Stratigraphy, Geochemistry and Geochronometry of Sedimentary Archives Around Hisarlik 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 Hisarlik 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 12 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 were 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. As to infrared stimulated luminescence (IRSL) age determination of colluvial and alluvial sediments, the former 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 limestone. 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 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.

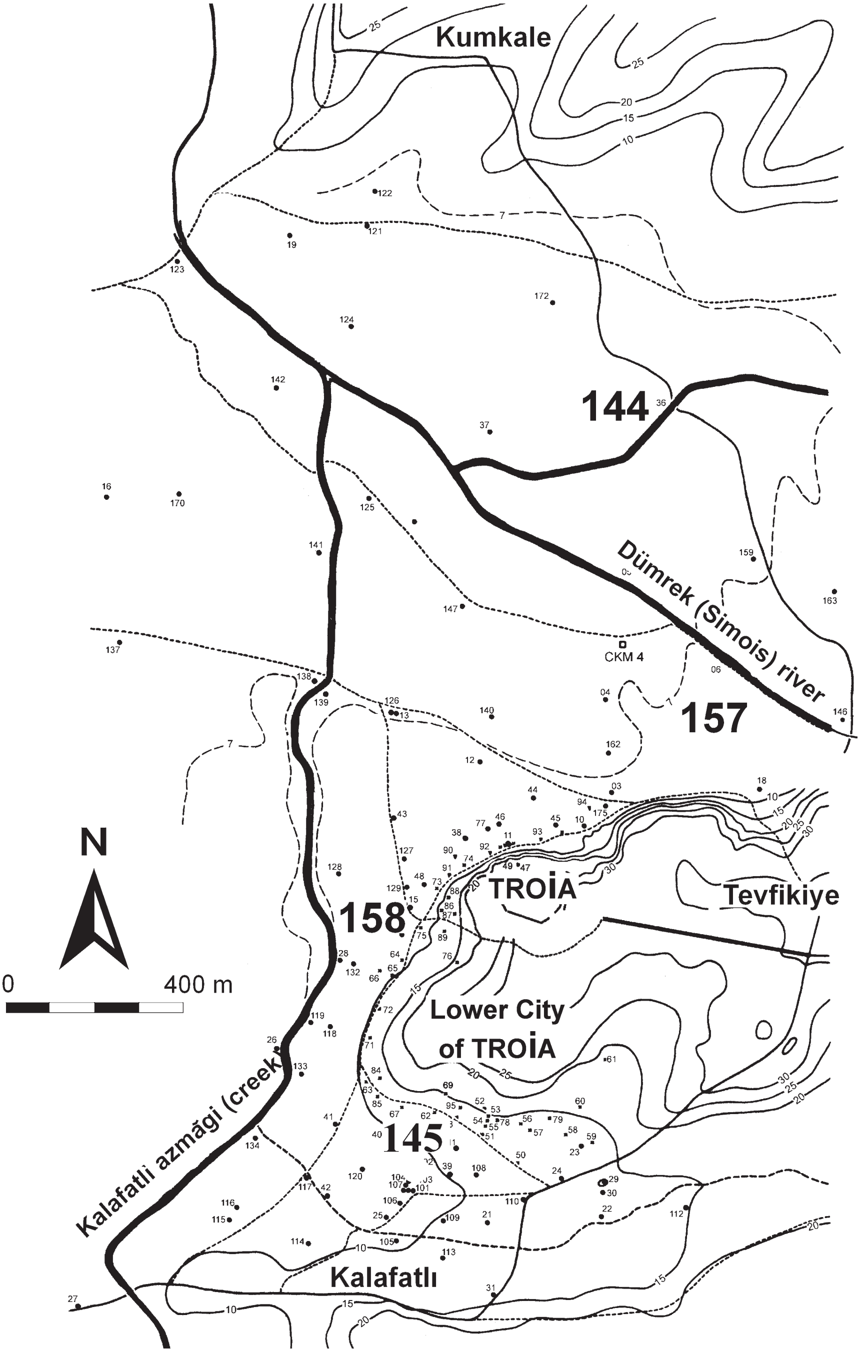


Fig. 1. Topographic map of the vicinity of Troia with the location of the drill cores described in this paper

