the Troia VI period. The large number of subadults within this sample reflects the typical Near-East burial rites of newborns and infants in or near the housing area. For detailed chronology and age structure of the Angel subsample, see Wittwer-Backofen and Kiesewetter (1997).

4 Number of Human Remains and Population Estimation in Troia

The number of human remains recovered from Troia increased slightly with the recent excavations by Manfred Korfmann, which began in 1989 and continues today. Another 57 individuals from different layers of Troia were excavated and analysed (Wittwer-Backofen and Kiesewetter 1997). In addition, a Late Byzantine burial complex with the remains of 49 individuals from the spring cave area has been added recently (Kiesewetter 1999).

Up to now, all Troia layers are represented by a few individuals, with the heaviest concentrations originating from the periods of Troia VI and the Byzantine time period (Fig. 1).

Additionally, a Late Bronze Age cemetery from the Beşik-Tepe excavations delivered anthropological information from another 95 individuals to improve our knowledge about the population in the Troia plain (Wittwer-Backofen et al. 2002).

Recent aims of anthropological research in Troia are no longer fixed on the identification of specific persons, who may never have lived in Troia. Instead, anthropologists are interested in reconstructing the population who lived in Troia and the Troia plain and population development over the different settlement periods. This, indeed, will reflect the living conditions to which the population was exposed. Not only can a reflection of the natural living conditions be inferred, but also biological and cultural interrelationships. A human's environment includes a large amount of man-made aspects, which allow anthropologists to estimate the population's biological and cultural interrelationship. The archaeologists' view is focused on the cultural remains of the inhabitants of a specific area, while physical anthropologists concentrate on their biological capacity for dealing with the given conditions.

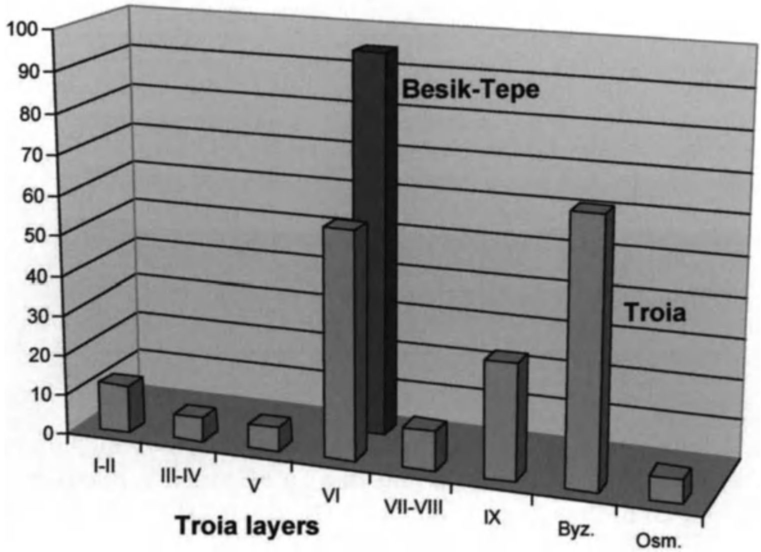

Fig. 1. The human remains from Troia and Beşik-Tepe

In accordance with this research goal, a representative sample of the population in the study must be available for anthropological research. Despite all efforts to obtain sufficient human skeletal remains, the data source is still very sparse. We realise the situation from the individuals representing the different settlement periods (Table 1). Calculating the mean number of individuals representing each century of the Troia settlement, we obtain numbers below 5 for almost all periods. The best-represented period is Troia VI, which yielded approximately 13 subadults and 17 adults per century, including the Beşik-Tepe graveyard. However, even these numbers are not useful for palaeodemographic calculations.

Our knowledge about the settlement size of Troia VI has changed dramatically with the detection of the lower city during the last few years, which has enabled researchers to roughly estimate the number of inhabitants by archaeological methods. One of these methods, based on the mean roofed space per person, yielded reliable results in ethnographic examples. Since the lower city wall limits the densely settled area, the estimation produced the enormous number of 6000–7000 inhabitants (Korfmann 1995). If we assume a mean life expectancy between 25 and 30 years, which seems to be a realistic estimation (Wittwer-Backofen 1991), the Troia VI period yielded between 16 and 20 generations. Altogether, Troia would have produced 100,000 to 140,000 death cases, out of which only 57 (0.05 %) have been excavated.

Table 1. Mean number of individuals represented by skeletal remains in the Troia layers

	Individuals/century	
	Subadults	Adults
Troia I, II	2.2	0.4
Troia II, IV	0.4	0.4
Troia V	2.0	0.4
Troia VI	13.4	17
Troia VII, VIII	0.4	0.6
Troia IX	1.1	4.2

The skeletal remains available are intramural burials, which do not reflect the typical burial rites for adults in a Late Bronze Age settlement. As we know for all Bronze Age periods in the Near East, stillbirths and infants up to a certain age used to be buried within the settlement structure, while adults were buried in extramural graveyards.

From the analysis of cultural remains we know that Troia is oriented towards and is part of the Anatolian tradition. Therefore, we expect the same burial rites as in other Anatolian settlements of that time. The best example, in that regard, is seen in the Demircihüyük population, where these burial habits have been proved quantitatively for the first time. The exact number of infants up to the age of 3 years, missing in the graveyard, were found in the settlement (Wittwer-Backofen 2000).

This is one of the reasons a large number of subadult remains were recovered in relation to the adult remains. Up to now, prospecting and excavations have not been extended to extramural areas, where the graveyards are to be expected. In addition, it is expected that mainly the remains of cremations will be recovered, as was the Hettite tradition in the Late Bronze Age. This reduces the chance of detecting graveyards with smaller burial complexes compared to uncremated burials.

5 Infant Burials in Troia

The quantitative relationship between subadult and adult individuals, as given at this state of research, may not be interpreted as high infant mortality or low mortality in adult age. Instead, this may be regarded as a mirror of burial rites, which reflect a population's mentality of mortality, religious beliefs, family relationships and more. In addition, the state of health of the infant skeletons will allow interpretations of nutrition and health risks during early childhood in Troia.

Since the individual numbers for most of the settlement periods in Troia are below 10 (Fig. 2), focus will be on the Troia VI level only. More than 60 subadult burials are available, mostly stillbirths and death due to other circumstances of perinatal mortality, or infants within the first year of life. Compared to other Near-East Bronze Age populations, the number of infants in the first year of life is extremely high within the group of children who died up to the age of 10 years.

High survival rates were calculated from the early Bronze Age of the south-east Anatolian cemetery of Lidar Hüyük, the Early Dynastic Tell Ahmed al-Hattu graveyard in the Iraqi Hamrin basin, and the large Early Bronze Age population from the Black Sea Coast, Ikiztepe (Fig. 3). These three samples represent extramural cemetery populations, whose lack of infant burials is obvious.

The graph for the Demircihükük sample is composed of cemetery and settlement burials of children below the age of 12 years. This delivers a fairly good estimation of the overall infant mortality in the corresponding settlement, as measured against ethnographic comparisons and world standards of model life tables (United Nations 1955; Weiss 1973), in the range 40–60% survivors within the first years of life. The mortality

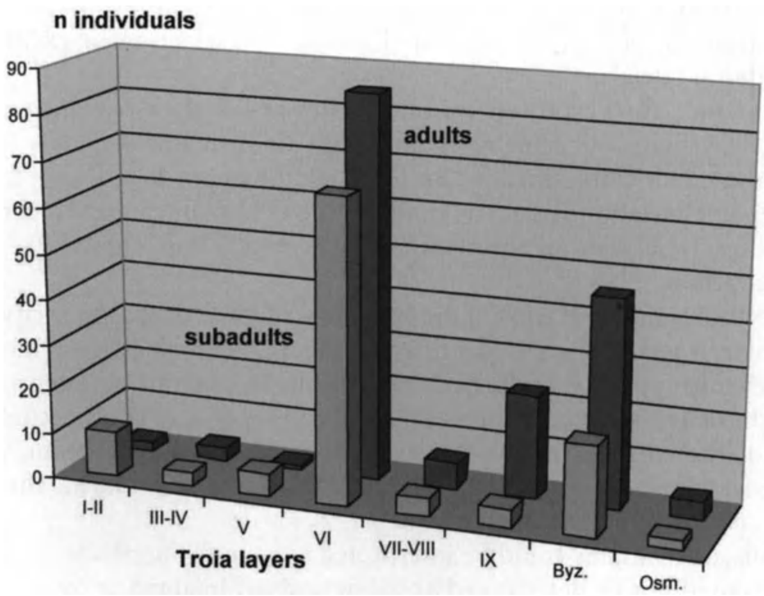

Fig. 2. Age at death distribution in the human remains from Troia and Beşik-Tepe

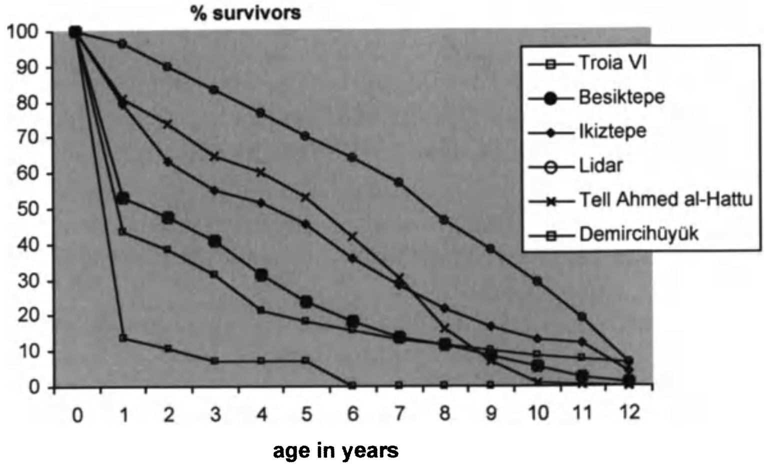

Fig. 3. Effects of burial rites on the "risk of death" parameter during early childhood in Near-East skeletal samples

pattern of high risk of death among the extramural Beşik-Tepe cemetery children will be discussed later. The graph suggests an extremely low survival rate for the Troia-VI children, if the age-specific relationship of burial number is representative, which cannot be assumed. In addition, such an extremely high infant mortality, as calculated, has not been observed in any case of modern population under unfavourable living conditions. This effect is simulated due to the selection of exclusively intramural burials.

Therefore, the graph reflects burial rites rather than realistic rates of survival. Whereas all cemetery populations simulate low mortality (Lidar, Tell Ahmed al-Hattu, Ikiztepe, Beşik-Tepe), the opposite is shown for the settlement burials of Troia. The combination of both intramural and cemetery burials, as seen in the Demircihüyük population, shows a realistic mean variant.

A burial complex in front of the citadel's wall towards the lower city, near the eastern gate is of particular interest (Fig. 4). It contained the remains of 16 skeletons: 3 premature births, 7 mature births, 5 infants between 3 and 9 months of age, and 1 child between 1 and 2 years of age. The age composition of the complex reveals the typical perinatal risks of death, which decreases during the weaning period and increases again during the transition period to normal food intake.

Thus, the complex could be interpreted as a small burial site. Causes of death could not be determined and diagnosis of infanticide could not be confirmed and seems unlikely due to the following reasons.

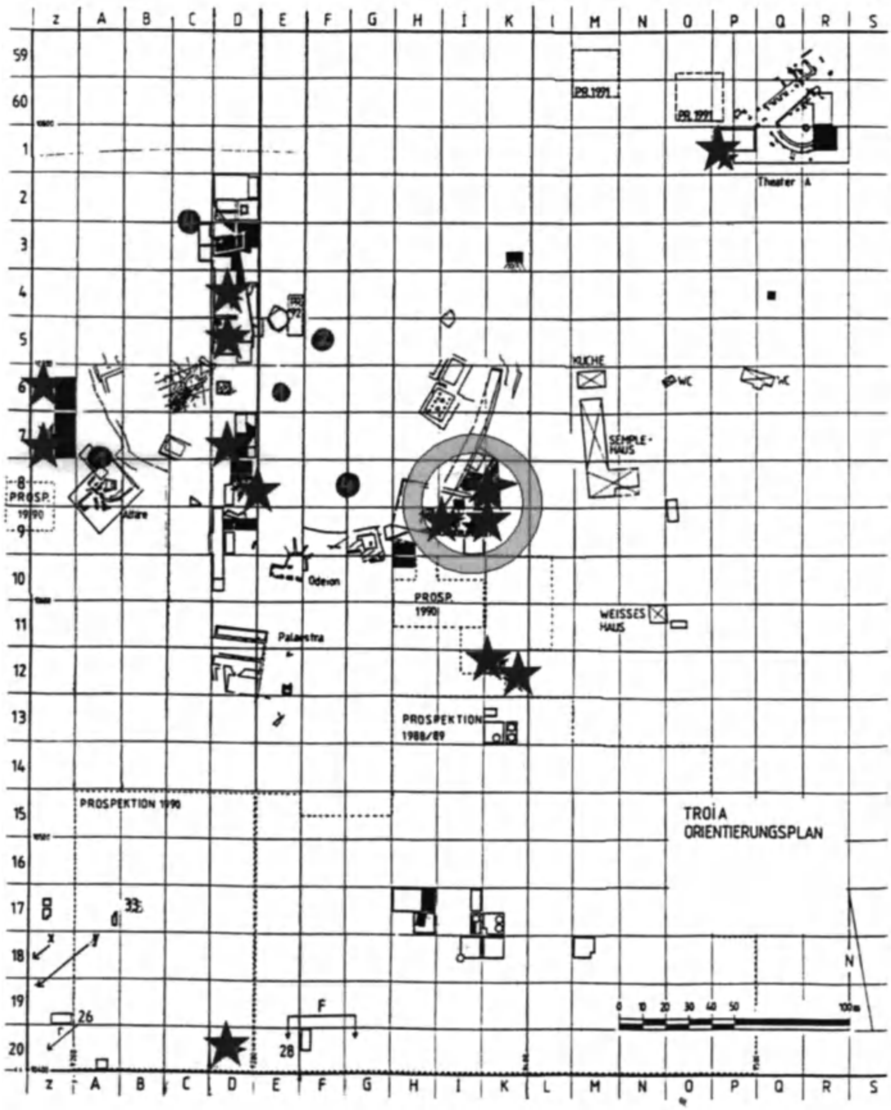

Fig. 4. Location of infant and child burials in Troia. The *circle* marks the burial complex of premature births and perinatal death in the Troia VI layer, *stars* indicate each location. (Kieserwetter, pers. comm.)

As seen throughout the world with other cases of reported infanticide, the infants' remains were concealed. Therefore, an exposed location, such as the Troia citadel wall, which is among the dense buildings where people walk and would remember an action like this, would not be an ideal location to place infanticide remains. In addition, the remains would not be carefully buried in graves, but instead, thrown away or left in an area where they would not be prone to being found.

A larger burial complex, consisting of 49 graves, was designated to the Late Byzantinian settlement of Troia (Kiesewetter 1999). In addition, it contains a significant number of 39 % subadults, whose age composition does not mirror a natural postnatal mortality. Again, it is not clear whether this part of the cemetery represents population selection.

6 The Beşik-Tepe Population

The Beşik-Tepe is the only skeletal sample out of the Troia plain that demonstrates a fairly good population group structure. Researchers hoped to gain information from this population, in order to infer reconstructions of living conditions of the Troia population. Although the original number of burials remains unknown due to severe soil erosion, approximately 100 individuals were recovered. The anthropological investigation of the skeletal material was devoted to reconstructing the type of settlement and population structure at the Beşik-Tepe, which was presumed to belong to the harbour function of the Beşik-Bay.

A highly stratified social society was indicated, which fits morphologically into the range of the Bronze Age Anatolian populations (Wittwer-Backofen et al. 2002). The balanced sex distribution and high number of subadults, especially infants, gave no sign of a specific function, such as a "pirate camp". Moreover, the social structure supports the archaeological suggestion of a population who partook in the trading and shipping of goods and guiding ships through the dangerous Dardanelles Passage.

Among the excavated remains, a relatively large number of young adult males were recovered. No traces of traumatic alterations or physical stress were observed on the bones, which might explain an increased risk of mortality at this young age. This may be an effect of the small sample size and/or soil erosion activity.

7 The Troia Plain – An Endemic Malaria Region?

The large number of subadults among the Troia settlement burials allowed us to focus on the same age group in the Beşik-Tepe cemetery population. Here as well, a large number of subadults may carefully suggest that both the Troia and the Beşik-Tepe material reflect a high infant and child mortality. Compared to other Anatolian Bronze Age populations this is a probable assessment (Fig. 5). Figure 5 shows the relation between child mortality and infant mortality as calculated from the cemetery populations and from a variety of data provided by the historical demography. For several methodological reasons, the historical data show higher mortality than the prehistoric samples.

In general, the graph shows a correlation in the risks of mortality according to age. With increasing mortality in the age-group 1–5 years, the weakest among the children, the infants below 1 year of age, were at a relatively higher risk of dying than the older age group. Within this constellation,

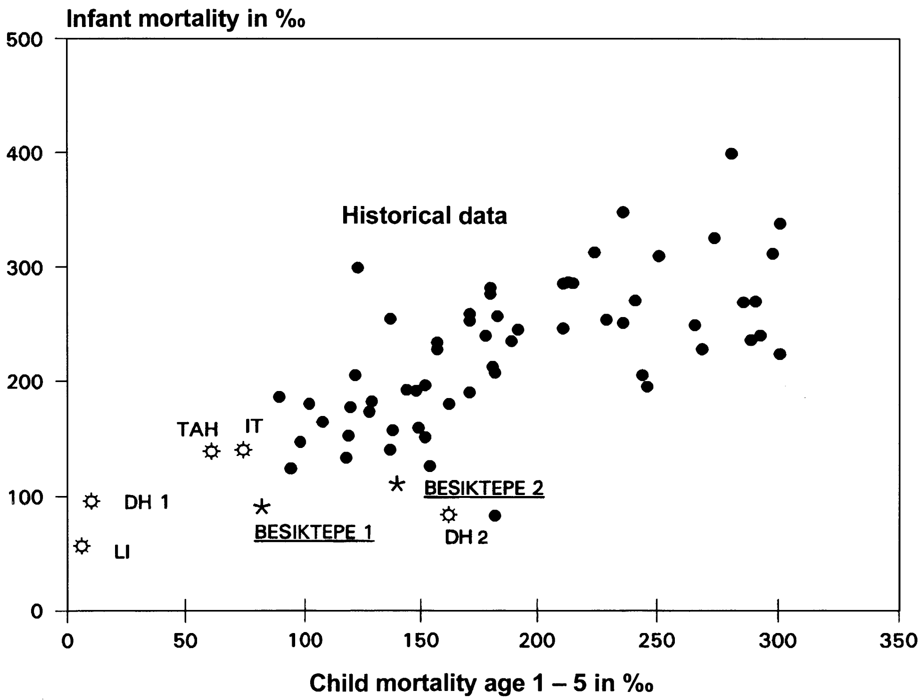

Fig. 5. Infant and child mortality rates in historical populations (*black dots*) and in Near-East Bronze Age populations. (Sources see Fig. 3)

however, the Beşik-Tepe children had a slightly increased risk in the older age group compared to other early Anatolian populations.

The palaeopathological investigation of these children showed almost no deficiency or chronic diseases among the children (Schultz and Schmidt-Schultz 1994), which could have led to death due to high morbidity. However, nutritional deficiencies can scarcely be expected, as the high agricultural, animal domestication (Uerpmann et al. 1992; von den Driesch 1999) and fishing activity (Uerpmann and van Neer 2000) produced a large variety of food which should have supplied the population with sufficient essential proteins, vitamins and trace elements.

This suggests that causes of death were relatively quick and had no time to affect the bones. For the children, this may include viral infections with high fever or other infectious diseases, which cause severe diarrhoea.

This might infer living conditions of the Troia plain. The Skamander mouth, between Troia and the Beşik-Tepe, was responsible for widespread marshes near the coastal line, which resulted in brackish water in the bays. This seems to be an ideal habitat for the malarial mosquito which, in turn, may have been responsible for the area being an endemic malaria region. This is supported by the fact that the inhabitants of Troia seem to have avoided entering the Skamander mouth area, as almost no traces of agricultural activities were found (Riehl 1999a), but only bird remains of the marshes and brackish coastal line (Krönneck 1996). As early as 1912, a climatic reconstruction described the lowland of Troia as marshy and flooded in winter and malarious in summer (Leaf 1912 after Riehl 1999b).

This would explain the presumably high child mortality and takes away some the glorification of the Troia myths through the time.

8 The Anthropological Perspective of Troia

It has been shown that the basis for anthropological research is extremely reduced and dependent on many small subsamples, which makes interpretation difficult. Nothing can demonstrate the problems of anthropologists dealing with palaeodemography better than glancing at the large Late Bronze Age settlement of Troia, with its densely populated lower city represented by a handful of bones. We can conclude from the archaeological data that the skeletons represent the remains of a local Anatolian population. The bad climatic conditions may be responsible for high morbidity of the population, leading to death among the children and weak adults.

It would be highly prudent to have at least a single population group of each Troia layer at our disposal to follow the settlement and population development chronologically. The reconstruction of living conditions, according to the ecological conditions, is one of the greatest endeavours of the anthropological research in Troia. However, even with the reduced states of preservation of skeletal material and cremated remains, which is expected for Troia skeletons according to the Hettite burial rites, our methods of analysis would help to contribute significantly to the reconstruction of living conditions in the ancient Troia plain.

Chapter 21

Some Open Questions About the Plain of Troia

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Abstract

After 130 years of archaeological excavations at Troia some questions regarding the site are open today as they were when Heinrich Schliemann's workers first set their spade to it. Such questions are, for instance: How was the plain optimised for human exploitation during the Late Bronze Age? Where were the ports of Troia? How far did the outskirts of the city extend into the plain? Reconstructions presented by the current excavation team of Troia suggest that the natural cove at Beşik Bay may have been the harbour and that the plain below the citadel was an inhospitable wasteland controlled by the floods of the Karamenderes River. However, complex hydraulic installations existed at many sites in Anatolia as early as the third millennium B.C. The mole at Limantepe shows that even during the Early Bronze Age ports were artificially optimised. In Syria and Palestine, man-made ports were common place during the second millennium B.C. Many prominent Late Bronze Age hydraulic installations are known from Greece. At Troia, too, wherever scientists looked, human interference with the hydraulic system was discovered: The artificial spring caves below the citadel and the two sizeable artificial cuts through the Yeniköy ridge are the best known examples. What is more, when Troia's significance faded during the Early Iron Age, the city of Alexandria Troas further south in the Troad with its artificial ports became the regional trading centre. Considering the high level of hydraulic engineering skills available during the Late Bronze Age, it is likely that the floodplain below the citadel of Troia was optimised for agriculture and naval traffic. No systematic investigation involving hydro-engineers and port experts has ever been conducted to develop a technical reconstruction of what the plain may have looked like. Thus, we suggested in 1999 to conduct in collaboration with the Troia excavation team a total-coverage helicopter-geophysics survey using ground-penetrating techniques to investigate the subsurface of the Troian plain. Alas, the excavation team rejected a collaboration and the Turkish Ministry of Culture never granted the permission.

1 Introduction

First the good news: I left science 2 years ago and changed fields completely. All my records and notes are either hidden or gone, and I have no intention whatsoever of returning to geoarchaeology. Instead of continuing to look back at the past, I decided to turn in a different direction. I am now engaged in strategic public relations for technology and research companies and operating my own agency in Zurich.

I very much welcome this opportunity to speak to the members of the Troia project directly. However, I am afraid that this opportunity comes years too late to be used in any constructive way. And to be honest, as the first step in communications between us, I would have preferred a more intimate meeting.

My talk today is entitled: "Some Open Questions About the Plain of Troia". I will state these questions at the end of my talk. Please allow me first to tell you how these questions arose and then to describe how I would address them. Using this approach, I believe it would be best to present my arguments in chronological order.

2 Mycenaean Hydraulic Engineering

I first entered the field of geoarchaeology about 20 years ago. One of my earliest projects is very well published. It was an investigation of the Argive Plain on the Peloponnese in southern Greece conducted between 1984 and 1988. The German Archaeological Institute later published this as a monograph (Zangger 1993). The study is well known – here, I just want to focus on the developments of the arguments regarding hydraulic engineering.

We now know that the Mycenaeans were great hydraulic engineers. Much knowledge about their engineering feats was gained during the past 20 years through the research of Jost Knauss from Munich Technical University (Knauss 2001). Knauss, for instance, described a dam below Mycenae, which was assumed to have been a Mycenaean bridge. Knauss, however, concluded that it was actually a dam built to create a water reservoir. He also investigated the drainage of Lake Kopais and concluded that a canal that was able to drain 700 million m^3 of water every year was dug there. This system functioned for a few hundred years during the Mycenaean period.

In my own research, I came across the Late Bronze Age redirection of a stream near the citadel of Tiryns (Zangger 1993). During the Late Bronze Age, a stream passed by the citadel, and in one instance, this stream flooded much of the lower town of Tiryns, burying parts of it up to 5 m deep under mud. To prevent this kind of flooding, the Mycenaeans at Tiryns built a dam and redirected the entire stream through a 1.5-km-long canal. The dam is about 100 m wide, 10 m high and 40 m wide – a construction of considerable size. Similarly impressive hydraulic installations have been detected at a number of other major Mycenaean sites (Knauss 2001).

3
The Pylos Regional Archaeological Project

During the 1990s, we took the methodology of geoarchaeological landscape reconstruction a step further (Zangger et al. 1997a). Now, I would like to show you the insights that were gained during the course of the interdisciplinary surface survey of the landscape around the Palace of Nestor in Pylos, a project conducted by the University of Cincinnati under the direction of Jack L. Davis. John C. Kraft and George Rapp, who are present here today, had investigated the area before (Kraft et al. 1980b). By paying great attention to detail, they were able to discover that the Selas stream that passes west of the palace follows what does not seem to be an entirely natural path. The stream used to feed the extensive floodplain at the northern end of the Gulf of Navarino during the Holocene. Today, however, the Selas River, being the largest stream in the entire region, no longer exits into the Gulf of Navarino, but instead passes over a small ridge and exits directly into the Ionian Sea. Kraft and Rapp interpreted this diversion as another Mycenaean engineering feat undertaken to prevent the coastal plain from flooding. Thus, according to them, the redirection was human-induced and most likely put in place during the Late Bronze Age.

During our research, we gathered evidence that supports this interpretation: a topographic cross section of the northern section of the floodplain between the Palace of Nestor and the Osmanaga Lagoon shows the old stream path during the early Holocene, when the river was feeding the floodplain. It also shows that the present stream is actually passing over a ridge consisting of extremely consolidated conglomerate – the hardest stone in the entire area. It looks as though the stream was forced to go right through the top of a conglomerate knoll. Such a river path can only be artificial. One can actually still today recognise the artificial canal. It is about 10 m deep and has almost perpendicular walls. Hence, people did indeed interfere with the landscape, and they clearly did so to adapt the landscape to their needs. The question is, why precisely did they want the stream to follow this new path?

When I visited the Pylos area in 1991 for the first time, I had just been to Troia a few days earlier. I went to Troia to look at a certain phenomenon in the landscape, and then at Pylos I discovered the same phenomenon: it is an alluvial plain representing a sedimentological environment that is different from its surroundings. At Pylos, I noticed a rectangular floodplain that does not seem to be completely natural. This rectangular plain lies right in the path of the redirected river near the Kokevis estate. I hypothesised that this basin was artificially made, and that it most likely represents a human-made port that is now silted up. I also assumed that the stream diversion must be somehow related to the basin.

The obvious thing to do was to drill into the plain to determine the subsurface stratigraphy. We did so and found marine clay at the bottom of the Holocene sequence, covered by coarse gravel and floodplain alluvium. Hence, the basin must have been artificial, because there is no reason for a marine pool to form in the middle of the landscape. We were able to date those deposits quite accurately to the fourteenth and thirteenth century B.C. (Zangger et al. 1997a). Since there is no need for a water reservoir so close to the coast, the only conceivable function of the basin is that it served as a port.

Continuing the inquiry at this stage required the consultation of experts on hydraulic engineering. We therefore invited Jost Knauss, the renowned expert on Mycenaean hydraulic engineering, to join the project. Not long after he set foot on our study area, Jost Knauss discovered yet another basin upstream from the first one. This second basin, now silted-up, of course, is more irregular in shape. It is connected with the proposed port through the artificial canal adjacent to the Kokevis estate.

As it turns out, it would have been pointless to excavate a cothon-type port by itself, because the long shore current would silt up the entrance to it very quickly. The engineers who constructed the port had to think about ways to prevent the sediment from entering the basin. To keep the basin sediment-free, they constructed a clean-water flushing mechanism. The clean water had to be derived from rivers, of course. Rivers, however, also contain sediment. Directing a river into an artificial basin means that the basin will also fill up over time. That is why a second basin was needed further upstream. The second basin was built by simply blocking the river with a dam. The stream entering this basin lost its energy and thus dropped its sediment load, so that the water at the surface of the lake was clean and sediment-free. This clean water was then diverted into the actual port basin through the artificial canal which is prominently visible even today. In this way, the port basin was always filled with freshwater and kept sediment-free. The freshwater ran out towards the sea and prevented marine water (and sediment) from entering the port.

This solution shows how sophisticated hydraulic engineering was during the Late Bronze Age. From constructions in Egypt, we know of the Birket Habu port basin even 20 times larger which was built under pharaoh

Amenhotep III. during the fourteenth century B.C. in western Thebes in Egypt, where a 1.5-km-long and 1-km-wide basin was created west of the Nile that is still recognisable in the landscape. I believe that we have considerably underestimated the engineering skills of the Late Bronze Age.

The Pylos project with its rigorous interdisciplinary – rather than simply multidisciplinary – approach was, in terms of methodology, a significant step forward from the geoarchaeological research in the Argolid. The scientists participating in the project at Pylos combined their reports in one paper to form a holistic reconstruction of the environment. However, the Pylos Regional Archaeological Project was conceived over 10 years ago. Today, we are able to conduct landscape reconstructions using a much more advanced methodology. Therefore, I suggested about 2 years ago to take the approach to geoarchaeological landscape reconstruction yet another step further – and I suggested to use the plain of Troia as a target for such a state-of-the-art investigation (Zangger et al. 1997b, 1998).

4
Traces of Hydraulic Installations at Troia

My interest in Troia focuses on the wetlands along the eastern side of the Yeniköy ridge running parallel to the coast. I first visited Troia in 1991 and was led over the site by its excavator Manfred Korfmann. Studies of topographic maps had indicated to me traces of silted up hydraulic installations similar to the ones I just described. In order to recognise these traces, one has to see the landscape with the eyes of an engineer who wanted to optimise it some 3000 years ago. Today, after thousands of years of ploughing, we are still able to see the handwriting of these engineers in the landscape, in particular, on the landward side of the coastal ridge. As I said earlier, just before I discovered the basin at Pylos, I saw a similar depression at Troia in the form of the Lisgar marsh. This basin is surrounded by unnaturally steeply sloping hills forming some fossil cliffs. I first saw this plain in the month of May and it was very dry. Later, I visited the area several times including once in February 1999 when the landscape was much wetter. As it turns out, the Lisgar marsh is actually under water during the winter – and, especially from the air, one can then see that it is not an entirely natural formation.

There are, however, other major indications of human interference with the landscape at Troia. In fact, I cannot think of any other Bronze Age site where we have so many indications for human-made landscape changes as we do at Troia. One of them is an impressive artificial cut through the coastal ridge connecting the Lisgar marsh with the beach at the Aegean Sea. In the winter the lake forming on the Lisgar marsh protrudes into this artificial cut. Hence, the cut is clearly related to the basin.

The basin is about 800 m wide. The canal forms a straight line, 500 m long, 50 m wide and about 30 m deep. This canal has been interpreted by members of the Troia project as an unfinished construction, as an irrigation channel, as a drainage channel, as a tectonic fault, as the result of some accidental trafficking of pedestrians walking from the plain to the beach and as a play of nature. After I announced my first theories about the function of the canal, it was investigated by Ilhan Kayan who through drillings determined that the bottom of the cut never reached sea level – in fact, it is up to 11 m above sea level (Kayan 1995).

In my opinion, the Kesik cut could well represent a slipway for ships. Before the canal at Corinth existed, ships were dragged along a track over a distance of 12 km – the cut at Troia is only 500 m long (Werner 1993). Accordingly, the whole basin on the landward side of the cut would have been used in a way similar to that of the port at Pylos. At Troia, too, there is a second basin, much bigger and more irregular than the first one.

What is more, there are two canals at Troia. In addition to the cut at Kesik, there is another canal further south. The two canals differ very much in shape and size. The southern one is much longer, very deep and very narrow. This one was clearly used to divert water – everybody agrees on that. The Kesik cut, however was not built to transport water. Its purpose was clearly to allow the transport of very large goods – goods the size of entire ships – to pass from the coast to the inner plain. All these components could have been combined to produce a clean water flushed port, precisely as we found it at Pylos. In this case, the water of the Karamenderes River would have been directed into the lake on the landward side of Beşik Tepe. Clean water from the lake would have been directed northward into the artificial port to flush it and keep it sediment free. The actual port entrance was at the northern end of the coastal plain at the Dardanelles. One of the major advantages of keeping the ships in a freshwater port basin is that algae and worms are expelled from the wooden hulls. In addition, the basin at Kesik presented an extremely protected port that would have been protected from winds and enemy attack.

We know that the ships at Troia would have had to wait for favourable sailing conditions if they wanted to continue their voyage upstream through the Dardanelles. The artificial entrance to the port through the Kesik cut is actually redundant and not needed to make the hydraulic system work, but it offers a number of additional advantages. The most important one is related to the current conditions in the Dardanelles. Ships sailing towards the mouth of the Dardanelles face an extremely strong current that is equally fast on all sides of the straits. A counter current picks up on the southern side of the straits approximately in the middle of the coastal plain at Troia. Thus, by dragging the ships into the basin at Kesik, they were able to enter first the freshwater current flooding the basin and taking them to the Dardanelles and then – at the Dardanelles – the countercurrent taking them upstream like an escalator. Additionally, the Kesik cut made it possible to circumvent a siege of the Dardanelles. Or the port could have been used to separate eastbound trade from westbound trade.

As I said before, this technical reconstruction of the harbour system at Troia is only a working hypothesis, but one that fits the pattern of hydraulic engineering during the Bronze Age. In order to prove or disprove these ideas, we suggested a few years ago that this landscape should be investigated in a broader fashion (Zangger et al. 1997b, 1998). I proposed to conduct a helicopter geophysics study which would have the advantage of covering the entire area of the coastal plain at Troia in about 2 months of fieldwork. In return, we would obtain subsurface information reaching to a depth of about 150 m – evidently, much further than needed. The helicopter of the "BGR" was made available for this investigation. The state-of-the-art system on board comprises a bird dragged by the helicopter holding electrotransmitters and receivers working at five different wavelengths. The electromagnetic signal produced by these transmitters creates a signal in the ground which is then measured by the receivers. Computer modelling allows the combination of the sequences of layers produced by the different transmitters. By using five different wavelengths and penetration depths, the system provides a very high resolution from the uppermost layers all the way down to 150 m. This method would be the ideal way to determine the subsurface shape of the basin and canals at Troia. These data can then be shown in maps, cross-sections and three-dimensional subsurface models.

This project, which I proposed in 1999, was never carried out because the Turkish ministry of culture did not grant permission.

5 The Open Questions

My talk bears the title "Some open questions about the plain of Troia" and I said earlier that I will name these questions at the conclusion of my presentation. In my opinion, the questions about the plain of Troia that remain open are:

1. How was the plain optimised for human exploitation during the Late Bronze Age? The artistic reconstructions we have seen come from the Troia project in which the whole area outside the citadel consists of wastelands and swamps do not seem credible in the light of our knowledge about Late Bronze Age landscape management systems.
2. Where were the ports of Troia? We have been looking for them for over 130 years. Eventually, somebody will film the water-filled Lisgar marsh

during the wet winter months from the air to demonstrate how obviously man-made it is.

3. How far did the outskirts of the city extend into the plain? Since 1988, we have seen how the known parts of the city were extended during almost every excavation season to the extent that they are now about thirty times larger than at the beginning of the current excavation campaign. However, we still do not know how far the city stretched.

6 Conclusion

What I have presented here today – the hydraulic engineering feats of the Late Bronze Age civilisations – has received surprisingly little attention in the scholarly community. Although some of these reconstructions should still be regarded as working hypotheses, there is no doubt that a sophisticated understanding of hydraulic engineering existed during the second millennium B.C. The 1.5 × 1 km large port in ancient Thebes, and the complex nautical installations that we know from Palestine (Raban 1997), as well as the Mycenaean drainage systems, speak for themselves. I believe that an enhanced research of these constructions would significantly boost our knowledge of the Late Bronze Age societies, perhaps even more then the investigation of yet another basket full of pot shards.

During the past 10 years, I have contacted many of the people in the audience, and offered them an open discussion or even collaboration on these issues. I wrote letters, sent faxes, made telephone calls. I visited some of you to propose cooperation. None of my requests ever received a positive response. My letters were not answered.

This setup here today is, in my opinion, not the right way to embark on a fruitful discussion. Thus, I have decided that for the first time, I will not answer questions. Those who are interested in talking to me will find my address on the list of participants. You are perfectly welcome to contact me at any time. I thank you for your willingness to finally listen to me and wish you best of luck with your future inquiries. Good bye.

The Geophysical Mapping of the Lower City of Troia/Ilion

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Abstract

The citadel of Troia had supplementary dwellings on the plateau to the south and southwest, the so-called Lower City. The investigations at Troia since 1988 integrate geophysical prospecting and subsequent archaeological trial trenches in order to reveal the remains in that area. During the field seasons up to 2000, more than 40 ha have been mapped mainly by magnetometry performed by different institutions with various instruments. The most prominent large-scale features are a Bronze Age ditch system (Troia VI) surrounding the plateau and Troia VIII/IX structures consisting of a part of the Hellenistic city wall of Ilion and the Roman street system with remains of the insulae. Yet unexplained features extend into the alluvial plain west of the Lower City.

The first excavators at Troia (H. Schliemann, W. Dörpfeld and later C.W. Blegen) were convinced that the most prominent architectural periods of late Bronze Age (Troia VI/VII) and Hellenistic/Roman Ilion (Troia VIII/IX) uncovered in the citadel of Troia must have had supplementary dwellings beyond the central walls. To them, as well as to the modern visitor, the natural candidate for such a lower settlement or lower city would be the plateau to the south and southwest of the citadel (Fig. 1). This area also shows numerous surface finds like sherds or building blocks unearthed by agricultural processes.

As a consequence, in the previous excavation campaigns by Schliemann, Dörpfeld, and Blegen, numerous, but unfortunately not well-documented, search trenches were excavated (orientation sketch, Fig. 2), which confirmed the surface observations, but fell by far short of a concise idea of architecture and a settlement structure.

For the new series of excavations started in 1988, a systematic investigation of this area was therefore an important objective. Prior to starting more trial trenches modern prospecting techniques should be applied. Since only a few settlement phases were expected in the target area, geophysical prospecting seemed to be promising. In a settlement with multi-

Fig. 1. Troia – citadel and southern plateau. Aerial photo 1988

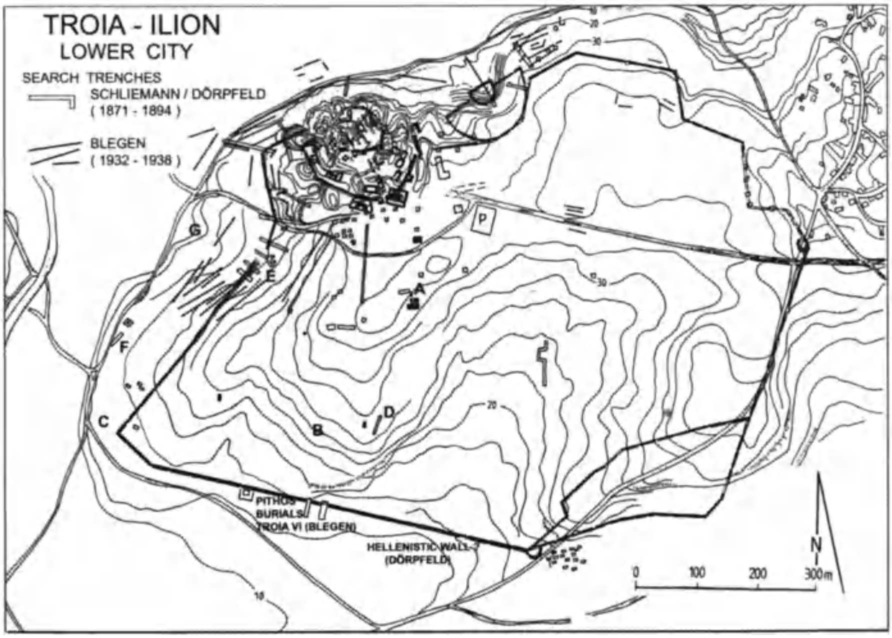

Fig. 2. Orientation sketch of the lower settlement region with location of the search trenches by Schliemann, Dörpfeld and Blegen. *A–G* refer to areas of investigation mentioned in the text

ple phases, as in the citadel, the differentiation of the various layers in the two-dimensional data would have been very difficult. It was expected that soil conditions would permit the application of the magnetic method, i.e. mapping of the magnetic field of the earth with a sensitive magnetometer. This method is usually the preferred choice for prospecting large areas because one can measure "on the fly" while walking over the area in a regular grid. In contrast, D.C. resistivity soundings are time-consuming, due to the insertion of probes into the soil at each point of measurement and thus are less efficient. Early tests showed that at Troia the iron oxide (magnetite) content of the topsoil provides a high contrast in magnetic susceptibility compared to the native limestone rock or to the walls built from limestone blocks. This contrast is an indication for the application of magnetics.

