Sonderdruck aus

STUDIA TROICA

Band 10 · 2000

VERLAG PHILIPP VON ZABERN · MAINZ AM RHEIN

THE WATER SUPPLY OF TROİA

İlhan Kayan

ABSTRACT

Although the surface and ground waters around Troia are relatively abundant, the ancient inhabitants were nevertheless consistently concerned with developing new ways of supplying the settlement with water. There were deep wells in the city, a big well or cistern below the Northeast Bastion, an artificial cave (KASKAL.KUR) to the west, and an aqueduct near the modern village of Kemerdere that brought water from the south to Troia. This article includes a discussion of the geomorphological and geological characteristics of the various water sources in the area of Troia, and analyzes the changes that occurred over time.

ZUSAMMENFASSUNG

Obwohl die Oberflächen- und Grundwasser um Troia relativ ergiebig sind, suchten seine Einwohner doch stets nach neuen Wegen der Wasserversorgung ihrer Siedlung. In der Stadt gab es tiefe Brunnen, einen großen Brunnen oder eine Zisterne unter der Nordostbastion, eine künstliche Höhle (KASKAL.KUR) im Westteil der Stadt und einen Aquädukt in der Nähe des heutigen Dorfes Kemerdere, über den Wasser von Süden nach Troia geleitet wurde. Dieser Beitrag enthält eine Diskussion der geomorphologischen und geologischen Charakteristik der verschiedenen Wasserressourcen Troias und untersucht deren zeitliche Veränderungen.

The origin of the surface and ground waters in the area of Troia is precipitation: the average annual precipitation is around 600 mm, with a maximum 900 mm and a minimum of 400 mm. But the existence of usable water is dependent on the geological structure of the area beneath the surface. Consequently, we should first briefly consider the geological and geomorphological characteristics of the environs of Troia.

Geological Structure

The geological structure of the area around Troia consists of two main units. One of them is the **older basement rock**, which is composed of crystalline schist, limestone and serpentine (fig. 1). A wide plateau about 200–250 m high (the High Plateau) to the south of the Karamenderes flood-delta plain was formed on this basement complex during a long erosional period (fig. 2). The other unit consists of **younger sediment cover**; this was deposited in a shallow marine embayment that extended from the north at the end of the Miocene epoch of the Neogene geological period. At that time, the southern area was an erosional upland and consisted of shallow marine sediments with sand, clay, and lime. These sediments were eventually deposited on the bottom of the sea to the north.

As a result of **uplift** movements in subsequent geological periods, the old sea floor rose and broke into long fault blocks. The plateau ridges (the Low Plateau ca. 50–100 m high) and valley depressions visible today were formed on these uplifted, down-faulted and tilted blocks of the Miocene marine sediments (figs. 3 and 4).

Rivers later settled in the long depressions between the uplifted ridges and filled them with