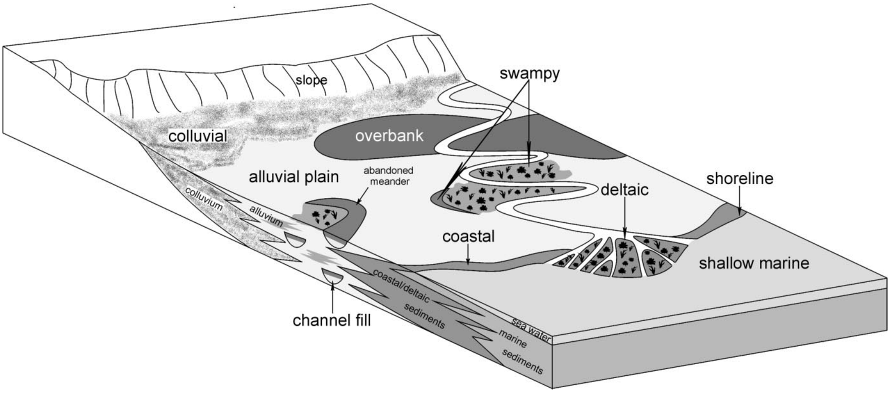


Fig. 2. Simplified model of sedimentary archives

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.

The 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

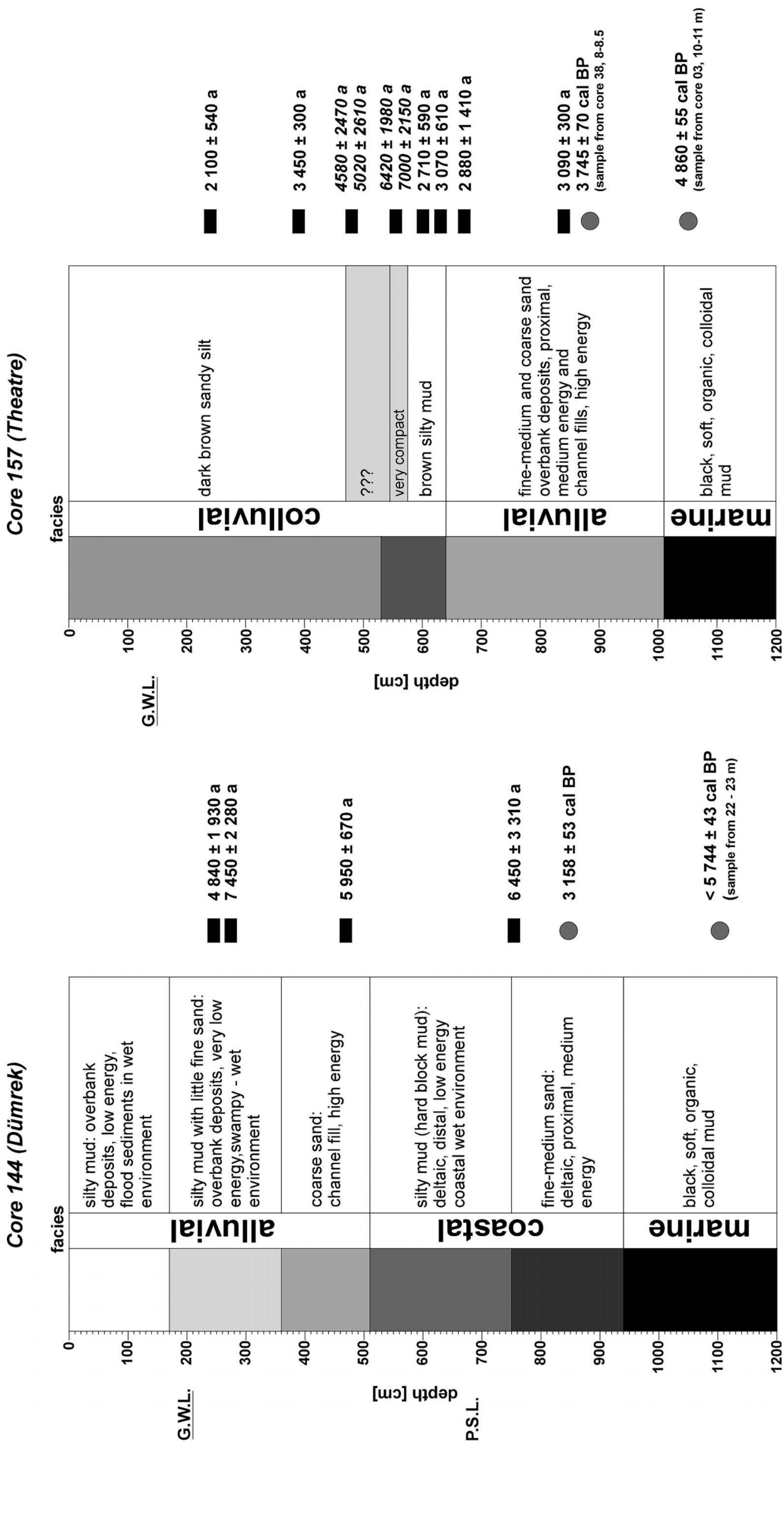
4.1.1 Core 144

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; more data can be obtained from the first author)

Drilling g core	Sampl e 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	0.53	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	0.15	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	47.01	0.13	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	0.13	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	0.04	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
158	925	1.69	57.5	0.148	150	93	10	27	99.8
	937	2.18	71.1	0.109	170	57	6	20	100.10
	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	0.44	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]
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
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)