In each of the 13 campaigns from 1988 to 2000, considerable effort was made to realize the ultimate aim of providing a complete geophysical image of the potential settlement area, which is more than 0.5 km^2. Rather than prospecting the total selected area in a short time, it was decided to operate in a sequential manner: after prospecting a few hectares a small, but apparently significant, area was selected and a small trial trench was opened by the archaeologists to verify the preliminary interpretation of the magnetogram. By this method the subsequent interpretations became increasingly certain and the possibility was provided of switching to different methods or prospecting equipment if the results suggested it. The annual results of earlier prospecting work have been published in Studia Troica (Jansen 1992; Becker et al. 1993; Becker and Jansen 1994; Korfmann 1995; Jansen et al. 1998; Blindow et al 2000).

The procedure explained above started with a small trench in 1988 in the area marked A in Fig. 2 and in the interpretation map (see Fig. 16). The trench (Fig. 3) revealed stone foundations of Roman houses (Troia IX) which reached clearly into Bronze Age Troia VI strata. The area around the trench was prospected with a flux gate gradiometer[1] (GEOSCAN-FM36, Fig. 4). The resulting magnetogram (Fig. 5, dynamics −10 nT/white to +10 nT/black) shows negative anomalies due to adjacent wall structures and a strong and extended positive anomaly. The area was subsequently excavated in order to identify the origin of the positive anomaly. It was identified to be due to a fairly deep ditch with a lining of Roman concrete[2] filled with cultural soil of enhanced magnetic susceptibility. The ditch ran

[1] This instrument was chosen as a compromise between cost, ease of handling, and sensitivity from the instruments then available.

[2] That is, "Opus Caementitium".

Fig. 3. First trial trench outside the citadel in area A, 1988. View from the north

Fig. 4. Magnetic prospecting near the agora of Troia with the fluxgate gradiometer. (H.G. Jansen 1988)

parallel to the almost intact pavement of a 5-m-wide Roman street (Fig. 6). Its interpretation as a sewer seems appropriate.

In the subsequent explorations covering an area of several hectares, a clear orthogonal and almost equidistant system of these positive anomalies was revealed which thus became the characteristic feature identifying the Roman/Hellenistic street system of Ilion. In some areas, the streets are additionally lined by the negative anomalies of stone walled houses fitting into this insular system.

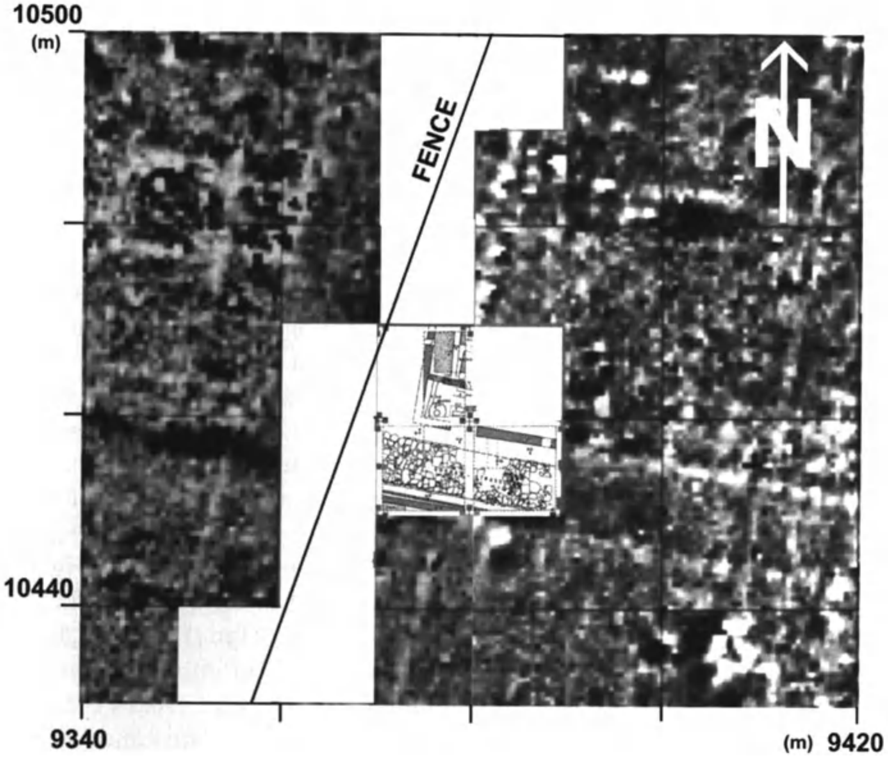

Fig. 5. Magnetogram produced with a fluxgate gradiometer in area A, 1988/1989. Gridlines correspond to the 20-m measurement grid, numbers to the excavation coordinates in meters. For orientation a drawing of the trial trench (Fig. 3) and the subsequent verification trench (Fig. 6) are inserted

Fig. 6. Verification trench based on magnetogram (Fig. 5) showing Roman street lined by a sewage canal, 1989

A second objective of the exploration was to find indications of Late Bronze Age (Troia VI) settlement features as well as fortifications around the settlement area which were assumed to consist of brick walls. The strong anomalies from the near-surface Roman structures unfortunately tend to conceal the weaker anomalies produced by Troia VI structures at a depth of 2–3 m. Even in areas with less Roman remains the fluxgate instrument, however, was not sensitive enough to provide a significant signal level. While exploration with the fluxgate gradiometer was continued in the eastern sections of Roman Ilion, where no Troia VI strata were anticipated, the project was able to obtain the assistance of Helmut Becker from the Bayerisches Landesamt für Denkmalpflege in Munich with his more sensitive cesium absorption magnetometers (Varian-Scintrex V 101, Fig. 7, and Picodas CS2/MEP720) to search for Troia VI. He and his coworkers produced beautiful magnetograms in three short measurement campaigns (1992–1994). However, no clear-cut settlement patterns of the Troia VI-level were found. Only to the south of the plateau area (marked B in Figs. 2 and 16) was a fairly wide and irregular positive anomaly detected (Fig. 8), which was first thought to originate from a burnt brick wall structure. A couple of archaeological test trenches (Jablonka et al. 1994) revealed, however, a ditch of 2–3 m width and about 1.5 m depth cut into the limestone bedrock (Fig. 9) and subsequently refilled by erosion with Troia VI material and high susceptibility soil from the surface, a circumstance which leads to a similar signal behavior as a brick wall. An interruption of the ditch anomaly in the magnetogram was interpreted as a ca. 10-m-wide gate which could subsequently be verified by excavation (Jablonka 1996). The ditch structure was well suited to serve as an obstacle for the single-axle chariots used in Bronze Age warfare. It has been postulated that the actual defense wall of the lower city of Troia VI was originally constructed at some distance towards the interior. This wall, however, has left no visible traces.

The identification of the irregular anomaly as due to a ditch then became the major indicator for the subsequent and successful explorations that searched for this apparent boundary of the lower city of Troia VI. It could be traced for a length of about 300 m in the south of the plateau. At both ends of its east–west orientation, however, we lost track of the ditch, which was expected to turn in a northerly direction to eventually connect to the walls of the citadel. In the southwesternmost corner of the prospected area we were able to locate a short section of a second outer ditch (marked C in Figs. 2 and 16), which was identified by a subsequent test dig as superposition of a Roman ditch cut into the fill of another Bronze Age Troia VI ditch. This second ditch may have delineated an extension of the Troia VI settlement area. The Roman structure seems to connect to a system of ditches

Fig. 7. Magnetic prospecting with a cesium magnetometer (Scintrex, one mobile sensor) in the south of the plateau (area B, H. Becker 1993)

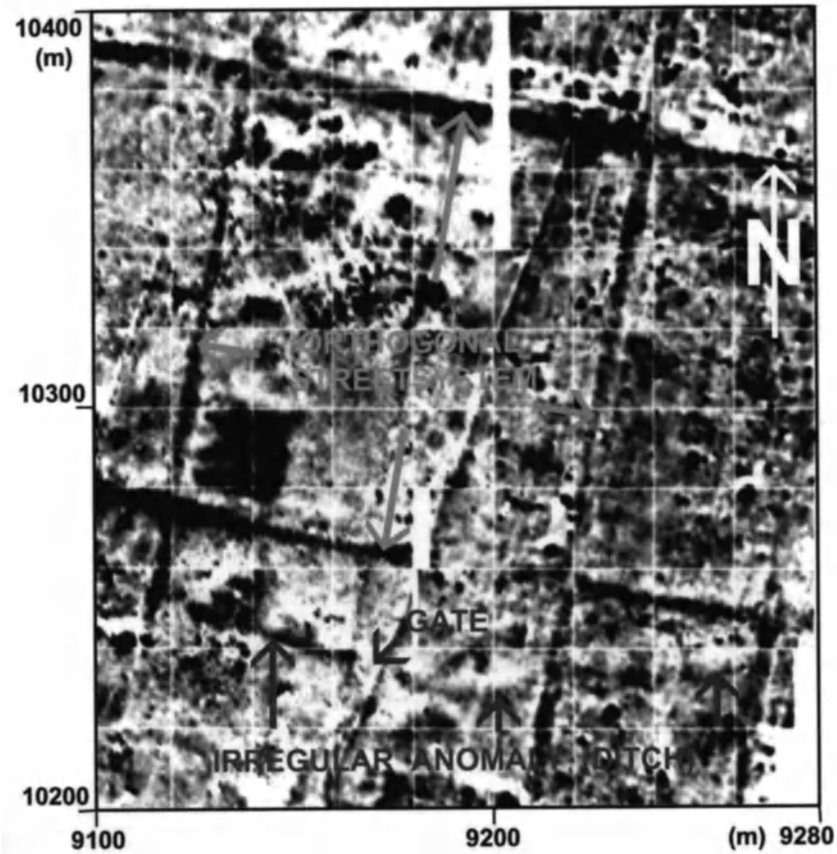

Fig. 8. Magnetogram produced with a cesium magnetometer showing the Roman insular street system and the irregular positive anomaly of Troia VI ditch (area B, 1993, extract)

Fig. 9. Trial trench to investigate the irregular anomaly representing the Troia VI ditch, 1993

which we were able to identify as potential sewage lines for the Roman settlement leading into the river plain.

An unsuccessful attempt was made in 1997 to use a ground-penetrating radar device to continue the search for the Troia VI ditches in the southeast as well as in the southwest, where the area is covered with several meters of colluvial layers eroded from the slopes of the plateau (Jansen et al. 1998).

From 1998 to 2000 support from the Institute of Geophysics of the University of Münster was offered to the second author and his students who adapted a number of geophysical instruments for archaeological field use. Their investigations were mainly directed to detect the continuation of the Bronze Age rock-cut ditches. Prospecting is not treated as a pure archaeometric service by the Münster team; the work should first of all help to improve measurement methods as well as train students in near-surface geophysics. As a consequence, a master's thesis resulted from this activity (Schröer 2000). Part of the work has been published in Studia Troica (Blindow et al. 2000); additional results are presented in this paper.

The Münster team used a cesium magnetometer (Geometrics G-858), which consists of two sensors in variable positions (usually in a vertical array, the bottom sensor ca. 0.4 m above ground, the top sensor at 1.4 m), a console with electronic control and data storage, and the power supply. The commercial system has been modified to allow ergonomic handling (Fig. 10). A third, fixed sensor (proton magnetometer G-856 seen in the background of Fig. 10) provides an independent time series of the natural (diurnal) variation of the earth's magnetic field needed to correct the absolute values measured by the mobile sensors. The combination of these three sensors allows the display and interpretation of the data either as anomalies from the bottom sensor or from the top sensor, or as a gradiometer measurement with a 1-m gradient.

Fig. 10. Magnetic prospecting with a cesium magnetometer (Geometrics, two mobile sensors, third stationary sensor seen in background) west of the citadel. (N. Blindow 1999)

Figure 11 shows a realistic model of the Bronze Age ditch together with scattered surface irregularities caused by the present agriculture. The total field signals of the two sensors are much larger than the signal of a fluxgate gradiometer. The difference between top and bottom provides the same characteristic as the flux gate and can be used for a joint display of both instruments. In practical application the gradient gives just a weak indication of the ditch, which is affected by some small-scale surface features. The top sensor clearly indicates the course of the ditch and suppresses most of the small features. The bottom sensor is a compromise between both and has been used predominantly for the display of magnetograms.

In addition, an electromagnetic (EM) device (Geonics EM 31) was tested. The measurement principle of this instrument is shown in Fig. 12. The EM method uses a coil which generates an alternating magnetic field. The electrical currents induced in the conductive subsurface generate a secondary magnetic field which is a measure of integrated resistivity. There is no need for electrodes and penetration reaches down to 5 m at the expense of spatial resolution.

Using the Geometrics magnetometer to follow the Bronze Age ditch in the southeast (marked D in Figs. 2 and 16) resulted in an additional 50 m in an easterly direction. Beyond that point the signal is lost due to a lot of

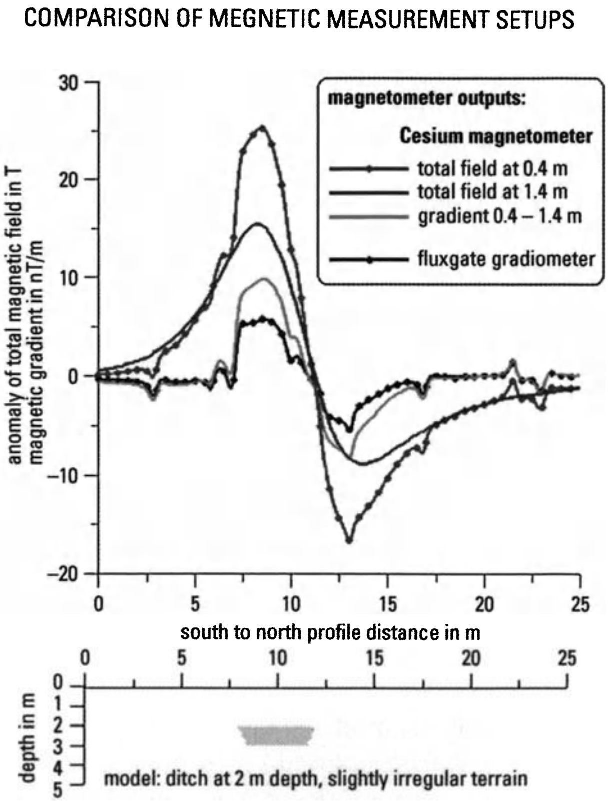

Fig. 11. Calculated anomalies of the total field and the gradients on profiles perpendicular to a buried ditch on slightly irregular terrain (program: Geomodel (c) G.R.J. Cooper 1992)

strong scattered anomalies. EM prospecting, however, reveals a possible continuation of the ditch which seems to be bending towards the northeast (Fig. 13). This is a first pass interpretation of a fairly wide minimum of resistivity, which would have to be verified by a test trench.

EM prospecting was also successfully employed for tracing about 60 m of an artificial step of about 1 m height in the limestone bedrock (Blindow et al. 2000) west of the entrance of an extended cave. The man-made cave is presently being thoroughly investigated as an important Bronze Age system for collecting fresh water (Korfmann 2000, area E in Figs. 2 and 16). The parameters and the interpretation of the EM tracking were verified by D.C. geoelectric soundings. These also provided a physical explanation why the previous ground-penetrating radar measurements were unsuccessful: the surprisingly high conductivity of some of the limestone strata leads to considerable absorption and dispersion of the high frequency signals.

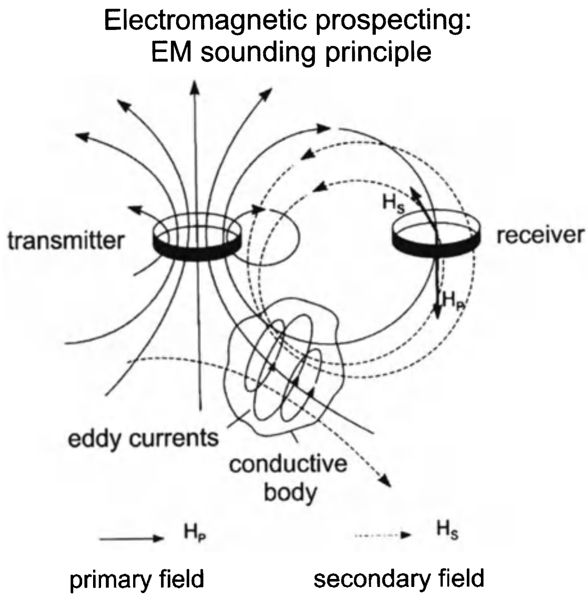

Fig. 12. Principle of electromagnetic measurement (Geonics)

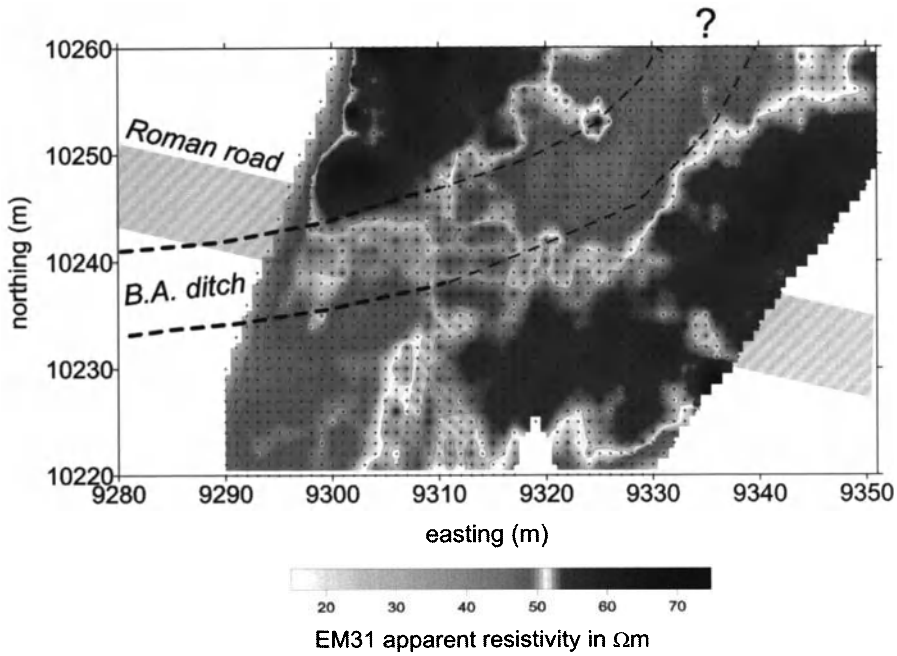

Fig. 13. Search for continuation of Troia VI ditch in the southeast of the plateau (area D), probable bend obtained by EM, 1999

The second area investigated by the Münster team is the western edge of the lower city (designated F in the maps). The magnetic survey covers the complete western hillside bounded by a field road – in three areas the survey was continued into the alluvial plain. The anomaly patterns can best be followed in the combined view of Fig. 15. As already reported (Blindow et al. 2000), a first interpretation of the positive anomalies in the southwest indicates that the outer Troia VI-ditch turns around in a northerly direction and combines with the inner ditch in a complex fashion. A trial trench in summer 2000, however, did not entirely confirm this interpretation: the presence of a superimposed system of Roman and/or Byzantine ditches complicates the situation which might only be clarified by a large-scale excavation. In addition, the area surveyed close by in the alluvial plain also provides a complex pattern of anomalies: the magnetogram shows positive anomalies, which might be ditches of Roman time continuing for about 70 m. In addition, there is a set of lineaments which is as yet unexplained and which will be further investigated.

Further to the north an extended and pronounced negative anomaly running north–south is visible in the magnetogram. It can be followed across a number of field boundaries and is obviously not connected with agriculture in a specific field. A trial trench (Fig. 16, G) revealed the remains of the Hellenistic city wall (Fig. 14). This is the first time the city wall, supposedly built by Lysimachos, has actually been found outside the immediate neighborhood of the citadel wall. Its location was postulated by Dörpfeld and successors on the embankment running north–south about 100 m to the east, but was never found by excavation. The wall actually consists of two foundations running parallel. Only a few courses of stones are still in place, the others have been stolen. The course of the wall can be followed on the magnetogram for about 400 m.

Fig. 14. Trial trench to investigate the negative anomaly in the west of the cave (area G) showing stone blocks of Hellenistic city wall, 2000

The trial trench (G) also revealed that 5 m to the east of the Hellenistic wall the Troia VI ditch was cut into the limestone with the same proportions as in the south. The corresponding magnetic anomaly is rather weak and at a first glance did not seem to demand attention. The evidence of this piece of ditch is important as it is the missing link in the hypothesized location of the ditch and its overall function as a deterring defense structure around the lower city of Troia VI. Assuming the ditch as the outer boundary of the lower city of Troia VI (apparently connecting to the citadel), previous estimates of a total area of about 20 ha for the Troia VI settlement appear fully justified.

Measurements in this area closer to the citadel were again extended into the alluvial plain. The magnetograms show interesting features like an indication of the former bed of the Simoeis River, confirming Ilhan Kayan's drill core analysis (Kayan 1996) and a strong anomaly tentatively called "Roman road".

In the combined view (Fig. 15), a summary of the data collected in the geophysical campaigns is presented. The total area measured with the various instruments exceeds 40 ha and covers roughly half of the city area of Roman Ilion including the more densely populated parts of the town. Except for the first studies the measurement data were obtained at intervals of 0.25 m with a traverse spacing of 0.5 m. Thus the visualization is based on more than 3,000,000 readings. The difference in contrast and quality of the various parts of the magnetogram is due to the different data processing schemes for the different instruments used and the fact that H. Becker's original data are not available – they had to be inserted from analog data published in Studia Troica. The magnetograms are displayed with a 256 gray scale, dark areas represent positive anomalies caused by structures like ditches, pits or furnaces, bright areas represent negative anomalies as from limestone walls. The total magnetogram is superimposed on a high-resolution satellite image generated by the IKONOS satellite from a 680-km orbit obtained in summer 2000 (courtesy of NASA and Space Imaging Inc., the owners of IKONOS).

Figure 16 shows the interpretation of the main structures, which was achieved by the sequence of prospecting and selected excavations described above. In summary, we can state that this interdisciplinary cooperation and combination of results have provided us with fairly good knowledge of the extent of the Troia VI settlement – although we have not detected clear traces of houses because the building material in that area was either reused in the later Hellenistic/Roman settlement or was perishable – as well as a city map of Roman Ilion. The size of the Roman insulae is roughly 100 × 50 m which corresponds to about 250 × 125 Roman feet, an insula size larger than in the western part of the Roman Empire, but not uncommon in the eastern regions.

Fig. 15. Combination of all magnetograms since 1988, superimposed on Ikonos satellite image of Troia. (Courtesy NASA and Space Imaging Inc. 2000)

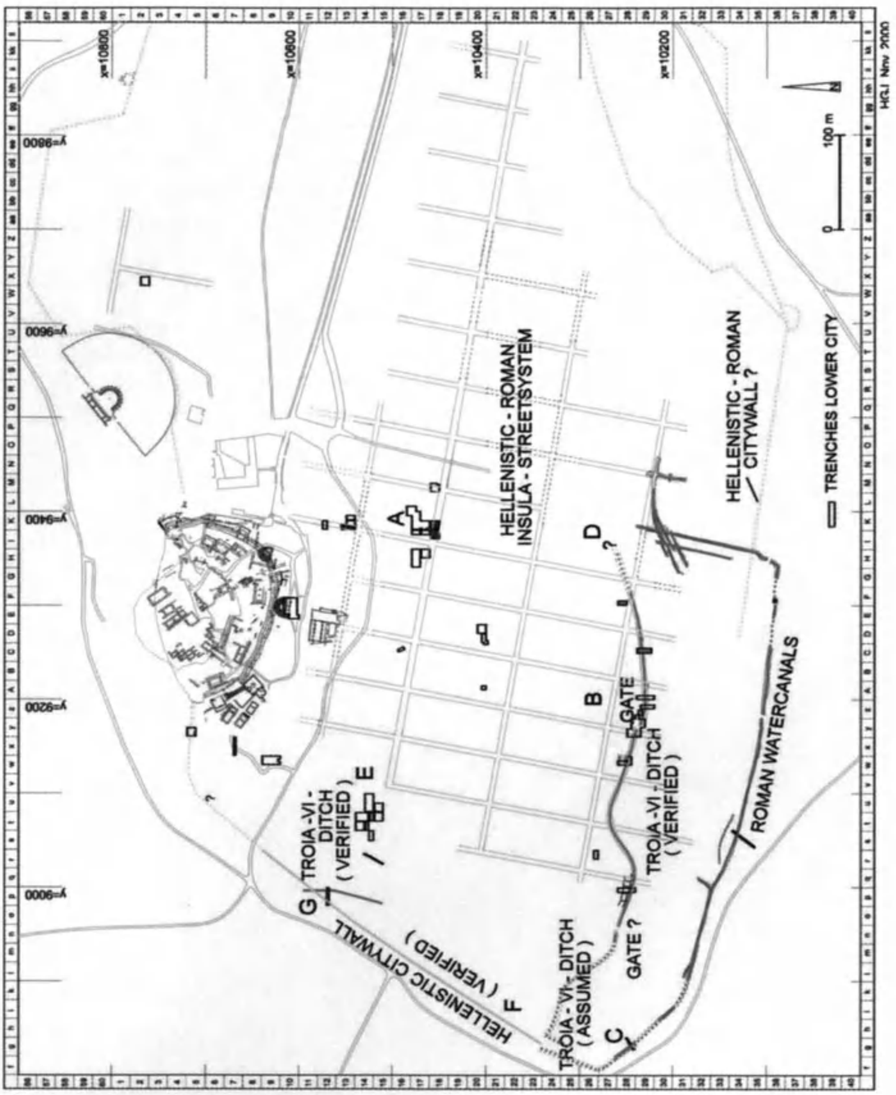

Fig. 16. Interpretation map of main features of the combined magnetogram of Fig. 15 showing the insular street system of Ilion, the Hellenistic city wall and the Troia VI ditch. *A* - *G* refer to areas of investigation mentioned in the text

While the present state of results would be very well suited for detailed planning of a potential future excavation of the Roman city one important question of the archaeologists remains unanswered: where are the Bronze Age cemeteries? The search for these extramural burials means an extension of the exploration into those areas which are heavily covered by the colluvium of the river plain. It will be the predominant task of future geophysical work at Troia with sensitive instruments and the use of a differential global positioning system (DGPS).

Acknowledgements. Thanks are due to the director of the Troia excavations, Prof. Manfred Korfmann, his team, and many colleagues who continuously encouraged and supported the geophysical prospecting, and to Prof. Manfred Lange, head of the Institute of Geophysics at the University of Münster, who actively supported the fruitful cooperation between the institutions.

Stratigraphy, Geochemistry and Geochronometry of Sedimentary Archives Around Hisarlık Hill – a Pilot Study

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Abstract

The aim of this geoarchaeological pilot study is to investigate to what extent geochemical and geochronometric techniques can be used in order to decipher the landscape development around Hisarlık hill and to detect events that left traces in the sedimentary archives encircling the Troia settlement area. Three drill holes close to and one further away from the hill were sunk up to 23 m below ground level into the sediments at today's footslope and alluvial plain positions. The stratigraphy and sedimentology of the cores were investigated. In addition, geochemical analyses as well as luminescence (OSL) and ^{14}C dating were carried out on samples taken from the drill cores. Detailed stratigraphic and geochemical analyses are not only relevant for landscape reconstruction, but also for identifying the facies suitable for luminescence dating. Hill-slope sediments and some alluvial deposits are considered to yield reliable ages. Major landscape changes by sediment accumulation occurred during the Troia VI and IX periods.

1 Introduction

Because Troia was almost continuously inhabited over 4000 years (3500 B.C. – 500 A.D.), it is an important reference point in the chronology of the Old World from the Early Bronze Age until the Roman Imperial Times (Korfmann and Mannsperger 1998). Therefore, this site is of special interest for investigating the interaction between man and environment.

Exploring and measuring the living space and its changes during time are very important in order to understand ancient civilized people. This seems particularly true in the case of Troia owing to its geostrategic location at the southern entrance of the Dardanelles. Thus, it can be expected that any changes – natural or man-made – of the surrounding landscape had crucial effects on Troia's culture-historical role. Studies adjacent to the settlement of Troia give the possibility to conclude from scientific results both natural and historical events, as the sediments represent and archive geological and geomorphological events as well as historical and archaeological ones.

Besides the extensive archaeological excavations, started in 1870/1871 by Heinrich Schliemann and going on today by Manfred Korfmann's team, a great number of geomorphological investigations in the plain of Troia was done by Ilhan Kayan (cf. Kayan et al., this Vol.) within the last years. Kayan and his colleagues drew up the stratigraphy of that area forming the basis for the studies and analyses presented here. Four drill cores, described in this paper, are part of that geomorphological work. To our knowledge, it is the first time that geochemical methods together with sedimentological and chronometric studies were performed on the deposits of the plain of Troia. An aim of this study is to quantify the sedimentary processes.

The deposits in the plain of Troia consist mostly of alluvial sediments of the two rivers Karamenderes and Dümrek, which have eroded the Mesozoic and Palaeozoic marbles and serpentinites as well as the Tertiary volcanic deposits in the hinterland. Occasionally, colluvial and marine deposits are included in the alluvial sediments the expression 'colluvial' here is used in its meaning according to Dalrymple et al. (1968). Infrared stimulated luminescence (IRSL) can be used for age determination of colluvial and alluvial sediments; the former ones have mostly been dated successfully (e.g., Lang 1996; Kadereit 2000), whereas the latter ones commonly are problematic.

2 Material

The vicinity of Troia is characterized by a low and a high plateau which consists of shallow marine limestones. Troia itself is located on a ridge of the lower plateau. In the north, west and south the ridge is surrounded by the delta plains of the Karamenderes and Dümrek Rivers (Kayan 1995, 1996).

The actual study area is situated close to the ancient city of Troia. Sediment samples have been taken from four drill cores, three of them (numbers 145, 157, 158) being located quite near the "Troia-ridge", the fourth, number 144, in the delta plain of the Dümrek about 1.5 km north of Troia (Fig. 1). This latter drill core reached a depth of 23 m. Drill site 157, situated about 500 m northeast of the great theatre of Troia and about 100 m away from the slope, reached a depth of 12 m. Located about 100 m away from the cave to the west of Troia, drill hole 158 reached a depth of 11.2 m. Drill site 145, reaching a

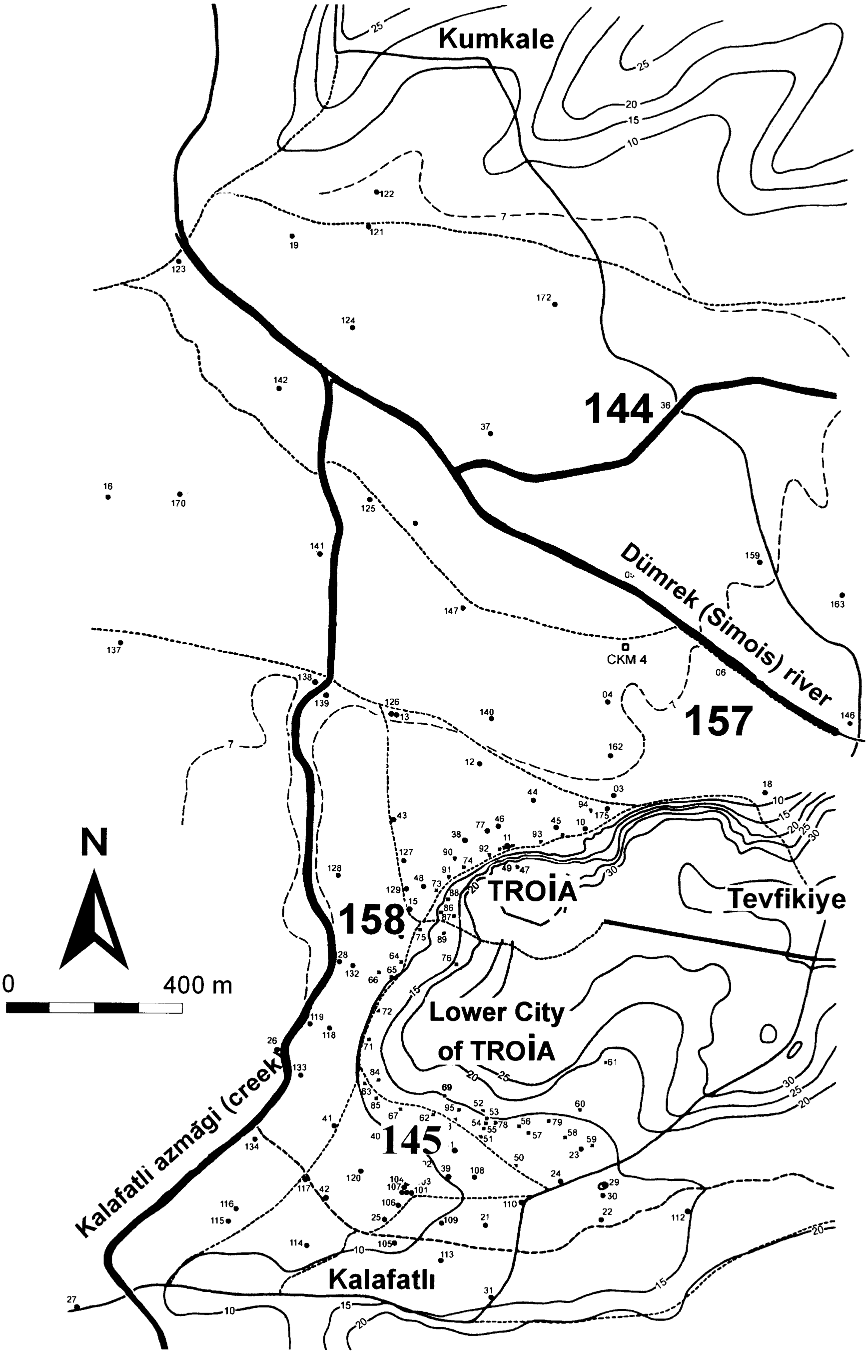


Fig. 1. Topographic map of the vicinity of Troia with the location of the drill cores described in this paper

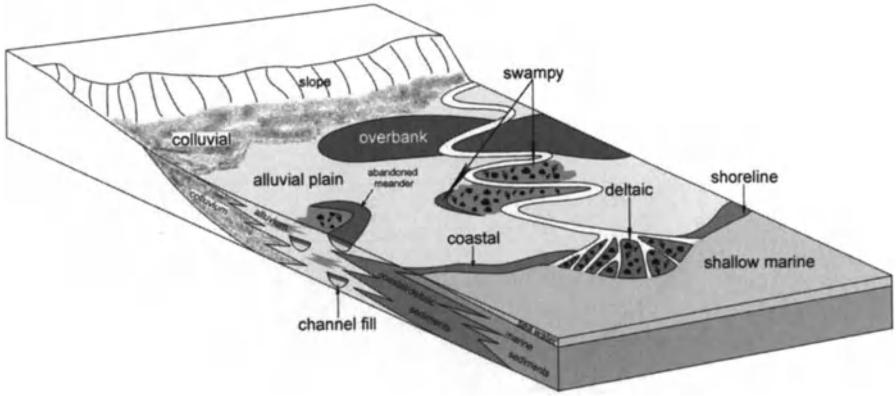


Fig. 2. Simplified model of sedimentary archives

depth of 7.3 m, is located in the vicinity of the lower city of Troia in the Çiplak valley, at a distance of about 250 m from the old town wall.

Within the various sedimentary environments and depositional systems, which can be distinguished by sedimentology, four different types of sedimentary archives were identified and sampled. Besides marine and partly coastal deposits, mostly alluvial and colluvial sediments were encountered. The alluvial sediments were subdivided into deposits of alluvial plains (overbank deposits in wet and well-drained environment as well as in swampy environments) and deposits of active river channels. The colluvial deposits were divided into real slope-washed sediments and sediment bodies that were restored by human activity (Fig. 2).

3 Methods

By using optical stimulated luminescence, the exposure to daylight of the last constituent grains – and thus the last deposition of the sediments – is dated (Aitken 1998; Wagner 1998). Therefore, special precautions are necessary during sampling in order to prevent the exposure of samples to daylight. Furthermore, each drilling had do be done twice, whereby the first one served the purpose of sedimentological description and based thereon it was decided which layer should be dated. The second one was done under exclusion of light by protecting the samples from light exposure with a plastic-pipe put inside the coring tube. Both ends of each 1-m drill-core section were covered by aluminium foil for transport. In the laboratory, the samples to be used for dating were removed under strongly subdued red light. After this procedure the remaining work was done under daylight.

First, the drill cores were described sedimentologically. Besides the visual documentation of the structure, texture, colour and the grain roundness, the grain-size distribution and the water content were also determined.

All specimens for geochemical analysis were taken strictly in the same layer that was sampled for dating. The bulk sediment samples were analysed by X-ray fluorescence (main elements and trace elements). After crushing, subsamples of 1.5 g each were mixed with 7.5 g of lithium borate as flux and homogenised. For each sample two tablets were produced and analysed. Table 1 shows the arithmetic mean value of both aliquots.

IRSL dating is based on the ability of non-conducting solids, such as feldspars, to store a measurable part of the energy of ionising radiation in the crystal lattice. The ionising radiation arises from natural radioactivity and cosmic rays. When interacting with lattice atoms it releases charges, which are trapped at lattice imperfections over time. This stored energy can be set free as an emission of light during the supply of stimulation energy, in the case of IRSL, by infrared illumination. The intensity of the luminescence signal can be used for dating.

In the laboratory dark room the samples were taken from the drill cores. The material was removed from both ends, because it may have been exposed to daylight during the field sampling. After splitting the plastic tubes in half, the sediments were sampled from the inner part of the core. Dose rate and moisture were determined on the material from the outer parts. For luminescence dating the polymineral fine-grain fraction (4–11 µm) was used. In order to remove organic material and calcareous components, the samples were treated with H_2O_2 and CH_3COOH. After this, the desired grain fraction was separated. Finally, the samples were divided into 80–100 parts (aliquots) and deposited on aluminium discs. Each disc carries 1–2 mg of the sample material. For more information of the laboratory procedure, see Lang et al. (1996).