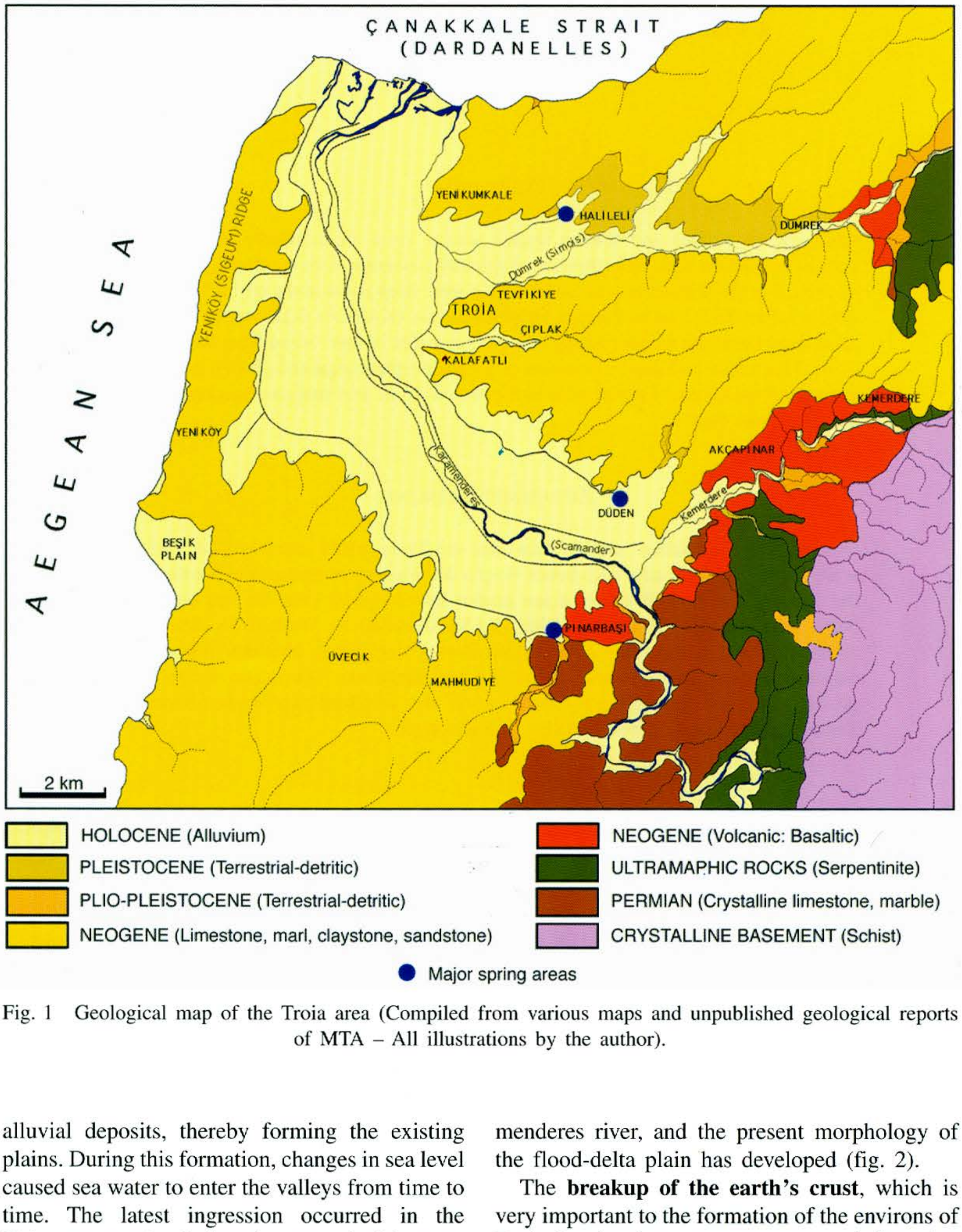

Fig. 1 Geological map of the Troia area (Compiled from various maps and unpublished geological reports of MTA – All illustrations by the author).

alluvial deposits, thereby forming the existing plains. During this formation, changes in sea level caused sea water to enter the valleys from time to time. The latest ingression occurred in the Holocene epoch, during the post-glacial transgression, and the sea covered the embayment along the lowest part of the Karamenderes valley about 7000–6000 B.P.[1] Since then, this narrow bay has been filled by the alluvium of the Karamenderes river, and the present morphology of the flood-delta plain has developed (fig. 2).

The **breakup of the earth's crust**, which is very important to the formation of the environs of Troia, is related to strong movements influencing the entire Anatolian peninsula. According to the movements of the earth plates in the region, Anatolia shows a rotational shift from east to west or southwest. This movement occurs on the southern