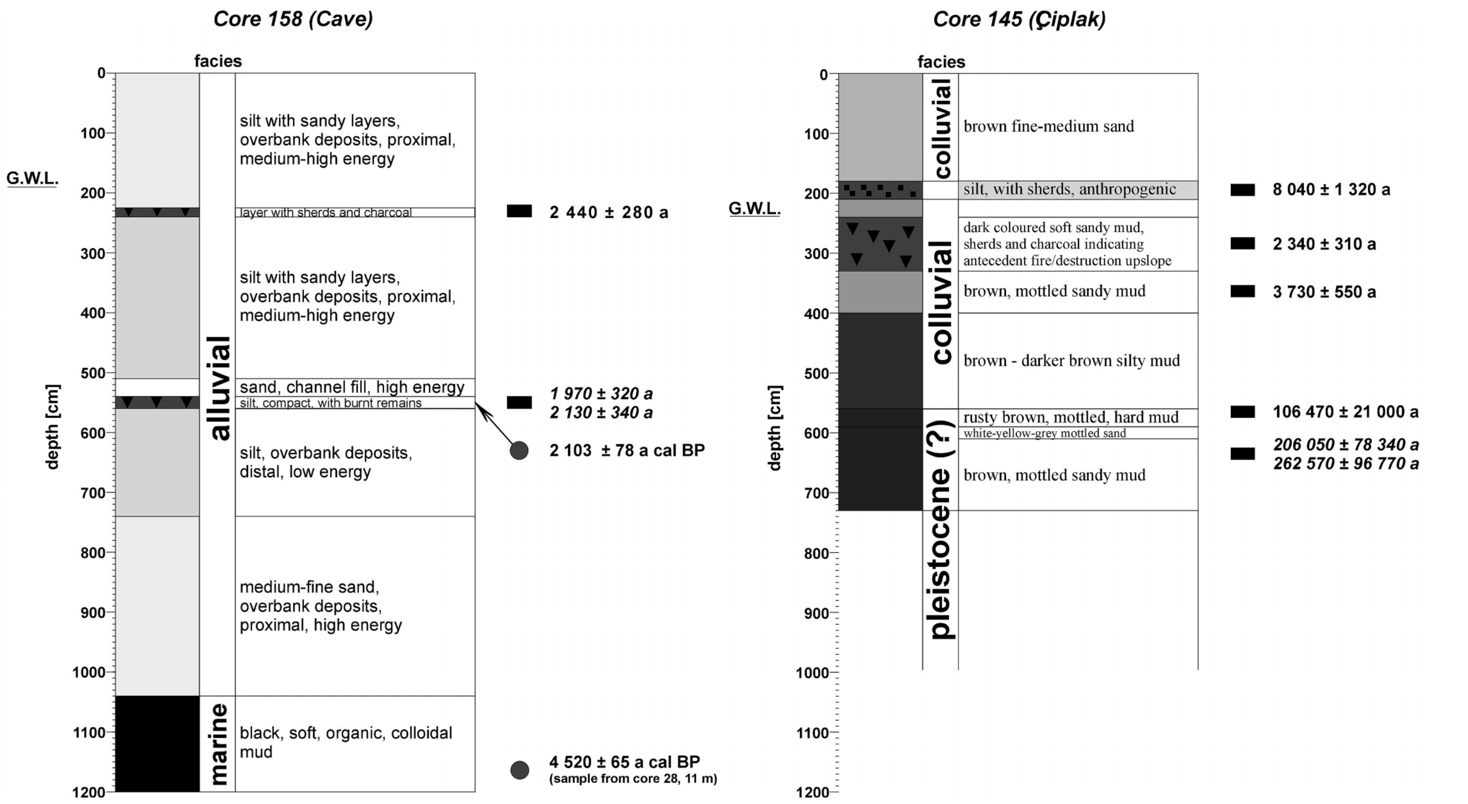


Fig. 3. Schematic sedimentary and stratigraphic profiles with IRSL and ^{14}C ages (minimum age:1970 ± 320 a; maximum age: 2130 ± 340 a)

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. Until 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. Until 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 43and 76%. 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% 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%. 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 shows an inverse order of ages.