4 Results

4.1 Sedimentology

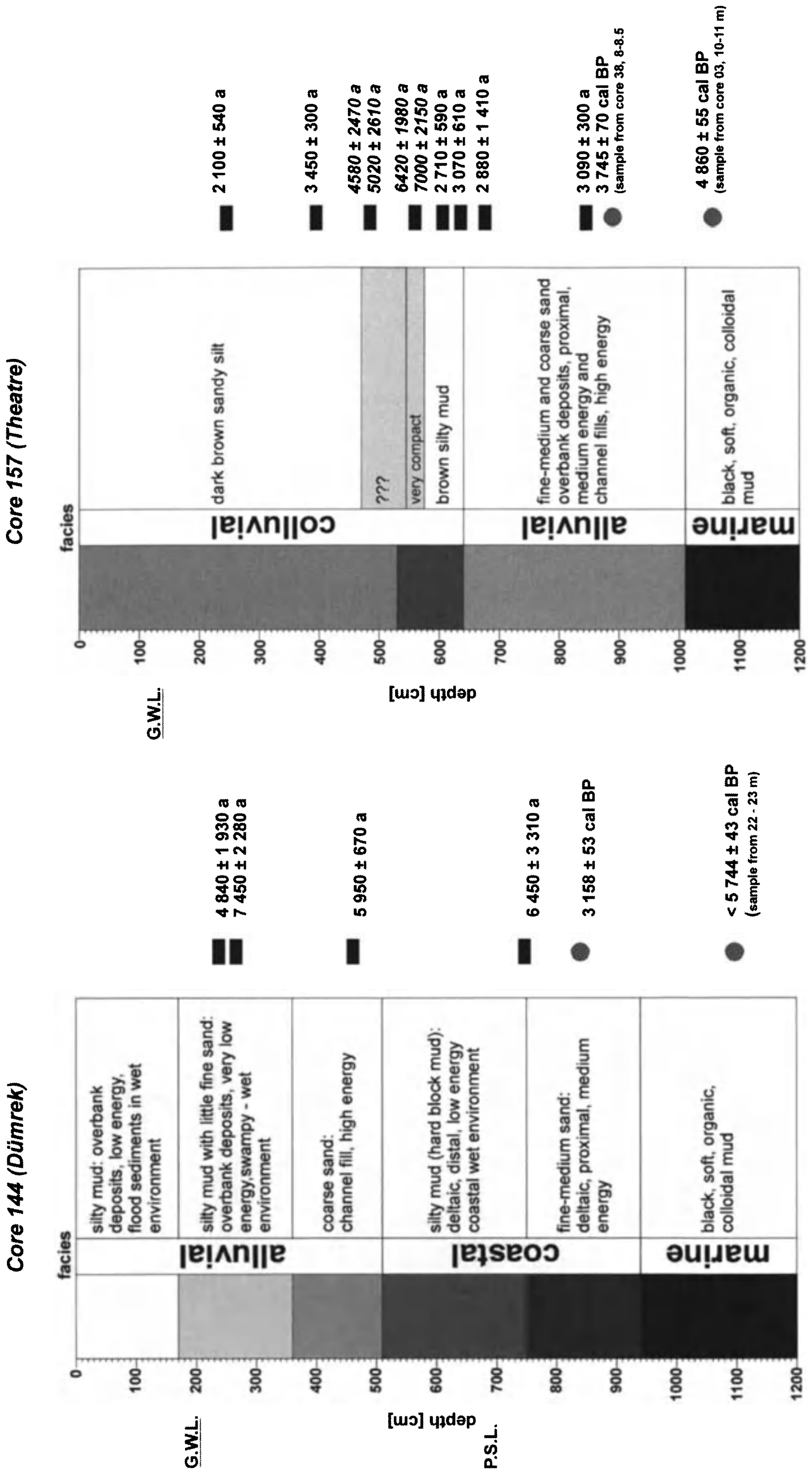
4.1.1 Core 144

Between the base and up to 9.40 m depth of the drill core, a black, soft, colloidal mud with a high content of organic material was found (Fig. 3). In the following 4.30 m, the colour changes from grey-brown to olive. This layer shows graded bedding from medium sand to silty mud, which forms a very

Table 1. Selected XRF analyses of some main and trace elements (u.n. denotes below detection limit; Σ = sum of all analysed elements including moisture; % is mass percent more data can be obtained from the first author)

Drilling core	Sample HDS No.	Mean depth (m)	SiO_2 (%)	P_2O_5 (%)	Cr (µg/g)	Ni (µg/g)	Nb (µg/g)	Y (µg/g)	Σ (%)
145	749	1.96	66.3	0.052	u.n.	22	6	14	100.4
	750	2.70	50.3	0.530	83	52	8	14	100.5
	751	3.64	62.6	0.123	342	40	10	20	100.4
	752	5.59	56.3	0.071	74	36	8	20	100.5
	753	6.35	50.1	0.065	67	42	8	21	100.6
144	754	2.52	44.6	0.094	408	460	8	22	100.4
	755/756	2.75	54.2	0.078	410	303	11	19	100.3
	757	3.94	70.5	0.067	392	194	8	15	99.6
	758	4.78	59.4	0.085	474	372	11	20	100.1
	759	7.52	64.6	0.066	504	256	6	15	100.0
	760	7.88	52.3	0.150	156	152	11	28	100.3
157	909	0.61	46.6	0.094	408	360	5	23	100.6
	910	1.60	43.2	0.126	465	472	8	26	100.4
	911	2.41	51.4	0.143	243	233	12	27	100.2
	912	3.27	48.5	0.147	157	153	9	26	100.5
	913	3.94	47.8	0.153	158	142	11	28	100.3
	914	4.77	47.00	0.130	251	235	9	28	100.6
	915	5.54	44.1	0.073	365	373	10	21	100.0
	916	5.99	51.8	0.117	179	167	8	25	99.9
	917	6.26	59.4	0.130	193	116	10	29	99.8
	918	6.70	53.9	0.164	163	113	11	29	99.7

919	6.99	54.0	0.187	181	128	9	25	100.1
920	7.59	51.7	0.166	135	127	8	27	99.6
921	8.38	47.8	0.144	217	201	6	24	99.8
922	8.99	45.3	0.114	265	250	5	21	99.2
923	9.33	70.5	0.040	758	413	u.n.	10	98.0
924	9.99	60.1	0.128	196	159	12	30	98.2
938	10.87	50.8	0.138	222	231	14	30	99.2
925	1.69	57.5	0.148	150	93	10	27	99.8
937	2.18	71.1	0.109	170	57	6	20	100.1
926	2.32	57.8	0.176	126	127	8	26	99.7
927	3.56	70.5	0.109	104	38	8	18	99.5
928	3.75	56.8	0.440	108	80	7	20	100.0
929	4.57	54.0	0.602	110	46	u.n.	15	99.3
930	5.50	46.9	0.898	106	65	u.n.	17	100.0
931	5.78	50.9	0.764	112	56	6	15	100.6
932	6.59	51.9	0.515	94	71	7	23	100.2
933	7.66	58.4	0.201	194	103	9	25	100.3
935	8.81	76.3	0.108	227	91	6	14	99.8
936	9.53	66.0	0.104	137	55	6	21	100.4



Core 144 (Dümrek)
facies
G.W.L.
P.S.L.
depth [cm]
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
alluvial
coastal
marine
silty mud: overbank deposits, low energy, flood sediments in wet environment
silty mud with little fine sand: overbank deposits, very low energy,swampy - wet environment
coarse sand: channel fill, high energy
silty mud (hard block mud): deltaic, distal, low energy coastal wet environment
fine-medium sand: deltaic, proximal, medium energy
black, soft, organic, colloidal mud
4 840 ± 1 930 a
7 450 ± 2 280 a
5 950 ± 670 a
6 450 ± 3 310 a
3 158 ± 53 cal BP
< 5 744 ± 43 cal BP
(sample from 22 - 23 m)
Core 157 (Theatre)
facies
G.W.L.
depth [cm]
colluvial
alluvial
marine
dark brown sandy silt
???
very compact
brown silty mud
fine-medium and coarse sand overbank deposits, proximal, medium energy and channel fills, high energy
black, soft, organic, colloidal mud
2 100 ± 540 a
3 450 ± 300 a
4580 ± 2470 a
5020 ± 2610 a
6420 ± 1980 a
7000 ± 2150 a
2 710 ± 590 a
3 070 ± 610 a
2 880 ± 1 410 a
3 090 ± 300 a
3 745 ± 70 cal BP
(sample from core 38, 8-8.5
4 860 ± 55 cal BP
(sample from core 03, 10-11 m)

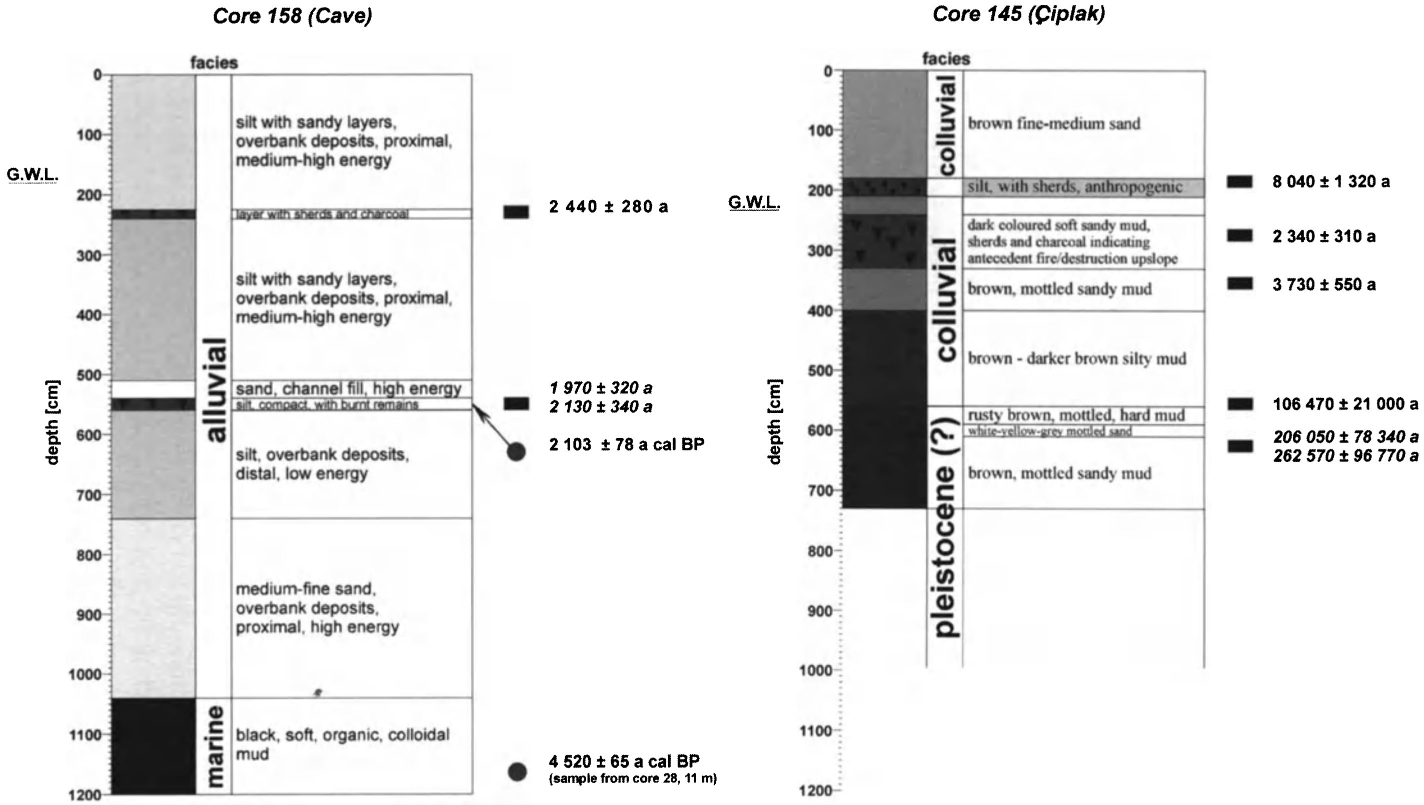


Fig. 3. Schematic sedimentary and stratigraphic profiles with IRSL and ^{14}C ages (minimum and maximum IRSL ages are shown in italics)

hard block above 7.50 m depth. Above 5.10 m depth, an olive-coloured coarse sand that includes a few well-rounded pebbles occurs up to the 3.60 m level. From there to the top follows a light brown silty mud with some organic material and at the base a little fine sand.

4.1.2
Core 157

From the base of the drilling up to 10.10 m depth, there is a black, soft, colloidal, laminated mud, which includes organic material (Fig. 3). Above, a light brown-yellowish coloured sediment package follows up to 6.40 m. It consists of fine to medium and coarse sands with some silty layers in between. Up to a depth of 5.30 m a brown to light brown-yellowish layer of silty mud was observed. This layer is very compact between 5.70 and 5.60 m in depth. Up to the surface a dark-brown, homogeneous, sandy silt occurs containing tiny fragments of ceramics.

4.1.3
Core 158

As before, a black, soft, colloidal, laminated mud with organic material was found from the base up to 10.40 m depth (Fig. 3). Within the following 3.00 m, multicoloured medium sands interchange with fine sands. A dark-brown, homogeneous silt with little organic material forms the next layer up to the 5.60-m level. A ca. 20-cm-thick, compact, dark-brown layer contains a lot of charcoal and ceramic fragments in a silty matrix. It is overlain by a brown-yellowish, 30-cm-thick medium-sized sand. From 5.10 m up to the surface the profile consists of silt with partly sandy zones. Its colour changes from brown-orange to brown-yellowish. In this layer another layer, containing charcoal and ceramic fragments in silty matrix, is included from 2.40 to 2.25 m depth.

4.1.4
Core 145

Core 145 consists at the base of a brown-mottled sandy mud (Fig. 3), which contains a few pebbles up to 1 cm in size. Up to a depth of 5.90 m a gradual change in sedimentation and colour takes place. A fine sand turns into a mottled, compact mud, the brown colour alters to a white-yellow-grey shade. At 5.90 m a sudden change in colour to rusty brown takes place, which changes gradually from dark to medium brown. Between 5.90 and 4.00 m a homogeneous, mottled mud was found. A clear boundary at

4.00 m marks the beginning of a new layer. It is a brown, densely pressed mud with sandy particles at the base. At a depth of 3.20 up to 2.40 m a dark-coloured, soft, sandy mud is included, which contains charcoal and numerous ceramic fragments. Above a distinct boundary at 2.40 m, a light olive-coloured, medium-sized sandy, soft mud with layers of coarse sand at the base follows. This mud changes into a light-brown, medium-sized sand and on the top to a dark brown-coloured fine to medium sand. At around 2 m a silty layer with ceramic fragments is intercalated.

4.2 Geochemistry

In Table 1 and Fig. 4, some representative results of the XRF analysis are summarised. Most element concentrations are rather high and range widely. Because the whole-rock fraction was analysed, the SiO_2 contents are relatively high and range between 43 and 76 mass %. Especially remarkable are some very high values of P_2O_5. Five samples of drill core 157 show a higher content than the other samples. Samples HDS 928 and HDS 929 have much higher contents of P_2O_5, reaching a maximum of 0.90 mass % in sample HDS 930 and decreasing gradually in the following samples: sample HDS 933 still shows a high content while sample HDS 935 reaches a lower value around 0.12 mass %. A second maximum value shows sample HDS 750 from drill core 145. Some trace elements also display a very high variation of their contents. So the sediments of drill core 144 and drill core 157 have evidently higher contents of Cr (156–504 µg/g, drill core 144; 135–758 µg/g, drill core 157) and Ni (152–460 µg/g, drill core 144; 113–472 µg/g, drill core 157) compared to the sediments of the other two drill cores.

4.3 Dating

Altogether, 40 samples were taken for IRSL dating. Table 2 shows the dates received so far. For core 144 the ages range from 4.8 ± 1.9 to 7.5 ± 2.3 ka (ka = 1000 years). The ages for core 157 are mostly around 2.9 ± 0.6 ka, and only samples HDS 914 and HDS 915 yield higher ages up to 7.0 ± 2.2 ka. For core 158 only two ages are currently available. Both are around 2.2 ± 0.3 ka, but for the second one only lower and upper limits can be given. For core 145 the ages range between 2.3 ± 0.3 and 263 ± 96.8 ka, the last age is only a maximum age. Again, the sediments of this drilling show an inverse order of ages.

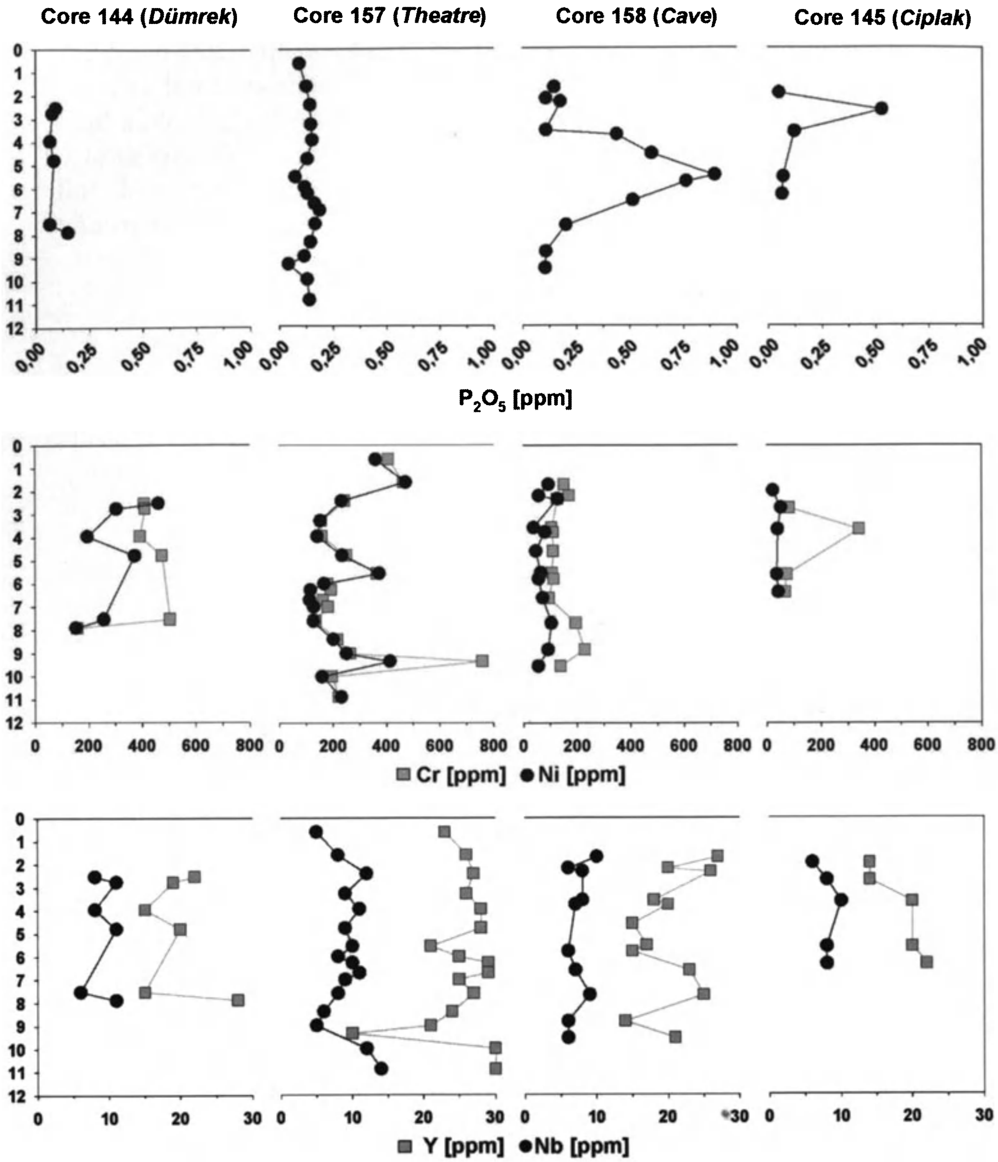


Fig. 4. Selected results of some main and trace elements of XRF analyses

Table 2. IRSL ages

Core	Sample HDS No.	Mean depth (m)	Facies	Age ± 1σ (a)	Date ± 1σ (B.C./A.D.)
144	754	2.52	Alluvial, swampy	4840 ± 1930	2840 ± 1930 B.C.
	756	2.75	Alluvial, swampy	7450 ± 2280	5450 ± 2280 B.C.
	758	4.78	Alluvial, channel fill	5950 ± 670	3950 ± 670 B.C.
	759	7.52	Coastal deltaic	6450 ± 3310	4450 ± 3310 B.C.
157	909	0.61	Colluvial	Not datable	–
	910	1.60	Colluvial	Not datable	–
	911	2.41	Colluvial	2100 ± 540	100 ± 540 B.C.
	913	3.94	Colluvial	3450 ± 300	1450 ± 300 B.C.
	914	4.77	Landslip	>4580 ± 2470	2580 ± 2470 B.C.
				<5020 ± 2610	3020 ± 2610 B.C.
	915	5.54	Landslip	>6420 ± 1980	4420 ± 1980 B.C.
				<7000 ± 2150	5000 ± 2150 B.C.
	916	5.99	Colluvial	2710 ± 590	710 ± 590 B.C.
	917	6.26	Colluvial	3070 ± 610	1070 ± 610 B.C.
	918	6.70	Alluvial, overbank	2880 ± 1410	880 ± 1410 B.C.
	921	8.38	Alluvial, overbank	3090 ± 300	1090 ± 300 B.C.
158	926	2.32	Archaeological layer	2440 ± 280	440 ± 280 B.C.
	930	5.50	Archaeological layer	>1970 ± 320	30 ± 320 A.D.
				<2130 ± 340	130 ± 340 B.C.
145	749	1.96	Anthrop. fill, sherds	8040 ± 1320	6040 ± 1320 B.C.
	750	2.70	Colluvial, burnt layer	2340 ± 310	340 ± 310 B.C.
	751	3.64	Colluvial	3730 ± 550	1730 ± 550 B.C.
	752	5.59	Pleistocene	106 ± 21 ka	–
	753	6.35	Pleistocene	>206 ± 78 ka	–
				<263 ± 97 ka	

5 Discussion

5.1 Sedimentology and Dating

5.1.1 Core 144

Very fine-grained sediments and an apparent absence of sedimentary structures indicate a low-energy environment deposit. Above the marine basis at 9.40 m the sediments are fluvial, while up to a depth of 5.10 m there is a prograding delta situation with some disturbance by wave action. The coastal sediments change from a proximal delta situation at the bottom to a distal low energy facies. The uppermost 5.10 m were deposited in a proper terrestrial floodplain. The alluvial deposits consist either of coarse sandy channel fills or muddy overbank deposits of a swampy, badly drained environment. Four samples were taken for OSL dating: from the proximal deltaic sediments at 7.52 m, the sandy channel fills at 4.78 m, the muddy overbank deposits at 2.75 and 2.52 m depths. As an independent age control two ^{14}C-ages of organic material from the coastal and marine sediments of this drill core (sample 1: 8.50-m level, coastal environment, plant remains; sample 2: 22.00 – 23.00 m level, marine environment, plant remains) are available. Sample 1 gave an age of 3158 ± 53 cal B.P. (i.e., 1208 ± 53 B.C.) and sample 2 an age of 5744 ± 43 cal B.P. (i.e., 3794 ± 43 B.C.). The IRSL ages of samples (from the base up) HDS 759, 758, 756 and 754 (Table 2, Fig. 3a) clearly show that all these IRSL ages are significantly overestimated. This result came as no surprise to us, because these samples all come from environments where sediments are not properly bleached. Both the deltaic proximal and the channel infills are situations where the sediment is transported at the bottom of the fluvial channels. The other ones are muddy deposits that were laid down in a badly drained overbank situation with colloidal transport. For OSL dating this means that fine-grain material is transported as aggregates, the interior of which certainly would not be struck by daylight.

5.1.2 Core 157

Core 157 also begins with a marine section at the base, but the horizontal lamination indicates a depositional environment of the beach zone. Above, the profile contains sand of different grain-sizes characterising different subfacies within an alluvial environment. As before, the coarser sands represent channel fills, which cut the finer-grained overbank deposits. On top of the alluvial sediments follow colluvial deposits. These slope-washed sediments exhibit an enormous thickness of 6 m, a lack of any sedimentological structures and contain scattered small ceramic fragments. Near the basis of this package, between 4.70 and 5.75 depth, there is a layer embedded that definitely cannot be interpreted as colluvium, with the lower 30 cm being very compact, and the material above exhibiting unusual geochemical characteristics. This clearly shows that this layer could be interpreted either as an anthropogenic filling or as a landslip from the alluvial material rather than being colluvial in origin.

As to dating, two ^{14}C ages from two nearby cores with alluvial and marine facies (sample 1: 3745 ± 70 cal B.P., i.e., 1795 ± 70 B.C., core 38, depth: 8.00 – 8.70 m, limestone; sample 2: 4860 ± 55 cal B.P., i.e., 2910 ± 55 B.C., core 03, depth: 10.00 – 11.50 m, marine shell) are available. Apart from the two samples collected from the problematic non-colluvial section (HDS 914, 915, giving abnormally high OSL ages) all OSL ages are either equally older or younger than the independent ^{14}C ages and, thus, are stratigraphically consistent. Figure 3 shows that all materials between 8.38 and 2.41 m depth were deposited within the same interval, most probably between Troia VI and VIII.

5.1.3
Core 158

Above the marine sediments at the base of core 158, the whole sediments of the profile are interpreted as alluvial deposits. Channel fills alternate closely with overbank sediments. Intercalated are layers full of archaeological remains such as charcoal, ceramic fragments and other burnt materials ("archaeological layers"). Such layers were found at 2.25 – 2.40 and 5.40 – 5.60 m depth. For this core there are also two independent age controls by ^{14}C-dating. One was taken from the nearby core 28 (depth: 10.80 – 11.30 m, limestone giving an age of 4520 ± 65 cal B.P., i.e., 2570 ± 65 B.C.). The other one was taken from the very archaeological layer at core 158 (5.50 m depth) yielding an age of 2103 ± 78 cal B.P. (i.e., 153 ± 78 B.C.). IRSL analysis of the sedimentary matrix of sample HDS 930 gives an upper limit of $<$2130 ± 340 a (i.e., 130 ± 340 B.C.) and a lower limit of $>$1970 ± 320 a (i.e., 30 ± 320 A.D.). The notation of possible minimum and maximum ages is due to radioactive disequilibrium determined by low-level gamma spectrometry in the ^{238}U chain. This age range, however, is concordant with ^{14}C-age of the charcoal from this layer. Therefore, this fire event took place in the late Hellenistic or early Roman periods. For the second archaeological layer (HDS 926) at 2.30 m depth an IRSL age of 2440 ± 280 a, i.e., 440 ± 280 B.C. was determined which, within the error limits, agrees with the age of the lower archaeological layer. This implies that both layers belong to the same cultural period in which intermittently 3 m thick alluvial overbank material was accumulated.

5.1.4
Core 145

This core is completely made up of slope-wash material apart from a 30-cm-thick layer between 1.80 and 2.10 m depth that contains many sherds and is very compact. It most probably has to be interpreted as anthropogenic filling. At a depth between 2.40 and 2.30 m another archaeological layer was found which is dark in colour and contains abundant sherds and charcoal, indicating a conflagration uphill. Whereas from stratigraphical analysis the uppermost 5.60 m are interpreted as Holocene colluvial material, the deposits below were, due to their different appearance, considered to be of pre-Holocene (Pleistocene) age.

Altogether five samples were collected from this core for OSL dating. Apart from sample HDS 749, which was taken from the anthropogenic layer the OSL ages show decreasing stratigraphically consistent values from bottom to top. The stratigraphically inconsistent overestimated age of sample HDS 749 is not surprising as the material was dumped by man, and thus had certainly not been properly bleached with the interior of the lumps. The lowermost samples HDS 752 (106 ± 21 ka) and HDS 753 (lower and upper limits of 206 ± 78 and 263 ± 97 ka, respectively) give pre-Holocene ages, thus confirming the assumption of their Pleistocene origin. The colluvial sample HDS 751 (3730 ± 550 a) thus gives an age belonging somewhere between Troia II and Troia VII. For the archaeological layer (HDS 750, 2340 ± 310 a, i.e., 340 ± 110 B.C.), as for the other two archaeological layers, found in core 158, again an OSL age is observed which, according to the Troia stratigraphy by Korfmann and Mannsperger (1998), either belongs to the late Hellenistic or early Roman periods.

5.2
Geochemistry

With the results of the geochemical analyses it is possible to support the sedimentology and the stratigraphy. The P_2O_5 content enables us to detect an anthropogenic influence. This fact explains itself by the existence of bone particles with hydroxyl apatite ($Ca_5[PO_4]_3[OH]$) as surviving material. Unusually high phosphate contents indicate the archaeological layers in

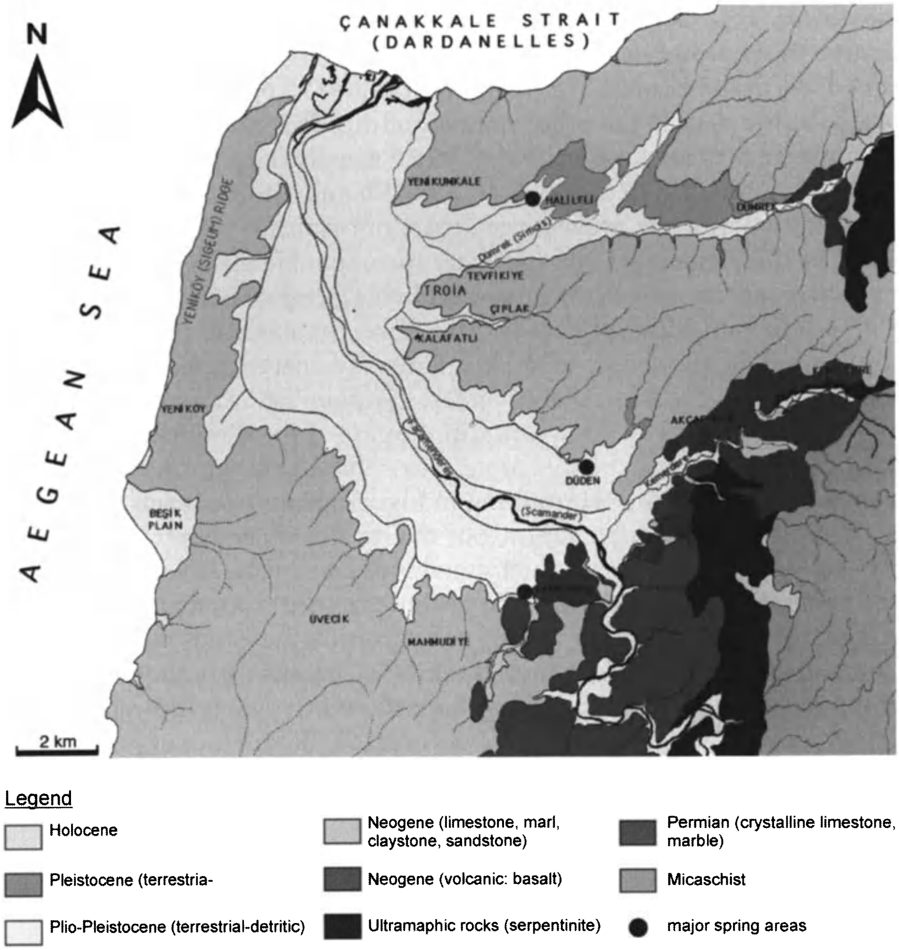


Fig. 5. Simplified geological map of the Troad (Kayan 2000)

core 145 at 2.8 m and in core 158 at of 5.5 m depth (Figs. 3c, d, 4a). However, no geoarchaeological layer was found in core 157. Here, also, an unusually high phosphate content indicates influx of bony material although macroscopically no archaeological layer could be identified. This, however, means that apart from core 144, being located some 800 m north of Hisarlık hill and even north of Dümrek River, the three other cores, being closely situated around Hisarlık hill and thus received material from there, all have an archaeological layer at ca. 2.5 m depth below surface.

With the trace elements Cr and Ni it is possible to identify different provenance areas of the sediments. In the sediments of core 144 and core 157 their average contents are considerably higher than those of the other two cores. This fact reflects the chemical composition of the geological setting of the Dümrek drainage area which differs from that of the Karamenderes drainage area (Fig. 5). In core 145 the Cr content in sample HDS 752 is higher than in the other samples of this drill core. This is possibly an outlayer, because the Cr/Ni ratio, which usually ranges between 1.6 and 2.1 at this site, is 8.6 in that sample. Also, Nb and Y mirror the petrologic characteristics of the provenance area. Core 157 shows a slightly higher value of these elements. Nb and Y are incompatible elements, which are enriched, for example, in the minerals olivine, plagioclase and amphibole. These minerals occur in basalts. Therefore, the basaltic rocks south of Troia might be the source of these sediments of core 157. As a medium of transport only the River Karamenderes is possible. Although the River Dümrek also passes basaltic rocks, in the case of the Karamenderes both the drainage area and the spreading area of basalt are significantly larger compared to the Dümrek, resulting in higher Nd and Y signals. Core 145 should have similar high values, but due to the wider branching of the River Karamenderes the original signal is diluted by the River Çiplak. For future studies a sample would be essential in order to analyse the surrounding rocks of the river catchments accordingly. Core 157 at 5.0 – 5.5 m depth possesses anomalous high Ni and Cr contents (just above the very compact layer at 5.6 – 5.7 m). These high Ni and Cr values indicate fluvial input from the east, whereas low ones reveal the dominance of slope wash from Hisarlık hill.

6
Conclusion

The geochemical studies show that such data are important for stratigraphical, sedimentological and facies analysis as well as the identification of source areas for sediments.

OSL dating was applied to slope-wash material (Pleistocene deposits, Holocene colluvium), alluvium (channel fills and overbank deposits from well-drained and swampy regions), archaeological layers, anthropogenic fills and probably land-slip material. Additive multiple aliquot protocols were used for polymineral fine-grain fractions (IRSL) of these sediments. The results show that slope-wash material is reliably datable – a finding that is consistent with earlier experiences in Middle Europe (Lang and Wagner 1996; Lang et al. 1999; Kadereit 2000). Alluvial sediments, however, turned out to be rather problematic. Not surprisingly, channel fill and overbank deposits from swampy areas were apparently not properly bleached and consequently show significant age over-estimation. Overbank deposits from well-drained areas are stratigraphically consistent and thus seem to be more suitable for OSL dating. Of course, anthropogenic deposits and land-slip blocks are not datable, since the interior grains have not been exposed to light.

As this is only a pilot study, error margins are still quite large. In the future the error limits can be significantly reduced for the dose by using single aliquot techniques and for the dose-rate when more information on the moisture content of the sediments becomes available.

For the archaeological layers in the cores 145 and 158 a mean OSL age of 202 ± 313 B.C. was calculated, which together with the ^{14}C age (153 ± 78 B.C.) from below the layers in core 158 is in accordance with the archaeological assumption that these layers may be either from the cultural periods of Troia VII or IX (Korfmann, pers. comm.). Considering the numerical dates one can exclude Troia VII. Thus, drilling cores taken close to Hisarlık hill prove to be excellent archives storing information about the destructive event upslope.

The observation that sediment packages of several m thickness, namely in core 157 and 158, were deposited probably during the periods Troia VI to IX show that enormous landscape changes in the alluvial plain took place and that the landscape found today. These results are in full agreement with Kayan's findings of the delta progradation (this Vol.).

Acknowledgements. The present project is part of the interdisciplinary research within the DFG Graduate School „Anatolia and its neighbours“ at the University of Tübingen and a co-operation between the „Forschungsstelle Archäometrie“ in Heidelberg and the Institute of Geochemistry at the University of Tübingen. Dr. B. Kromer, Forschungsstelle Radiometrie der Heidelberger Akademie der Wissenschaften, graciously supplied the ^{14}C ages. Thanks are extended to G. Bartholomä, S. Lindauer and M. Schumann for their help with laboratory procedure. Discussions with Dr. Ch. Wolkersdorfer improved an earlier version of this paper.

Sedimentary Facies Patterns and the Interpretation of Paleogeographies of Ancient Troia

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Abstract

We present a series of maps of ancient geographies in the Aegean area, based on sedimentological and fossil evidence. Coupled with information from the Classics and comparative modern vs. ancient analogs, we present interpretations of geographic changes in the vicinity of Troia over the past six millennia. Our geomorphologies of ancient Troia might well aid classicists and archaeologists in their understanding of the past and the events in Homer's Iliad.

1 Introduction

From the last Würm glacial low sea level of –125 m, the Aegean Sea rose to its present level approximately 6000 years ago. Since then, Aegean sea levels fluctuated to a low of –1 to –2 m ca. 3500 years ago and thence upward again to the present level (Kayan 1995). During the marine transgression, a sedimentary record was deposited layer by layer in the ancestral valleys of the Scamander (Karamenderes) and Simois (Dümrek Su) Rivers. Since 6000 years ago, accompanied by accelerated erosion in the hinterlands, fluvial and coastal/marine environments prograded over 6 km seaward to the present Dardanelles (Hellespont) coastline: (Kayan 1991, 1995, 1996, 1997a; Kraft et al. 1980a, 1982). Thus, over 50 m of sedimentary strata provide a depositional record of the geometry of past coastal landscapes between the Sigeum ridge to the west and the cuestas Hisarlık (site of ancient Troia) and Yenikumkale to the east and northeast.

To us, sedimentary environments of deposition are both geomorphologic features and stratigraphic units which include a record of landscape evolution over times past. Thus, floodplains and their river channels, backswamps, levees and ponds; coastal barriers, lagoons, marshes and asmaks (small drowned river estuaries); and shallow marine embayments are the surficial expressions of past sedimentary processes and their resultant strata. Coupled with evidence from their lineaments or geometries, internal sedimentary structures, floral and faunal (fossil) remains, and ^{14}C dates there from, they form geomorphic models upon which we may base interpretations of ancient landforms, processes, salinities, etc. To do this we use basic geological principles and methodologies. Walther's principle of *the correlation of sedimentary facies* is the concept whereby we can interpret conformable and nonconformable sedimentary strata both laterally and vertically into possible map delineations of the past. Allied with the concept of *uniformitarianism* or its modern variant *actualism*, we use present geometries of sedimentary environments of deposition as analogs for our interpretation of past morphologies. The study of modern depositional environments and morphologies and their ancient equivalents become an exercise in reasoning based on the partial information available to us in the stratigraphic record. This is also an exercise in ontologic methodology based on the observations of present interrelationships of sedimentary depositional body shapes and structures versus the processes impinging upon, molding, and constantly reforming fluvial, coastal, and nearshore marine environments (Kraft 1971; Kraft and Chrzastowski 1985).

Perhaps nowhere are such analyses more useful than in the reconstruction of ancient coastal landscapes associated with historical and archaeological sites. We present a series of modern/ancient studies in coastal Greece and Turkey to illustrate possible variants in the coastal morphologies for Troia and its environs over the past six millennia. These, coupled with evidence from archaeology and history, allow more precise paleogeographic reconstructions of the locales long associated with the events in Homer's Iliad.

2 Sedimentary Environments of Deposition

The surface of the floodplain and delta of the Scamander and Simois Rivers, the dunes of Kumburnu (Kum Kale), and the accretionary coastal plain at Beşik Bay show large numbers of geomorphic lineaments that are evidence of past depositional processes (Fig. 1). With up to 20 m of alluvium on the southern Scamander plain, we cannot hope to locate precisely the river channels of antiquity. Rather, we can assert with confidence that river channels shifted frequently by normal fluvial processes, meandering, eroding and developing new channels through past millennia. Flanking backswamps were common throughout history until altered by modern

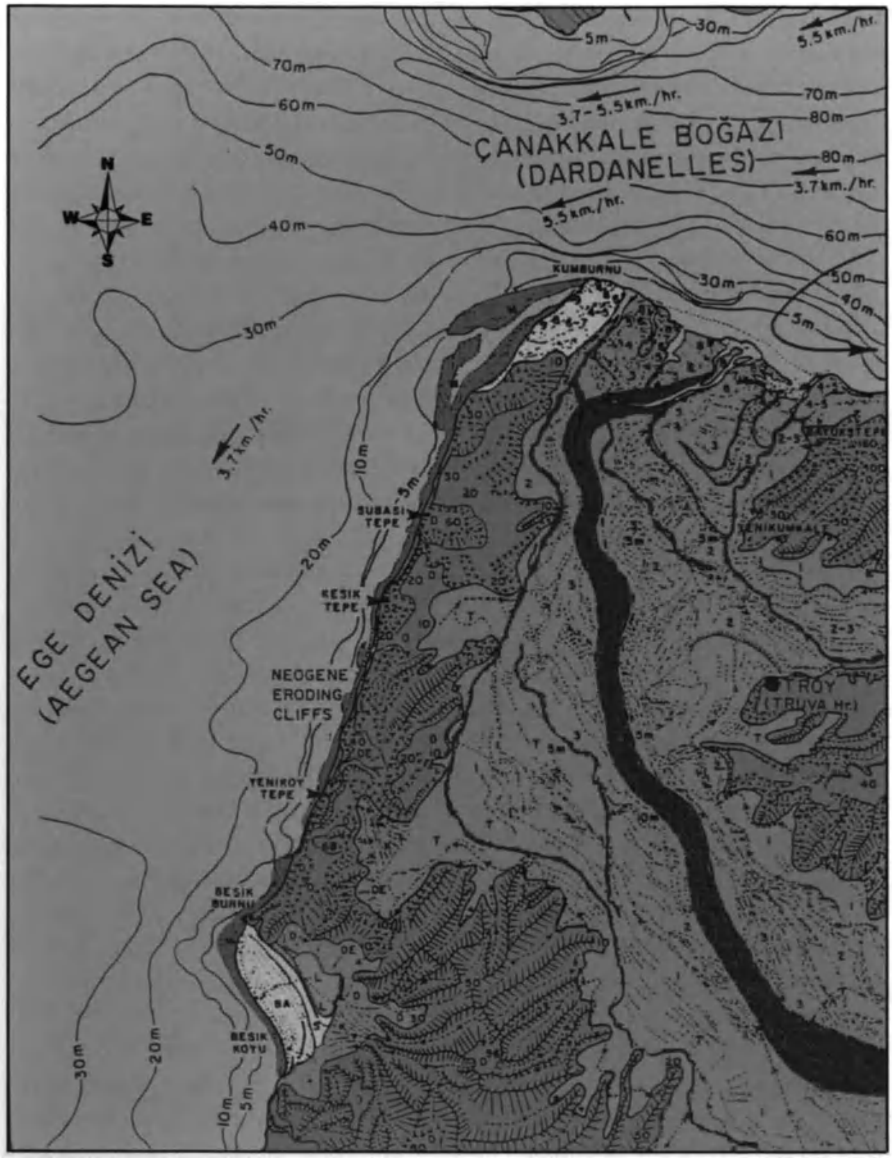

Fig. 1. Troia and its environs showing physiographic lineaments on the Scamander and Simois floodplains and the Beşik embayment coastal plain (from air photo analysis by O. Erol 1972). Fluvial lineaments dominate, with coast-parallel lineaments only near the Dardanelles. The sand dunes of Kumburnu lie adjacent to shallow marine shoals and coast-parallel littoral transport sands of the Aegean shore

drainage and irrigation structures of the twentieth century. As noted on some early maps, irregularities along the flanking hills sheltered remanent lakes or ponds and swamps, possible loci of ancient anchorages or harbors. Coast-parallel lineaments occur only in the lower 2 km of the Scamander floodplain. Barrier accretion ridges do occur on the Beşik coastal plain. T. Spratt of the HMSN Beacon mapped the Troad in 1839 A.D. and showed the natural flood channels of the Scamander River (Fig. 2).

The cross section in Fig. 3 shows Holocene sedimentary strata indicating environments of deposition ranging from shallow nearshore marine silt-clay, nearshore marine, lagoon and estuarine sandy silts, organic silts of brackish to saline coastal marshes, and fresh water sand, silt and clay of the prograding delta channels, floodplain, ponds and backswamps.

Fossil pelecypods and gastropods are sometimes indicative of strictly marine conditions, but in shallow marine embayments, such as the vicinity of ancient Troia, the common molluscs present were tolerant of ranges from brackish to normal marine salinity.

Yang (1982) identified five biofacies based on microfaunal analysis of seven drill cores: IA fluvial including freshwater charophytes; IB marsh or coastal swamp and tidal creeks, seasonally variable from freshwater to brackish; II nearshore restricted marine to brackish marsh and shallow marine embayments, lagoons; III brackish to moderately saline lagoons, estuaries or marshes (with rare freshwater incursions); and IV very shallow nearshore marine embayment or lagoon with variable salinities and water depth to 40 m (see also Kraft et al. 1980a, 1982). Microfauna such as foraminifers and ostracods serve as environmental indicators in bays, lagoons, and streams in the lower valleys that vary significantly from fresh to variable brackish to marine (and even hypersaline) dependent on season, variable freshwater input from local rain or floods, and summer drought evaporation. It is important to note that coastal lagoons, lower delta flanking lakes, and even stream channels often have bases below sea level. This may be caused by delta distributary bypassing, sedimentary subsidence and compaction, and the inherent fact that river distributary channels incise below sea level in lower delta regions. The depth of incision is dependent on stream flow volume.