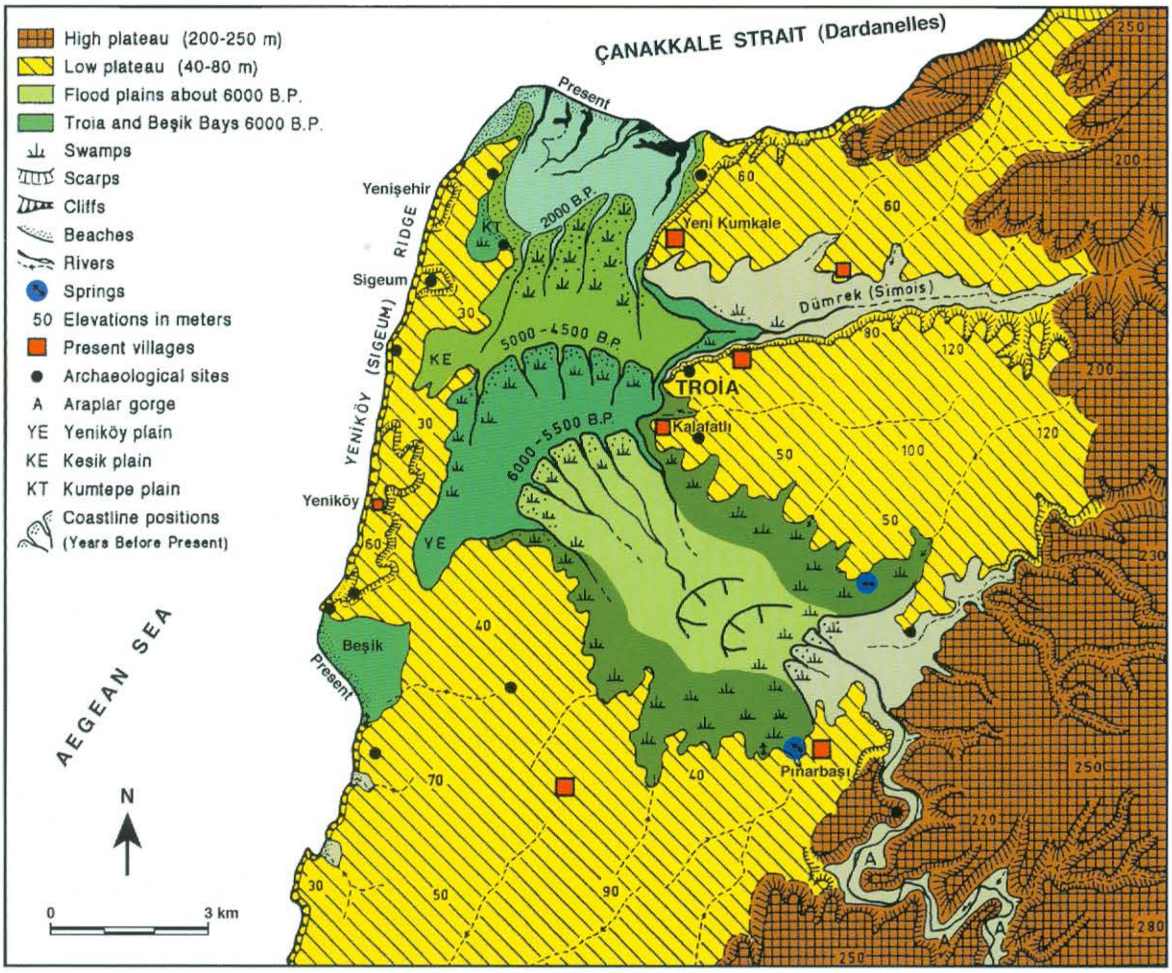

Fig. 2 Geomorphological units and development of the Karamenderes (Scamander) plain.

plates of a long strike-slip fault zone running along the Northern Anatolian Mountain Belt. The north Anatolian Fault Zone divides into branches on the Marmara basin, and the Biga peninsula is located just to the southern flank of this zone. This is why the people who lived at Troia suffered earthquakes of different magnitudes through the ages.[2]

The effects of tectonic movements on the geomorphological formation of the Troia area are clearly seen on a **lineation map** (fig. 3). Here the main morpho-structural lineaments of the pre-Neogene basement follow a NE-SW direction. The direction of the Ezine-Bayramiç depression and the Ida mountains in the south, and the Gelibolu peninsula and Çanakkale strait in the north are the major features in the morphology of this structural lineament. The boundary between the basement and younger structural units to the southeast of Troia also follow the same direction. There is enough evidence to prove that it is an important fault zone (the Pınarbaşı fault). The Late Miocene basaltic lava flows and the great fault springs along this zone are the most outstanding evidence of the fault zone (figs. 1 and 3).

The **NE-SW cuts** and southwesterly shifts of the fault blocks on the Neogene sedimentary structure are clearly seen on the lineation map of the Trojan area. These lineations on the main blocks between N-S, W-E and NW-SE major faults indicate their shift by the most recent horizontal tectonic compressions. In conclusion, this region has been broken up in various directions by a great number of faults.

