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Holocene coastal changes in the Acheloos alluvial plain (northwestern Greece) and their effects on the ancient site of Oiniadai

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Holocene coastal sediments are valuable geoarchives for the reconstruction of past landscapes and their changes through space and time (cf. Brückner *et al.*, 2002; Brückner 2003a, 2003b; see also Brückner *et al.*, this volume). The Acheloos alluvial plain is situated in the westernmost part of the Greek mainland. It is the largest plain along the coast of the Ionian Sea and therefore of decisive importance for the understanding of Holocene changes in this area. Oiniadai, an ancient site in the southern part of the plain, was famous for its shipsheds of the 3rd century B.C.. Due to siltation processes caused by the progradation of the Acheloos delta, it lost its function as an important harbour site (see also Sakellariou and Lykousis, this volume). Nowadays Oiniadai lies some 9 km distant from the open sea.

The results presented herein are part of a paleogeographical-geomorphological study dealing with the whole Akarnanian coast as well as adjacent regions. The main objectives are to find out more about the causes of Holocene environmental changes and their local to regional characteristics. Eustatic sea level rise, the neotectonic setting, sedimentological factors such as subsidence, and anthropogenic influences all will be taken into consideration.

Sediment core profiles document lateral as well as vertical environmental changes, and serve as the basis on which spatial and chronological scenarios can be built up. The model used is Johannes Walther's "law of correlation of facies" from 1894 (Middleton, 1973, quoted in Kraft and Chrzastowski, 1985: 636).

To find out more about the Holocene genesis of the Acheloos alluvial plain, the following questions must be answered: (i) Was there a typical delta evolution in a classical sense? (ii) What was the sedimentological role played by the former Echinades islands which are today joined to the mainland by sediment? (iii) What scenarios can be developed for the siltation history of the area?

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GEOLOGY AND TECTONICS OF AKARNANIA

The Acheloos alluvial plain lies southeast of the Akarnanian mountains which are the southern continuation of the Epirus mountains. Both ranges belong to the western Hellenic nappe of the Ionian zone of the Hellenides. The sedimentary cover is made up of a sequence of evaporites with a thickness of ca. 3.5 km, followed by a 2 km thickness of limestone and dolomite strata (Jacobshagen, 1986). The strike is generally from north to south with NE-SW- and NW-SE-faults due to extensional movements of the Aegean microplate in the back arc basin (Doutsos *et al.*, 1987; Sachpazi *et al.*, 2000; Doutsos and Kokkalas, 2001). Most of the grabens and half-grabens are filled with younger flysch-sediments (up to 600 m thickness) of the Ionian zone. Where these intersect the coast, they are responsible for the existence of the few coastal plains of Akarnania (Philippson, 1958, see Fig. 1). The tectonic setting of the region is dominated by the nearby boundary between the Aegean and the Adriatic microplate. South of the Cephalonia transform fault there is evidence of the first plate being subducted under the latter (McKenzie, 1978; Laigle *et al.*, 2002). The Katouna fault separates the Akarnanian mountains from their hinterland; from here, Akarnania is moving 5 mm per year faster to the southwest than the central mainland (Cocard *et al.* 1999; Haslinger *et al.*, 1999) and therefore actively pushes the overriding plate (Sachpazi *et al.*, 2000). The tectonic dynamic is the reason for the high seismic activity of Akarnania and the adjacent Ionian islands (Papazachos and Comninakis 1971: Fig. 7; Scordilis *et al.*, 1985: Fig. 1; see also Morhange and Pirazzoli, this volume). Additionally, there are studies which show the geomorphological and neotectonic influence of karst processes within the Triassic evaporites (Philippson, 1958; Galanopoulos and Ekonomides, 1973).