3
Modern-Ancient Analogs

The creation of maps of ancient sedimentary environmental landforms by use of modern analogs is a process with roots in early geological principles. However, it is with the detailed studies of the internal structure of sedimentary strata and their enclosed biofauna/fossils, as developed in the late

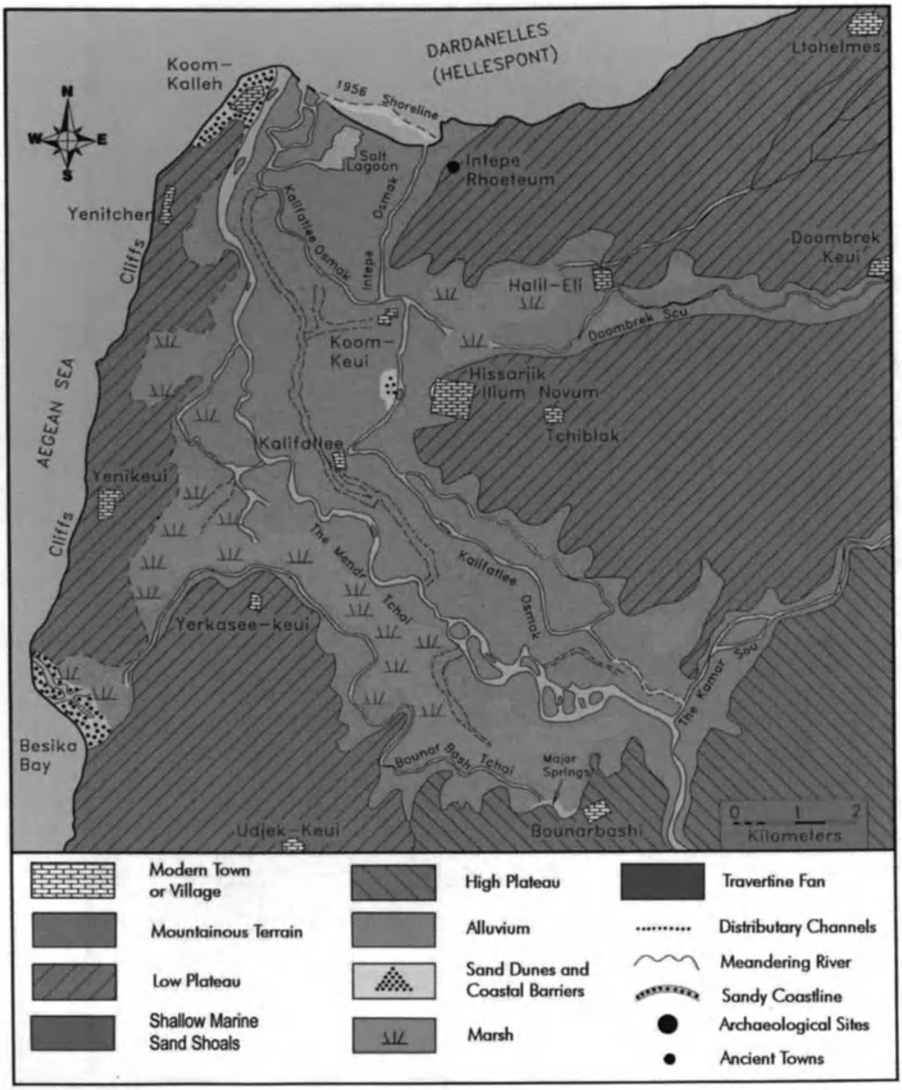

Fig. 2. Geomorphic elements in the Troad, pre-modern agricultural development (T. Spratt, 1839 A.D., HMSN Beacon). Five river channels and a canal to a mill on the Beşik plain may be compared with the larger number of relict river channel lineaments visible in air photo analysis (see Fig. 1). Legend applies for most figures herein

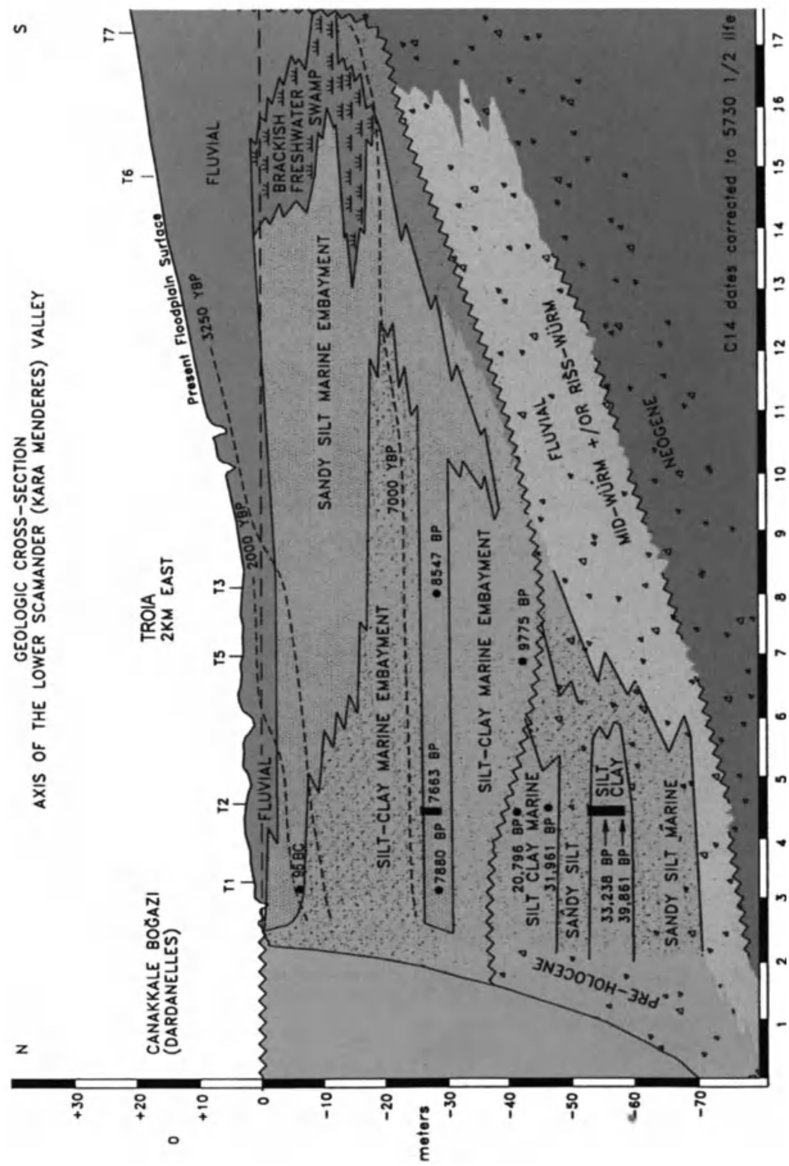

Fig. 3. Geologic cross section of the Holocene floodplain of the Scamander River (Karamenderes) showing the dominance of marine and coastal (variable salinity) sedimentary environments overlain by a thinner cover of fluvial sediments of the Simois and Scamander Rivers. A similar marine sequence of mid Würm or Riss-Würm times underlies the Holocene stratigraphic section. Note ^{14}C dates in the pre-Holocene sediments may be incorrect as they approach laboratory limits of the 1970s. (Kraft et al. 1980a)

twentieth century, that paleogeographic analyses became a norm in relation to archaeological and historic sites. We present four examples of delta floodplain and coastline reconstructions that relate to archaeological/historic settings in the Aegean region. Each example includes useful concepts and information applicable to our analysis of the morphology of paleosedimentary environments in the Troad.

The Spherchios river delta in Greece progrades into the quiescent, sheltered, low wave energy shallow waters of the Gulf of Malia (Kraft et al. 1987; Szemler et al. 1996). Microfaunal analysis of foraminifer and ostracod assemblages resemble those from our studies at Troia (Tziavos 1977). The Spherchios river channels in flood state carry a sediment load ranging in grain size from clay to coarse sand and gravel. Yet no coastal barriers form and many distributary channels remain occupied at flood times (Fig. 4). The complex swamp, marsh, distributary channel coastline in the Thermopylae region has prograded seaward over 15 km in the past 2500 years, bypassing the narrow "middle gate" at Thermopylae, now 4–6 km to the southwest.

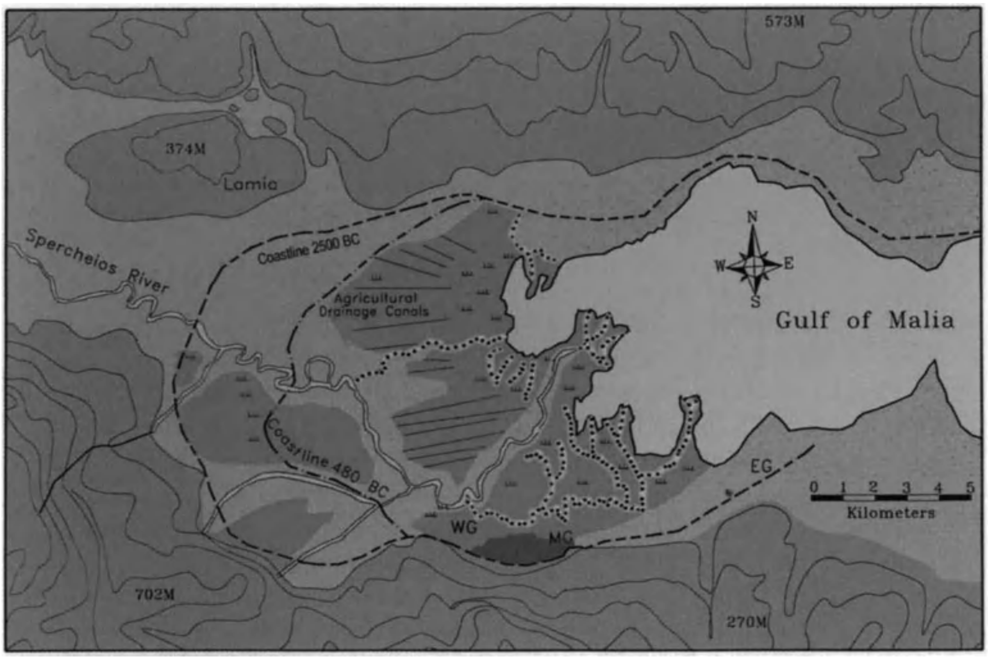

Fig. 4. Fluvial environments in the Spherchios river delta, Gulf of Malia, Greece. In this sheltered embayment, distributary progradation into shallow marine waters is dominant. The West Gate (*WG*), Middle Gate (*MG*), and East Gate (*EG*) of the pass at Thermopylae are shown relative to the modern delta floodplain and "schematic" coastlines to the west in 480 B.C. and ca. 2500 B.C.

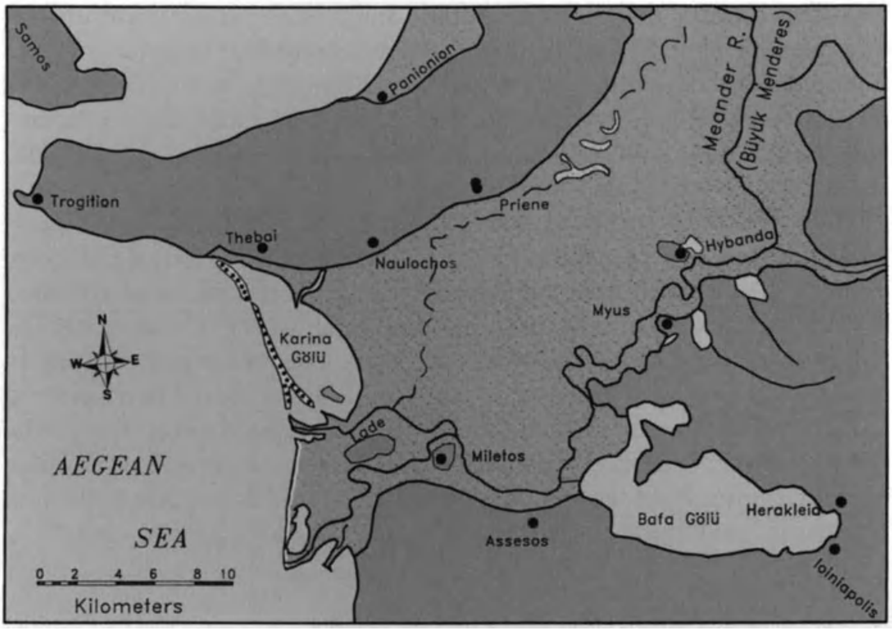

Fig. 5. The Meander River (Büyük Menderes) delta floodplain in Aegean coastal Anatolia showing a wave-modified prograding delta and shallow marine coastal lagoon and sandy barrier. Sediment supply has been reduced by irrigation engineering. Wave action is moderate and periodic. The major ancient seaport cities of Miletus, Priene, and Herakleia in Classical times, amongst others, are shown. The boundary between the alluvium and mountainous terrain delineates the coastline of Neolithic and Early Bronze age times. (With modifications, after Brückner 2000)

The Meander River (Büyük Menderes) delta floodplain at Miletus in western Anatolia also continues to prograde seaward (Brückner 2000 and this Vol.). Here, Bronze Age to Classical sites such as former port cities Miletus, Heracleia, Priene and others now lie far inland (Fig. 5). Although twentieth century irrigation practices have sharply decreased the flow of the Meander River, a complex delta of narrow distributaries, swamps and lagoons occur in the active delta to the south, while former distributary remanents have subsided under a large coastal lagoon behind a long arcuate sandy barrier to the north. There is no evidence of former barrier accretion ridges in the adjacent landward floodplain, now marked by numerous abandoned meandering river channels and oxbow lakes. Wave energy is moderate, sheltered from the strong northerly Aegean winds by a mountainous cape and the island of Samos to the northwest. It is possible that the former Meander embayment may have extended inland, more than 30–40 km at the beginning of the Bronze Age.

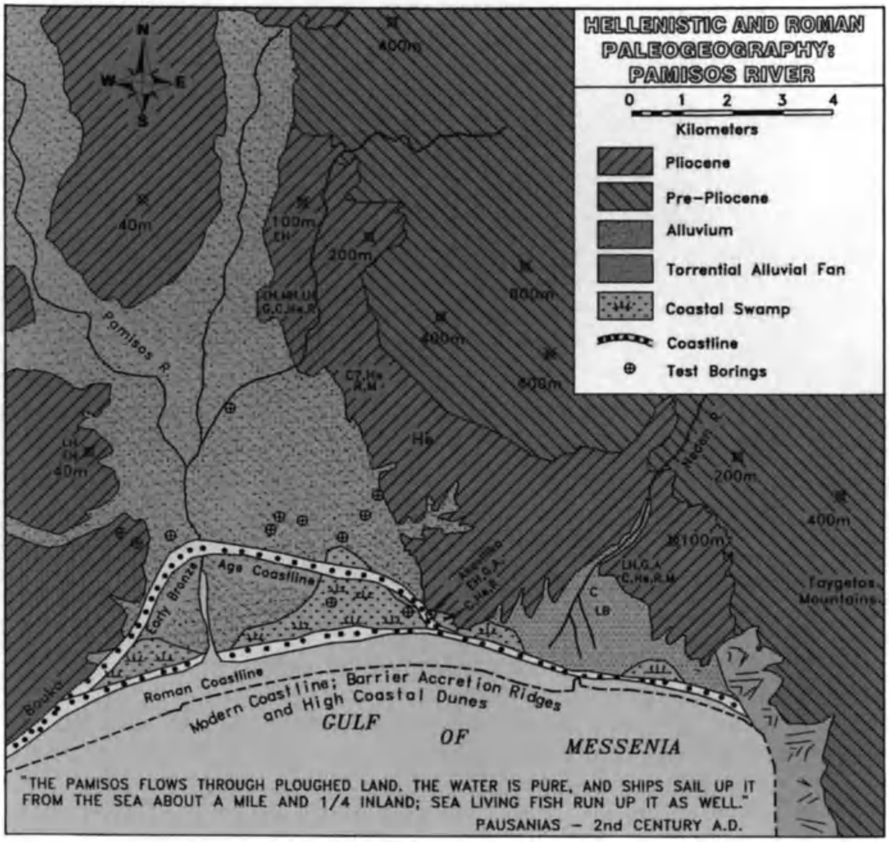

Fig. 6. The Pamisos river delta floodplain in southern Peloponnese is shown relative to the modern, Roman, and Early Bronze Age coastlines. These coastlines are dominated by high energy storm waves with a large amount of sand and gravel in littoral transport. Archaeological sites are shown: *M* Medieval, *R* Roman, *He* Hellenistic, *C* Classical, *A* Archaic, *G* Geometric, and *EH*, *MH*, *LH* Early, Middle and Late Helladic. (Based on Kraft et al. 1975)

The Pamisos river delta at the head of the Gulf of Messenia in southern Peloponnese presents an extreme of high wave energy, with a long southerly wind wave fetching across the Mediterranean Sea from the shores of Africa (Kraft et al. 1975). In this sandy coastline and narrow marine shelf, a barrier accretion plain has prograded 5 km seaward since early Bronze Age time, (Fig. 6). Torrential streams carry sediment as large as cobbles and borders into the sea where they are transported along the shore by winter storm waves large enough to make the coastal hills tremble up to 100 m inland. Large amounts of sediment are lost to the adjacent shelf in this extreme wave regime.

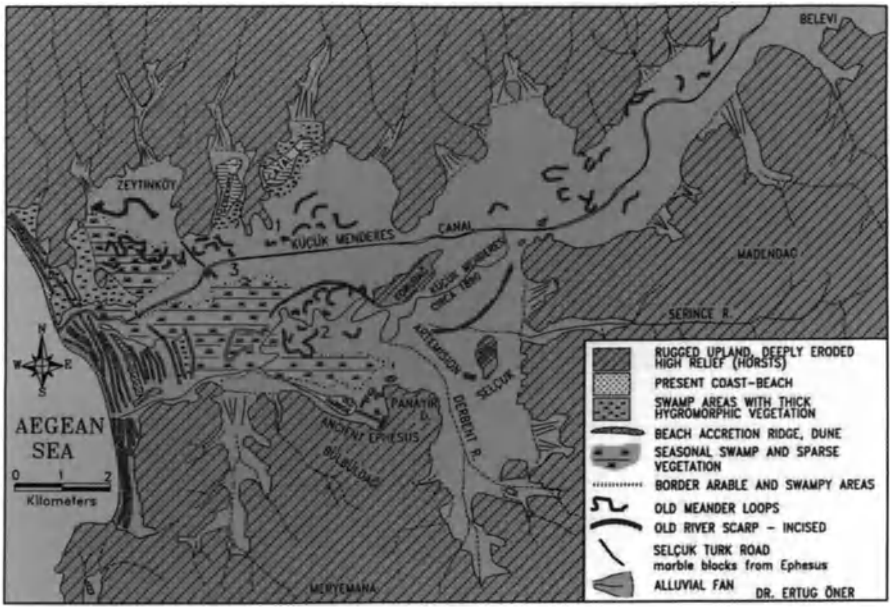

Fig. 7. Present geomorphic features on the floodplain, delta, and coast of the Cayster River (Küçük Menderes) in the vicinity of the ancient harbors and cities of Ephesus and the Artemision in Aegean coastal Anatolia. The coastal barrier accretion plain, large swamps, and abundant meander loops indicate major coarse sediment input by the Cayster River as partially modified by strong wave activity. However, these features are in fact surficial and mask underlying much thicker shallow marine and prodelta strata deposited in a more sheltered marine embayment of pre-Late Byzantine times. *1* Older river channel oxbows, *2* abandoned younger river channels, *3* modern irrigation/drainage canal. Photo-geomorphic study by Dr. E. Öner. (With permission, Österreichisches Archäologisches Institut, Wien)

At Ephesus and the Artemision on the southern flank of the Cayster River (Küçük Menderes), surficial morphologic elements show a present floodplain dominated by backswamps and numerous meandering river channels (Fig. 7). Only in the lowermost 2 km are prograding sandy barrier accretion ridges evident, an indicator of high wave energies. The ancient Cayster river delta has prograded seaward over 14 km since Neolithic time and infilled the former 30-m-deep embayment with marine silts overlain by only a thin 2–3 m alluvial floodplain backswamp and delta complex to the north of the great harbor of ancient Ephesus (Kraft et al. 2000). Clearly, wave-generated littoral transport of sand has been dominant (since late Byzantine time), whereas, from Neolithic to High Byzantine times, an irregular complex of bays, lagoons, marsh and swamp and multiple distributary channels predominated (Fig. 8).

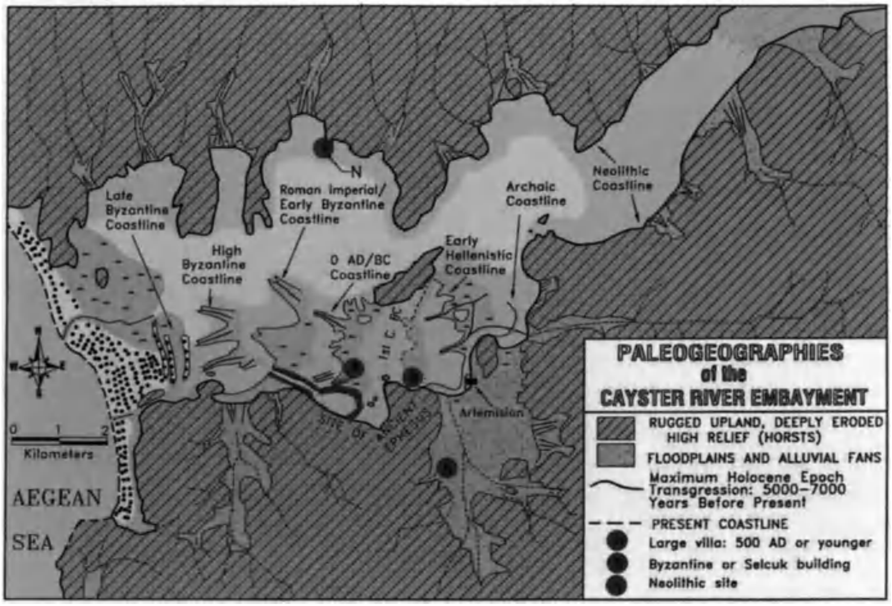

Fig. 8. Ancient geographies of the lower Cayster River (Küçük Menderes) delta floodplain in the vicinity of Ephesus and the Artemision. Coastline positions and geometries from Neolithic to High Byzantine times were dominated by an irregular delta distributary pattern typical of a low wave energy coastline changing to higher wave energies indicated by the evolution of a barrier accretion plain from Late Byzantine to present times

4
Paleogeographies at Troia

The four modern analogs presented above show highly variable lower delta coastal landforms under variable wind-wave conditions, yet, each example shown includes deltas actively prograding seaward with marine and coastal sediments aggrading upwards in space and time over the past six millennia. Drill core evidence from the floodplains of the Scamander and Simois Rivers show similar sedimentary sequences. Our drill control to the south near Pınarbaşı indicates fluvial to brackish sedimentary environments with the possibility of a few thin brackish/marine sediments (Kraft et al. 1980a, 1982). Thus, we know that the coastal projections of Schliemann–Virchow were in error, as they did not dig deep enough to encounter the very evident Holocene Epoch marine strata. We do not have enough drill control to attempt any shoreline configurations that may (or may not) underlie the southern 4 km of the Scamander delta floodplain.

We do, however, have the benefit of a large amount of drill core evidence from Kayan's research of the past decade. Thus, our delineation of lower delta coastline paleogeographies can be extremely precise in some local areas while elsewhere overall patterns of coastline morphology remain in question (see Kayan 1991, 1995, 1996, 1997a; Kraft et al. 1980a, 1982 for drill core sites, stratigraphic cross sections and discussion).

Clearly, Kayan's pioneering study of the Beşik coastal plain demonstrates a mid-Holocene marine embayment, evolving to a barrier-lagoon, and accretion plain backed by a coastal swamp (now drained). Using the asmak (multiple stream channel estuarine) model of the Scamander delta (Figs. 1, 2), Kayan reasonably adopts this modern-ancient analog (Kayan 1995). The location of shorelines in Fig. 9 is based on Kayan's explanation of a sea-level drop to −2 m ca. 3400 years ago and back to the sea level of today. The dominant thought and process is that an accelerated progradation of the shoreline seaward must have occurred in the second and third millennium B.C. Further, this interpretation emphasizes older ^{14}C dates in seaward positions.

Our alternate interpretation of the ancient geographies of the Scamander embayment is presented in Fig. 10. In this interpretation of ancient coastal morphologies, we emphasize quiescent, low wave climate, analogs such as the Spherchios delta in the Gulf of Malia (Fig. 4), the moderate wave climate of the Meander delta (Fig. 5) and Cayster river delta floodplain in part (Figs. 7, 8). Further, we used the youngest marine-brackish water molluscan ^{14}C dates, noting that some of our data are from the very complex sedimentary interface between clearly marine and brackish water morphologies such as lagoons, coastal marshes, bypassed flanking marine embayments – later to become freshwater lakes and then marsh or swamps (see the three indentations on the eastern flank of the Sigeum ridge). Thus, we envisage a complex of river distributary and/or asmak configurations, with abandoned distributary channels, "blind mouths", and lagoons with fringing fresh to brackish marsh. Such deltaic and shallow marine environments rapidly change in both salinity and morphology over short-term time (years, decades, and centuries).

Finally, we should note that it is unlikely that the Scamander delta will significantly prograde further into the Dardanelles. Irrigation practices have severely reduced the volume of sediment transport in the twentieth century. Further, the strong westerly currents in the Dardanelles sweep increasing sediment loads from the delta to the Aegean Shoals to the southwest (Fig. 1).

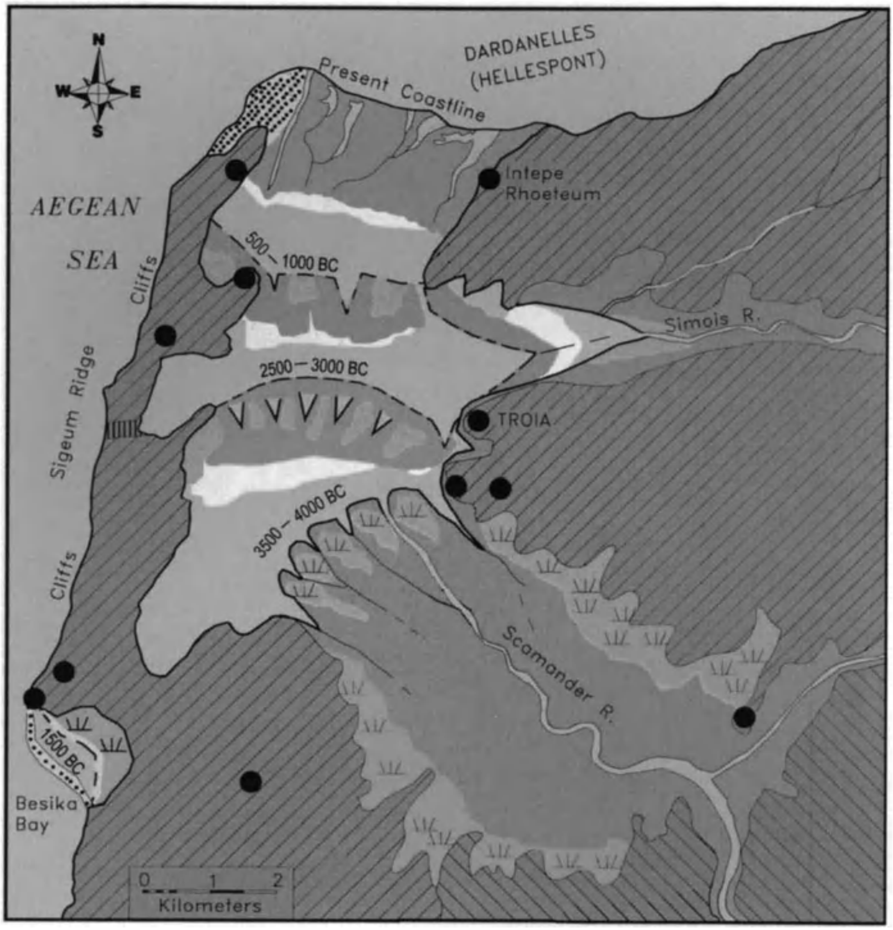

Fig. 9. Holocene Epoch paleogeographies of Troia and its environs from Neolithic to present times using the present asmak-dominated coastline of the Dardanelles as the interpretive model and a 2-m sea level drop to ca. 1400 B.C. as an indicator of accelerated delta progradation. (Kayan 1995)

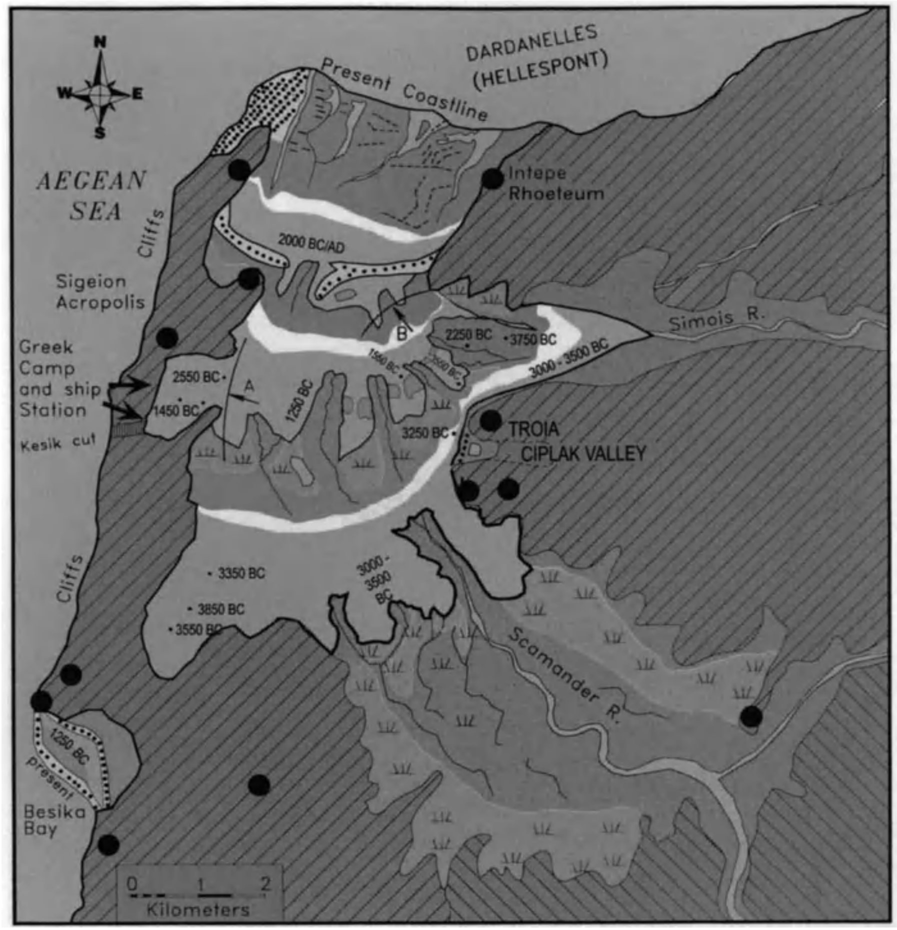

Fig. 10. Holocene Epoch paleogeographies of Troia and its environs in Neolithic-Early Bronze Age times, 1250 B.C. ca. the time of the Iliad, 0 B.C./A.D. in Strabo's time, and the present coastline. This interpretation emphasizes quiescent embayment coastal environments gradually changing to the current dominated Dardanelles shoreline of present time. Selected ^{14}C dates from Kayan (1995, 1996, 1997a) are shown along with J.V. Luce's (1998) location of the Greek camp and ship station at 20 stades (*A*) from Troia and (*B*) the Achaean harbor as perceived by the people of New Ilion at 12 stades from Troia (false harbor of Strabo 13, 1, 36). Note that all ^{14}C dates are from molluscs, indicating marine to brackish salinity environments of deposition

5
Strabo and the Iliad

In our research over the past three decades, we attempted to test phrases in the Iliad. Nothing in our research negates the writings of Homer! However, we believe that Strabo, among others, provides important clues as to the ancient geographies surrounding Troia, particularly when coupled with the lateral and vertical sedimentary and fossil data from drill cores. We are indebted to J.V. Luce for his detailed translation as follows:

Strabo 13. 1. 36
ἔστι γὰρ τὸ ναύσταθμν πρὸς Σιγείῳ, πλησίον δὲ καὶ ὁ Σκάμανδρης ἐκδίδωσι διέχων τοῦ 'Ιλίου σταδίους εἴκοσνεί δὲ φήσει τις τὸν νῦν λεγόμενον 'Αχαιῶν λιμένα εἶναι το ναύσταθμον, ἐγγυτέρω τινὰ λὲξει τόπον ὅσον δώδεκα αταδίους διεστῶτα τῆς πόλεως, ϊὸ πρὸ τῆς πόλεως ἐπὶ θαλάττῃ πεδίον συμποστιθείς, διότι τοῦτο πᾶν πρόχωμα τῶν ποταμῶν ἐστιν, ὥοτε εἰ δωδεκαστάδιόν ἐστι νῦν τὸ διάστημα τότε καὶ τῷ ἡμὶσει ἔλαττον ὑπῆρχε

The [Homeric] Ship Station is actually close to Sigeion, and the [main] mouth of the Scamander is also nearby, being 20 stades distant from Ilion, and if anyone says that the so-called "Achaian's harbour" is the Ship Station he will be speaking about a place that is too close [to Ilion], since it is about 12 stades distant from the city, taking account of the plain to the north of the city towards the sea, because this plain consists wholly of alluvium from the rivers, so that if the distance is now [ca. 0 B.C./A.D.] 12 stades, then [ca. 1250 B.C.] it would have been half that.

Strabo 13.1.31
συμπεσὸντες γάρ ὅ τε Σιμόεις καὶ ὁ Σκάμανδρος ἐν τῷ πεδίῳ πολλὴν καταφέροντες ἰλὺν προσχοῦσι τὴν παραλίαν καὶ τυφλὸν στόμα τε καὶ λιμνοθάλάττας καὶ ἕλη ποιοῦσι

The Simoeis and the Scamander effect a confluence in the plain, and since they carry down a great quantity of silt they advance the coastline and create a blind mouth, and saltwater lagoons, and marshes.

To some critics, Strabo's text in regard to Troia is questioned as being "second-hand." However, we know it to be derived from two local authorities, Demetrios of Scepsis who in turn relied on the lady Hestiaea of Alexandria Troas. As Luce (1998) notes, "She also raised questions about Homer's conception of the plain of Troy, pointing out that 'the plain now visible in front of the city', was not then in existence, an insight for which she deserves much credit."

Strabo 13.1.31 is quite specific about the Scamander and Simois confluence in the plain at Troia and the "blind mouth and salt water lagoons and marshes." From this point alone more involute quiescent embayment shorelines as shown in Fig. 10 might be posited. However, Strabo's comments about distances may be of greater import. Note the 12 stades to the "*Achaian's harbour*" as thought by New Ilium peoples of 0 B.C./A.D., and Strabo's note that the 12 stade distance would have only been half that, ca. 6 stades at the time of the Iliad. Further note Strabo's comment that the (Homeric) Ship Station is actually 20 stades from Ilion and close to Sigeum. Figure 10 shows 20- and 12-stade arcs from Troia (Ilion). Strabo's comment that the (main) mouth of the Scamander is nearby (Sigeum and the shipstation) can be interpreted two ways: (1) the (main) mouth of the Scamander was near Sigeum in Strabo's time (see also fifth century B.C. Herodotus' "Sigeum on the Scamander" 5.65) or (2) the Scamander mouth was close to Sigeum in the time of the Iliad. Neither interpretation is incompatible with the stratigraphic data; and, we cannot at present date and delineate specific channels of the Scamander river from the many dozens of river channel sands that lie buried in the Scamander alluvium. See Fig. 10 for our geomorphologic interpretation of the deltaic-coastal environments of 1250 B.C., the controlling ^{14}C dates used, and the distance noted by Strabo. J.V. Luce expands upon Homeric Troia and its ancient geography and "locales" in another chapter of this volume.

The Kesik cut immediately south of the Greek camp and Ship station may be a defensive trench before a palisade constructed by the Greeks if proven to be of three millennia or greater age (Luce 1998). It is certainly a man-made trench as proven by Kayan (1996). E. Zangger, (this Vol.), proposes that the Kesik cut was either a failed attempt to create a ship canal from the Aegean Sea to the "harbor" or a deep cut to facilitate the dragging of ships into an interior harbor to avoid the strong currents of the Dardanelles. Zangger further proposes that three possible harbors were used in the three western embayments of the Scamandrian Gulf in Bronze Age times. We agree that all three embayments southwest, west, and northwest of Troia, at the foot of the Sigeum ridge, had excellent harbor potentials. However, the southerly embayment northeast of Beşik Bay was bypassed by the prograding Scamander delta before Late Bronze Age times. Finally, we agree, along with J.V. Luce that the Beşik embayment always provided a place of shelter for ships; particularly, those wishing to sail up the Dardanelles against its strong currents. Beşik Bay was an important roadstead for sailing ships until late in the nineteenth century (see Kraft et al 1982).

6
Conclusions

Questions remain about precise delineation of the lower delta floodplain and coastal environments of the past six millennia. However, a correlation of the ancient literature with the physical and fossil evidence from the late Holocene strata that underlie the Scamander and Simois river floodplains surely allows for conclusions greater then the separate sum of the two disciplines. The detail of our physical geographic/geologic evidence and analyses over recent decades has significantly increased. Thus, paleogeographic delineations in the immediate vicinity of Troia are significantly improved. Yet, in some areas the nature of precise positions of sedimentary environmental facies boundaries leaves much work for the future; perhaps degrees of magnitude of additional drill core data and ^{14}C dates and/or geophysical applications not yet developed.

Acknowledgments. We thank the Institute of Aegean Prehistory (INSTAP) for its long-term support.

CHAPTER 25

Geoarchaeological Interpretations of the "Troian Bay"

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Abstract

Sea-level rise during the Holocene brought about a ria-type bay (Troian Bay) in the lower part of the Karamenderes (Scamander) valley which intruded approx. 17 km up to the south of the present plain about 7000–6000 years ago. Since then, alluviation and deltaic progradation has moved the shoreline north of the Çanakkale Strait (Dardanelles). A relative fall in sea level of about 2 m in the Bronze Age accelerated this process. Thus, Troia was a coastal settlement at first, while the area to the west in periods IV, V and VI was a broad deltaic swamp. The sea in the coastal zone of the Karamenderes delta plain was very shallow, and the land was covered by swamps during the entire progradation period. Therefore, the geographical environment has never been suitable for the establishment of an important harbour or city development based on harbour activity.

1
Introduction: Aim, Method and Investigations

Troia, being important in archaeology and the history of culture, is a very special site with respect to the geographical changes in the surrounding area, and has been the subject of great interest and scientific research. Of course, the most important reason for this interest is the detailed description of the geographical environment made by Homer as he narrates events occurring in Troia and its surroundings. However, suspicions as to how much Homer's descriptions represent reality have provoked much discussion. Nevertheless, descriptions of the geographical environment of around 3250 years ago, which reached the present day as written text, are an important original feature of Troia offered by Homer.

Curious travellers in the nineteenth century carefully followed and interpreted the descriptions of Homer in order to find the site of Troia. The most outstanding subject of interest was the changes of the coastline. The idea that Troia was a coastal settlement during its early stages is generally accepted. However, the major curiosity was concerned with the location of the coastline, naval harbours and battlefields during the supposed Troian War about 3250 years ago in the period of Troia VI. This requires that environmental characteristics and landscape changes in Troia should be taken into account and correlated with archaeological interpretations. Thus, the importance attached to the landscape by Homer has given impetus to the present scientific research in Troia.

Our investigations in Troia have been continuing since 1988 in the new Troia Project led by Prof. Manfred Korfmann, on the formation of the present geographical environment, its past progress and changes, and interrelations between landscape changes and the cultural periods of Troia. In our plan, at the same time, general geographical and geomorphological characteristics of the Troia area were investigated, the ridge where Troia is situated and its surrounding alluvial plains were also examined in detail (Fig. 1).