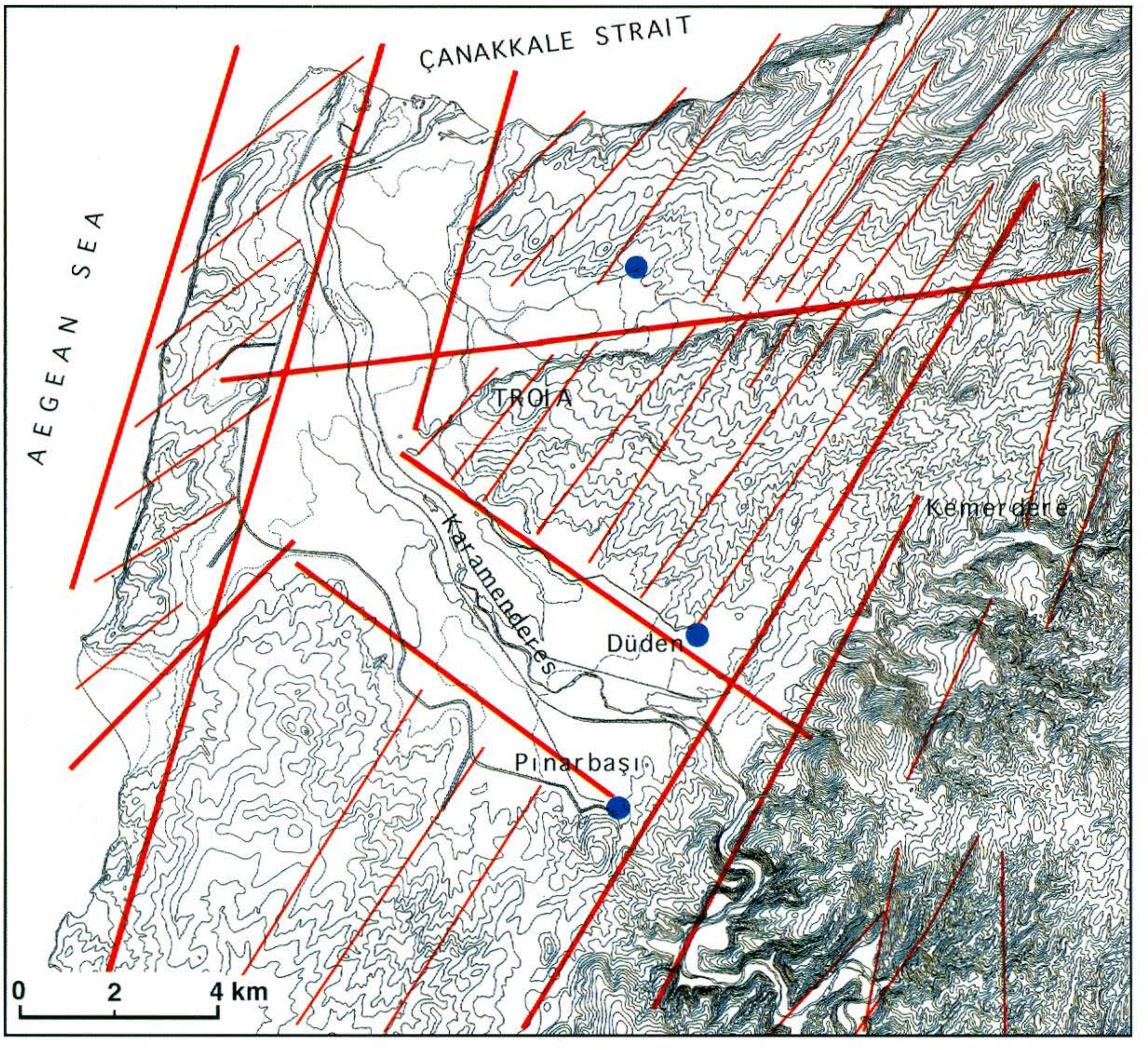

Fig. 3 Morpho-structural lineations of the Troia area.

Sources of fresh water

The most important source of fresh **water** in the environs of Troia is the **Karamenderes** (Scamander) river. This river originates in the northern slopes of the Ida mountains, and collects surface waters from the greater part of the Biga peninsula; it then brings them to the flood-delta plain to the west of Troia.[3] **Alluvium** in the plain also has great importance as a medium to hold fresh water and facilitate the formation of the water-table.

The depth of the **water table** from the surface of the plain changes according to seasonal rainfall, but it is not deeper than about 3 m even at the end of the driest summer period. This water can be easily reached and used in many parts of the plain by digging **wells**. There is not enough water at present, however, to be pumped to the fields for agricultural irrigation and human use. Where the plain has been drilled to deeper levels, for example deeper than 10 m near Troia, Early-Middle Holocene marine sediments are encountered (fig. 5). They are not convenient sources of usable water due to their fine grained texture and a salty-acidic chemical composition of the water. Because engine-use was out of question throughout ancient times, water may have been supplied

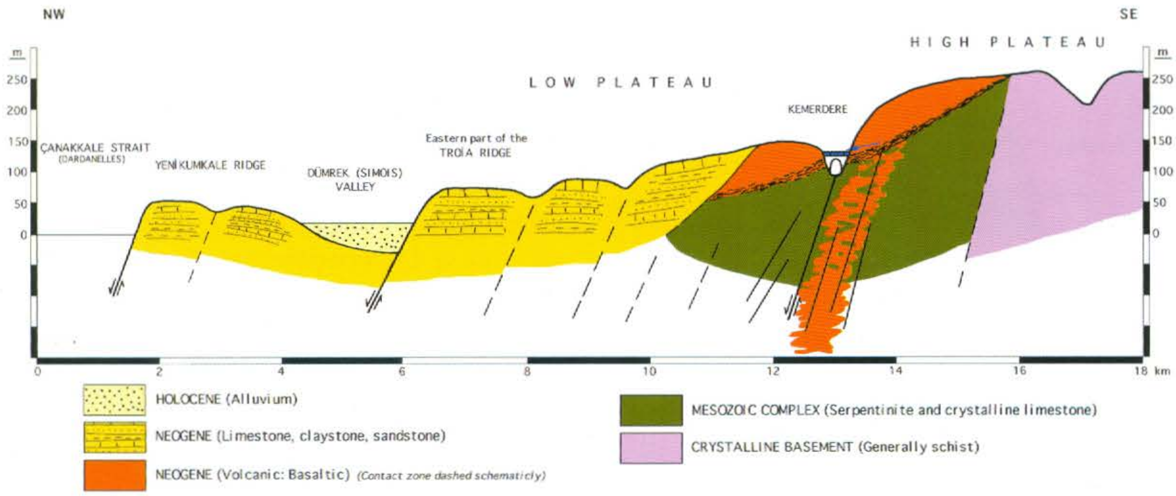

Fig. 4 A schematic cross-section of morpho-structural units of the Troia area.