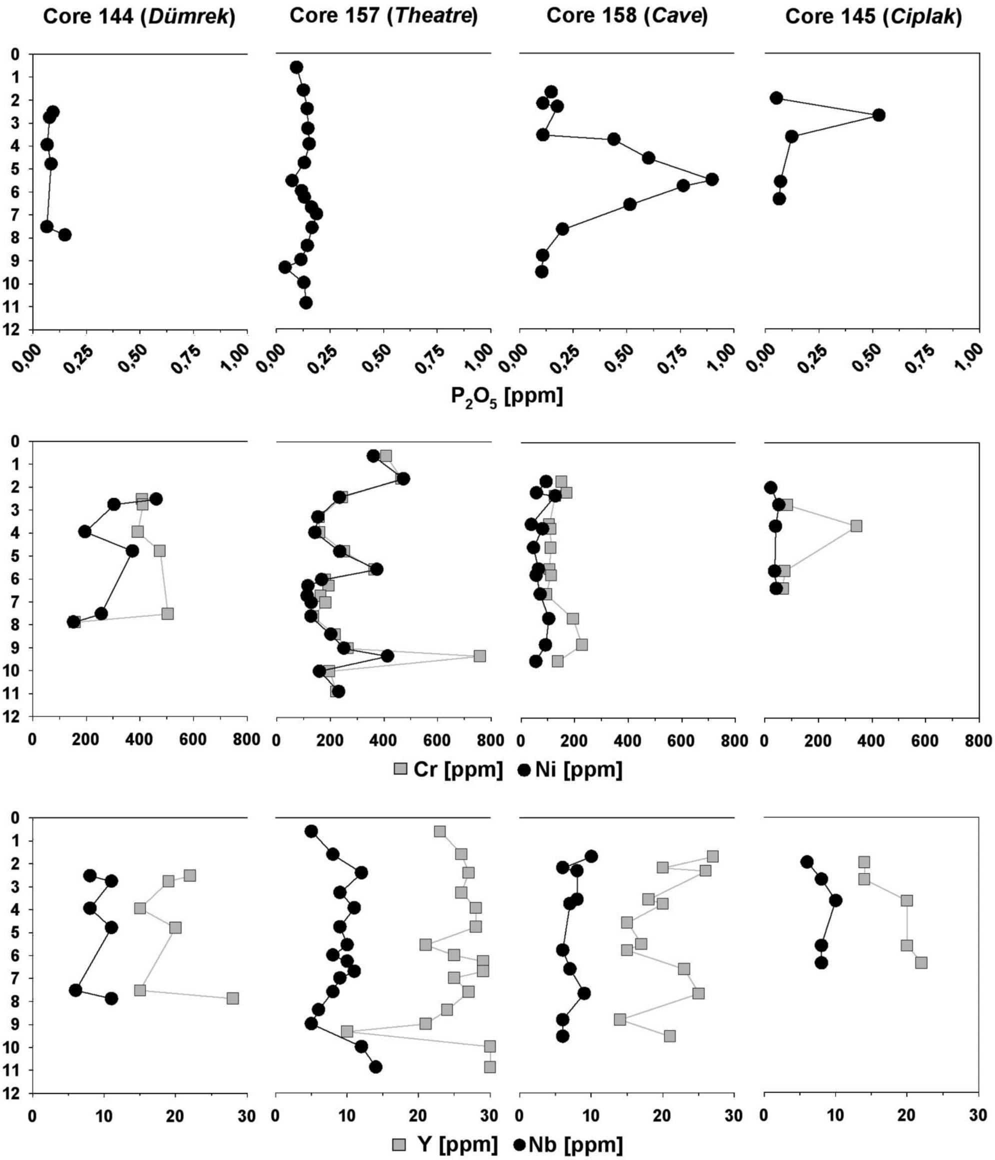


Fig. 4. Selected results of some main and trace elements of XRF analyses

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 was 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 ca. 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 is interpreted as Holocene, colluvial material, the deposits below were, due to their different appearance, considered to be of pre-Holocene (Pleistocene) age (Kayan, unpubl. data).

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 ± 78and 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 giving 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

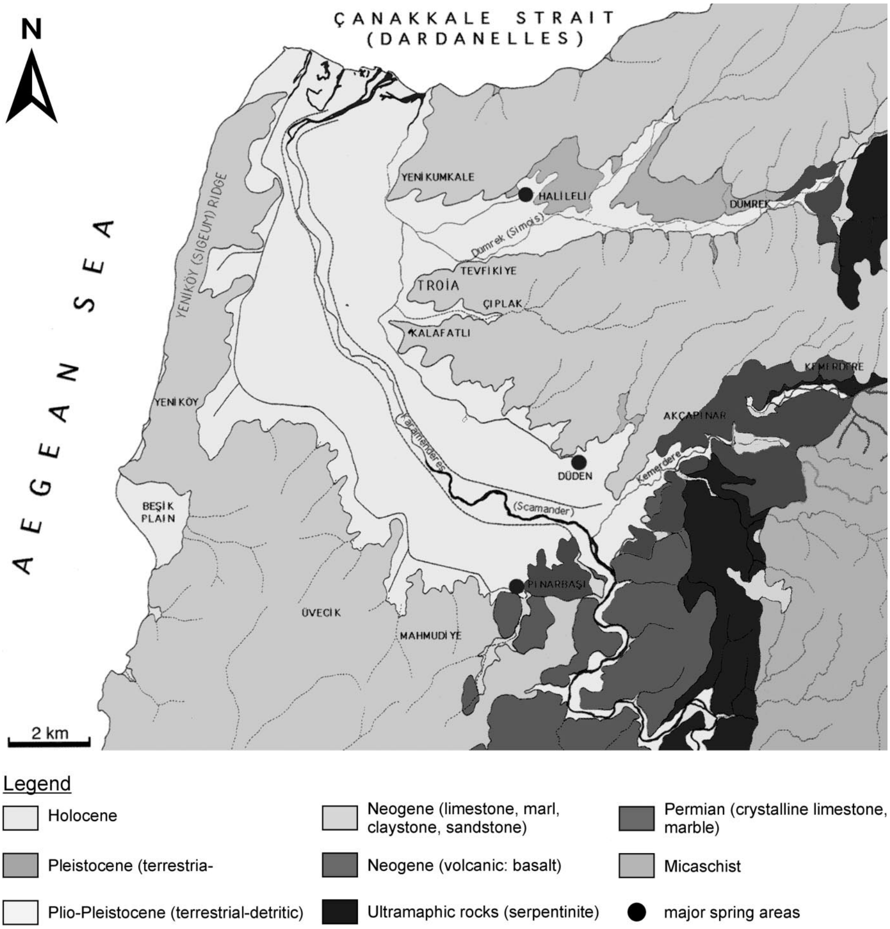


Fig. 5. Simplified geological map of the Troad. (Kayan 2000)

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 Hisarlik hill and even north of Dümrek River, the three other cores, being closely situated around Hisarlik 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 Scamander 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 Hisarlik 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 (IR-OSL) 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 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, oral comm.). Considering the numerical dates one can exclude Troia VII. Thus, drilling cores taken close to Hisarlik 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.).

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