High areas are generally subject to erosional conditions, and investigations made only in such areas are not enough to interpret all environmental development. It is necessary also to examine alluvial and colluvial sediments which are deposited in the surrounding lower areas, and data ob-

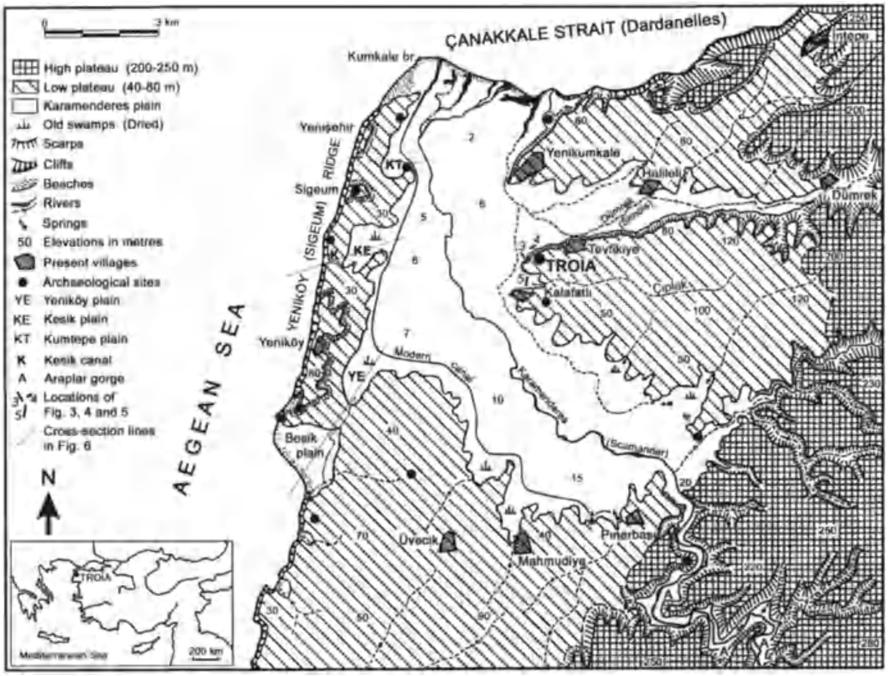

Fig. 1. Geomorphological outlines of the Troia area and the Karamenderes plain. (Kayan 1995)

tained from both erosional and depositional areas should be evaluated comparatively. In this way, it can be understood how the environment in an archaeological site has changed over thousands of years and in which way these changes have affected the land-use pattern of people who lived there. For example, the pattern of life and eating habits of the people who lived in Troia clearly changed greatly from the time when the area surrounding the ridge was sea to when the same area changed into arable land due to alluvial deposition. At this point, in order to illuminate the man-environment interrelation, it was necessary to determine what the former environmental characteristics or palaeogeography of the present alluvial plains surrounding Troia were. The sedimentary units deposited on the bottom of depressions under various environmental conditions are the best tools to bring out the environment during their formation, and the dynamic effects under which they were worked, transported and deposited. To reach different sedimentary units below the present alluvial surfaces and interpret what kind of geographical environment they represent is only possible by bore-hole drillings. Horizontal and vertical distribution of sedimentary units and three-dimensional geometry of the changing environments can only be delineated using a sufficient number of drill-hole profiles.

Dating is an important part of the interpretation. To construct an interrelation between the environment and human activity is only possible if the time of the environmental changes is known. In order to do this, it was necessary to date when the Troia ridge was surrounded by sea and until what time this condition continued, and to follow the progress of alluviation. Currently, archaeological and radiometric dating methods are the most common for age determination. Small findings like potsherds encountered in drill holes can sometimes be dated by archaeologists. However, this is not a generally convenient method, and ^{14}C dating is a more widely used technique. Resistant carbonaceous shells of marine or coastal environments, and in some places plant remains, are the most suitable material for dating. Important chronological data have been obtained from these materials by laboratory analysis in the USA and Germany. In particular, ^{14}C analyses made by Dr. B. Kromer at the Institut für Umweltphysik der Heidelberger Akademie der Wissenschaften in Germany have made great contributions to our palaeogeographical interpretations.

The number of drilling holes made since 1977 in the surroundings of Troia on the Karamenderes-Dümrek alluvial valley floor, including the Be°ik plain on the Aegean coast, totalled 285 in 2001. Various techniques and equipment were used for these drillings as our resources and needs progressed over time.

Our first geoarchaeological studies in the environs of Troia started with Professors J. C. Kraft and O. Erol in 1975. In 1977, seven rotary core drillings were made on the Karamenderes and Dümrek alluvial plains surrounding Troia, with the support of the Mineral Research and Exploration Institute of Turkey (MTA). In most of these drill holes, of which the deepest went down 75 m to pre-Holocene bedrock, Neogene sediments were reached. This work revealed that following a sea-level fall in the last glacial stage, the Karamenderes incised a deep bed on a surface about 30 m below the present plain, and about 10,000 years ago in the post-glacial period, during the Holocene, the rising sea intruded into this incision, covering the entire old valley floor. Thus, it is concluded that about 7000–6000 years ago, an estuarine bay in the present lower Karamenderes valley west of Troia, extended southwards as far as the north of Pınarbaşı-Mahmudiye (Fig. 1). The sea-level rise stopped about 6000 years ago, and then the present alluvial plain began to prograde to the north presently reaching about 5 km northwest of Troia (Kraft et al. 1980a, 1982).

In 1982, Prof. Korfmann began an archaeological research and excavation project on Beşik Sivritepe and Beşik Yassıtepe north of the Beşik plain on the Aegean coast to the west of the Karamenderes plain. Our aim in joining this project was to bring out the geomorphological evolution of the Beşik plain and especially to understand whether or not this plain was in a bay during the Bronze Age. Thus, we intended to interpret palaeogeographical evidence for the possibility of a natural harbour for the Achaean navy in the Beşik bay during the supposed Troian war. Eighty hand drillings were performed to a maximum of 8 m, and some ^{14}C dates were obtained. We showed that the present Beşik plain formed as a small bay about 6000 years ago. Afterwards, a coastal barrier separated a small lagoon. There is no major stream behind the Beşik plain to bring any great amount of alluvium. Therefore, coastal landforms developed here only under the control of marine processes. This made it possible to delineate small relative sea-level changes during the middle and late Holocene. Thus, the sea, which had reached its present level about 6000 years ago, fell about 2 m in the period 5000–3500 years ago, then rose again to its present level at the time of Christ. A small sea-level fall in the Late Bronze Age may have caused widening of the coastal barrier and reduced the lagoon (Fig. 2). Thus, it can be interpreted that no Bronze Age natural harbour with an open water surface seems to have been possible here (Kayan 1991).

A new Troia project led by Prof. Korfmann started in 1988. A multi-purpose "Unimog" vehicle was granted to the project by Daimler-Benz for the heavy excavation work. In particular, it has a hydraulically powered rotary-auger drilling rig, providing powerful, fast and productive drilling capabilities down to 20.50 m. Using this equipment, tens of drill holes were bored every year, especially on the alluvial plain around Troia.

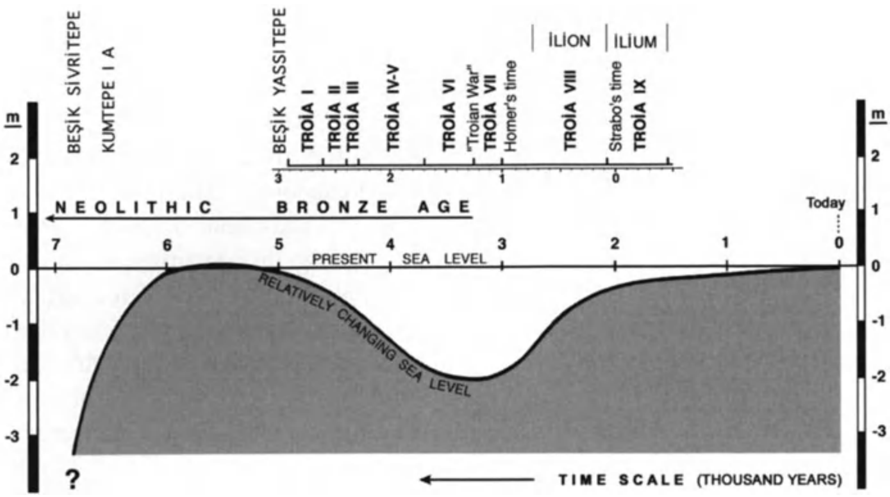

Fig. 2. Middle–Late Holocene relative sea-level changes in the Troia area. (Kayan 1991)

The Unimog was also used to excavate trenches down to 2.5 m in some places, especially on the colluvial deposits along the foot of slopes, in order to carry out detailed examinations of soil formations and dispersion of archaeological material from the mound. In addition, an Eijkelkamp hand-drilling tool was used in places where it was more convenient. Down to a depth of 8–10 m the Eijkelkamp is quite good for examining surface sediment layers which formed during historical or even prehistoric times.

In 1992–1994, our research was concentrated on the Yeniköy (Sigeion in archaeology) ridge which separates the Karamenderes plain from the Aegean Sea to the west, and its eastern foot which slopes gently towards the plain (Fig. 1). Here, geomorphological characteristics along the western edge of the Karamenderes plain suggest some old harbour locations, and there is some discussion in the literature about this. New data on this area were obtained from our study and they have made it possible to clarify some speculation. These will be given below.

Although the number of our drilling holes, most of which were made by the Unimog after 1988, reached 200 in 1996, the great variety of marine, coastal, deltaic, floodplain and swampy environments in the research area, in addition to colluvial and archaeological deposits, and their vertical and horizontal changes in short distances, brought about the necessity to increase the number of drillings and the variety of techniques. The Unimog provided very useful data by means of its great hydraulic power. It was a great advantage to be able to sink drill holes down to 20 m in a short time, cutting through all kinds of sediment sections. However, samples could not be taken as undisturbed cores because of the mixing effect of rotary-auger drilling. In addition, due to the large volume of the auger-rods, sediments climb upward under high pressure during operation and samples cannot be located to their real depths. This was a great disadvantage for precise correlations, and for this reason percussion drilling equipment has been preferred in more recent studies. Our suggestion to obtain percussion drilling equipment was accepted by Prof. Manfred Korfmann, and the Troia Expedition provided a set for our studies. Using this equipment, 1 m of gouge-auger rod is driven into the ground by an engine-powered driller (Cobra), and is then driven deeper with extension rods of 1 m each. Thus, it is possible to have fairly undisturbed sediment samples, though they are slightly compressed. The diametre of the auger may be 65, 50 or 35 mm, and it is possible to reach down to 30 m in suitable sediments. However, 15–20 m is a good depth under normal conditions. In addition, deeper test drillings are also possible using thinner rods of 25 mm diametre. This is useful in order to find bottom depth or bedrock surface below marine sediments. After we obtained a hydraulic lifter in 1997 to take out the augers and extension rods, our drilling work reached very productive conditions for data collection. In 2001, the number of Cobra drillings reached 85 and the total number of Troia drillings is 285.

Sediment samples taken from the drilling-holes are first analysed in our laboratory in the Department of Geography, Ege University. These are simple grain size, pH and calcimetric analyses. Then if necessary, we prepare samples for ^{14}C or other analyses and send them to the relevant laboratories. In 1997 and 1999, OSL (optically simulated luminescence) analyses were tried and good results were obtained by a research team from the Heidelberger Akademie der Wissenschaften (see Chap. 23, Göbel et al., this Vol.).

Finally, drilling data are evaluated by computer in a standard format and prepared for drawing desired cross sections. Based on a great number of cross sections in various directions, palaeogeographical maps can be drawn and geographical reconstructions of coastline positions for various times are possible. Knowing the precise topographical elevations of the drilling points from the present sea level is especially important for stratigraphical correlations between the drilling holes. The primary source of this information were 1/25,000 scale maps. Because some corrections were necessary, special topographical measurements were made and linked to the Troia measurements. In addition, GPS measurements have been very useful in recent years, especially for some drilling points away from the Troia site. However, in recent years, a new agricultural development of the entire Karamenderes plain has changed the surface elevations of drilling points, and their locations have been difficult to find because all of them were located according to old field roads or boundaries. Thus, vertical shifts of up to some 10 cm must be taken into account in certain drill-hole correlations.

Our studies in the Troia area have been summarised above. Results of the studies have been published in various places, but were first published in Studia Troica, which is the annual book of the Troia Project. A brief summary of the results is given below.

2 Geological Structure and General Geomorphology

The formation of the present geographical appearance of Troia and its surroundings should be considered in terms of two phases. The first phase is the formation of the geological structure and its development. The succeeding phase is the shaping of the present geography on this geological structure. The last part of the second phase is the period in which prehistoric settlement began in the Troad. Therefore, this stage is of major importance to archaeology and the history of culture.

When examining the geological structure of the Troia area, account must be taken of the Biga and Gelibolu peninsulas and their formation over a long period of geological time. The Biga Peninsula consists of various sedimentary and volcanic rocks underlain by an older igneous and metamorphic base (Bilgin 1969). During the Neogene period, depressions were formed between raised mountain blocks. What was once a lake in what is now the Bayramiç-Ezine Basin, for instance, filled up in the course of aeons with material washed down from the surrounding slopes. Moreover, to the northwest, in the place where today the Gelibolu Peninsula and the Çanakkale Strait (Dardanelles) are situated, the Black Sea extended from the north into a basin where it formed a broad, but shallow gulf. The low ridges around Troia were formed from sediment laid down on the bottom of this sea. During this time the Aegean was land with several lake basins. This palaeogeography existed within a period from 12–2 million years ago (geological periods of Late Miocene and Pliocene).

While the land continued to rise, layers of sedimentary rocks consisting of sand, clay and limestone which had been deposited on the bed of the shallow Neogene sea broke into three main blocks. These have formed the present Yeniköy Ridge to the west, and the Kumkale and Troia ridges to the east (Fig. 1). The Karamenderes (Scamander) River and its tributary, the Dümrek (Simois), settled in the depressions between the ridges and filled them with alluvial deposits, which formed the plain around Troia. Because this region is situated on the southern flank of the North Anatolian Fault Zone, tectonic movements have taken place, and recent earthquakes indicate that the region still has remarkable tectonic activity (Yılmaz, this Vol.).

The surface of the ridges around Troia is at an elevation of 40–50 m and to the east rises to an elevation of up to 100 m. This brings about a low plateau formation (Fig. 1). A fault zone with a steep slope bounds this area to the south, running from northeast to southwest. In this zone there are more recent lava flows and rich springs of water. Above this rise, that is, on the igneous and metamorphic bedrock and other geological formations, there extends a slightly undulating higher plateau surface at an elevation of 200–250 m. The Karamenderes River has incised this surface and opened the Araplar Gorge which connects the Bayramiç-Ezine basin to the south and lower Karamenderes delta floodplain to the west of Troia.

The Quaternary period, as we know, is much shorter than the preceding geological times (less than 2 million years). During this period of geological history, tectonic movements had less influence on geomorphology, yet climate changes shaped the environment more strongly. Unlike in Europe, there was no ice age in Turkey because it is so far south. However, the fall in sea level during the glacial periods brought about changes in coastal regions all over the world, including Turkey. Low-lying coastal areas, especially delta floodplains, underwent a great deal of geomorphological-environmental changes. This included the alluvial plain on the lower part of the Karamenderes River, west of Troia.

In the Quaternary Period at least four glacial ages occurred during which the sea level fell appreciably. In the interglacial ages, however, the seas of the world reached approximately their present level. At the end of the Late Glacial Maximum, about 20,000–18,000 years ago, the sea level was about 100 m lower than today, turning the Sea of Marmara and the Black Sea into lakes (Jablonka, this Vol.; Govedarica, this Vol.). The Dardanelles and the Bosporus were river valleys and the Karamenderes (Scamander) was a tributary of the main river in the Dardanelles. Sandy-gravelly alluvial sediments at a depth of about 30–40 m, which were encountered by drilling studies in the plain west of Troia, indicate the bottom of the valley at that time.

In the following warmer period (Holocene), the level of the sea continued to rise due to melting ice in the Polar regions and high mountains. About 10,000 years ago the sea reached into the lowest parts of the lower Karamenderes delta floodplain. It can be assumed that, even during the time the sea inundated it, the Karamenderes continued to bring alluvium, and deposited it in the bay. Thus, the position of the coastline in the bay changed continuously depending on the balance between the rise of the sea level and alluvial sedimentation. During the period of more rapid sea-level rise, until about 7000 years ago, the coastline continued to advance south, covering former delta plains and reaching the vicinity of Pınarbaşı.

It is known that the rise in the sea level slowed down and that by about 6000 years ago the sea reached today's level (Fig. 2; Kayan 1988a). During this time, the shore began to be filled with alluvium which the Karamenderes brought from the Bayramiç-Ezine depression, and the new deltaic coastline prograded northward. Drilling studies have shown that swampy areas of vast dimensions stretched south of Troia during that time (Kayan 1995).

Geomorphological investigations on the Aegean coast of Anatolia have shown that the sea level has also changed during the last 6000 years (Kayan 1999). Under the auspices of the Beşik Project headed by Manfred Korfmann (1983–1988), about 80 bore holes were drilled 7–8 m deep with a hand drill. These operations proved that the sea level fell by about 2 m between 5000 and 3500 years ago, and by the time of Christ rose again to its present level (Fig. 2; Kayan 1991). These are relative sea level changes and the reasons are not entirely known. However, the sea level fall during the Bronze Age is attributed to tectonic movements (Bronze Age Regression; Kayan 1997b). This slight sea level fluctuation influenced the development of the alluvial plain of the Karamenderes and the Dümrek around Troia, and consequently, also had a bearing on the activities of the Troians in the Bronze Age.

3 Geographical Changes in the Holocene

Sedimentological data obtained from corings made on the alluvial plains surrounding Troia show that the Holocene stratigraphical sequence consists of three main units. These units and their palaeogeographical environments are summarised below in chrono-stratigraphical order, from bottom to top (Fig. 3).

3.1 Early Holocene Palaeogeography and Marine Transgression

Drilling evidence indicates that towards the end of the last Glacial period about 15,000 years ago, when the sea level was about –100 m, the bottom of the lower part of the Karamenderes valley was a slightly undulated plain on older (Pleistocene) marine and terrestrial sediments. ^{14}C dates of marine sediments and OSL dates of terrestrial deposits support this interpretation (see Chap. 23, Göbel et al., this Vol.). The bottom of the valley at that time was about 30 m below the present plain. The ancestral Karamenderes River had an incised bed close to the western slope of Troia.

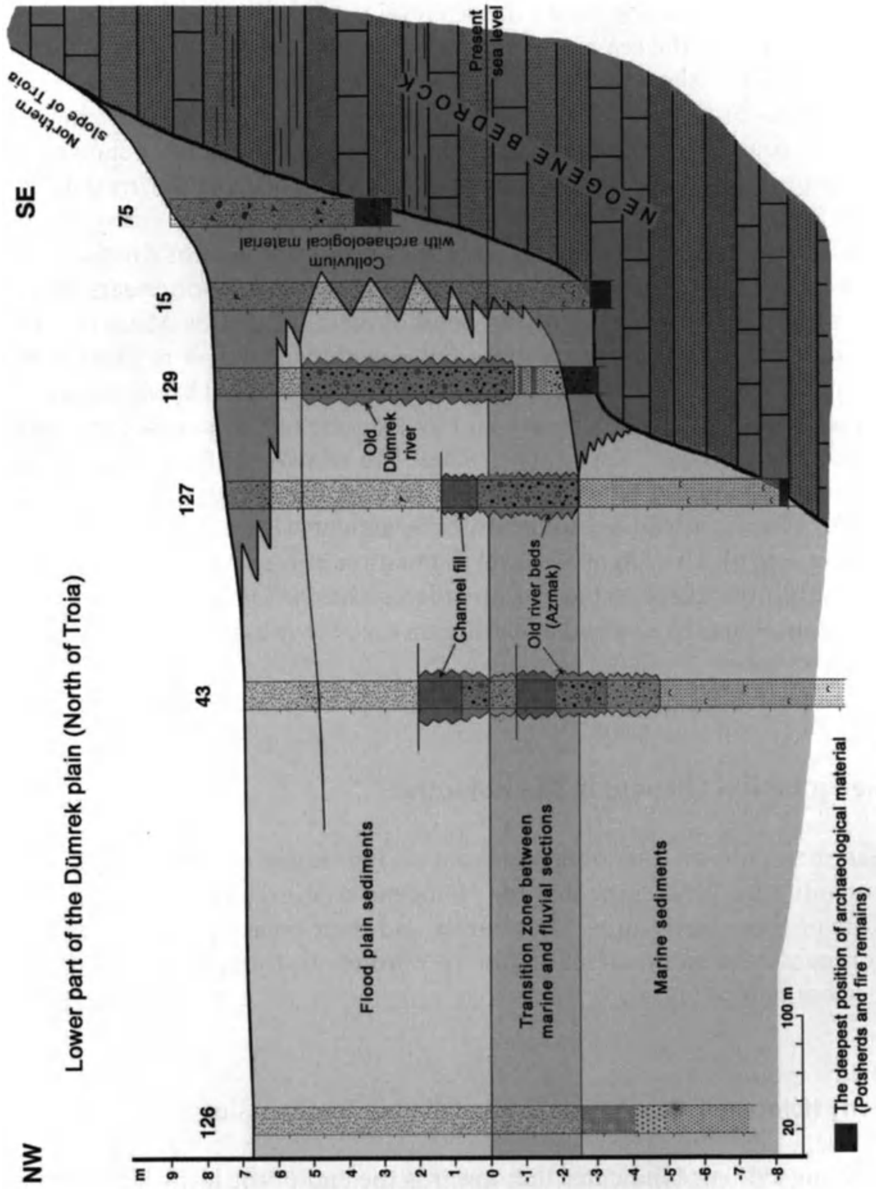

Fig. 3. Cross section of the steep northern slope of Troia (Kayan 1996, 2000). The *numbered columns* are drill cores

The rapidly rising sea during the Early Holocene intruded into the incised part of the ancestral Karamenderes River at the bottom of the valley. ^{14}C dates of large marine shells (especially *Cardium* and *Ostrea* shells) taken from about 50 m below the present surface were dated to 10 000 years ago. By 7000 years ago, the old valley bottom was completely covered by sea water and the shoreline was near Pınarbaşı-Mahmudiye to the south (Fig. 1). In drill holes which reached the Neogene bedrock marine sediments start with coarse lag deposits (gravelly and coarse sandy transgression facies). Large oyster shells are generally abundant in this bottom deposit. Overlying fine-grained and generally very homogeneous marine mud is the main sediment unit of the Holocene transgression. This has varying sedimentological characteristics from place to place, from well sorted very fine sand to very sticky black mud. Sticky black mud is related to organic colloids. However, marine shells are very rare because of anoxic and acidic conditions. Some small methane explosions were experienced during the drilling operations in the south.

Although the bay at the mouth of the Karamenderes River was of an estuarine (or ria) type, neither gravelly coarse sandy old river channels nor clean sandy beach sediments are encountered in the fine grained marine sediments. This is related to the bedrock types. The bedrock in the surrounding area consists completely of sandy-silty-clayey-carbonaceous Miocene shallow marine sediments. In addition, the Karamenderes leaves most of the coarser alluvium in the Bayramiç-Ezine basin behind the Araplar gorge and brings generally finer grained material to its lower delta plain. The homogeneously fine grained nature of the Holocene sediments causes difficulties of detailed interpretation of the morpho-dynamic characteristics of the sedimentary environments, such as delineating old river channels or old shoreline positions.

^{14}C dates of marine-coastal shells obtained from coastal deposits at the approximate present sea level below the present surface along the foot of the Neogene slopes are always found to be close to 6000 years ago. This means that the sea-level rise stopped at its present level about 6000 years ago. However, maximum extension of the sea to the south close to the old river mouth may be a little earlier, about 7000 years ago, because of the balance between alluviation and sea-level rise. Towards the end of the transgression, the sea-level rise slowed down and intrusion was more than compensated by alluviation, so that in the period 7000–6000 years ago, the shoreline must have prograded northward in spite of the slow sea level rise.

3.2 Middle Holocene Deltaic Progradation

The top surface of the marine sediment unit extends for a few metres, generally 2 m below the present sea level under almost the whole surface of the present plain, except along the foot of the edge slopes (Fig. 3). On this very flat surface, there is no clear change in the physical characteristics of the sediments. They are still blackish dark grey silty, fine tovery fine sandy somehow marine or marine-connected sediments. Organic colloids and marine shells are generally less frequent than below true marine sediments.

These sediments vary from place to place. For example they are homogeneous in some places, but laminated in others. Towards the lower parts of the lower tributaries, such as the Dümrek or Çıplak Rivers, they have a terrestrial content and show a hard block structure with carbonaceous concretions. Marine shells are rare and mixed with brackish-freshwater species. All of these characteristics indicate that this is a transition zone between lower marine and upper terrestrial units. The sediments must have been deposited in the very shallow coastal environment of a delta floodplain. There is no beach or lagoon formation. Instead, sediments indicate swampy or seasonally wet environments. The upper surface of this unit is almost at the present sea level. Thus, it is possible to interpret that the transition zone belongs to the most recent water zone which is filled with deltaic sediments following the end of the sea-level rise.

One of the characteristics of the transition zone is a number of sediment belts which represent former deltaic distributary channels ("azmak" is a more specific term in Turkish). These are medium-coarse sandy, generally muddy and contain high amounts of organic colloids. While coarse sand implies water flow, their muddy nature and organic content represents stagnant conditions at least from time to time (or seasonally). Their depth below the present sea level is concordant with the interpretation as "azmak"s.

Over such a very shallow coastal zone, a small sea-level fall would cause a wide area to be turned into dry land. This interpretation is supported by sediment characteristics and ^{14}C dates which point to a regressive sequence in the period between 5000 and 3500 years ago. Thus, the transition surface represents an important change from a wet environment to dry land suitable for human use. This makes it important from a geoarchaeological point of view.

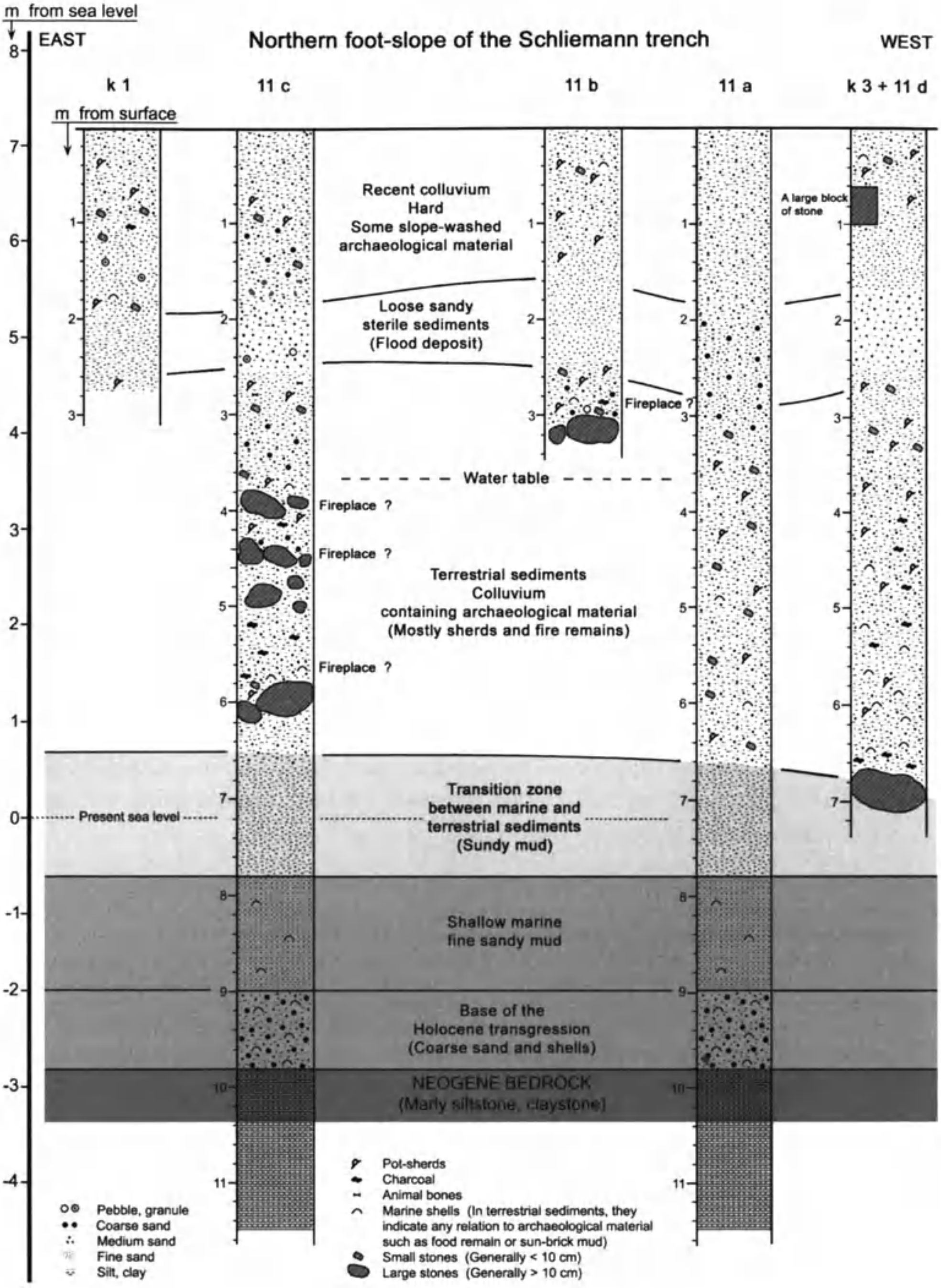

Fig. 4. Details of drill holes along the foot of the slope of Schliemann's north–south trench, looking south from the Dümrek plain. (Kayan 1996)

3.3
Late Holocene Deltaic Progradation, Aggradation and Colluvial Sedimentation

The uppermost unit of sedimentation above the present sea level consists of fine sandy-silty floodplain deposits (alluvium). Its colour varies according to the level of the groundwater. Below the water table grey to dark grey sediments look like the lower units and sometimes it is difficult to separate them. However, they are different regarding their nature of hard block mud and carbonate content. As for the layers above the water table, these are generally brownish-olive colours. In the upper layers, grain size homogeneity is disturbed and denudational flow marks, coarser flood bands and pedogenetic horizons can be viewed. However, great stream channels, recognisable by coarser sediments, are rare. As stated above, this is because the bedrock in the area produces only fine-grained sediments.

Towards the foot of the slopes along the edges of the alluvial plain, colluvial material mixes into floodplain sediments. These are also fine sandy and originate from the slopes, consisting of Neogene bedrock. In addition, they contain clayey soil material which has been produced by weathering on the slopes. Therefore, they can be easily distinguished. They have great importance because of their content of archaeological material. For example, in the near surroundings of Troia, colluvium contains potsherds, pieces of brick and tile, fire remains such as charcoal, ashes and burned soil, and food remains like bones and shells. The rounded shapes of potsherds implies that they were transported for some distance by water flow on the surface. Their abundance, shapes and ages are all very important tools for geoarchaeological interpretations (Figs. 3 and 4).

4
Geoarchaeological Interpretations Around Troia

Some interesting results have been obtained from the studies performed on the northern and southern foot slopes of the Troia ridge.

The present surface to the north of the Troia ridge is about 7 m above sea level. Based on data obtained from a great number of drilling holes which were made to the north of the Schliemann trench, there is a platform on the Neogene bedrock about 50 m wide, beneath the alluvial-colluvial sediments and just below the present sea level (Fig. 3; Kayan 1996). The surface of the platform is covered with marine sediments up to the present sea level. ^{14}C dates show that the coarse sandy coastal sediments belong to 5800–5200 years ago, which is well in concordance with other evidence in the region. The upper section, above sea level, consists of colluvial deposits containing archaeological material. These are generally related to fire:

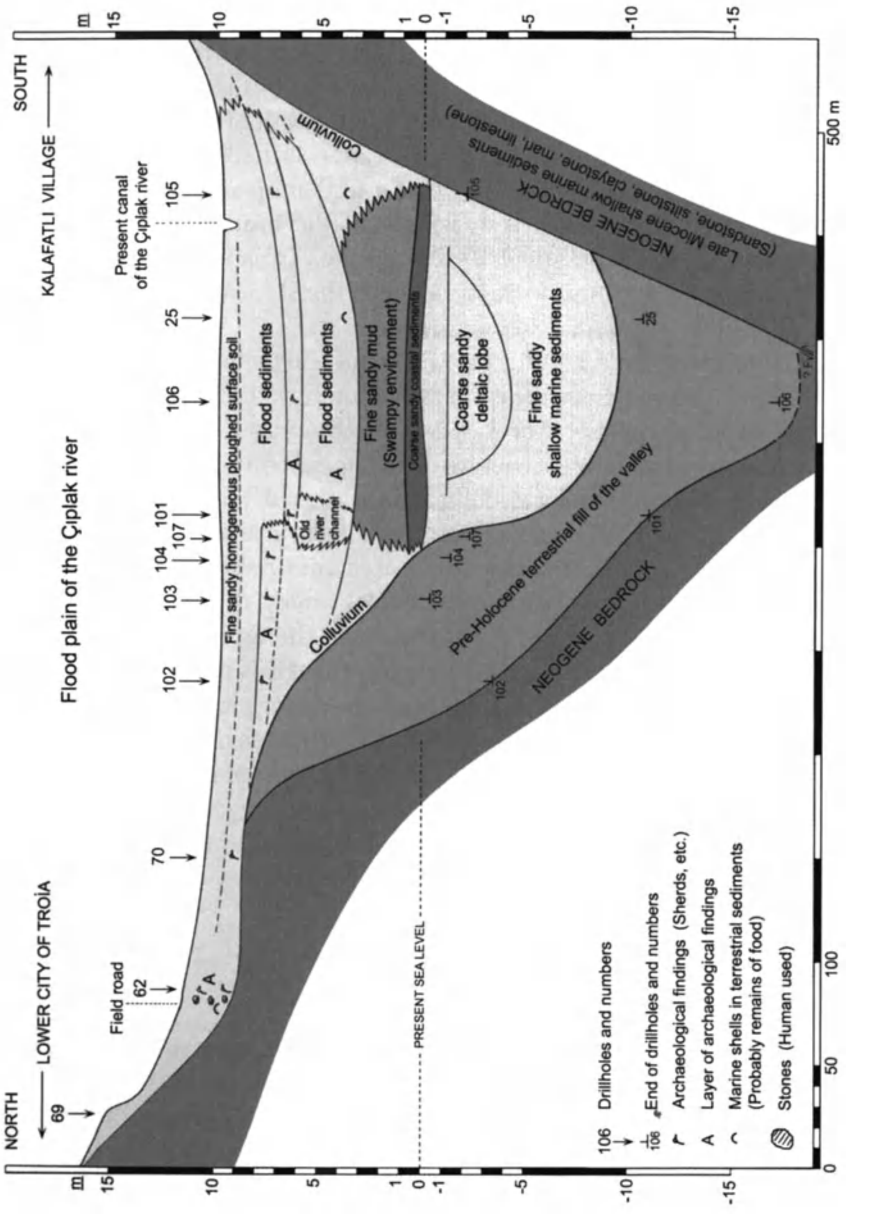

Fig. 5. North–south cross section across the western part of the flood plain in the lower Çıplak valley, from the Lower City of Troia to the south. (Kayan 1997a)

stone remains of fireplaces, burned bones and shells and ashy mud are abundant (Fig. 4). Some potsherds have been dated as Troia IV, V, and VI by archaeologists. This deposit can be followed up to the old channel of the Dümrek River, which was located about 50 m north of the foot of the steep Troia slope. Because the Dümrek River later shifted northward, the old river course is covered by finer sediments at the top and disappears. Thus, it is understood that the sea was right at the foot of the "Schliemann trench" during the earliest periods of Troia, i.e., Troia I and II. During Troia IV–VI, a strip of dry land formed between the slope and the old Dümrek channel, which was suitable for human use.

To the south of Troia, another detailed study on the outskirts of the Lower City of Troia showed that a layer of earth about 1 m thick containing archaeological material spreads over a wide area about 2–4 m below the surface (Fig. 5; Kayan 1997a). The archaeological material consists of densely packed pieces of potsherds, bricks and tiles, and burned material in colluvium. Pieces of archaeological material must have been washed down by rainwater from the city and spread over the lower area following great destruction including a fire in the city. Here, in the Çıplak valley, the lower marine sediments do not extend much to the east because the Çıplak valley is not deep on the Neogene bedrock and the river easily filled this small valley with alluvial-colluvial sediments originating from the lower plateau surface (Fig. 1). Preliminary results of OSL datings of these sediments indicate that it is possible to correlate them with pre-Holocene (Pleistocene) marine sediments in the deeper parts of the Karamenderes valley, and suggest them as their terrestrial equivalent (see Chap. 23, Göbel et al., this Vol.).

5
About the Potential Harbour Sites

Since the Karamenderes plain was a long bay for several millennia 7000 years ago, Troia must have had a harbour or harbours in different places following changes of coastline positions during deltaic progradation. An important question then arises as to where the Troia harbours were. This is one of the main topics of discussion related to the paleogeographical changes in the Troia area.

As stated above, three low plateau ridges, which consist of uplifted Miocene shallow marine sediments, delineate the geomorphological outlines of the Troia area. One of them is Yeniköy ridge (or Sigeion ridge in archaeology) in the west, which separates the Karamenderes plain from the Aegean Sea (Fig. 1). This north–south trending ridge is about 40–80 m high and 1 km wide. Its western slope forms a steep cliff line, cutting almost horizontal Miocene beds of carbonaceous sandstone and claystone. In contrast to the straight shape of the western cliff line, the eastern slopes descend gently to the Karamenderes plain and then give way to alluvial deposits. On this eastern side, the line between the alluvial surface and the Miocene bedrock slopes is greatly indented. Three particular indentations on this side have been interpreted by Troia visitors and explorers as possible ancient harbour sites. These are, from south to north, the Yeniköy, Kesik and Kumtepe indentations as extensions of the Karamenderes plain.

There are very shallow thresholds between the Yeniköy and Kesik plains and the sea. In addition, there are small canals or ditches across the thresholds, which have caused some speculation about water passages between the Aegean sea and supposed inner harbours in the Bronze Age (Cook 1973; Zangger 1992; Zangger et al. 1999). Kayan carried out detailed geomorphological research including drilling studies in this area in order to elucidate this matter under the light of new evidence (Kayan 1995).

5.1 Yeniköy Plain

The Yeniköy (Sigeion) ridge is interrupted towards its southern end by a structural depression extending north-east–southwest. The Beşik plain is situated on the coastal part, while the Yeniköy plain extends from the Karamenderes plain on the inner part of this depression. The Beşik and Yeniköy plains are separated from each other by a very flat threshold only about 10 m above sea level (Figs. 6 and 7). The bedrock, which consists of Miocene marine sandstone here, is open to the surface. This geomorphology has been interpreted by some explorers to show that the sea overflowed this threshold at one time and intruded into the Yeniköy plain, and thus the Yeniköy ridge formed as an island. Sandy cover and some shell fragments supported this idea. However, there is no true evidence for such a marine connection.

There is a simple man-made trench a few metres deep across the threshold. This implied to some explorers that even if there was no natural marine connection over the threshold, a man-made canal might have connected the Yeniköy and Beşik bays. Thus, the supposed Yeniköy bay would have been a very convenient harbour site in ancient times. Our drilling evidence clearly showed that Beşik and Yeniköy embayments were covered by seawater when the sea reached its present level about 6000 years ago. However, there was no evidence to indicate any natural or artificial connection between the two bays. On the contrary, detailed investigations showed a 2-m sea-level fall about 5000–3500 years ago, that is, during the Bronze Age, causing wide areas to dry up into land in both embayments (Kayan 1991, 1995).