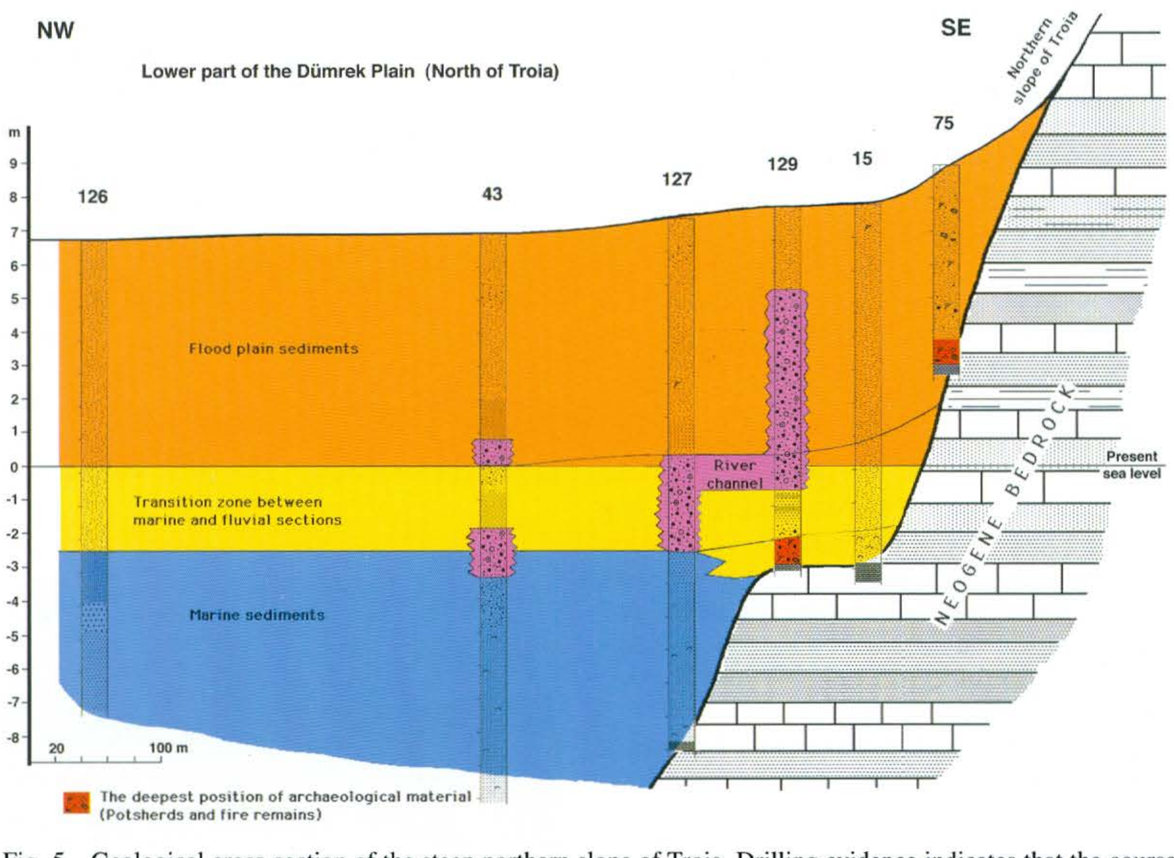

Fig. 5 Geological cross-section of the steep northern slope of Troia. Drilling evidence indicates that the course of the Dümrek river occurred first near the steep slope after the area turned over to dry land (yellow transition zone between blue marine and orange flood plain sediments). The Trojans used the area between the slope and the river after the marine environment had changed to a dry strip of land (Kayan 1996).

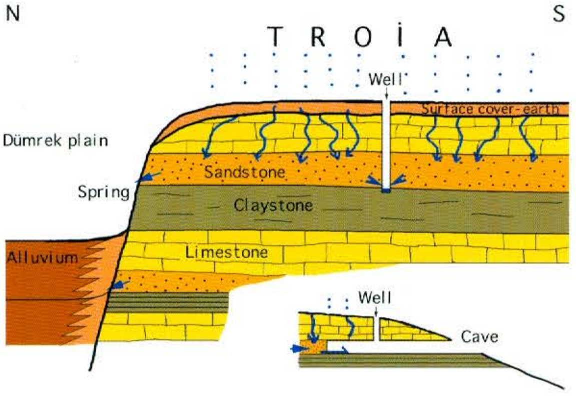

Fig. 6 Schematic geological structure of the Trojan ridge related to the ground water, wells and spring formation. The small figure represents the stratigraphical sequence of the bedrock layers of the man-made cave (KASKAL.KUR) on the western slope of Troia (See also fig. 10).

by digging wells on the plain that were not too deep. However, there is no archaeological evidence that the Trojans dug such wells. This may be related to different environmental characteristics of the plain in ancient times.[4]

The Trojan area is also rich in regard to other ground water types. Great fresh water **springs** in the southwestern part of the Karamenderes plain are the first outstanding examples of this richness. The springs are grouped in two areas today. One of them is to the south of the Karamenderes river course, near **Pınarbaşı** (Kırkgöz springs) (fig. 7), and the other is the Düden springs to the north. They have similar characteristics concerning their geological structure and formation. Both of these springs occur on the Pınarbaşı fault, which is a main structural line of the region in the direction of NE-SW. As stated above, this is an old joint zone between the pre-Neogene basement and younger structural units, and a basaltic lava formation can be followed along this zone (figs. 1, 2, 3).