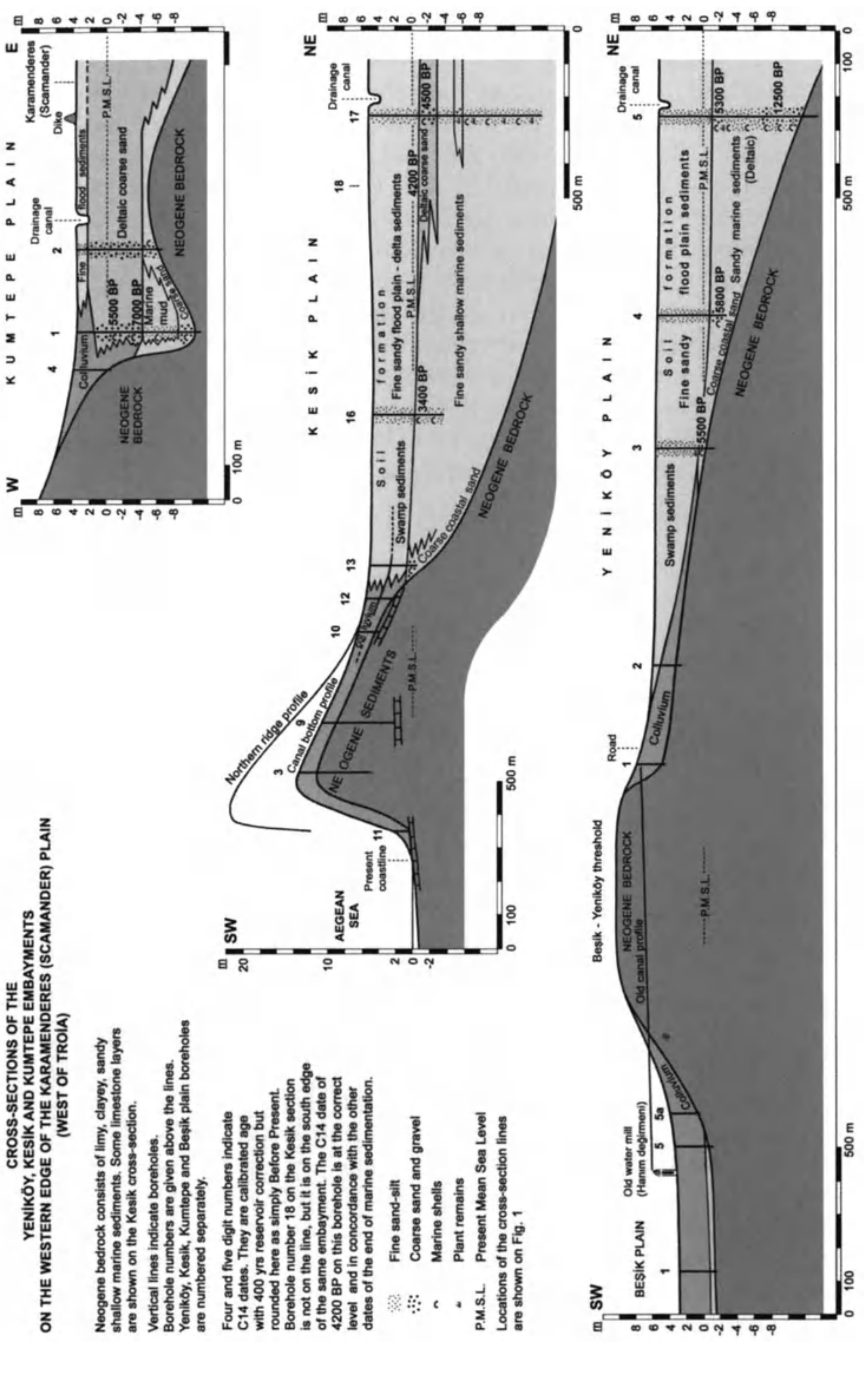

Fig. 6. Cross section of the Yeniköy, Kesik, Kumtepe embayments. (Kayan 1995)

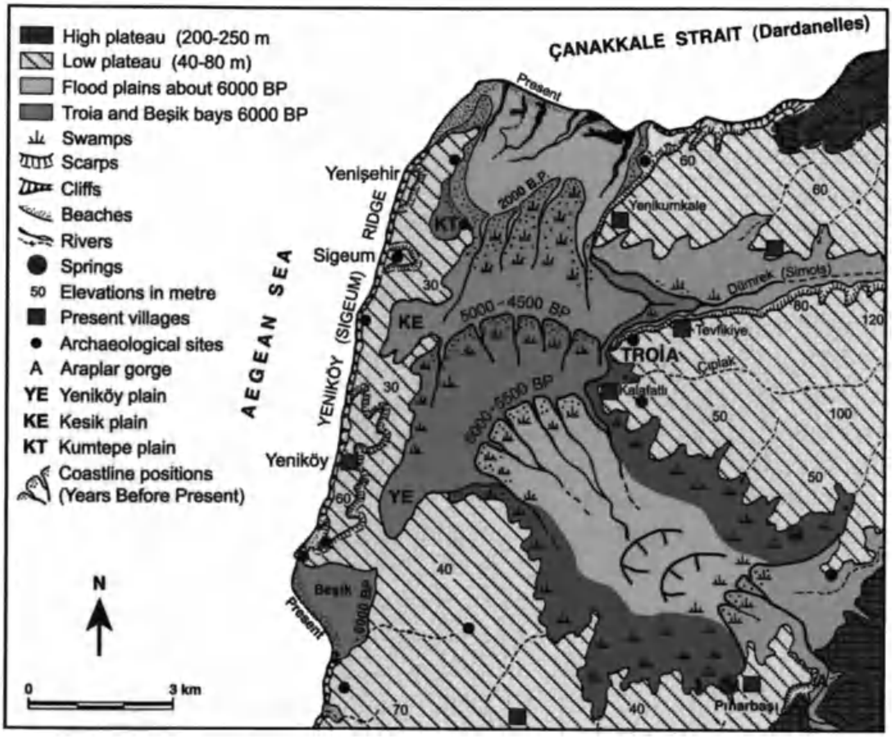

Fig. 7. Geomorphological development of the Karamenderes (Scamander) plain. (Kayan 2000)

Although it is not known when the ditch on the Yeniköy threshold was dug, it is almost certain that the purpose was to take fresh water from the Pınarbaşı; springs to people who lived on the Beşik plain in historical times. It was last cleaned and used in the 1950s. This usage was limited to running a water-mill (Hanımdeğirmeni) which was located at the point where the canal reaches the Beşik plain. This was subsequently abandoned. Yeniköy plain was covered with swamp until the 1960s because it was the natural area where the waters of Pınarbaşı; springs spread. With various improvements and the digging of some new canals over the past decade, the swamp has dried up and the plain has been made arable.

5.2 Kesik Plain

The Kesik plain is the middle indentation along the western edge of the Karamenderes plain to the north of the Yeniköy plain. It is situated just to the west of the site of Troia, across the Karamenderes plain (Fig. 1). It has also formed on a north-east–southwest structural line similar to the Yeniköy plain, and it extends toward a low gate between two horizontal limestone platforms, Yeniköy and Subaşı, on the Yeniköy (Sigeum) ridge (forming a threshold between the plain and the sea). The Kesik plain, like the Yeniköy plain, was covered by swamp until the 1960s, but then it was drained and made into an arable area.

To the west of the Kesik plain, the Yeniköy ridge is only about 600 m wide. Elevation is a little more than 20 m at the top. The eastern slope is gentle, but the western slope is a steep cliff. A dry canal-like feature cuts straight across the lowest part of the Yeniköy ridge in an east–west direction. "Kesik" means "cut" or "cleft" in Turkish and the name of the area comes from this feature. The lengthwise profile of this cleft-like feature is asymmetric in accordance with the shape of the ridge itself (Fig. 6). The highest point in the bottom is 13.7 m above sea level at a distance of about 150 m from the sea, but the inner side profile is gentle and opens on to the Kesik plain at an elevation of 6.3 m about 400 m east of the top. The crosswise profile of the Kesik "canal" is also asymmetrical. The southern slope is steeper and higher than the northern slope because of the geological structure. The Kesik "canal" has no floor. It looks like a V-shaped valley, but there is only an earth road at the bottom which is used by people walking between the plain and the coast. Drilling holes and trench profiles on the bottom of Kesik "canal" clearly showed that the Neogene marl is covered by 2 m colluvium. No archaeological material was encountered in the many drillings which were made in the bottom of the cut (Kayan 1995).

If the geomorphological characteristics of the Kesik plain and Kesik "canal" are interpreted together with the Holocene marine transgression, in which the rising sea covered the Kesik plain to form a small bay, one can easily imagine that the Kesik plain could have been an excellent harbour which was connected to the Aegean Sea by the Kesik "canal". Concerning this idea, there are various interpretations in the literature (Cook 1973), and the Kesik "canal" has been the subject of great interest in this respect. It is thought that the canal was opened by man to connect the harbour of Kesik bay, which was an extension of the Holocene Karamenderes bay, as a short cut to the Aegean Sea to the west. Although the canal is too high for direct water connection, there are some ideas that it could have been used as a dry slipway to transport ships between the Aegean Sea and the Kesik bay (Zangger et al. 1999).

Drilling evidence clearly showed that the Kesik plain was a small bay forming an extension of the main Karamenderes (or Troia) bay during the Holocene transgression (Kayan 1995). ^{14}C dates indicate that marine conditions continued up to 3500 years ago. Then, the area of Kesik bay silted up rapidly and changed into swampy land (Fig. 7). This area has never been completely dry because large amounts of karstic water from the Pınarbaşı springs to the south spread over it. Like Yeniköy plain, Kesik plain was also drained in the 1960s and turned into arable land.

Although the present configuration and paleogeographical characteristics of the Kesik plain imply that this area could have been used as a harbour in ancient times, all geomorphological and various drilling evidence, including ^{14}C datings, clearly show that the Kesik bay was covered with very shallow sea water which was not convenient for boats, and was then swampy during the Bronze Age.

The Kesik "canal" was never used as a waterway. Although the shape of the Kesik implies that it was dug by man, there is no information about the purpose and time of construction. The only obvious feature is that it facilitates passage from the steep, high and continuous cliff coast to the inner plain on foot. It might have been opened, and deepened from time to time, for the transportation needs of the inhabitants of Sigeion and then Yenişehir. Perhaps it took shape slowly rather than in one planned excavation. Or perhaps it is an unfinished canal construction. Finally, there is an unanswered question; where are the earth piles resulting from the excavation? There is no trace of additional earth in the area.

5.3 Kumtepe Plain

Kumtepe plain is the northerly indentation of the Karamenderes plain of the Yeniköy ridge (Fig. 1). It has the same geomorphological characteristics as Yeniköy and Kesik plains, that is, it is formed in a northeast–southwest secondary structural depression. To the west of the Kumtepe plain, the Yeniköy ridge is lower (35 m) between higher (70 m) limestone platforms to the north and south. These are the sites of the ancient Sigeion and later Yeni°ehir settlements. A very low and flat secondary ridge extends eastward, then bends to the north from the Yeniköy-Sigeion ridge. One of the oldest known settlements of the area, Kumtepe mound, is situated at the northern tip of this low ridge. The small plain separated from the Karamenderes plain by this low ridge is named Kumtepe plain here after the Kumtepe mound. Because of its geomorphological configuration, the Kumtepe plain has also been interpreted as an old harbour site.

Thus, the lowest part of the Karamenderes plain was described by Strabo at the time of Christ, and mapped by Leake based on his descriptions (1824, Kraft et al. 1982). No marine indentation was shown on this map. Also, there is no evidence indicating that Kumtepe bay was used as harbour. Since it has similar characteristics to the southern indentations, we made several drilling-holes in this area to determine this matter (Kayan

1995). Based on core interpretations, there is no difference in the stratigraphical sequence (Fig. 6). Colluvial deposition is widely spread along the inner edges of the embayment. On the bottom, a coarse sandy, thick deltaic deposit is dominant. The reason for coarse sandy deposition is that the Karamenderes River first filled the western edge of the bay during the final stage of deltaic progradation, keeping its original direction as in the south. Later, deltaic progradation stopped in front of the northern extension of the Yeniköy ridge, and during the last stage, the Karamenderes river and its deltaic progradation shifted northeast to the present position.

Today, the amount of water and sediment which the Karamenderes river can carry down to the coast and eventually to the sea is considerably reduced because of a dam (Bayramiç dam) which has been constructed in the upper basin, and also because of the extraction of large amounts of ground water for agricultural irrigation. Thus, the surface flow has greatly decreased. Furthermore, the strong current in the Çanakkale Strait hinders the formation of a deltaic promontory. The very little sediment reaching the sea (Çanakkale Strait) today is carried towards the Aegean Sea by the current, and accumulates partly at the northern tip of the Yeniköy ridge and partly in various places along the western coast of the Yeniköy ridge such as the Beºik coast.

6 Conclusions

There is some argument as to whether the indentations along the foot of the east-facing slopes of the Yeniköy ridge to the west of Karamenderes plain were used as ancient harbour sites, especially during the Bronze Ages. Concerning this matter, we offer the following comments:

1. Following the rise in sea level in the Holocene, the lower Karamenderes plain changed into a ria-type bay between 10,000 and 6000 years ago. During this period, indentations on the western edge formed small bays. However, the low thresholds which separate these bays from the Aegean Sea to the west have never been covered by sea. Thus, no natural water connections ever formed over them. Clearly, the man-made canal or ditches on the Yeniköy and Kesik thresholds were not dug for use as a water connection between the bays and Aegean Sea (Fig. 6).
2. Based on chrono-stratigraphical evidence, after the maximum extension of the marine environment, the Yeniköy and Kesik embayments changed into land following alluviation and deltaic progradation about 5000 and 4000 years ago, respectively (Fig. 7). Therefore, Yeniköy and Kesik bays could not have been used as harbours during the Later

Bronze Age, especially during Troia VI. Since the water coming from the Pınarbaşı springs spread along this edge of the Karamenderes plain, the area was continuously covered by swamps until drainage canals were dug in the 1950s, and sedimentation continued with mud containing large amounts of organic colloids. These are not to be confused with marine sediments.

3. It is obvious that the shoreline, which extended south of the Troia–Yeniköy line about 6000 years ago, continuously changed its location toward the north, until it reached its present position, because of alluviation and deltaic progradation. Suitable places on the changing shoreline could have been used according to necessity as natural harbours during the various periods of Troia culture (Fig. 7). However, there is no evidence to indicate that the natural embayments along the western edge of "Troia Bay" were arranged and used as principal harbours. In addition, the progressive coastal environment of the Karamenderes delta plain has always been covered with very shallow water or swamps. This is not a suitable place for big harbour sites. Therefore, we suggest there is no reason to create great harbour theories relating to Troia.

Acknowledgements. İ. Kayan and Prof. O. Erol were kindly invited by Prof. M. Korfmann to join this project to study environmental characteristics and change, as well as their effects on human activity in this area. Later, Prof. Kayan continued this research alone. İ. Kayan was also invited by Prof. M. Korfmann to join this project, and he has been working continuously since then. Kayan thanks his many assistants and students who helped him on the drilling works, notably, Dr. Ertuğ Öner, and research assistants Serdar Vardar, Levent Uncu and Beycan Hocaoğlu.

References

Adrieans A, Veny P, Adams F, Sporken R, Louette P, Earl B, Özbal H, Yener KA (1999) Analytical investigations of archaeological powders from Göltepe (Turkey). Archaeometry 41:81–90

Aitken MJ (1998) An introduction to optical dating – the dating of quaternary sediments by the use of photon-stimulated luminescence. Oxford University Press, Oxford

Akarcalı A (1978) Troas'ta Asağı Kara Menderes Ovası Cevresindeki Şehirler. Belleten 165:1–52

Akdağ M (1975) Türk Halkının Dirlik ve Düzenlik Kavgası. Bilgi Yayınevi, Ankara

Aksu AE, Piper DJ, Konuk T (1987) Quaternary growth patterns of Büyük Menderes and Küçük Menderes deltas, western Turkey. Sediment Geol 52:227–250

Aksu AE, Hiscott RN, Yaşar D (1999) Oscillating quarternary water levels of the Marmara Sea and vigorous outflow into the Aegean Sea from the Marmara Sea-Black Sea drainage corridor. Mar Geol 153:298–299

Akurgal E (1993) Ancient civilizations and ruins of Turkey, 8th edn. Net Turisktik Yayinlar AS, Ankara, 112 pp

Alimov K, Boroffka N, Bubnova M., Burjakov J, Cierny J, Jakubov J, Lutz J, Parzinger H, Pernicka E, Radililovskij V, Ruzanov V, Şirinov T, Weisgerber G (1998) Prähistorischer Zinnbergbau in Mittelasien. Vorbericht der ersten Kampagne 1997. Eurasia Antiqua 4:137–199

Angel JL (1951) Troy. The human remains. Supplementary monograph 1. Princeton University Press, Princeton

Anthony DW (1990) Migration in archaeology: the baby and the bathwater. Am Anthropol 92:895–914

Anthony DW (1997) Prehistoric migrations as a social process. In: Chapman J, Hamerow H (eds) Migrations and invasions in archaeological explanation. British Archaeological Reports International Series 664. Archaeopress, Oxford, pp 21–32

Anthony DW (2000) Comment to S. Burmeister. Curr Anthropol 41/4:554–555

Asheri D (1990) Herodotus on Thracian society and history. In: Reverdin O (ed) Hérodote et les peuples non Grecs. Vandoeuvres-Genève, 22–26 Aout 1988. Entretiens sur l'antiquité classique, tome XXXV. Genève 1990, pp 131–163

Atanassova JR, Bozilova ED (1992) Palynological investigation of marine sediments from the western sector of the Black Sea. Okeanologiya (Sofiya) 1:97–103

Baer KE von (1876) Von wo das Zinn zu den ganz alten Bronzen gekommmen sein mag? Arch Anthropol 9:263

Bailey DW, Panayotov I (eds) (1995) Prehistoric Bulgaria. Monographs in world archaeology 22. Prehistory Press, Madison

Bakoş A, Hell P (1999) Pol'ovníctvo 1. PaPRESS, Bratislava
Balabanov JP, Kvirkvelia BD, Ostrovsky AB (1981) The recent evolution in engineering geology and long-term shoreline changes in Pitzunda Peninsula (in Russian). Ministry of Geology of the USSR, 2nd Hydrogeological Division, Tbilisi, p 202 (in Russian)
Ballard RD, Coleman DF, Rosenberg GD (2000) Further evidence for abrupt Holocene drowning of the Black Sea shelf. Mar Geol 170:253–261
Barbin V, Ramseyer K, Debenay JP, Schein E, Roux M, Decrouez D (1991) Cathodoluminescence of recent biogenic carbonates: an environmental and ontogenic fingerprint. Geol Mag 128:19–26
Barbin V, Ramseyer K, Decrouez D (1992) Cathodoluminescence of white marbles: an overview. Archaeometry 34/2:175–183
Barka A (1992) The North Anatolian Fault. Ann Tect 6:164–195
Barnes IL, Shields WR, Murphy TJ, Brill, RH (1974) Isotopic analysis of Laurion lead ores. In: Beck CW (ed) Archaeological chemistry. Am Chem Soc, Washington, DC, pp 1–10
Basedow MA (2000) Beşik-Tepe: Das spätbronzezeitliche Gräberfeld. Studia Troica Monographien. Philip von Zabern, Mainz
Bay B (1999a) Geoarchäologie, anthropogene Bodenerosion und Deltavorbau im Büyük Menderes Delta (SW-Türkei). GCA-Verlag, Herdecke
Bay B (1999b) Geoarchäologische Auswertung der Brunnengrabungen nördlich von Yeniköy. Archäologischer Anzeiger, Berlin, New York, pp 77–88
Bailey DW, Panayotov I (eds) (1995) Prehistoric Bulgaria. Monographs in world archaeology 22. Prehistory Press, Madison
Becker C (1986) Kastanas: Ausgrabungen in einem Siedlungshügel der Bronze- und Eisenzeit Makedoniens 1975–1979 – die Tierknochenfunde. Wissenschaftsverlag Volker Speiss, Berlin
Becker C (1999) Damhirsche in Europa und im Vorderen Orient – Jahrtausendealte Inspiration für Kunst und Mythen, Tierhaltung und Jagd. Mitt Berl Ges Anthropol Ethnol Urgesch 20:15–32
Becker H, Jansen HG (1994) Magnetische Prospektion 1993 der Unterstadt von Troia und Ilion. Stud Troica 4:105–114
Becker H, Fassbinder J, Jansen HG (1993) Magnetische Prospektion in der Untersiedlung von Troia 1992. Stud Troica 3:117–134
Begemann F, Schmitt-Strecker S, Pernicka E (1992) The metal finds from Thermi III-V: a chemical and lead isotope study. Stud Troica 2:219–239
Begemann F, Pernicka E, Schmitt-Strecker S (1995) Thermi on Lesbos: a case study of changing trade patterns. Oxf J Archaeol 14:123–136
Begemann F, Pernicka E, Schmitt-Strecker S (1994) Metal finds from Ilipinar and the advent of arsenical copper. Anatolica XX:203–219
Begemann F, Kallas K, Schmitt-Strecker S, Pernicka E (1999) Tracing ancient tin via isotope analyses. In: Hauptmann A, Pernicka E, Rehren T, Yalcın Ü (eds) The beginnings of metallurgy. Der Anschnitt. Beiheft 9. Deutsches Bergbau-Museum, Bochum, pp 277–284
Benda L, Meulenkamp J E (1979) Biostratigraphic correlations in the eastern Mediterranean Neogene. 5. Calibration of sporomorph associations, marine microfossils and mammal zones, marina and continental stages and the radiometric scale. Ann Geol Pays Helen 1:61–70
Bernabo-Brea L (1964) Citta preistorica nell' isola di Lemnos, vol I. Bretschneider, Rome

Bernabo-Brea L (1976) Citta preistorica nell' isola di Lemnos, vol II. Bretschneider, Rome
Bibra E von (1869) Die Bronzen und Kupferlegierungen der alten und ältesten Völker, mit Rücksichtnahme auf jene der Neuzeit. Erlangen
Bilgi Ö (1984) Metal objects from Ikiztepe – Turkey. Beitr Allg Vergl Archäol 6:31–96
Bilgi Ö (1990) Metal objects from Ikiztepe – Turkey. Beitr Allg Vergl Archäol 10:119–219
Bilgin T (1969) Biga yarımadası güneybatı kısmının jeomorfolojisi. İstanbul Üniversitesi Yay. No. 1433. Coğ;. Enst Yay, No 55, p 273
Bingöl E, Akyürek B, Korkmazer B (1973) Biga yarımadasının jeolojisi ve Karakaya formasyonunun bazı özellikleri, Cumhuriyetin 50. Yılı Yerbilimleri Kongresi Bildiriler kitabı, pp 70–76
Bingöl E, Akyürek B, Korkmazer B (1975) Geology of the Biga Peninsula and some characteristics of the Karakaya Formation. Proceedings of the Congress of Earth Science. 50th Anniversary of the Turkish Republic. Ankara University Press, Ankara, pp 70–76
Birgi SE (1950) Notes on the influence of the Ergani copper mine on the development of the metal industry in the ancient Near East. Jahrb Kleinasiatischer Forsch 1:337–343
Birkle P (1992) Petrologie, Geochemie und Geochronologie des miozänen Magmatismus auf der Biga-Halbinsel (Ezine, NW-Türkei). Diploma, University of Tübingen, Tübingen
Birkle P, Satır M (1994) Geological aspects of the use of Kestanbol quartz-monzonite intrusion (Troas/Turkey) as constructing material in archaeological sites around the Mediterranean Sea. Stud Troica 4:143–155
Birkle P, Satır M (1995) Dating, geochemistry and geodynamic significance of the tertiary magmatism of the Biga peninsula, NW-Turkey. In: Erler A, Ercan T, Bingöl E, Örçen S (eds) Geology of the Black Sea region. Mineral Research and Exploration Inst of Turkey (MTA), Ankara, pp 171–180
Bittel K (1959) Beitrag zur Kenntnis anatolischer Metallgefäße der zweiten Hälfte des dritten Jahrtausends v. Chr. Jahrb DAI 74:1–34
Blegen C, Caskey JL, Rawson M (1951) Troy – the third, fourth, and fifth settlements, vol II, part 1. Princeton University Press, Princeton
Blegen CW (1963) Troy and the Trojans. Thames and Hudson, London
Blegen CW, Caskey JL, Rawson M (1953) Troy. vol III, The sixth settlement. Princeton University Press, Princeton
Blegen CW, Boulter CG, Caskey JL, Rawson M (1958) Troy. Settlements VIIa, VIIb and VIII. Princeton University Press, Princeton
Blindow N, Jansen HG, Schröer K (2000) Geophysikalische Prospektion 1998/99 in der Unterstadt von Troia. Stud Troica 10:123–133
Bloedow EF (1985) Handmade burnished ware or "Barbarian" pottery and Troy VIIb. La Parola del Passato. Riv Stud Antichi XL:161–199
Blume R (2000) Arbeitsgruppe Didaktik der Chemie II um Prof. Dr. R. Blume. An der Fakultät für Chemie der Universität Bielefeld erstellte Web-Seite.
Boer J (1994) Computer aided reconstruction of underwater sites Sozopol 1990 A test-case. Thracia Pontica V:13–22
Boessneck J (1988) Die Tierwelt Ägyptens. Beck, München
Bolomey A (1983) Les populations néo- et énéolithiques de la période de transition. Leurs relations avec le milieu biotique. In: Dumitrescu V, Bolomey A, Mogoşanu F (eds) Esquisse d'une prèhistoire de la Roumanie. Stientifica si Enciclopedica, Bucarest, pp 140–142

Bond G, Kromer B, Beer J, Muscheler R, Evans M, Showers W, Hoffmann S, Lotti-Bond R, Hajdas I, Bonani G (2001) Persistent solar influence on North Atlantic surface circulation during the Holocene. Science 294:2130–2136

Bond GC, Showers W, Cheseby M, Lotti R, Almasi P, deMenocal P, Priore P, Cullen H, Hajdas I, Bonani G (1997) A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climates. Science 278:1257–1266

Bond GC, Showers W, Elliot M, Evans M, Lotti R, Hajdas I, Bonani G, Johnson S (1999) The North Atlantic's 1–2 kyr climate rhythm: relation to Heinrich Events, Dansgaard/Oeschger Cycles and the Little Ice Age. In: Clark PU, Webb RS, Keigwin LD (eds) Mechanisms of global climate change at millennial time scales. Geophysical monograph 112. American Geophysical Union, Washington, DC, pp 35–58

Borsi S, Ferrara G, Innocenti F, Mazzouli R (1972) Geochronology and petrology of recent volcanics in the Eastern Aegean Sea (West Anatolia and Lesvos Island). Bull Volcanol 36:473–496

Bouzek J (1985) The Aegean, Anatolia and Europe: cultural relations in the second Millenium B.C. Studies in Mediterranean archaeology 29. Paul Åströms Förlag, Göteborg

Branigan K (1974) Aegean metalwork of the Early and Middle Bronze Age. Clarendon Press, Oxford

Braudel F (1994) Das Mittelmeer und die mediterrane Welt in der Epoche Philipps II, vol I. Suhrkamp, Frankfurt am Main

Brinkmann R (1976) Geology of Turkey. Enke, Stuttgart

Brinkmann R, Köhler B, Heins J-U, Rösler S (1991) Menderes-Delta. Zustand und Gefährdung eines ostmediterranen Flußdeltas. Arbeitsbericht des Fachbereichs Stadt- und Landschaftsplanung 99. Fachbereich Stadt- und Landschaftsplanung, Kassel

Bronson B, White JC (1992) Radiocarbon and chronology in Southeast Asia. In: Ehrich RW (ed) Chronologies in old world archaeology, vol 1. University of Chicago Press, Chicago, pp 491–515

Brückner H (1986) Man's impact on the evolution of the physical environment in the Mediterranean region in historical times. GeoJournal 13.1:7–17

Brückner H (1995) Geomorphologie und Paläo-Environment der Milesia. Archäologischer Anzeiger 1995, Berlin, pp 329–330

Brückner H (1996) Geoarchäologie an der türkischen Ägäisküste – Landschaftswandel im Spiegel geologischer und archäologischer Zeugnisse. Geogr Rundsch Braunschweig 48 (10/1996):568–574

Brückner H (1997a) Coastal changes in western Turkey – rapid delta progradation in historical times. In: Briand F, Maldonado A (eds) Transformations and evolution of the Mediterranean coastline. CIESM Science Series 3. (Bulletin de l'Institut océanographique, numéro spécial 18. Musée océanographique, Monaco) Institut Océanographique, Monaco, pp 63–74

Brückner H (1997b) Geoarchäologische Forschungen in der Westtürkei – das Beispiel Ephesos. Passauer Schr Geogr 15:39–51

Brückner H (1998) Coastal research and geoarchaeology in the Mediterranean region. In: Kelletat DH (ed) German geographical coastal research – the last decade. Institute for Scientific Co-operation, Tübingen and Committee of the Federal Republic of Germany for the Int Geographical Union, Tübingen, pp 235–258

Brückner H (1999) Küsten – sensible Geo- und Ökosysteme unter zunehmendem Stress. Petermanns Geogr Mitt 143 (Jg Pilotheft 2000) Gotha:6–21

Brückner H (2000) Palaeogeographic studies in the Büyük Menderes deltaplain, 1998. In: Kültür Bakanlığı Anıtlar ve Müzeler Genel Müdürlüğü TC (ed) 17. Arastirma Sonuçlari Toplantisi, 24–28 Mayis 1999, 1. Cilt, Kültür Bakanlığı Milli Kütüphane Basimevi, Yayin No. 2345/1. TC Kültür Bakanlığı Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 255–262
Bryson RA, Bryson RU (1999) Holocene climates of Anatolia: as simulated with archaeoclimatic models. TÜBA AR (Turk Acad Sci Archaeol) 2:1–13
Buchholz HG (1987) Ägäische Bronzezeit. Wissenschaftliche Buchgesellschaft, Darmstadt
Buchholz HG (1990) Jagd und Fischfang. Archaeologia Homerica Band 2, Kap. J Vandenhoek and Ruprecht, Göttingen
Buchholz HG (1999) Ein außergewöhnliches Steinszepter im östlichen Mittelmeer. Prähist Z 74:68–78
Buchholz HG, Wagner P (1987) Zu frühbronzezeitlichen Verbindungen zwischen dem Balkanraum und Hellas. In: Buchholz HG (ed) Ägäische Bronzezeit. Wissenschaftliche Buchgesellschaft, Darmstadt, pp 121–136
Burmeister S (2000) Archaeology and migration. Approaches to an archaeological proof of migration. Curr Anthropol 41/4:539–567
Burns S, Matter A, Frank N, Mangini A (1998) Speleothem-based paleoclimate record from northern Oman. Geology 26:499–502
Çağatay M, Görür N, Algan O, Eastoe C, Tchapalyga A, Ongan D, Kuhn T, Kuşcu I (2000) Late Glacial-Holocene palaeoceanography of the Sea of Marmara: timing of connections with the Mediterranean and the Black Seas. Mar Geol 167:191–206
Çağatay A, Pehlivan N (1988) Celaller (Nigde-Çamardı) kalay cevherlesmesinin mineralojisi. Jeol Mühendisligi 32–33:27–31
Cağatay A, Altun Y, Arman B (1981) Mineralogy of the Madenbelenitepe (Soğukpınar-Bursa) tin mineralization. MTA, Ankara
Çağatay A, Altun Y, Arman B (1989) Mineralogy of the tin bearing Bolkardağ Sulucadere (Ulukısla-Niğde) lead-zinc mineralization. Turk Jeol Bulteni 32:15–20
Calvert F (1881) Thymbra, Hanai Tepeh. In: Schliemann H (ed) Ilios. Brockhaus, Leipzig, pp 706–720
Caneva C, Frangipane M, Palmieri AM (1985) I metalli di Arslantepe nel quadro dei piu antichi sviluppi della metallurgia vicino-orientale. Quad La Ricerca Sci 112 (1976–1979):115–137
Carvalho E (1992) Schliemann in Asia 1864/65. In: Hermann J (ed) Heinrich Schliemann. Grundlagen und Ergebnisse moderner Archäologie 100 Jahre nach Schliemanns Tod. Akademie Verlag, Berlin, pp 29–37
Catling HW, Catling EA (1981) "Barbarian" pottery from the Mycenaean settlement at the Menelaion, Sparta. Annu Br School, Athens 76:71–82
Catling RWV (1998) The typology of the protogeometric and subprotogeometric pottery from Troia and its Aegean context. Stud Troica 8:151–187
Chalkias S, Vavelidis M, Schmitt-Strecker S, Begemann F (1988) Geologische Interpretation der Blei-Isotopen-Verhältnisse von Erzen der Insel Thasos, der Ägäis und Nordgriechenlands. In: Wagner GA, Weisgerber G (eds) Antike Edel- und Buntmetallgewinnung auf Thasos. Der Anschnitt. Beiheft 6. Deutsches Bergbaumuseum, Bochum, pp 59–74
Chandler R (1776) Reisen in Kleinasien Leipzig. Olms, Hildesheim (reprint 1976, Weidmann and Reich, Olms)
Chepalyga A (1984) Inland sea basins. In: Velichko AA (ed) Late quaternary environments of the Soviet Union. University of Minnesota Press, Minneapolis, pp 237–240

Chernykh EN (1992) Ancient metallurgy in the USSR: Cambridge University Press, Cambridge
Chichikova M (1968) Keramika ot starata zeliazna epocha v Trakia. Archeologija (Sofia) 10(4):15–27
Childe VG 81957) The dawn of European civilisation. Routledge, London
Choiseul-Gouffier MGFA (1822) Voyage Pittoresque de la Grèce, vol II. Blaise Librairie, Paris
Clarke ED (1817) Travels in various countries of Europa, Asia, Africa, 4th edn., Cadell and Davies, London
Cook JM (1973) The Troad. An anchaeological and topographical study. Oxford University Press, Oxford, p 443
Cowell RM (1987) Scientific appendix I, chemical analysis. In: Davies WV (ed) Catalogue of Egyptian antiquities in the British Museum. VII. Tools and weapons I, axes. British Museum Publ, London
Craig H, Craig V (1972) Greek marbles: determination of provenance by isotopic analysis. Science 176/II:401–403
Cronin TA (1999) Principles of paleoclimatology. Perspectives in paleobiology and earth history. Columbia University Press, New York
Dallaway J (1799) Constantinopole ancienne et moderne et description des Cotes et Isles de l'archipel et dela Troade. Denné, Paris
Dalrymple JB, Blong RJ, Conacher AJ (1968) A hypothetical nine unit landsurface model. Z Geomorph 12:60–76
Darkot B (1938) Boğazların Mensei. Coğrafi Araştırmalar I:1–14
De Jesus PS (1980) The development of prehistoric mining and metallurgy in Anatolia. BAR Int Ser 74 Oxford (II):208–276
Defter-i Hakanı Dizisi (1995) 166 Numarali Muhasebe-i Vilayet-i Anadolu Defteri. 937/1530. Başbakanlık Arsivleri, Ankara
Degens ET, Paluska A (1979) Tectonic and climatic pulses recorded in quaternary sediments of the Caspian-Black Sea region. Sediment Geol 23:149–163
Degens ET, Ross DA (eds) (1974) The Black Sea – geology, chemistry and biology. Memoirs American association of petroleum geologists 20. American Association of Petroleum Geologists, Tulsa, pp 133–136
Deger-Jalkotzy S (1977) Fremde Zuwanderer im Spätmykenischen Griechenland: zu einer Gruppe handgemachter Keramik aus den Myk. IIIC Siedlungsschichten von Aigeira. Österreichische Akademie der Wissenschaften, Wien
Deger-Jalkotzy S (1983) Das Problem der "Handmade Burnished Ware" von Myk. III C. In: Deger-Jalkotzy S (ed) Akten des Symposions von Stift Zwettl. Griechenland, die Ägäis und die Levante während der "Dark Ages", vom 12 bis 9 Jh. v. Chr., 11–14 Oct. 1980. Komission für Mykenische Forschung. SB Wien, Wien, pp 161–178
Demangel R (1926) Le tumulus dit de Protesilas. E De Boccard, Paris
Demirok MH (1982) Kütahya Gümüşkoy maden yatağı. MTA Haberleri Sayi 1:3–4
Deuser ET, Ross DA (1974) Evolution of anoxic conditions in the Black Sea during the Holocene. In: Degens ET, Ross DA (eds) The Black Sea – geology, chemistry and biology. Memoirs American Association of Petroleum Geologists 20. American Association of Petroleum Geologists, Tulsa, pp 133–136
Deuser WG (1972) Late-Pleistocene and Holocene history of the Black Sea as indicated by stable-isotope studies. J Geophys Res 77/6:1071–1077
Dimitrov DP (1968) Troia VIIb$_2$ i balkanskite trakijski i mizijski plemena. Archeologija (Sofia) 10(4):1–15

Dimitrov DP (1971) Troia VIIb$_2$ und die Thrakischen und mösischen Stämme auf dem Balkan. Studia Balcanica V. L' Ethnogenèse des peuples balkaniques. Editions de l'Académie Bulgare des Sciences, Sofia, pp 63–78

Dörpfeld W (1902) Troja und Ilion. Ergebnisse der Ausgrabungen in den vorhistorischen und historischen Schichten von Ilion 1870–1894. Beck and Barth, Athen

Draganov V (1995) Submerged coastal settlements from the final Eneolithic and the Early Bronze Age in the Sea around Sozopol and Urdovitza Bay near Kiten. In: Bailey DW, Panayotov I, Alexandrov S (eds) Prehistoric Bulgaria. Prehistory Press, Madison, Wisconsin pp 225–241

Dürr S (1975) Über Alter geotektonische Stellung des Menderes-Kristallins/SW-Anatolien und seine Äquivalente in der mittleren Ägäis. Habilitation Thesis, Univ Marburg/Lahn, Marburg/Lahn, p 107

Eddy JA (1977) Climate and the changing sun. Climate Change 1:173–190

Earl B, Özbal H (1996) Early Bronze Age tin processing at Kestel/Göltepe, Anatolia. Archaeometry 38:28–303

Ediger VŞ (1988) Biga yarımadasındaki kömürlü birimlerden alınan örneklerin palinolojik analizi. Turkish Petroleum Co Report No 1269:17

Eisma D (1978) Stream deposition and erosion by the eastern shore of the Aegean. In: Brice WC (ed) The environmental history of the Near and Middle East since the last ice age. Academic Press, London, pp 67–81

Ercan T, Satır M, Türkecan A, Akyürek B, Cevikbaş A, Günay E, Ates M, Çan B (1986) Geologie und Petrologie der Vulkanite von Ayvalık und seiner Umgebung. Chamb Geol Eng Türkei 27:19–30

Ercan T, Satır M, Steinitz G, Dora A, Sarıfakıoğlu E, Adis C, Walter HJ, Yıldırım T (1995) Biga Yarımadası ile Gökçeada, Bozcaada ve Tavşan adalarındaki (KB Anadolu) Tersiyer volkanizmasının özellikleri. MTA Dergisi 117:55–86

Ercan T, Satır M, Sevin D, Türkecan A (1997) Batı Anadoludakı Tersiyer ve Kuvaterner yaslı volkanik kayaclarda yeni yapılan radyometrik yas ölcümlerinin yorumu. MTA Dergisi 119:103–112

Ercan T, Türkecan A, Guilliou H, Satır M, Sevin D, Saroğlu F (1998) Marmara Deınizi cevresindeki volkanizmanın özellikleri. Maden Tektik Arama Derg 120:197–216

Ergin K, Güçlü U, Uz Z (1967) Türkiye ve civarının deprem kataloğu. İTÜ Maden Fak. Arz Fizigi Ens. Yayınları, 24

Ergin M, Kazanci N, Varol B, İleri Ö, Karadenizli L (1997) Sea-level changes and related depositional environments on the southern Marmara shelf. Mar Geol 140:391–403

Erinç S (1978) Changes in the physical environment in Turkey since the end of the last glacial. In: Brice WC (ed) The environmental history of the Near and Middle East since the last ice age. Academic Press, London, pp 87–110

Erol O (1972) Truva Çevresinin Foto-Jeomorfolojik Haritasi. Jeomorfoloji Dergísi 4:1–12

Erol O (1992) Çanakkale yöresinin jeomorfolojik ve neotektonik evrimi. Bull Turk Assoc Petrol Geol C-4/1:147–165

Erol O (1996) Büyük Menderes deltasinin foto-jeomorfolojik incelenmesi (Photogeomorphological study of the Büyük Menderes delta). Ege Cografya Dergisi (Aegean Geomorphol J) Izmir 9:1–42

Esin U (1969) Kuantitatif Spektral Analiz Yardimiyla Anadolu'da Başlangıcından Asur Kolonileri Çagına Kadar Bakır ve Tunç Madenciliği. Vol I. University of Istanbul, Istanbul

Euronatur (2000) Workshop: die Troas – Landschaft zwischen Orient und Okzident – gestern, heute, morgen – nachhaltige Entwicklung in der Troas. (1. bis 2. Dezember 2000). Unveröffentlichtes Manuskript der Stiftung Europäisches Naturerbe (Euronatur)
Europarc IUCN (1999) Guidelines for protected area management categories – interpretation and application of the protected area management categories in Europe. Europarc und WCPA, Grafenau, Germany, p 48
Evans A (1921–35) The palace of Minos. Macmillan, London
Extröm GA, England PC (1989) Seismic strain rates in regions of distributed continental deformation. J Geophys Res 94:231–257
Fabiš M (1999) Studies in Hellenistic Ilion: the archaeofaunal remains of C29, w28, and y28, Lower City. Stud Troica 9:237–252
Fairbanks RG (1989) A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature 342:637–642
Faure G (1986) Principles of isotope geology. Wiley, New York
Fedorov PV (1977) Late quarternary history of the Black Sea and the evolution of the South Europe Seas. Nauka Press, Moskow, pp 25–32 (in Russian)
Fellenberg LR von (1860–66) Analysen antiker Bronzen. Mitteilungen der naturforschenden Gesellschaft Bern 1860–1866, Bern
Fıratlı N (1978) New discoveries concerning the first settlement of ancient Istanbul-Byzantine. In: Akurgal E (ed) Proceedings of the 10th International Congress of Classical Archaeology Ankara-Izmir 1973. 1–3. Türk Tarih Kurumu Başımevi, Ankara, pp 565–574
Fitton JL (1989) Esse quam videri: A Reconsideration of the Kythnos Hoard of Early Cycladic Tools. Am J Archaeol 93:31–39
Flemming NC, Webb CO (1986) Tectonic and eustatic coastal changes during the last 10,000 years derived from archaeological data. Z Geomorphol NF Suppl62:1–29
Forchammer PW (1842) Observations on the topography of Troy. J R Geogr Soc xii:28–44
Forchhammer PW (1850) Die Beschreibung der Ebene von Troia. Bronner, Frankfurt
French E, Rutter JB (1977) The handmade burnished ware of the Late Helladic IIIC Period: its modern historical context. Am J Archaeol 81:111–112
Fytikas M, Giuliano O, Innocenti F, Marinelli G, Mazzuoli R (1976) Geochronological data on recent magmatism of the Aegean Sea. Tectonophysics 31:T29–T34
Gabriel U (2000) Mitteilung zum Stand der Neolithikumsforschung in der Umgebung von Troia (Kumtepe 1993-1995; Beşik-Sivritepe 1983-1984, 1987, 1998-1999). Stud Troica 10:233-238
Gale NH, Stos-Gale ZA (1982) Bronze Age copper sources in the Mediterranean. Science 216:11–19
Gale NH, Gentner W, Wagner GA (1980) Mineralogical and geographical silver sources of archaic Greek coinage. Metallurgy in numismatics. Oxford University Press, Oxford, pp 1–49
Gale NH, Picard O, Barrandon JN (1988) The archaic Thasian silver coinage. In: Wagner GA, Weisgerber G (eds) Antike Edel- und Buntmetallgewinnung auf Thasos. Der Anschnitt. Beiheft 6. Deutsches Bergbaumuseum, Bochum, pp 212–23
Gast PW (1960) Limitations on the composition of the upper mantle. J Geophys Res 65:1287–1297
Gejvall NG (1937/38) The fauna of Troy. Kungliga Hujmanistika Vetenskapssamfundet Årsberättelse 1937/38:51–57