The **Pınarbaşı** and **Düden** springs are located at the intersection of the Pınarbaşı fault and other major faults extending NW-SE, which form the southern part of the Karamenderes plain. It seems that weak points at the intersections of major fault zones facilitate ground waters that rise to the surface. In addition, the limestone basement in this area indicates karstic effects on the formation of the springs. They are therefore karstic-fault springs.

The Pınarbaşı and Düden springs are located on the southern part of the plain about **17 m higher** than present sea level. However, our drilling evidence indicates that the sea intruded near this area in the mid-Holocene, about 7000–6000 years ago.[5] This means that the surface of the plain here was not as high as it is today. Accordingly, the springs must have been about 10–15 m below the current surface during that period. If it were possible to take out about 15 m of alluvium from this area, many springs would be seen along the line between the two spring points that are currently visible.

During the geomorphological development of the plain, the alluvium brought by the Karamenderes always filled the middle part of the plain first, while side areas received less alluvium. In addition, the spring waters do not contain solid sediments and they also wash down little alluvium in the course of their flow. The eastern and western sides of the Karamenderes plain have therefore always been lower and covered by **swamps** (fig. 2). Our drilling data is in harmony with this conclusion. The water flow of the Pınarbaşı springs in the west was greater and swamps covered wider areas, while water of the Düden springs in the east was drained by the Kalafatlı creek (azmak), and swampy areas in the east were more limited.

In historical times it is known that some fresh water was taken from the Pınarbaşı springs to the Beşik plain by a canal.[6] This canal was last used

Fig. 7 Pınarbaşı springs in 1977.

in the 1950's to work a water mill (Hanımdeğirmeni) to the east of the Beşik plain. The swamps were subsequently drained to make arable land. More recently, the Pınarbaşı spring waters have been taken by pumps and collected near villages for distribution. The area around the Pınarbaşı springs is therefore dry today.

The relationship between the springs and the fault lines suggests that some **hot springs** existed in this area. In fact, there are some well-known hot springs on the other main fault zones of the region. The Kestanbol and Tuzla hot springs to the south of Alexandria Troas are the nearest examples. In the *Iliad* Homer mentions hot and cold springs, although there are no hot springs today in the vicinity of Troia. This may be because of thick alluvial sedimentation along the base of the slopes. It can be assumed that some warm-water may have continually come from rather small springs beneath the alluvium, which is about 10–15 m thick in some places. This water may be diffuse in the loose alluvium and mixed into the present water-table. It may therefore not be possible to find it on the surface (figs. 5 and 6).

Another kind of ground water in the area of Troia is the water in **sandy strata**. As stated above, the low plateau ridges derive from muddy sediments stratified on the bottom of a wide and shallow marine embayment in the Neogene. They consist of various lithological elements like limestone, claystone, siltstone and sandstone. These stratified sediments formed the current low plateau ridges, and the beds of the sedimentary rocks are slightly inclined. The ridges therefore have asymmetrical shapes and their northern slopes, for example on the Troia ridge, are very steep.

Various lithological units or beds can be seen on the steep slopes (figs. 5 and 6). In general, the uppermost section on the Trojan ridge consists of limestone beds. They are not porous but permeable or pervious because of their interconnected joints and cracks through which rain water can readily flow downwards. This water has been sucked by sandy layers beneath the limestone. The sandy unit does not consist of pure sand and is not very porous in this area, but at least the leaking water can be sucked up. In some places, where a bed of clay exists beneath the sandy strata, small springs can emerge along the steep slopes, such as the area north of the Trojan ridge (fig. 6).

Fig. 8 One of the present-day running fountains (1) of Troia on the northern steep slope, north of Tevfikiye, and uppermost limestone layers (2).

Two running **fountains** are the present-day examples of these springs on the steep slope facing the Dümrek plain to the north of Tevfikiye (fig. 8). In addition, some old, dry fountain points can be recognized on the same slope at the west (fig. 9). The water flow is generally low in this type of spring and cannot survive long because the water seeping from the upper limestone unit has much residual material, and causes the porous sandy layers to be filled and cemented. The springs consequently dry up or change location in the course of time. It is obvious that the Trojans used this kind of water source in ancient times.


Fig. 9 An old fountain on the foot of the steep northern slope of the Trojan ridge (east of the Roman Theatre A of Troia) which dried up in the course of time because limy precipitation from seeping water filled the pores of sandy-silty strata (See fig. 6).

Fig. 10 Artificial cave (KASKAL.KUR) on the western slope of Troia in 1997, before excavation. The upper section of the strata is limestone and rain water can easily penetrate down by following the cracks (1, clearly seen on the right, in the excavated area). Then the water is sucked by a sandy-silty layer (2, left of the entrance) and oozes above clayey beds (See fig. 6).

Even the occurrence of such water sources in this area must be taken into account as one of the reasons why Trojans preferred this area for a settlement.

The Trojans appear to have perceived this geological characteristic and they dug **wells** on the surface of the ridge to a depth at which water-saturated sandy beds were encountered. The water in the wells probably was not enough, but at least it partly satisfied their needs. The large well or cistern connected with the **Northeast Bastion** is another example of oozing water coming from porous layers which were used in ancient times.[7]

In addition, a man-made cave (KASKAL.KUR) on the western slope of the Trojan ridge is a special example of water taking advantage of the stratigraphical sequence of the strata in ancient times. In this area silty-fine sandy beds also preserve ground water between the upper limestone and lower clay layers of sediments (figs. 6 and 10). This water was collected as seepage in the horizontally dug, narrow galleries and taken out from the mouth of the cave. Archaeological excavations have been continuing here and in the Bastion.[8]

Today water does not exist in the old wells at Troia. The amount of water seepage in the artificial cave is also not substantial. One of the rea-

Fig. 11 Kemerdere valley from the southwest. The valley is deeply incised between the upper and lower plateau surfaces following a structural line (fault zone). This line is also evident with a basaltic lava flow and its reddish cinder-like contact zone (B). This is the main source of small springs (See fig. 4).

sons is that an adequate supply of water cannot be collected in the small catchment areas. The other is that the lithological characteristics of the porous layers are not sufficient for the preservation of water. In addition, there is an earth cover on the surface today. This cover is interesting because it is full of archaeological material like potsherds from top to bottom, as far as the surface of the limestone bedrock layers. This is always clearly seen on the profiles of excavated trenches. This implies that the bedrock surface was exposed; there was not any earth or natural soil formation on the surface in ancient times. Consequently, rain water could easily enter the cracks of the limestone layers on the surface, especially in the area where the surface inclination is gentle, and this water soaked into the porous layers underneath (fig. 6). Thus, we can conclude that more water could be supplied from the springs on the northern slope, and from the wells and man-made galleries at the west. Today, however, the ruins form an impervious cover over the surface, and rain water flows over the ground rather than percolating down into the porous layers. As a result there is, in general, less ground water in the area today.

Similar springs or seepage may have occurred along the lowermost parts of the steep slopes in ancient times, before these areas were covered by alluvium. Our drilling evidence shows that since the Bronze Age about 8–10 m of alluvial-colluvial sediment has buried the lower parts of the slopes surrounding Troia (fig. 5). It can be assumed that the water may be continuing to seep from these springs today but they do not have enough pressure to reach the present surface. They may disperse in the alluvial cover and feed only the water-table.

One of the water sources of the Trojan area which was used in ancient times lay in the **Kemerdere** valley to the southeast of the Karamenderes plain (fig. 1). It is one of the biggest tributaries of the Karamenderes river, which comes from the east to the lower plain. The main valley of Kemerdere extends over the boundary between the geological basement to the south and the younger (Neogene) cover formation to the north (fig. 4). Thus, the southern tributaries of Kemerdere are incised into the southern basement rocks of the higher plateau, and the northern tributaries into the Neogene sedimentary and volcanic rocks of the lower plateau. All of the valleys of the incised drainage basin of the Kemerdere have steep slopes, and deep, narrow morphology.

There is an interesting feature of the Kemerdere valley related to the ground water. This valley has been dug on a young **basaltic lava** formation extending along the NE-SW joint line between two structural units. The lava formation has a porous structure related to cracks and gas bubbles formed while cooling. In addition, the lava flow formed a **cinder-like** layer. This reddish layer, which is very porous, is especially visible between the serpentine formation of the basement and the lava flow on top of it (fig. 11). Carbonaceous-sandy Neogene sediments overlie the basaltic formation from the north. During the uplift of the region, Kemerdere valley **incised** into the weak fault zone and opened the basalt and cinder-like baked zone along its deep valley. Rain water enters cracks and gas-blown cavities and reaches a very porous cinder-like baked zone. Because of the existence of impervious rocks (generally serpentine) below, ground water seeps out from the contact zone. This constitutes lines of small springs on both sides of the Kemerdere valley. Small cuts of tributaries are the main localities of springs along the main valley slopes.

Water from the Kemerdere springs was directed down to Troia in Roman times. It was necessary first to transfer the water from the southern slope to the north. The water of the southern slope was therefore collected in earth pipes and crossed little creeks in small aqueducts. All of the collected southern water was then carried to the northern slope by a magnificent **aqueduct**, and added to the collected seeping water of the northern slope. It subsequently flowed about 10 km to Troia closely following the topographical gradient (figs. 4 and 12).

All these efforts indicate that water obtained from the small slope springs and deep wells in Troia were not enough for the Roman city. It seems that water from the water-table in the plain was still not sufficient to supply the city during this period. The residents of the area therefore devoted considerable energy to bringing water to the area from distant sources.

Fig. 12 Kemerköy aqueduct in the Kemerdere valley which was constructed to channel water collected from the southern slope (right) to the north (See fig. 4).