Gejvall NG (1938/39) The fauna of Troy. Kungliga Hujmanistika Vetenskapssamfundet Årsberättelse 1938/39:1–7
Gell W (1804) The topography of Troy and its vicinity. Longman and O Ress, London
Gelzer H (1873) Eine Wanderung nach Troja. Schweighauserische Verlagsbuchhandlung, Basel
Genç ŞC (1998) Evolution of the Bayramiç magmatic complex northwestern Anatolia. J Volcanol Geotherm Res 85/1-4:233–249
Genç ŞC, Yılmaz Y (1995) Evolution of the Triassic continental margin, Northwest Anatolia. Tectonophysics 243:193–207
Gentner W, Müller O, Wagner GA, Gale NH (1978) Silver sources of archaic Greek coinage. Naturwissenschaften 65:273–284
Georgiev M, Petkov A, Velkovski K (1994) Geophysical prospecting of the Aquatoria of the southern Black Sea Coast aimed at reconstructing of the palaeorelief. Thracia Pontica V:317–328
Gialoglou G, Vavelidis M, Wagner GA (1988) Die antiken Blei-Silberwerkwerke auf Thasos. In: Wagner GA, Weisgerber G (eds) Antike Edel- und Buntmetallgewinnung auf Thasos. Der Anschnitt. Beiheft 6. Deutsches Bergbaumuseum, Bochum, pp 75–87
Göbel F (1842) Über den Einfluß der Chemie auf die Ermitlung der Völker der Vorzeit oder Resultate der chemischen Untersuchung metallischer Alterhümer, insbesondere der in den Ostseegouvernements vorkommenden, behufs der Ermittlung der Völker, von welchen sie abstammen. Enke, Erlangen
Gökaşan E, Demirbağ E, Oktay FY, Ecevitoğlu B, Simşek M, Yüce H (1997) On the origin of the Bosporus. Mar Geol 140:183–199
Gönçüoğlu MC, Erendil M (1990) Pre-Late Cretaceous tectonic units of the Armutlu Peninsula. In: Saner S (ed) Proceedings of the 8th Petroleum Congress of Turkey. Ankara, pp 161–168
Görsdorf J, Bojadziev J (1996) Zur absoluten Chronologie der bulgarischen Urgeschichte. Eurasia Antiqua 2:105–173
Gouffier Count C (1819) Voyage pittoresque de la Grece. Blaise Librairie, Paris
Grimal P (ed) (1967) Mythen der Völker 1–3. Fischer, Frankfurt am Main
Grosswald MG (1980) Late Weichselian Ice Sheet of northern Eurasia. Quat Res 13:1–32
Grund A (1906) Vorläufiger Bericht über physiogeographische Untersuchungen in den Deltagebieten des Großen und Kleinen Mäanders. In: Akademie der Wissenschaften (ed) Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Math-Naturwiss Klasse 115 (H 10). Holder, Wien, pp 1757–1769
Grupe G (1985) Ein deduktives Modell für die historische Anthropologie. Beitrag zu einem ökosystemorientierten Interpretationsraster. Z Morphol Anthropol 75:189–195
Güney A, Yılmaz Y, Demirbağ E, Ecevitoğlu B, Arzuman S, Kuşçu İ (2002) Reflection seismic study across the continental shelf of Baba Burnu Promontory of Biga Peninsula, NW Turkey. Mar Geol 176:75–85
Güngör T, Erdoğan B (2001) Emplacement age and direction of the Lycian nappes in the Söke-Selçuk region, western Turkey. Int J Earth Sci 89:874–882
Gürkan G, Seeher J (1991) Die Frühbronzezeithische Nekropole von Küçükhüyük bei Bozüyük. Istanbuler Mitt 41:39–96
Guzowska M (2000) The Troian connection. Question of survival of Troian external relations towards the end of the Bronze Age. Paper presented at the international conference: Lighten our darkness: cultural transformations at the beginning of the first Millennium B.C. – from the Alps to Anatolia, University of Birmingham, 6–9 January 2000

Haas JN, Richoz I, Tinner W, Wick L (1998) Synchronous Holocene climatic oscillations recorded on the Swiss Plateau and the timberline in the Alps. Holocene 8:301–309

Hänsel B (1976) Beiträge zur regionalen und chronologischen Gliederung der älteren Hallstattzeit an der unteren Donau. Beiträge zur Ur- und Frühgeschichtlichen Archäologie des Mittelmeerkulturraums, Bd 16. Bonn

Hall ME, Steadman SR (1991) Tin and Anatolia: another look. J Mediterr Arch 4:217–234

Hammond NGL (1980) Atlas of the Greek and Roman world in antiquity. Noyes Press, New Jersey

Handl M, Mostafawi N, Brückner H (1999) Ostracodenforschung als Werkzeug der Paläogeographie. In: Brückner H (ed) Dynamik, Datierung, Ökologie und Management von Küsten. Marburger Geographische Schriften 134. Marburger Geographische Gesellschaft, Marburg, pp 116–153

Hanle A (1973) Meyers Kontinente und Meere. Asien (ohne Sowjetunion), Australien, Inseln und Meere. Bibliographisches Institut, Mannheim

Harbottle G (1976) Activation analysis in archaeology. In: Newton GWA (ed) Radiochemistry, vol 3. The Chemical Society, London, pp 33–72

Harmankaya NS (1995) Kozman Deresi Mevkii (Sarköy, Tekirdağ) maden buluntuları. In: Prehistorya Anabilim Dalı – İstanbul Üniversitesi (ed) Halet Çambel için prehistorya yazıları. Readings in prehistory. Studies presented to Halet Çambel. Graphis yayınları, İstanbul, pp 217–254

Hartmann A (1982) Prähistorische Goldfunde aus Europa II. Studien zu den Anfängen der Metallurgie (SAM), Band 5. Gebr Mann, Berlin

Hauptmann A, Begemann F, Heitkemper E, Pernicka E, Schmitt-Strecker S (1992) Early copper produced at Feinan, Wadi Araba, Jordan. Part I: the composition of ores and copper. Archeomaterials 6:1–33

Hegner E, Roddick JC, Fortier SM, Hulbert L (1995) Nd, Sr, Pb, Ar and O isotopics of Sturgeon lake kimberlite, Saskatchevan, Canada: constraints on emplacement age, alteration, and source composition. Contrib Mineral Petrol 120:212–222

Hermann J (ed) (1992) Heinrich Schliemann. Grundlagen und Ergebnisse moderner Archäologie 100 Jahre nach Schliemanns Tod. Akademie Verlag, Berlin

Herrmann J, Maass E (eds) (1990) Die Korrespondenz zwischen Heinrich Schliemann und Rudolf Virchow 1876–1890. Akademie Verlag, Berlin

Herrn C-P (2000) Ökologie – Naturbewahrung – nachhaltige Entwicklung in der The Troad. Eine Projektstudie der Stiftung Europäisches Naturerbe. Euronatur, Radolfzell

Herz N (1988) The oxygen and carbon isotopic data base for classical marble. In: Herz N, Waelkens M (eds) Classical marble: geochemistry, technology, trade. Kluwer, Dordrecht, pp 305–314

Herz N (ed) (1998) A history of the association for the study of marble and other stones in antiquity. Abstracts. Kluwer, Boston

Heskel D, Lamberg-Karlovsky CC (1980) An alternative sequence for the development of metallurgy: Tepe Yahya, Iran. In: Wertime TA, Muhly JD (eds) The coming of the Age of Iron. Yale University Press, New Haven, pp 229–265

Hess J, Bender ML, Schilling JG (1986) Evolution of the ratio of strontium-87 to strontium-86 in seawater from Cretaceous to present. Science 231:979–984

Hetzel R, Ronner RL, Candan O, Passchier CW (1998) Geology of the Bozdağ area, central Menderes massif, SW Turkey: Pan-African basement and Alpine deformation. Int J Earth Sci 87:394–406

Heurtley WA (1939) Prehistoric Macedonia. An archaeological reconnaissance of Greek Macedonia (west of the Struma) in the Neolithic, Bronze, and early Iron Ages. Cambridge University Press, Cambridge

Higgs ES, Vita-Finzi C (1972) Prehistoric economies: a territorial approach. In: Higgs ES (ed) Papers in economic prehistory. Cambridge University Press, Cambridge, pp 27–36

Hochstetter A (1984) Kastanas. Ausgrabungen in einem Siedlungshügel der Bronze- und Eisenzeit Makedoniens 1975–1979. Die handgemachte Keramik Schichten 19 bis 1. Prähistorische Archäologie in Südosteuropa, Bd 3. Wissenschaftsverlag Volker Spieß, Berlin

Höhfeld V (1989) Siedlung und Wirstschaftsgang im ländlichen Raum der Troas. In: Gress H (ed) Ostmittel- und Osteuropa. Beiträge zur Landeskunde. Festschrift für Adolf Karger-vol 1. Tübinger Geographische Studien, Tübingen, pp 337–352

Höhfeld V (2001) Die Landschaft Homers heute – Naturraum und Landschaftsressourcen in einer Abwanderungsregion. In: Archäologisches Landesmuseum Baden-Württemberg (ed) Troia – Traum und Wirklichkeit. Konrad Theiss Verlag, Stuttgart pp 300–304

Hunt (1817) Diary of a journey in the Troad with Carlyle March (1801) In: Memoirs relating to European and Asiatic Turkey and other countries of the East. London, pp 84–140

Hutter C-P, Schwaderer G (2001) Natur und Kultur Hand in Hand – die Troas im System des Vogelzugs. In: Archäologisches Landesmuseum Baden-Württemberg (ed) Troia – Traum und Wirklichkeit. Konrad Theiss Verlag, Stuttgart, pp 305–308

IFREMER (Institut francais de recherche pour l'exploitation de la mer) (2000) La mission Blason (Black Sea Over the Neoeuxinian). http://www.ifremer.fr/drogm/Realisation/Publi/Articles/Lericolais/Blason.html

İnci U (1984) Demirci ve Burhaniye bitümlü şeyllerinin stratigrafisi ve organik özellikleri. Bull Geol Soc Turk 5:27–40

Islam Ansiklopedisi (1993) Milli Egitim Başımevi, vol 3. Türkiye Diyanet Vakfi, Istanbul

Jablonka P (1996) Ausgrabungen im Süden der Unterstadt von Troia. Grabungsbericht 1995. Stud Troica 6:65–96

Jablonka P, König H, Riehl S (1994) Ein Verteidigungsgraben in der Unterstadt von Troia VI. Grabungsbericht 1993. Stud Troica 4:51–73

Jackson JA, Mc Kenzie D (1988) Rates of active deformation in the Aegean Sea and surrounding areas. Basin Res 1:121–128

Jacobeit J, Wanner H, Koslowski G, Gudd M (1999) European surface pressure patterns for months with outstanding climatic anomalies during the sixteenth century. Climate Change 43:201–221

Jacomet S, Kreuz A (1999) Archäobotanik. UTB 8158. Ulmer, Stuttgart

Jaczewski Z (1983) Paroží jelenovitıch. SZN, Praha

Jansen HG (1992) Geomagnetische Prospektion in der Untersiedlung von Troia. Stud Troica 2:61–69

Jansen HG, Kienlin TL, Patzelt AE, Waldhör M, Wilhelm J (1998) Geophysikalische Prospektion 1996/97 in der Unterstadt von Troia. Stud Troica 8:275–284

Jenner GA, Longerich HP, Jackson SE, Fryer BJ (1990) ICP-MS; a powerful tool for high-precision trace-element analysis in earth sciences; evidence from analysis of selected U.S.G.S. reference samples. Chem Geol 83:133–148

Jones GA, Gagnon AA (1994) Radiocarbon chronology of Black Sea Sediments. Deep Sea Res 1 41:555

Jopp W, Hanle A (1971) Meyers Kontinente und Meere. Europa 1. Bibliographisches Institut, Mannheim

Kadereit A (2000) IR-OSL-datierte Kolluvien als Archive zur Rekonstruktion anthropogen bedingter Landschaftsveränderungen – das Fallbeispiel Bretten-Bauerbach/Kraichgau. Dissertation, Universität Heidelberg, Heidelberg

Kalicki T (1995) Lateglacial and Holocene evolution of some river valleys in Byelorussia. In: Frenzel B (ed) (1995) European river activity and climatic change during the Lateglacial and Early Holocene. Paläoklimaforschung – palaeoclimate research 14. Gustav Fischer, Stuttgart, pp 89–100

Kalicz N, Szénászky JG (2001) Spondylus-Schmuck im Neolithikum des Komitats Békés, Südostungarn. Prähist Z 76:24–54

Kammler W (2000) Der Deltavorbau des Büyük Menderes im Umfeld von Priene (Westanatolien/Türkei) – ein Beitrag zur Rekonstruktion der Landschaftsentwicklung mit Hilfe geoarchäologischer Methoden. Diploma Thesis, Marburg

Kaplin PA, Svitoch AA, Parunin OB (1993) Radiocarbon chronology of paleogeographic events of the Late Pleistocene and Holocene in Russia. Radiocarbon 35:399–407

Kaptan E (1983) The significance of tin in Turkish mining history and its origin. Bull Mineral Resour Explor Inst Turk 95/96:106–114

Karacık Z (1995) Ezine-Ayvacık (Çanakkale) dolayında genç volkanizma-plütonizma ilişkileri. PhD Thesis, İstanbul Technical University, Institute of Science, Istanbul

Karacık Z, Yılmaz Y (1998) Geology of the ignimbrites and the associated volcano-plutonic complex of the Ezine area, northwestern Anatolia. J Volcanol Geotherm Res 85/1–4:251–264

Karageorghis V (1986) "Barbarian" Ware in Cyprus. In: Karageorghis V (ed) Acts of the international archaeological symposium, Cyprus between the Orient and Occident. Zavallis Press, Nicosia, pp 246–253

Kasparek A, Kasparek M (1990) Reiseführer Natur Türkei. BLV, München

Kaya O (1982) Gülpınar (Çanakkale) Hipparionlarının odontolojik özellikleri. Bull Geol Soc Turk 25:127–135

Kayan İ (1988a) Late Holocene sea-level changes on the Western Anatolian coast. Palaeogeogr Palaeoclimatol Palaeoecol 68(2–4):205–218; Spec Issue: Pirazzoli PA, Scott DB (eds) Quaternary coastal changes. A selection of papers presented at the IGCP-200 meetings. Elsevier, Amsterdam

Kayan İ (1988b) Holocene geomorphic evolution of the Beşik plain and changing environment of ancient man. Stud Troica 1:79–92

Kayan İ (1991) Holocene geomorphic evolution of the Beşik plain and changing environment of ancient man. Stud Troica 1:79–92

Kayan I (1995) The Troia Bay and supposed harbour sites in the Bronze Age. Stud Troica 5: 211–235

Kayan I (1996) Holocene stratigraphy of the lower Karamenderes-Dümrek plain and archaeological material in the alluvial sediments to the north of the Troia ridge. Stud Troica 6:239–249

Kayan İ (1997a) Geomorphological evolution of the Çıplak valley and archaeological material in the alluvial sediments to the south of the Lower City of Troia. Stud Troica 7:489–507

Kayan İ (1997b) Bronze Age regression and change of sedimentation on the Aegean coastal plains of Anatolia (Turkey). In: Dalfes HN, Kukla G, Weiss H (eds) Third Millennium B.C. climate change and old world collapse. NATO Advanced Research

Workshop. September 19-23, 1994. NATO ASI Series 1. Global environmental change, vol I 49. Springer, Berlin Heidelberg New York, pp 431–450

Kayan İ (1999) Holocene stratigraphy and geomorphological evolution of the Aegean coastal plains of Anatolia. The late Quaternary in the eastern Mediterranean region. Quat Sci Rev 18(4–5)541–548

Kayan I (2000) The water supply of Troia. Stud Troica 10:135–144

Kiesewetter H (1999) Spätbyzantinische Gräber bei der Quellhöhle in der Unterstadt von Troia/Ilion. Stud Troica 9:411–438

Kirk GS, Hainsworth B, Janko R, Edwards MW, Richardson N (eds) (1985–1993) The Iliad: a commentary. Cambridge University Press, Cambridge (This work comprises 6 vols edited as follows: vol 1 (= bks 1–4) Kirk GS (1985); vol 2 (= bks 5–8) Kirk GS (1990); vol 3 (= bks 9–12) Hainsworth B (1993); vol 4 (= bks 13–16) Janko R (1992); vol 5 (= bks 17–20) Edwards MW (1991); vol 6 (= bks 21–24) Richardson N (1993))

Knacke-Loy O (1994) Isotopengeochemische, chemische und petrographische Untersuchungen zur Herkunftbestimmung der bronzezeitlichen Keramik von Troia. Heidelberger Geowiss Abh 77. Universität Heidelberg, Heidelberg, p 193

Knacke-Loy O, Satır M, Pernicka E (1995a) Provenance Studies on Trojan Bronze Age pottery, mineralogical and geochemical investigations. Proceedings of Int Symp Geol Black Sea region, Ankara, pp 181–189

Knacke-Loy O, Satır M, Pernicka E (1995b) Zur Herkunftsbestimmung der bronzezeitlichen Keramik von Troia; chemische und isotopengeochemische (Nd, Sr, Pb) Untersuchungen. Stud Troica 5:145–176

Knauss J (2001) Späthelladische Wasserbauten – Erkundungen zu wasserwirtschaftlichen Infrastrukturen der mykenischen Welt. Berichte des Lehrstuhls und der Versuchsanstalt für Wasserwirtschaft, Nr 90. Technische Universität München, München

Kohlmeyer K (1994) Zur frühen Geschichte von Blei und Silber. In: Wartke R-B (ed) Handwerk und Technologie im Alten Orient. Philipp von Zabern, Mainz, pp 59–66

Koppenhöfer D (1997) Troia VII – Versuch einer Zusammenschau einschließlich der Ergebnisse des Jahres 1995. Stud Troica 7:295–353

Korfmann M (1984) Beşik-Tepe. Vorbericht über die Ergebnisse der Grabung von 1982. Die Hafenbucht vor "Troja" (Hisarlik), Grabungen am Beşik-Yassıtepe. Archäologischer Anzeiger, Berlin, pp 165–195

Korfmann M (1985) Vorbericht über die Ergebnisse der Grabung von 1983. Grabungen am Besik-Yassıtepe und Beşik-Sivritepe. Archäologischer Anzeiger, Berlin, pp 157–194

Korfmann M (1986) Beşik-Tepe. Vorbericht über die Ergebnisse der Grabungen von 1984. Grabungen am Beşik-Yassıtepe, Beşik-Sivritepe und Beşik-Gräberfeld. Archäologischer Anzeiger, Berlin, pp 303–363

Korfmann M (1988) Beşik-Tepe. Vorbericht über die Ergebnisse der Grabungen von 1985 und 1986. Grabungen am Beşik-Yassıtepe und im Beşik-Gräberfeld. Archäologischer Anzeiger, Berlin, pp 391–404

Korfmann M (1994) Troia – Ausgrabungen 1993. Stud Troica 4:1–50

Korfmann M (1995a) Troia – Ausgrabungen 1994. Stud Troica 5:5–9

Korfmann M (1995b) Troia: a residential and trading city at the Dardanelles. Aegaeum 12:173–183

Korfmann M (1996) Troia – Ausgrabungen 1995. Stud Troica 6:1–64

Korfmann M (1997) Hisarlık und das Troia Homers. Festschrift für Wolfgang Röllig, Kevelaer, Neukirchen-Vluyn, pp 171–184

Korfmann M (2000) Troia – Ausgrabungen 1999. Stud Troica 10:1–52

Korfmann M. (2001)Troia als Drehscheibe des Handels im 2. und 3. vorchristlichen Jahrtausend. In: Archäologisches Landesmuseum Baden-Württemberg (ed) Troia – Traum und Wirklichkeit. Konrad Theiss Verlag, Stuttgart, pp 355–369

Korfmann M (2002) Some Observations on equating Troia with the Atlantis Myth. Festschrift für Ufuk Esin. Istanbul (in press)

Korfmann M, Kromer B (1993) Demircihüyük, Beşik-Tepe, Troia – Eine Zwischenbilanz zur Chronologie dreier Orte in Westanatolien. Stud Troica 3:135–172

Korfmann M, Mannsperger D (1998) Troia, ein historischer Überblick und Rundgang. Theiss, Stuttgart

Korfmann M, Baykal-Seeher A, Kilic S (1994) Anatolien in der Frühen und Mittleren Bronzezeit. TAVO 73/1. Ludwig Reichert, Wiesbaden

Koukouli-Chrysantaki C (1970) Προιστορικη Θασος, Αρχαιολογικη Εφημερις Χρονικα:16–22

Koukouli-Chrysantaki C (1982) Die frühe Eisenzeit auf Thasos. In: Hänsel B (ed) Südosteuropa zwischen 1600 und 1000 v. Chr. Prähistorische Archäologie in Südosteuropa, Bd 1. Wissenschaftsverlag Volker Spiess, Berlin, pp 65–86; 119–143

Kraft JC (1971) Sedimentary facies patterns and geologic history of a Holocene marine transgression. Bull Geol Soc Am 82:2131–2158

Kraft JC, Chrzastowski MJ (1985) Coastal stratigraphic sequences. In: Davis RA (ed) Coastal sedimentary environments, second revised and expanded edn. Springer, Berlin Heidelberg New York, pp 625–663

Kraft JC, Rapp G Jr, Aschenbrenner S (1975) Late Holocene paleogeography of the coastal plain of the Gulf of Messenia, Greece, and its relationships to archaeological settings and coastal change. Bull Geol Soc Am 86:1191–1208

Kraft JC, Kayan İ, Erol O (1980a) Geomorphic reconstructions in the environs of ancient Troy. Science 209:776–782

Kraft JC, Rapp G Jr, Aschenbrenner S (1980b) Late Holocene paleogeomorphic reconstructions in the area of the Bay of Navarino: Sandy Pylos. J Archaeol Sci 7:187–210

Kraft JC, Kayan İ, Erol O (1982) Geology and paleogeographic reconstructions of the vicinity of Troy. In: Rapp G, Gifford JA (eds) The archaeological geology. Supplementary monograph 4. Princeton University Press, Princeton, pp 11–40

Kraft JC, Rapp G Jr, Szemler GJ, Tziavos C, Kase E (1987) The pass at Thermopylae, Greece. J Field Archaeol 12,2:181–198

Kraft JC, Brückner H, Kayan I (1999) Paleogeographies of ancient coastal environments in the environs of the Feigengarten excavation and the 'Via(e) Sacra(e)' to the Artemision at Ephesus. Sonderschriften Bd 32. Österreichisches Archäologisches Institut, Wien, pp 91–100

Kraft JC, Kayan İ, Brückner H, Rapp G (2000) Geologic analysis of ancient landscapes and the harbors of Ephesus and the Artemision in Anatolia. Ergänzungshefte Jahreshefte des Österreichischen Archäologischen Instituts, 69. Wien, pp 175–233

Kraft JC, Kayan I, Brückner H (2001) The geological and paleogeographical environs of the Artemision. In: Muss U (ed) Der Kosmos der Artemis von Ephesos. Österreichisches Archäologisches Institut, Sonderschriften 37:123–133, Wien

Kratochvíl J (1966) Použitá zoologie. Obratlovci 2. SZN, Praha

Krönneck P (1996) Vogelknochen aus Troia. Ein Beitrag zur Umweltrekonstruktion. Stud Troica 6:229–236

Kroll H (1983) Kastanas. Ausgrabungen in einem Siedlungshügel der Bronze- und Eisenzeit Makedoniens 1975–1979. Die Pflanzenfunde. Prähist Archäol Südosteuropa 2. Wissenschaftsverlag Volker Spiess, Berlin

Kroll H (1991) Südosteuropa. In: Zeist W van, Wasylikowa K, Behre K-E (eds) Progress in old world palaeoethnobotany. A retrospective view on the occasion of 20 years of the International Work Group for palaeoethnobotany. Balkema, Rotterdam, pp 161–177

Kroll H (1993) Kulturpflanzen von Kalapodi. Archäologischer Anzeiger, Berlin, pp 155–176

Kroll H (1999) Byzantinischer Roggen von Agios Mamas, Chalkidike. Byzant Z 92:474–478

Kroll H, Neef R (1997) Bohnen von Agios Mamas. In: Becker C, Dunkelmann M-L, Metzner-Nebelsick C, Peter-Röcher H, Roeder M, Teran B (eds) Χϱονος [Chronos]. Beiträge zur prähistorischen Archäologie zwischen Nord- und Südosteuropa. Festschrift für Bernhard Hänsel. Int Archäol Stud Honoraria 1. Espelkamp, pp 543–547

Kuleff I, Pernicka E (2002) INAA of some geological standard reference materials. J Radioanal Nuclear Chem (in press)

Kuleff I, Pernicka E, Gergova D (in press) Knobbed Ware from Thrace l'archipel et de la Troade. Denne, Paris

Kuniholm PI, Kromer, B, Tarter SL, Griggs CB (1998) An Early Bronze Age settlement at Sozopol, near Burgas, Bulgaria. Dated by dendrochronology and radiocarbon. In: Stefanovich M, Todorova H, Hauptmann H (eds) James Harvey Gaul in Memoriam. In the steps of James Harvey Gaul 1. James Harvey Gaul Foundation, Sofia, pp 399–409

Kyriatzi E, Andreou S, Dimitriadis S, Kostakis K (1997) Co-existing traditions: handmade and wheelmade pottery in Late Bronze Age central Macedonia. In Laffineur R, Betancourt P (eds) Aegaeum 16. TEXNH Craftsmen, craftswomen and craftsmanship in the Aegean Bronze Age. Proceedings of the 6th International Aegean Conference, Philadelphia, Temple University, 18–21 April 1996. Université de Liège, Liège, pp 361–367

Lamb W (1932) Prähistorische Zeitschrift xxiii:111–131

Lamb W (1936) Excavations at Thermi in Lesbos. Cambridge University Press, Cambridge

Lambeck K (1996) Sea-level change and shore-line evolution in Aegean Greece since Upper Palaeolithic time. Antiquity 70:588–611

Lane-Serff G, Rohling EJ, Bryden HL, Charnock H (1997) Postglacial connection of the Black Sea to the Mediterranean and its relation to the timing of the Sapropel formation. Paleoceanography 12:169–174

Lang A (1996) Die Infrarot-Stimulierte-Lumineszenz als Datierungmethode für holozäne Lössderivate: ein Beitrag zur Chronometrie kolluvialer, alluvialer und limnischer Sedimente in Südwestdeutschland. In: Barsch D, Fricke W, Meusburger P (eds) Heidelberger Geographische Arbeiten. Bd 103. Geographisches Institut der Universität Heidelberg, Heidelberg

Lang A, Wagner GA (1996) Infrared stimulated luminescence dating of archaeosediments. Archaeometry 38 (1):129–141

Lang A, Lindauer S, Kuhn R, Wagner GA (1996) Procedures used for optically and infrared stimulated luminescence dating of sediments in Heidelberg. Ancient TL 14 (3):7–11

Lang A, Kadereit A, Behrends R-H, Wagner GA (1999) Optical dating of anthropogenic sediments at the archaeological site of Herrenbrunnenbuckel, Bretten-Bauerbach (Germany). Archaeometry 41 (2):397–411

Lapuente PM, Turi B, Blanc P (2000) Marbles from Roman Hispania: stable isotope and cathodoluminescence characterisation. Appl Geochem 15:1469–1493

Larsen MT (1982) Caravans and trade in ancient Mesopotamia and Asia Minor. Bull Soc Mesopotamian Stud (Toronto) 4:33–45

Latacz J (2001) Troia und Homer: der Weg zur Lösung eines alten Rätsels. Koehler and Amelang, München

Lazzarini L (1988) The occurrence, use, and deterioration of Marmor Troadense. Kodewey-Gesellschaft (ed) Bericht über die 34. Tagung für Ausgrabungswissenschaft und Bauforschung, Venedig 1986. Butzon and Berker, Kevelaer, pp 22–26

Lazzarini L, Moschini G, Stievano BM (1980a) Contributi all'identificazione di marmi italiani, greci, e anatolici mediante uno studio petrografico e la deteminazione del rapporto Ca/Sr. Quaderni della Soprintendenza ai beni artistici e storici di Venezia 9:8–32

Lazzarini L, Moschini G, Stievano BM (1980b) Alcuni esempi di identificazione di marmi antichi mediante uno studio petrografico e la determinazione del rapporto Ca/Sr. Quaderni della Soprintendenza ai beni artistici e storici di Venezia 9:34–51

Leaf W (1912) Troy: a study in homeric geography. Macmillan, London

Lechevalier JB (1792) Beschreibung der Ebene von Troja mit Anmerkkungen and Erläuterung von Andreas Dalzel. Vorede. Anm. und Zusätze von Chr G. Heyne (Leipzig) 1972

Lechevalier JB (1800) Reise nach Troas oder Gemählde der Ebene von Troja in ihrem gegenwärigen Zustande von Bürger Lechevalier. Rinck and Schnuphase, Altenburg-Erfurt

Lenz CG (1798) Die Ebene von Troja nach dem Grafen Choiseul Gouffier. Michaelis, Neu-Strelitz

Lenz D, Ruppenstein F, Baumann M, Catling R (1998) Protogeometric pottery at Troia. Stud Troica 8:189–211

Le Pichon X (2000) Active tectonics of Eastern Mediterranean Sea. Nato Advenced Research Seminar, NATO, TÜBİTAK, İTÜ, 14–17 May, 2

Le Pichon X, Angellier J (1979) The Hellenic arc and trench system: a key to the neotetonic evolution of the eastern Mediterranean area. Tectonophysics 60:1–42

Le Pichon X, Chamot Rooke N, Lallemant S, Noomen R, Veis G (1995) Deodetic determination of the kinematics of central Greece with respect to Europe: Implications for eastern Mediterranean tectonics. J Geophys Res 100:12675–12690

Lepsius R (1890) Griechische Marmorstudien. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, philosophisch-historische Klasse, Anhang. Königlichen Akademie der Wissenschaften zu Berlin, Berlin, pp 1–135

Lestakov K (1993a) The end of the Early Bronze Age in Thrace. Actes du XII Cong Int des CPP Bratislava 1991 II:556–559

Lestakov K (1993b) Die Mittlerebronzezeitliche Besiedlung des Siedlunghügels von Galabovo in Südostbulgarien. Saarbrücker Studien und Materialien zur Altertumskunde 2:191–222

Lestakov K (1994) The detachment of the Early Bronze Age ceramics along the South Bulgarian Black Sea Coast I. Thracia Pontica V:23–38

Levine M, Rassamakin Y, Kislenko A, Tatarintseva N (1999) Late prehistoric exploitation of the Eurasian Steppe. McDonald Institute Monographs. McDonald Institute for Archaeological Research, Cambridge

Lichardus J (1991) Die Kupferzeit als historische Epoche. Ein forschungsgeschichtlicher Überblick. In: Lichardus J (ed) Die Kupferzeit als historische Epoche. Rudolf Habelt, Bonn, pp 13–34

Lichardus J, Iliev IK, Christov CJ (1999) Die spätbronzezeitlichen "Steinstößel-Zepter" in Südostbulgarien und die Frage der nordpontischen Verbindungen zur Ägäis. Eurasia Antiqua 5:95–110

Lichardus J, Fol A, Getov L, Bertemes F, Echt R, Katincarov R, Krastev I (2000) Forschungen in der Mikroregion Drama (Südostbulgarien). Zusammenfassung der Hauptergebnisse der bulgarisch-deutschen Grabungen in den Jahren 1983–1999. Habelt, Bonn

Limet H (1960) Le travail du métal au pays de Sumer au temps de la III^{ème} Dynastie d'Ur. Les Belles Lettres, Paris

Lohmann H (2002) Milet und die Milesia. Eine antike Großstadt und ihr Umland im Wandel der Zeiten. In: Kolb F (ed) Chora und Polis. Kolloquium des historischen Kollegs, München, 05-08.04.2000. Stuttgart (in press)

Luce JV (1984) The Homeric topography of the Trojan Plain reconsidered. Oxf J Archaeol 3:31–43

Luce JV (1998) Celebrating Homer's landscapes: Troy and Ithaca revisited. Yale University Press, New Haven

Lutz J, Pernicka E, Wagner GA (1994) Chalcolithische Kupferverhüttung in Murgul, Ostanatolien. In: Wartke RB (ed) Handwerk und Technologie im Alten Orient. Philipp von Zabern, Mainz, pp 59–66

Maclaren C (1822) Dissertation on the plain of Troy. Edinburgh

Maclaren C (1863) The plain of Troy described and the identity of the Ilium of Homer with the New Ilium of Strabo proved. Adam and Charles Black, Edinburg

Maddin R (1989) The copper and tin ingots from the Kaş shipwreck. In: Hauptmann A, Pernicka E, Wagner GA (eds) Old world archaeometallurgy. Der Anschnitt. Beiheft 7. Deutsches Bergbau-Museum, Bochum, pp 99–105

Magny M (1993) Solar influences on Holocene climatic changes illustrated by correlations between past lake-level fluctuations and the atmospheric 14C record. Quat Res 40:1–9

Main IG, Burton PW (1989) Seismotectonics and the earthquake frequency-magnitude distribution in the Aegean area. Geophys J R Astron Soc 98:575–586

Makris J, Stobbe C (1984) Physical properties and state of the crust and upper mantle of the eastern Mediterranean Sea deduced from geophysical data. Mar Geol 55:347–363

Maniatis Y, Kromer B (1990) Radiocarbon dating of the neolithic early bronze age site of Mandalo, W. Macedonia. Radiocarbon 32:149–153

Manning SW (1995) The absolute chronology of the Aegean Early Bronze Age: archaeology, history and radiocarbon. Monographs in Mediterranean Archaeololgoy 1. Sheffield University Press, Sheffield

Manning SW (1997) Troy, radiocarbon, and the chronology of the northeast Aegean in the Early Bronze Age. He Poliochni kai he proimi epoche tou Chalkou sto Voreio Aigaio/Poliochni e l'antica et del bronzo nell'Egeo settentrionale. V. La Rosa and C. Doumas. Scuolaarcheologica italiana di Atene and Panepistimio Athenon, Athens, pp 498–520

Mansfeld G (2001) Die Kontroll-Ausgrabung des "Pinnacles E4/5" im Zentrum der Burg von Troia. Stud Troica 11:51–307

Masters PM, Flemming NC (eds) (1983) Quaternary coastlines and marine archaeology. Academic Press, London

Mauduit AF (1840) Découvertes dans la Troade. Firmin Didot, Paris
Mayer H, Aksoy H (1986) Wälder der Türkei. Fischer, Stuttgart
McClusky S, Balassanian S, Barka A, Demir C, Ergintav S, Georgiev I, Gurkan O, Hamburger M, Hurst K, Kahle H, Kastens K, Kekelidze G, King R, Kotzev V, Lenk O, Mahmoud S, Mishin A, Nadariya M, Ouzounis A, Paradissis Dpeter Y, Prilepin M, Reilinger R, Sanli I, Seeger H, Tealeb A, Toksöz MN, Veis G (2000) Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus. J Geophys Res 105 B3:5695–5719
McKenzie DP, Yılmaz Y (1991) Deformation and volcanism in western Turkey and the Aegean. Bull Tech Univ Istanbul 44:345–373
Meissner R, Wever TH, Flüh ER (1987) The Moho in Europe: implications for crustal development. Ann Geophys 513:357–364
Meriç E (ed) (1990) Late quaternary bottom sediments of the Southern Bosphorus and Golden Horn. ITÜ Publications, Istanbul
Meriç E (ed) (1995) İzmit körfezi'nin kuvaterner istifi. Quaternary Sequence in the Gulf of Izmit. Deniz Harp Okulu Basımevi, İstanbul
Mindevalli OY, Mitchell BJ (1989) Crustal structure and possible anisotropy in Turkey from seismic wave dispersion. Geophys J Int 98:93–106
Moens L, Roos P, De Rudder J, De Paepe P, Waelkens M (1987) Identification of archaeological interesting white marbles by instrumental neutron activation analysis (INAA) and petrography: comparision between samples from Afyon and Uhak (Turkey). J Trace Microprobe Tech 5:101–114
Mommsen H, Kreuser A, Weber J (1988) A method for grouping pottery by chemical composition. Archaeometry 30:47–57
Moorey PRS (1994) Ancient Mesopotamian materials and industries. Clarendon Press, Oxford
Morhange C, Laborel J, Hesnard A (2001) Changes of relative sea level during the past 5000 years in the ancient harbor of Marseilles, Southern France. Palaeogeogr Palaeoclimatol Palaeoecol 166:319–329
Morintz S (1964) Quelques problèmes concernant la période ancienne de Hallstatt au Bas-Danube à la lumière des foilles de Babadag. Dacia (NS) 8:101–118
Morris I, Powell B (eds) (1997) A new companion to Homer. Brill, Leiden
Mountjoy PA (1997) Troia phase VIf and phase VIg: the Mycenaean pottery. Stud Troica 7:275–294
Mountjoy PA (1999a) The destruction of Troia VIh. Stud Troica 9:253–293
Mountjoy PA (1999b) Troia VII reconsidered. Stud Troica 9:295–346
Müller J (1997) Neolithische und chalkolithische Spondylus-Artefakte. Anmerkungen zu Verbreitung, Tauschgebiet und sozialer Funktion. In: Becker C, Dunkelmann ML, Metzner-Nebelsick C, Roeder M, Teran B (eds) Chronos. Beiträge zur prähistorischen Archäologie zwischen Nord- und Südosteuropa. Festschrift für Bernhard Hänsel. Internationale Archäologie Studia Honoraria 1. Leidorf, Espelkamp, pp 91–106
Müller LR (1919) Bericht über die Malaria in der Türkei im Jahre 1916. Sammlung Klinischer Vorträge 1914–1919:711–727
Muhly JD (1973) Copper and tin. The distribution of mineral resources and the nature of the metals trade in the Bronze Age. Trans Connecticut Acad Sci 43:157–535 (Reprint by Archon Books, Hamden, Connecticut)
Muhly JD (1985) Sources of tin and the beginning of Bronze Metallurgy. Am J Archeol 89:275–291

Muhly JD (1989) Cayönü Tepesi and the beginnings of metallurgy in the ancient world. In: Hauptmann A, Pernicka E, Wagner GA (eds) Old world archaeometallurgy. Der Anschnitt. Beiheft 7. Deutsches Bergbaumuseum, Bochum, pp 1–11
Muhly JD (1993) Early Bronze Age tin and the Taurus. Am J Archaeol 97:239–253
Muhly JD; Begemann F, Öztunali Ö, Pernicka E, Schmitt-Strecker S, Wagner GA (1991) The bronze metallurgy of Anatolia and the question of local tin sources. In: Pernicka E, Wagner GA (eds) Archaeometry 90. Birkhäuser Verlag, Basel, pp 209–220
Nemejcova V (1992) Kulturhistorische Verhältnisse in Südosteuropa zu Beginn des Horizontes Ezero-Baden und die möglichen Wege von Kontakten mit dem Ägäisch-Anatolischen Gebiet. Stud Praehist 11–12:362–384
Neumann J (1991) Number of days that Black Sea bound sailing ships were delayed by winds at the entrance to the Dardanelles near Troy's site. Stud Troica 1:93–100
Newton CT (1865) Travels and Discoveries in the Levant. London
Niederschlag E, Pernicka E, Seifert T (in press) Determination of lead isotope ratios by multiple collector ICP-MS: application to Early Bronze Age artefacts from central Germany and their possible relation to the Erzgebirge. Archaeometry
Niemeier B, Niemeier WD (1997) Milet 1994–1995. Projekt 'Minoisch-Mykenisches bis Protogeometrisches Milet': Zielsetzung und Grabungen auf dem Stadionhügel und am Athenatempel. Archäologischer Anzeiger, Berlin, pp 189–248
Nikolova L (1999) Cultural and ceramic sequence. BAR Int Ser 791. Archaeopress, Oxford
Noack K-H, Loysa M (1992) Schliemanns Ohrleiden und sein plötzlicher Tod. In: Hermann J (ed) Heinrich Schliemann. Grundlagen und Ergebnisse moderner Archäologie 100 Jahre nach Schliemanns Tod. Akademie Verlag, Berlin, pp 87–89
Nowakiewicz T, Wróblewski W (in press) Ceramika "pruska" i "słowiańska" we wczesnośredniowiecznej Galindii. Festschrift for Prof. W. Szymañski. Institute of Archaeology, Warsaw University Warszawa
Önal N (1986) Sedimentary facies and tectonic evolution of central part of the Gelibolu Peninsula, NW Anatolia, Turkey. Geol Eng 29:37–46
Öngen S (1992) Les échanges métasomatique entre granitoides et encaissants particuliers (calcaires, dolomies, ultrabasites, séries manganésiferes) N. L'éxemple de la Peninsula de Biga, anatolie Nord-Ouest, Turquie. Université de Nancy, Nancy
Öngen S (1994) Le pluton calco-alcalin d'Evciler (Peninsule de Biga, Turquie-W): Age, geochimie et signification geodynamique. CR Acad Sci Paris 319 Ser II: 1033–1039
Özcan A, Göncüo¡lu MC, Turan N, Uysal S, Sentürk K, Ihik A (1988) Late Paleozoic evolution of the Kütahya-Bolkardağ belt. Middle East Tech Univ J Pure Appl Sci 21:211–220
Özdoğan M (1983) Doğu Marmara ve Trakya Araştırmaları 1982. Araştırma Sonuçları Toplantısı I. Kültür Bakanlığı, Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 238–240
Özdoğan M (1984) 1983 Yılı Doğu Marmara ve Trakya Araştırmaları. Araştırma Sonuçları Toplantısı II. Kültür Bakanlığı, Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 221–232
Özdoğan M (1985a) Marmara Bölgesinde Kültür Tarihi Ile Ilgili Bazı Sorunçlar ve Bunların Çözümüne Jeomorfoloji Araştırmalarının Katkısı. Arkeometri Toplantısı Sonuçları II. Kültür Bakanlığı, Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 39–162