In the following period the Kemerdere waterway seems not to have been used, not because the Trojans found another source of water, but as a result of reduced water demand in the city. One can conclude that the population of the city decreased after the late Roman period, and this is also evident in the ceramic assemblages from Troia. This reduced demand for water continued until the 1950's, after which a new period of use began. A great deal of ground water from the upper water-table in the plain and from deep ground water aquifers was sucked up by pumps for agricultural irrigation and human use in the modern villages. Today few are interested in the small slope springs, the wells on the surface of the plateau ridge, and the Kemerdere water system.

Bibliography

AREL, AYDA. 1993. About the "Hasan Paşa Tower" at Yerkesiği, on the plain of Troia, *Studia Troica* 3: 183–189.

BILGİN, TURGUT. 1969. *Biga Yarımadası Güneybatı Kısmının Jeomorfolojisi*. İstanbul Üniversitesi Coğrafya Enstitüsü Yayın 1433. İstanbul.

KAYAN, İLHAN. 1995. The Troia bay and supposed harbour sites in the Bronze Age, *Studia Troica* 5: 211–235.

KAYAN, İLHAN. 1996. Holocene stratigraphy of the lower Karamenderes-Dümrek plain and archaeological material in the alluvial sediments to the North of the Troia ridge, *Studia Troica* 6: 239–249.

KAYAN, İLHAN. 1999. Holocene stratigraphy and geomorphological evolution of the Aegean coastal plains of Anatolia. The Late Quaternary in the Eastern Mediterranean Region, *Quaternary Science Reviews* 18: 541–548.

KORFMANN, MANFRED. 1999. Troia – Ausgrabungen 1998, *Studia Troica* 9: 1–34.

KRAFT, JOHN C. – İLHAN KAYAN – OĞUZ EROL. 1980. Geomorphic reconstructions in the environs of ancient Troy, *Science* 209: 776–782.

RAPP JR., GEORGE. 1982. Earthquakes in the Troad, in: RAPP JR., GEORGE – JOHN A. GIFFORD (EDS.). *Troy Supplementary Monograph 4. The Archaeological Geology*. 43–58. Princeton.

ROSE, CH. BRIAN. 1999. The 1998 Post-Bronze Age excavations at Troia, *Studia Troica* 9: 35–71.

Notes

[1] Kayan 1999.
[2] Rapp 1982.
[3] Bilgin 1969.
[4] Kayan 1995, 1996.
[5] Kraft et al. 1980.
[6] Arel 1993.
[7] Korfmann 1999.
[8] Korfmann 1999, Rose 1999.

Prof. Dr. İlhan Kayan
Ege Üniversitesi – Edebiyat Fakültesi
Coğrafya Bölümü
TR-35100 Bornova – İzmir
Türkiye
Email: ikayan@edebiyat.ege.edu.tr

INHALT – CONTENTS

Teil A: Troia und Troas – Aktuelle Ausgrabungen und Umfeld

1. TROIA, GRABUNGSBERICHTE

Manfred Korfmann:
Troia – Ausgrabungen 1999 1

Charles Brian Rose:
The 1999 Post-Bronze Age Excavations at Troia 53

2. TROIA, ARCHITEKTUR, BEFUNDE UND FUNDE

Donald F. Easton:
Schliemann's "Burnt City" 73

Billur Tekkök:
The City Wall of Ilion: New evidence for Dating 85

Kent J. Rigsby:
A Greek Inscription from Troia, 1998 .. 97

Peter Jablonka:
Computergestützte Rekonstruktion und Darstellung der Stratigraphie von Troia . 99

3. TROIA, NATURWISSENSCHAFTLICHE UNTERSUCHUNGEN

Norbert Blindow, Hans Günter Jansen und Kathrin Schröer:
Geophysikalische Prospektion 1998/99 in der Unterstadt von Troia 123

İlhan Kayan:
The Water Supply of Troia 135

Margarete Uerpmann und Wim Van Neer:
Fischreste aus den Grabungen in Troia (1989–1999) 145

Teil B: Weitere Forschungen

4. PHILOLOGIE UND ALTE GESCHICHTE

Peter Högemann:
Zum Iliasdichter – Ein anatolischer Standpunkt 183

Jörg Weilhartner:
Ober- und Unterstadt von Troia im archäologischen Befund und in den homerischen Epen 199

Michael Sage:
Roman Visitors to Ilium in the Roman Imperial and late Antique Period: The Symbolic Functions of a Landscape 211

5. TROAS UND ANATOLIEN

Utta Gabriel:
Mitteilung zum Stand der Neolithikumsforschung in der Umgebung von Troia . 233

Donald F. Easton:
A Pair of Pendent Earrings of Trojan Type . 239

Hans-Günter Buchholz:
Ergänzungen zu einer Obsidian-Bibliographie 251

ANHANG

Corrigenda 279

Danksagung – Acknowledgements 280

Video 284

IX, 286 Seiten mit 11 Farbabbildungen, 97 Schwarzweißabbildungen, 8 Strichtafeln, 2 Faltabbildungen, 20 Tabellen

ISBN 3-8053-2702-X
ISSN 0942-7635