Özdoğan M (1985b) 1984 Yılı Trakya ve Doğu Marmara Araştırmaları. Araştırma Sonuçları Toplantısı III. Kültür Bakanlığı, Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 409–420

Özdoğan M (1986a) Prehistoric Sites in the Gelibolu Peninsula. Anadolu Arastirmalari X:51–66

Özdoğan M (1986b) Trakya Bölgesinde Yapılan Tarihöncesi Araştırmalar IX. Türk Tarih Kurumu Kongresi I. Türk Tarih Kurumu, Ankara, pp 29–37

Özdoğan M (1990) 1989 Yılı Marmara Araştırmaları ve Toptepe Kazısı. Kazı Sonuçları Toplantısı XII(1). Kültür Bakanlığı, Anıtlar ve Müzeler Genel Müdürlüğü, Ankara, pp 345–375

Özdoğan M (1991) Eastern Thrace before the beginning of Troy I – an archaeological dilemma. In: Lichardus J (ed) Die Kupferzeit als historische Epoche. Saarbrücker Beiträge zur Altertumskunde. Rufolf Habelt, Bonn, pp 217–225

Özdoğan M (1993) The second millenium of the Marmara region. The perspective of a prehistorian on a controversial issue. Istanbuler Mitt 43:151–163

Özdoğan M (1996) Neolithization of Europe: A view from Anatolia. Part 1: The problem and the evidence of East Anatolia. Procilo XX:25–61

Özdoğan M (1997) The beginning of Neolithic economies in southeastern Europe: An Anatolian perspective. J Eur Arch 5:(2):1–3

Özdoğan M (1998a) Tarihöncesi Dönemlerde Anadolu ile Balkanlar Arasðndaki Kültür Ðliþkilerive Trakyada Yapðlan Yeni Kazð Çaðþmalarð TUBA-AR 1, pp 63–73

Özdoğan M (1998b) Anatolia from the last glacial maximum to the holocene climatic optimum: cultural formations and the impact of the environmental setting. Paléorient 23(2):25–38

Özdoğan M (1999a) Northwestern Turkey: neolithic cultures in between the Balkans and Anatolia. In: Özdoğan M, Başgelen N (eds) Neolithic in Turkey. The cradle of civilization. New discoveries. Ancient Anatolian civilizations series 3. Arkeoloji ve Sanat Yayınları, İstanbul, pp 203–224

Özdoğan M (1999b) Anadolu'dan Avrupa'ya acılan kapı Trakya. Arkeoloji ve Sanat 21 90:2–28

Özdoğan M, Başgelen N (eds) (1999) Neolithic in Turkey. The cradle of civilization. New discoveries. Ancient Anatolian civilizations series 3. Arkeoloji ve Sanat Yayınları, İstanbul

Özdoğan M, Parzinger H, Karul N (1997) Kðrklareli Kazðlarð (Aþağð Pðnar ve Kanlðgeçit Höyükleri), Arkeloloji ve Sanat 77, pp 2–11

Özer S, Sözbilir H, Özkar I, Toker V, Sari B (2001) Stratigraphy of Upper Cretaceous-Palaeogene sequences in the southern and eastern Menderes Massif (western Turkey). Int J Earth Sciences 89:852–866

Okay AI, Satır M (2000a) An extensional metamorphic core complex in a latest Oligocene magmatic arc in northwest Turkey. Geol Mag 137:495–516

Okay AI, Satır M (2000b) Upper Cretaceous Eclogite – Facies metamorphic rocks from the Biga Peninsula, northwest Turkey. Turk J Earth Sci 9:47–56

Okay AI, Sengör AMC (1994) Kinematic history of the opening of the Back Sea and its effect on the surrounding regions. Geology 22:267–270

Okay AI, Tüysüz O (1999) Tethyan sutures of northern Turkey. Geol Soc Lond Spec Publ 156:475–515

Okay AI, Siyako M, Bürkan KA (1990) Biga yarımadasının jeolojisi ve tektonik evrimi. Bull Turk Assoc Petrol Geol 2 1:83–121

Okay AI, Siyako M, Bürkan KA (1991) Geology and tectonic evolution of the Biga Peninsula, Northwest Turkey. Istanbul Teknik Üniversitesi Bülteni. Bull Tech Univ Istanbul 44:191–256

Okay AI, Satır M, Maluski H, Siyako M, Monie P, Metzger R, Akyüz S (1996) Paleo- and Neo-Tethyan events in northwestern Turkey: Geologic and geochronologic constraints. In: Yin A, Harrison TM (eds) The tectonic evolution of Asia. Cambridge University Press, Cambridge, pp 420–444

Orachev A (1990) Contributions to the paleogeography of the coast of Dobroudja. Dobrudca Zbornik 7:32–52

Ostrovsky AB, Izmaylov YA, Balabanov IP, Skiba SI, Skryabina NG, Arslanov SA, Gey NA, Suprunova NI (1977) New data on the paleohydrological regime of the Black Sea in the Upper Pleistocene and Holocene. In: Kaplin PA, Shcherbakow IA (eds) Paleogeography and deposits of the Pleistocene of the southern seas of the USSR. Nauka Press, Moskow, pp 131–141 (in Russian)

Ozansoy F (1973) Les caracteristiques fauniques du Neogene des Dardanelles. Ankara Üniversitesi Dil Tarih Coğrafya Fakültesi Antropol Dergisi 6:171–180

Palmer MR, Elderfield H (1985) Sr isotope composition of sea water over the past 75 Myr. Nature 314:526–528

Panajatov Ü, Leshtakov K (1991) The settlement mound of Galabovo-Late Chalcolithic. Early and Middle Bronze Age (summary in English). Maritsa Iztok I:139–204

Panajotov I (1989) Zur Chronologie und Periodisierung der Bronzezeit in den heutigen bulgarischen Gebieten. Thracia 9:74–103

Panajotov I (1991) Le site submerge d'Ourdoviza. Thracia Pontica IV:109–112

Panajotov I (1995) The Bronze Age in Bulgaria: studies and problems. In: Bailey D (ed) Prehistoric Bulgaria. Monographs in world archaeology 22. Prehistory Press, Wisconsin, pp 243–252

Panzac D (1985) La Peste dans I'Empire Ottoman. 1700–1850. Peeters, Leuven

Panzac D (1996) Commerce et navigation dans l'Empire Ottoman au XIII Sciècle. Isis, Istanbul

Parakenings B, Kerschner M (1991) Eine Notgrabung in der römischen Nekropole. Istanbuler Mitt 41:141–148

Parzinger H, Özdoğan M (1996) Die Ausgrabungen in Kırklareli and ihre Bedeutung für die Kulturbeziehungen zwischen Anatolien und dem Balkan vom Neolithikum bis zur Frühbronzezeit. Ber Röm-Germ Komm 76:5–29

Parzinger H (1998) Kulturverhältnisse in der eurasischen Steppe während der Bronzezeit. In: Hänsel B (ed) Mensch und Umwelt in der Bronzezeit Europas. Man and environment in European Bronze Age. Oetker Voges, Kiel, pp 457–479

Paton S (1992) Active normal faulting, drainage patterns and sedimentation in southwestern Turkey. J Geol Soc Lond 149:1031–1044

Penhallurick RD (1986) Tin in Antiquity. Institute of Metals, London

Pernicka E (1990) Entstehung und Ausbreitung der Metallurgie in prähistorischer Zeit. Jahrb Röm-Germ Zentralmus 37:21–129

Pernicka E, Schleiter M (1997) Untersuchung der Metallproben vom Tell el-Fara'în (Buto). In: Th. von der Way: Tell el-Fara'în – Buto I. Ergebnisse zum frühen Kontext; Kampagnen der Jahre 1983–1989. Arch Veröff des Deutschen Archäologischen Institutes, Abt Kairo (AVDAIK) Philipp von Zabern, Mainz. 83:219–223

Pernicka E, Wagner GA (1988) Thasos als Rohstoffquelle für Bunt- und Edelmetalle im Altertum. In: Wagner GA, Weisgerber G (eds) Antike Edel- und Buntmetallgewinnung auf Thasos. Der Anschnitt. Beiheft 6. Deutsches Bergbaumuseum, Bochum, pp 224–231

Pernicka E, Seeliger TC, Wagner GA, Begemann F, Schmitt-Strecker S, Eibner C, Öztunalı Ö, Baranyi I (1984) Archäometallurgische Untersuchungen in Nordwestanatolien. Jahrb Röm-Germ Zentralmus Mainz 31:533–599

Pernicka E, Begemann F, Schmitt-Strecker S, Grimanis AP (1990) On the composition and provenance of metal artefacts from Poliochni on Lemnos. Oxf J Archaeol 9:263–297

Pernicka E, Begemann F, Schmitt-Strecker S, Todorova H, Kuleff I (1997) Prehistoric copper in Bulgaria: Its composition and provenance. Eurasia Antiqua 3:41–180

Pernicka E, Rehren T, Schmitt-Strecker S (1998) Late Uruk silver production by cupellation at Habuba Kabira, Syria. In: Rehren T, Hauptmann A, Muhly JD (eds) Metallurgica Antiqua. In honour of Hans-Gert Bachmann and Robert Maddin. Der Anschnitt. Beiheft 8. Deutsches Bergbaumusem, Bochum, 123–134

Peterman ZE, Hedge CE, Tourtelot HA (1970) Isotopic composition of strontium in sea water throughout phanerozoic time. Geochim Cosmochim Acta 34/1:105–120

Pfannenstiel M (1944) Entwicklungstudien und die Urgeschichte von Dardanellen, Marmarameer und Bosporus. Geologische Rundschau

Pfeffer A (1990) Kupfer- und Bronzefunde der Nordostägäis. Ihre gegenseitigen und auswärtigen Beziehungen aufgrund typologischer Vergleiche und Analysen. Magisterarbeit, Institut für Ur- und Frühgeschichte, Universität Tübingen, Tübingen

Philippson A (1936) Das südliche Ionien. In: Wiegand T (ed) Milet, Ergebnisse der Ausgrabungen und Untersuchungen seit dem Jahre 1899, vol III 5. De Gruyter, Berlin

Pilides D (1992) Handmade burnished ware in Cyprus: an attempt at its interpretation. In: Ioannidis IK (ed) Αφιερωμα στο Βασο Καραγιωργη. Κυπριακαι Σπουδαι ΝΔ - ΝΕ (54–55), Λευκοσια, pp 179–189

Pilides D (1994) Handmade burnished wares of the Late Bronze Age in Cyprus. Paul Åström Verlag, Jonsered

Pirazzoli PA (1991) World atlas of Holocene sea-level changes. Elsevier, Amsterdam, pp 88–104

Pirazzoli PA (1996) Sea-level changes: the last 20,000 years. Wiley, Chichester

Pococke R (1745) A description of the East and some other countries. W Bowyer, London

Podzuweit C (1982) Die mykenische Welt und Troja. In: Hänsel B (ed) Südosteuropa zwischen 1600 und 1000 v. Chr. Prähistorische Archäologie in Südosteuropa, Band 1. Wissenschaftsverlag Volker Spiess, Berlin, pp 65–86

Pollard J (1977) Birds in Greek life and myth. Thames and Hudson, Plymouth

Poroıanov K (1991) Le site submergé d'Ourdoviza. In: Actes de Symposium International Thracica-Pontica 4 (6–12 October 1988). Bulgarian Academy of Sciences, Sofia, pp 109–112

Porojanov K, Popov V (1979) Les recherches archeologiques sous-marines conduites par le centre d'Histoire Maritime et Archeologie. Thracia Pontica I:311–316

Prag K (1978) Silver in the Levant in the fourth millenium B.C. In: Moorey PRS, Parr P (eds) Archaeology in the Levant. Festschrift K. Kenyon. Aris and Phillips, Warminster, pp 36–45

Price TD (ed) (2000) Europe's first farmers. Cambridge University Press, Cambridge

Primas M (1996) Velika Gruda I. Universitätsforschungen zur prähistorischen Archäologie, Bd 32. Habelt, Bonn

Prokesch A (1831) Erinnerungen aus Ägypten und Kleinasien, vol 3. Urmbrusster's Verlagbuchhandlung, Wien

Prokesch A (1836) Denkwürdigkeiten und Erinnerungen aus dem Orient, vol 1. Dallbergische Verlagshandlung, Stuttgart

Pustovoytov KE (1999) Die spätholozäne Bodenerosion von Troia im Spiegel der Bodendecke. Stud Troica 9:353–366

Raban A (1997) Near Eastern harbours: 13th–7th centuries B.C.E. In: Gittin S, Mazar A, Stein E (eds) Mediterranean people in transition – 13th to early 10th centuries B.C.E. Israel Exploration Society, Jerusalem

Reilinger RE, Mc Clusky SC, Oral MB, King RW, Toksöz MN, Barka AA, Kınık I, Lenk O, Sanli I (1997) Global Positioning System measurements of present-day crustal movements in the Arabia-Africa-Eurasia plate collision zone. J Geophys Res Solid Earth 102 B5:9983–9999

Renfrew C (1967) Cycladic metallurgy and the Aegean Early Bronze Age. Am J Archaeol 71:2–26

Renfrew C (1972) The emergence of civilization: The Cyclades and the Aegean in the third millennium B.C. Methuen, London

Riehl S (1999a) Archäobotanik in der Troas. Studia Troica 9:367–409

Riehl S (1999b) Bronze Age environment and economy in the Troad. BioArchaeologica 2. Mo Vince, Tübingen

Riehl S (1999c)The archaeobotany of Kumtepe and Troy. In: Uerpmann H-P (ed) Bronze Age environment and economy in the Troad. Tome 2

Riehl S (2000) Bronze Age environment and economy in the Troad – The archaeobotany of Kumtepe and Troy. BioArchaeology 2. Mo Vince, Tübingen, p 268

Robertson AHF, Picket EA (2000) Palaeozoic-early Tertiary Tethyan evolution of melanges, rift and passive margin units in the Karaburun Peninsula (western Turkey) and Chios Island (Greece). In: Bozkurt E, Winchester JA, Piper JDA (eds.) Tectonics and magmatism in Turkey and the surrounding area. Geological Society of London, London, pp 43–82

Roddick JC, Sullivan, RW, Dudas FÖ (1992) Precise calibration of Nd tracer isotopic composition for Sm-Nd studies. Chem Geol 97:1–8

Roodenberg J (1993) 1992 Ilıpınar Kazıları. XV. Kazı Sonuçları Toplantısı I. Ankara, pp 171–176

Roodenberg J (1994) 1993 Yılı Ilıpınar Kazıları. XVI. Kazı Sonuçları Toplantısı I. Ankara

Roodenberg J (1995) Ilipinar, vol I. Netherlands Historisch-Archaeologisch Instituut, Istanbul

Rose M (1999) Neolithic Noah. Are the claims of two geologists all wet? Archaeology 52 1:75–78

Ross DA, Degens ET, MacIlvaine J (1970) Black Sea; recent sedimentary history. Science 170 3954:163–165

Rossovsky LN, Mogarovsky VV, Chmirev VM (1987) The Metallogeny of tin and rare metals in the eastern part of the Mediterranean Folded Belt. In: Jankovic S (ed) Mineral deposits of the Tethyan Eurasian Metallogenic Belt between the Alps and the Pamirs (selected examples). Faculty of Mining and Geology, University of Belgrade, Belgrade (UNESCO/ICCP Project no. 169), pp 170–177

Rumscheid F (1998) Priene – Führer durch das 'Pompeji Kleinasiens'. Ege Yayinlari, Istanbul

Rutter J (1975) Ceramic Evidence for northern intruders in Southern Greece at the beginning of the Late Helladic IIIC period. Am J Archaeol 79:17–32

Ryan CW (1960) A guide to the known minerals in Turkey. MTA, Ankara

Ryan W, Pitman W (1998) Noah's flood. The new scientific discoveries about the event that changed history. Simon and Schuster, London, pp 167–194

Ryan WBF, Pitman WC (1992) The Early Holocene flooding of the Black Sea and its implications for the emergence of civilization. Mimeographed text

Ryan WBF, Pitman WC, Major CO, Shimkus K, Moskalenko V, Jones GA, Dimitrov P, Görür N, Sakinç M, Yüce H (1997) An abrupt drowning of the Black Sea shelf. Mar Geol 138:119–126

Şamilgil E (1966) Çanakkale'nin Tuzla ve Kestanbol sıcak su havzalarında jeotermal enerji araştırması yönünden hidrojeolojik etüdü. Mineral Research and Exploration Inst of Turkey (MTA) Technical Report, Ankara

Sandars NK (1971) From Bronze Age to Iron Age. A sequel to a sequel. In: Boardman J, Brown MA, Powell TGE (eds) The European community in later prehistory. Studies in memory of C.F.C. Hawkes. Routlege and Kegan, London, pp 3–29

Sangmeister E (1971) Aufkommen der Arsenbronze in SO-Europa. Actes di VIIIe Congrès International des Sciences Préhistoriques et Protohistoriques, I. Comité National d'Organisation, Beograd, pp 131–138

Sarıyildiz G (1996) Hıcaz Karantina Teskilati. Türk Tarih Kurumu, Ankara

Sarpaki A (1992) The palaeoethnobotanical approach. The mediterranean triad or is it a quartet? In: Wells B (ed) Agriculture in ancient Greece. Proceedings of the 7th International Symposium at the Swedish Institute at Athens, 16–17 May, 1990. Skr Svenska Inst Athen 4° 42, Göteborg, pp 61–76

Satır M, Friedrichsen H (1986) The origin and evolution of the Menderes Massif, W-Turkey: a rubidium/strontium and oxygen isotope study. Int J Earth Sci 75: 703–715

Satır M, Taubald H (2001) Hydrogen and oxygen isotope evidence for fluid-rock interaction in the Menderes Massif, western Turkey. Int J Earth Sci 89:812–821

Sayre E (1988) Comments on the Brookhaven data handling programs. Brookhaven National Laboratory, Brookhaven, USA

Schachermeyr F (1984) Griechische Frühgeschichte. Verlag der Österr Akademie der Wissenschaften, Wien

Schede M (1929) Anatolien. Archäologischer Anzeiger, Berlin, pp 358–370

Schiegl S, Weiner KL, El Goresy A (1990) Zusammensetzung und Provenienz von Blau- und Grünpigmenten in altägyptischer Malerei: ein Beitrag zur exakten Chronologie in Altägypten. Erzmetall 43:265–272

Schimitschek E, Werner G (1985) Malaria, Fleckfieber, Pest. Hirzel, Stuttgart

Schliemann H (1881) Ilios. Stadt und Land der Trojaner. Brockhaus, Leipzig

Schliemann H (1884) Troja. Brockhaus, Leipzig

Schmidt H (1902a) Die Keramik der verschiedenen Schichten. In: Dörpfeld W (1902) Troja und Ilion. Ergebnisse der Ausgrabungen in den vorhistorischen und historischen Schichten von Ilion 1870–1894. Beck and Barth, Athen, pp 243–319

Schmidt H (1902b) Heinrich Schliemann's Sammlung Trojanischer Altertümer. Reimer, Berlin

Schrader H (1979) Quaternary paleoclimatology of the Black Sea Basin. Sediment Geol 23:165–180

Schröder B (1998) Mittel- bis jungholozäne Landschaftsgeschichte am Unterlauf des Großen Mäanders (W-Anatolien). GeoArchaeoRhein Münster 2:91–101

Schröder B, Bay B (1996) Late Holocene rapid coastal change in Western Anatolia – Büyük Menderes plain as a case study. Z Geomorphol NF Suppl 102:61–70

Schröer K (2000) Archäo-geophysikalische Untersuchungen in Troia 1998–2000. Master Thesis, University of Münster, Münster

Schubert E (1981) Zur Frage der Arsenlegierungen in der Kupfer- und Frühbronzezeit Südosteuropas. In: Lorenz H (ed) Studien zur Bronzezeit. Festschrift für Wilhelm Albert von Brunn. Philipp von Zabern, Mainz, pp 447–459

Schultz B (1999) Die Genese des Bafa-Sees – geologische, sedimentologische und faunistische Befunde. Diploma Thesis, Marburg
Schultz M, Schmidt-Schultz T (1994) Krankheiten des Kindesalters in der mittelalterlichen Population von Pergamon. Istanbuler Mitt 44:181–201
Seeher J (1991) Die Nekropole von Demircihüyük-Sariket. Istanbuler Mitt 41:97–124
Seeher J (1992) Die Nekropole von Demircihüyük-Sariket. Istanbuler Mitt 42:5–19
Seeliger TC, Pernicka E, Wagner GA, Begemann F, Schmitt-Strecker S, Eibner C, Öztunali Ö, Baranyi I (1985) Archäometallurgische Untersuchungen in Nord- und Ostanatolien. Jahrb Röm-Germ Zentralmus Mainz 32:597–659
Sellers PC, Cross PA (1989, 1986, 1987) Wegener-Medlas baselines determine using the pseudo-short arc technique. Proceedings of the International Conference WEGENER-MEDLAS project. TU Delft, Scheveningen, The Netherlands, 456 pp
Şengör AMC, Yılmaz Y (1981) Tethyan evolution of Turkey; a plate tectonic approach. Tectonophysics 75:3-4, 181–241
Şengör AMC, Satır M, Akkök R (1984) Timing of tectonic events in the Menderes massif, western Turkey: implications for tectonic evolution and evidence for Pan-African basement in Turkey. Tectonics 3:693–707
Sevinç N, Körpe R, Tombul M, Rose CB, Strahan D, Kiesewetter H, Wallrodt J (2001) A new painted Graeco-Persian sarcophagus from Can. Stud Troica 11:383–426
Shilik KK (1997) Oscillations of the Black Sea and ancient landscapes. In: Chapman J, Dolukhanov P (eds) Landscapes in Flux Central and Eastern Europe in Antiquity. Colloquia Pontica 3. Oxbow, Oxford, pp 115–119
Siegenthaler U, Heimann M, Oeschger H (1980) 14C variations caused by changes in the global carbon cycle. Radiocarbon 22(2):177–191
Siyako M, Bürkan KA, Okay IA (1989) Biga ve Gelibolu yarımadalarının Tersiyer jeolojisi ve hidrokarbon olanakları. Bull Turk Assoc Petrol Geol 1/3:183–199
Sneath PHA, Sokal PR (1973) Numerical taxonomy. Freeman, San Francisco
Spanos PZ (1972) Untersuchungen über den bei Homer "depas amphikypellon" genannten Gefäßtyp. Istanbuler Mitteilungen Beiheft 6. Ernst Wasmuth, Tübingen
Speidel J (1929) Beiträge zur Kenntnis der Geologie und Lagerstätten der Insel Thasos. PhD Thesis, Universität Freiberg, Freiberg
Spindler K (1971) Zur Herstellung der Zinnbronze in der frühen Metallurgie Europas. Acta Praehist Arch 2:202–253
Spitaels P (1984) The early Helladic period in mine no. 3 (Theatre sector). In: Mussche HF, Bingen J, Servais J, Spitaels P (eds) Thorikos VIII, 1972/1976. Rapport préliminaire sur les 9e, 10e, 11e et 12e campagnes de fouilles. Comité des Fouilles Belges en Grèce, Gent, pp 151–174
Stanley DJ, Blanpied C (1980) Late quaternary water exchange between the Eastern Mediterranean and the Black Sea. Nature 285:537–541
Stefanovich M (1974) The possible origins of knobbed ware in Troy $VIIb_2$. Thracia 3:101–105
Stos-Gale ZA (1992) The origin of metal objects from the Early Bronze Age site of Thermi on the island of Lesbos. Oxf J Archaeol 11:155–177
Stos-Gale ZA, Gale NH, Gilmore GR (1984) Early Bronze Age Trojan metal sources and Anatolians in the Cyclades. Oxf J Archaeol 3:23–43
Stos-Gale ZA, Gale NH, Zwicker U (1986) The copper trade in the south-east Mediterranean region. Preliminary scientific evidence. Report of the Department of Antiquities Cyprus, Nicosia, Cyprus, pp 122–144
Strabo, Geographia (in 17 books), with special reference to Bk 13, I, 26–42 (The Greek text with English translation by HL Jones is conveniently accessible in the Loeb se-

ries, 1917, repr 1989, Harvard University Press, Cambridge (Mass) and London. Reference may also be made to Drijvers JW and Radt S (1993) Die Groningen Neuedition von Strabos Geographika, vorgestellt anhand des Abschnittes über Troia. Stud Troica 3:201–231

Stuiver M, Braziunas TF (1993) Sun, ocean, climate and atmospheric $^{14}CO_2$: an evaluation of causal and spectral relationships. Holocene 3(4):289–305

Stuiver M, Long A, Kra RS (eds) (1993) OxCal v2.0. Radiocarbon 35(1): 244

Szemler GJ, Cherf WJ, Kraft JC (1996) Thermopylai. Ares, Chicago

Taymaz T, Jackson J, Mc Kenzie D (1991) Active tectonics of the north and central Aegean Sea. Geophys J Int 106:433–490

Tekkaya I (1973) Gülpınar'daki fosil Bovidae kalıntıları hakkında bir not. Bull Geol Soc Turk 2:77–87

Todorova H (1993) Klima und Strandverschiebung im Postglazial Bulgariens. In: Georgieva P (ed), The fourth millennium B.C. Edition of New Bulgarian University, Sofia, pp 77–78

Todorova H (1998) Probleme der Umwelt der prähistorischen Kulturen zwischen 7000 und 100 v. Chr. In: Hänsel B, Machnik J (eds) Das Karpatenbecken und die osteuropäische Steppe. Südosteuropa-Schriften, Band 20. Prähistorische Archäologie in Südosteuropa, Band 12. Südosteuropa-Gesellschaft, München, pp 65–70

Topbaş A (1993) Seyitömer Höyüğü 1992 Yılı Kurtarma Kazıları. IV. Müze Kurtarma Kazıları Semineri, Ankara, pp 297–310

Turner W (1820) Journal of a tour in The Levant. John Murray, London

Tuttahs G (1998) Milet und das Wasser, ein Beispiel für die Wasserwirtschaft einer antiken Stadt. Forum Siedlungswasserwirtschaft und Abfallwirtschaft. Universität GH Essen 12, Essen

Tziavos C (1977) Sedimentology, ecology, and paleogeography of the Sperchios Valley and Maliakos Gulf, Greece. MS Thesis, The University of Delaware

Uchupi E, Ross DA (2000) Early Holocene marine flooding of the Black Sea. Quat Res 54:68–71

Uerpmann HP (1987) The Ancient Distribution of ungulate mammals in the Middle East. Beihefte zum TAVO, Reihe A Nr. 27. Dr Ludwig Reichert Verlag, Wiesbaden

Uerpmann HP, Uerpmann M (2000) Leben in Troia. Die Pflanzen- und Tierwelt. In: Archäologisches Landesmuseum Baden-Württemberg (ed) Troia – Traum und Wirklichkeit. Konrad Theiss Verlag, Stuttgart, pp 315–318

Uerpmann HP, Köhler K, Stephan E (1992) Tierreste aus den neueren Grabungen in Troia. Stud Troica 2:105–121

Uerpmann M, van Neer W (2000) Fischreste aus den neuen Grabungen in Troia (1989–1999). Stud Troica 10:145–177

Uerpmann M, Uerpmann H-P, Jasim SA (2000) Stone Age nomadism in SE-Arabia – palaeo-economic considerations on the neolithic site of Al-Buhais 18 in the Emirate of Sharjah, U.A.E. Proc Sem Arabian Stud 30:229–234

United Nations (1955) Age and sex patterns of mortality. Population studies 22. United Nations, New York

Utkular I (1954) Çanakkale Boğazında Fatih Kaleleri. Istanbul Teknik Üniversitesi, Istanbul

van den Driesch A (1976) A guide to the measurement of animal bones from archaeological sites. Peabody Museum Bulletins 1. Harvard University, Harvard

von den Driesch A (1999) Archäozoologische Untersuchungen an Tierknochen aus dem Dritten und Ersten Vorchristlichen Jahrtausend von Beşik-Yassitepe, Westtürkei. Stud Troica 9:439–459 van Geel B, van der Plicht J, Kilian MR, Klaver ER, Kouwenberg JHM, Renssen H, Reynaud-Farrera I, Waterbolk HT (1998) The sharp rise of DELTA14C ca. 800 cal BC: possible causes, related climatic teleconnections and the impact on human environments. Radiocarbon 40(1–2):531–550

van Zeist W, Bottema S (1991) Late quaternary vegetation of the Near East. Beihefte zum Tübinger Atlas des Vorderen Orients. Reihe A, Nr 18. Reichert, Wiesbaden

Vermeule E (1964) Greece in the Bronze Age. Chicago University Press, Chicago

Virchow R (1879) Beiträge zur Landeskunde der Troas. Abhandlung der Königlichen Akademie der Wissenschaften zu Berlin, Berlin, pp 1–90

Virchow R (1880) Beiträge zur Landeskunde der Troas. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin 1879, Physikalische Klasse, Abhandlung III, Berlin, pp 1–176

Virchow R (1881) Aerztliche Praxis in der Troas. In: Schliemann H (ed) Ilios. Brockhaus, Leipzig, pp 798–803

Virchow R (1882) Alttrojanische Gräber und Schädel. Abhandlungen der Preußischen Akademie der Wissenschaften zu Berlin, Physikalische Klasse, 2. Abhandlung, Berlin

Virchow R (1883) Alttrojanische Gräber und Schädel. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, Berlin

Voigtländer W (1985) Zur Topographie Milets. Ein neues Modell zur antiken Stadt. Archäologischer Anzeiger, Berlin, pp 77–91

Waetzoldt H, Bachmann HG (1984) Zinn- und Arsenbronzen in den Texten aus Ebla und aus dem Mesopotamien des 3. Jahrtausends. Oriens Antiquus 23:1–18

Wagner GA (1998) Age determination of young rocks and artifacts. Springer, Berlin Heidelberg New York

Wagner GA, Lorenz IB (1992) Thermolumineszenz-Datierungen an Keramik von Beşik-Yassıtepe. Stud Troica 2:147–156

Wagner GA, Öztunalı Ö (2000) Prehistoric copper sources in Turkey. In: Yalcın Ü (ed) Anatolian metal I. Der Anschnitt. Beiheft 13. Deutsches Bergbau-Museum, Bochum, pp 31–66

Wagner GA, Weisgerber G (eds) (1985) Silber, Blei und Gold auf Sifnos, prähistorische und antike Metallproduktion. Der Anschnitt. Beiheft 3. Deutsches Bergbau-Museum, Bochum, p 242

Wagner GA, Pernicka E, Seeliger TC, Öztunalı Ö, Baranyi I, Begemann F, Schmitt-Strecker S (1985) Geologische Untersuchungen zur frühen Metallurgie in NW-Anatolien. Bull Mineral Res Explor Inst Turk 101/102:45–81

Wagner GA, Pernicka E, Seeliger TC, Lorenz IB, Begemann F, Schmitt-Strecker S, Eibner C, Öztunalı Ö (1986) Geochemische und isotopische Charakteristika früher Rohstoffquellen für Kupfer, Blei, Silber und Gold in der Türkei. Jahrb Röm Germ Zentralmus Mainz 33:723–752

Wagner GA, Begemann F, Eibner C, Lutz J, Öztunalı Ö, Pernicka E, Schmitt-Strecker S (1989) Archäometallurgische Untersuchungen an Rohstoffquellen des frühen Kupfers Ostanatoliens. Jahrb Röm-Germ Zentralmus Mainz 36:637–686

Walpole R (1818) Memoirs relating to European and Asiatic Turkey. Longman, London

Weiss H (1997) Late third Millennium abrupt climate change and social collapse in West Asia and Egypt. In: Dalfes HN, Kukla G, Weiss H (eds) Third Millennium B.C., climate change and old world collapse. Springer, Berlin Heidelberg New York, pp 711–723

Weiss KM (1973) Demographic models for anthropology. Mem Soc Am Archaeol Paris 27:38/2

Werner W (1993) Der Kanal von Korinth und seine Vorläufer. Das Logbuch, Sonderheft. Arbeitskreis Historischer Schiffbau eV, Köln, pp 1–71

Wertime TA (1964) Man's first encounters with metallurgy. Science 146:1257–1267

Westaway R (1994) Present-day kinematics of the Middle East Mediterranean. J Geophys Res 99:12071–12090

Westhofen M (2001) Hals-Nasen-Ohrenheilkunde.Uni-Med, Bremen

Wheeler M (1968) The Indus civilization. Cambridge University Press, Cambridge

Whitbread I (1992) Petrographic analysis of barbarian ware from the Menelaion, Sparta. In: Sanders JM (ed) Φιλολακων. Laconian studies in honour of Hector Catling. Oxbow Books, London, pp 297–306

White WM (1997) Geochemistry. http://www.geo.cornell.edu

Wibel F (1865) Die Cultur der Bronze-Zeit Nord- und Mittel-Europas. Chemisch-antiquarische Studien über unsere vorgeschichtliche Vergangenheit und deren Bergbau, Hüttenkunde, Technik und Handel. 26. Bericht der Schleswig-Holsteinischen Lauenburger Gesellschaft zur Sammlung und Erhaltung vaterländischer Altertümer, Kiel

Wickert-Micknat G (1982) Die Frau. Archäol Homerica 3 Kap. R Vandenhoeck and Ruprecht, Göttingen

Wiegand T (1904) Reisen in Mysien. Mitt Kaiserl Dtsch Archäol Inst Athen 39:254–339

Wiegand T, Schrader H (1904) Priene. Ergebnisse der Ausgrabungen und Untersuchungen in den Jahren 1895–1898. Reimer, Berlin

Wiener MH (1984) Crete and the Cyclades in the LM I: the tale of the conical cups. In: Hägg R, Marinatos N (eds) The Minoan Thalassocracy. Myth and reality. Proceedings of the 3rd International Symposium at the Swedish Institute in Athens, 31 May–5 June, 1982. Paul Åstrom Verlag, Stockholm, pp 17–26

Wille M (1995) Pollenanalysen aus dem Löwenhafen von Milet – vorläufige Ergebnisse. Archäologischer Anzeiger , Berlin, pp 330–333

Williams M, Dunkerley D, De Decker D, Kershaw P, Chappell J (1998) Quaternary environments, 2nd edn. Arnold, London

Williams-Thorpe O, Henty MM (2000) The sources of roman granite columns in Israel. Levant 32:155–170

Wilski P (1906) Karte der Milesischen Halbinsel (1:50,000). In: Wiegand T (ed) Milet, Ergebnisse der Ausgrabungen und Untersuchungen seit dem Jahre 1899, vol I (1). De Gruyter, Berlin

Winnefield H (1902) In: Dörpfeld W (ed) Troja und Ilion. Beck and Barth, Athens

Wittwer-Backofen U (1982) Anthropologische Untersuchungen des Frühdynastisch-I-zeitlichen Gräberfeldes von Tell Ahmed-al-Hattu/Nordostirak. Dipl-Arbeit, Univ Mainz, Mainz

Wittwer-Backofen U (1987a) Anthropological study of the the skeleton material from Lidar. V. Araştırma Sonuçları Toplantısı Ankara, Ankara, pp 191–201

Wittwer-Backofen U (1987b) Palaeodemography of the Early Bronze Age Cemetery of Ikiztepe/Samsun. V. Araştırma Sonuçları Toplantısı Ankara, Ankara, pp 175–190

Wittwer-Backofen U (1991) Nekropole und Siedlung – Möglichkeiten und Grenzen der Rekonstruktion prähistorischer Bevölkerungsstrukturen. Mitt Berl Ges Ethnol Archäol 12:31–37

Wittwer-Backofen U (2000) Demircihüyük-Sariket – Anthropologische Bevölkerungsrekonstruktion. In: Seeher J (ed) Die Bronzezeitliche Nekropole von Demircihüyük-Sariket. Istanbuler Forsch 44:239–300

Wittwer-Backofen U, Kiesewetter H (1997) Menschliche Überreste der neuen Ausgrabungen in Troia – Funde der Kampagnen 1989–1995. Stud Troica 7:509–537

Wittwer-Backofen U, Wahl J, Dresely V, Schmidt-Schultz T, Schultz M (2000) Das spätbronzezeitliche Gräberfeld von Beşik-Tepe/Troas – Anthropologische Ansätze zur Sozialstruktur. In: Basedow MA (ed): Besik-Tepe. Monographien zu Studia Troica, Bd 1. Zabern-Verlag, Mainz

Wohlfarth B (1993) Landschaftsentwicklung im Spätglazial des oberen Würm und im frühen Holozän der Schweiz. In: Schweizerische Gesellschaft für Ur- und Frühgeschichte (ed) Die Schweiz vom Paläolithikum bis zum Frühmittelalter 1. Paläolithikum und Mesolithikum. Basel, pp 57–65

Wood R (1775) An Essay on the original genius and writings of Homer. Payne and Elmsly, London

Yakar J (1984) Regional and local schools of metalwork in Early Bronze Age Anatolia, part I. Anatolian Stud 34:59–86

Yaltırak C, Alpar B, Yüce H (1998) Tectonic elements controlling the evolution of the Gulf of Saros (northeastern Aegean Sea, Turkey). Tectonophysics 300:227–248

Yang L-C (1982) The distribution and taxonomy of ostracodes and benthic foraminifers in late Pleistocene and Holocene sediments of the Troad (Biga Peninsula), Turkey. MS Thesis, The University of Delaware

Yazman M (1996) Batı Anadolu grabenleri jeoloji gezisi. 13–20 Agustos 1996. TPAO Arama grubu. Trakya-Ege-Marmara proje danışmanlığı, 245, Ankara

Yener KA (2000) The domestication of metals. Brill, Leiden

Yener KA, Özbal H (1987) Tin in the Turkish Taurus mountains: The Bolkardağ mining district. Antiquity 61:220–226

Yener KA, Vandiver PB (1993) Tin processing at Göltepe, an Early Bronze Age site in Anatolia. Am J Archeol 97:207–238

Yener KA, Özbal, H, Kaptan E, Pehlivan AN, Goodway M (1989) Kestel: an Early Bronze Age source of tin ore in the Taurus mountains, Turkey. Science 144:200–203

Yılmaz Y (1990) Comparisons of the young volcanic associations of the west and the east Anatolia under the compressional regime: a review. J Volcanol Geotherm Res 44:69–87

Yılmaz Y (1997) Geology of Western Anatolia. In: Schindler C, Pfister M (eds) Active tectonics of northwestern Anatolia – the Marmara Poly-Project. A multi disciplinary approach by Space-geodesy, geology, hydrogeology, geothermics and seismology. Vdf Hochschulverlag AG an der ETH Zürich, Zürich, pp 31–53

Yılmaz Y, Karacık Z (2001) Geology of the northern side of the Gulf of Edremit and its tectonic significance for the development of the Aegean grabens. Geodin Acta 14:31–43

Yılmaz Y, Genç ŞC, Gürer FÖ, Karacık Z, Altunkaynak Ş, Bozcu M, Yılmaz K, Elmas A (1999) Ege denizi ve Ege bölgesinin jeolojisi ve evrimi. In: Görür N (ed) Türkiye Denizleri. Devlet Planlama Teşkilatı. Tubitak yayını, Ankara, pp 211–337

Yılmaz Y, Genç ŞC, Gürer FÖ, Bozcu M, Yılmaz K, Karacık Z, Altunkaynak Ş, Elmas A (2000) When did the western Anatolin grabens begin to develop? Geol Soc Lond Spec Publ 173:353–384

Zander, Erhardt W, Götz E, Bödeker N, Seybold S (2000) Handwörterbuch der Pflanzennamen. Dictionary of plant names. Dictionnaire des noms de plantes. 16th edn. Ulmer, Stuttgart

Zangger E (1992) The flood from heaven. Deciphering the Atlantis legend. Sidgwick and Jackson, London
Zangger E (1993) The geoarchaeology of the Argolid. Gebrüder Mann Verlag, Berlin, pp 1–149
Zangger E, Yazvenko SB, Timpson ME, Kuhnke F; Knauss J (1997a) The Pylos regional archaeological project, part 2: landscape evolution and site preservation: Hesperia 66 (4):549–641
Zangger E, Leiermann H, Noack W, Kuhnke F (1997b) A 21st century approach to the reconnaissance and reconstruction of archaeological landscapes. In: Kardulias PN, Shutes MT (eds) Aegean strategies: studies of culture and environment on the European fringe. Rowman and Littlefield, Savage, Maryland, pp 9–32
Zangger E, Timpson M, Yazvenko S, Leiermann H (1998) Searching for the ports of Troy. In: Leveau P, Walsh K, Barker G (eds) Environmental reconstruction in Mediterrannean landscape archaeology. Mediterranean landscape archaeology 2. Oxbow, Oxford
Zangger E, Timpson ME, Yazvenko SB, Leiermann H (1999) Searching for the ports of Troy. In: Leveau P, Trement F, Walsh K, Barker G (eds) Environmental reconstruction in Mediterranean landscape archaeology. Oxbow, Oxford, pp 89–103
Zeuner FE (1963) A history of domesticated animals. Hutchinson, London
Zöldföldi J, Satır M (2001a) Are the Anatolian marbles to distiguish? Tagungsband der 5. Geochemietagung, Tübingen, 2001. Terra Nostra 5/2001:87–89
Zöldföldi J, Satır M (2001b) Origin of the building stones in the monuments of the ancient Troia. In: Tagungsband Archäometrie und Denkmalpflege, Fachhochschule Köln, Köln, pp 53–55
Zubakov VA (1989) Climatostratigraphic scheme of the Black Sea Pleistocene and its correlation with the oxygen-isotope scale and glacial events. Quat Res 29:1–24

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