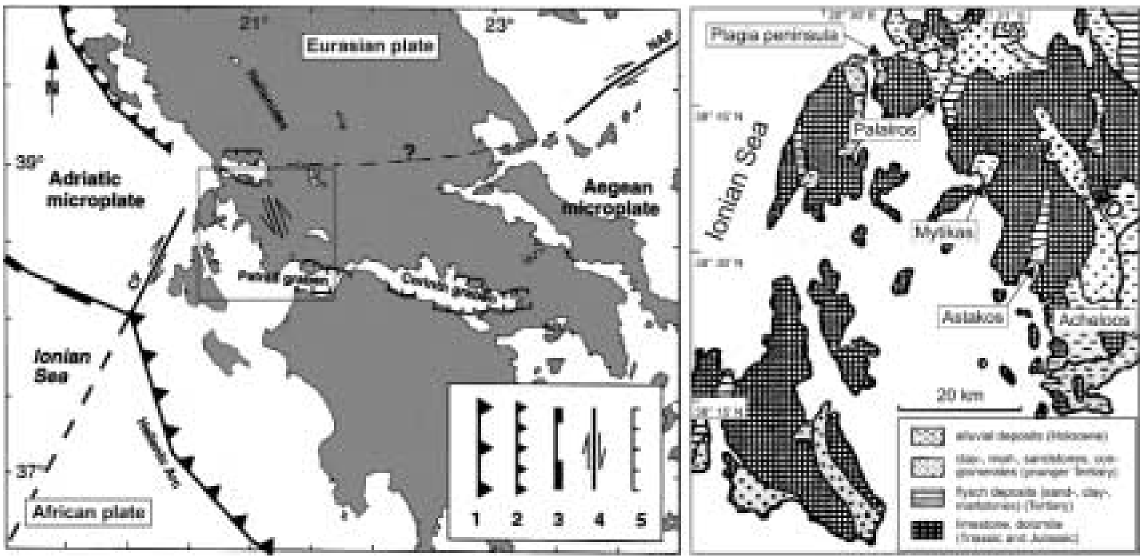

Fig. 1. The Acheloos river alluvial plain within the framework of the tectonic and geological setting of Greece and Akarnania (modified from Vött *et al.*, 2002; base maps from Haslinger *et al.* 1999 and Philippson 1958).
1 subduction, **2** continental collision, **3** Mesozoic passive margin, **4** strike-slip fault, **5** normal fault, **CF** Cephalonia fault, **NAF** western continuation of North Anatolian fault.

THE GENESIS OF THE ACHELOOS ALLUVIAL PLAIN

Neumann and Partsch (1885), referring to ancient writers such as Herodotus and Thukydides (both 5th century B.C.), were the first geomorphologists point out the role of the former Echinades islands, the arrangement of which had accelerated siltation of the marine embayments. Philippson (1958) who undertook his first travels to Akarnania in the end of the 19th century gave his account of a large inaccessible swamp area north of Oiniadai, called the swamps of Lesini. In his opinion they were the relics of the ancient lagoon Melite reported by Strabo. The ancient harbour of Oiniadai, according to Philippson, was connected to the sea via the Acheloos river. Philippson emphasized that the Acheloos area represents a mountain range drowned by sediments rather than a typical deltaic environment. As the distance from Oiniadai to the mouth of the river

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Acheloos given by Strabo (70 stadia = ca. 12.95 km) is still correct, he argued that the tremendous shifting of the coastline was already completed by the time of Strabo's account. Based on multitemporal remote sensing data and geomorphological studies, Piper and Panagos (1981) found three systems of abandoned river channels south and east of the modern river. According to their study, sea level rose rapidly until 5,000 B.P., then showed a weak decline at about 3,500 BP before rising again during the last 3,000 years (cf. Kelletat, 1975). Apart from just a few changes in the area of the actual river mouth, they concluded that for the last 2,300 years there had not been any larger environmental change. Furthermore, they reported that a subsidence rate of approx. 0.5 mm per year was responsible for the existence of today's lagoonal systems. Villas (1984) was the first who undertook systematic sediment cores in the alluvial plain. Her scenario suggests that deltaic sedimentation began approx. 5,700 B.P. to the southeast into the lagoon of Etoliko (Villas, 1984: Fig. 33; cf. Stanley and Warne, 1994: Tab. 1). Later, the river sedimentation became focused more towards the southwest and west. In her opinion around 500 B.P. the lagoon north of Oiniadai would have changed into a freshwater marsh. As a historian, Freitag (1994) studied ancient written sources and – in contrast to Philippson (1958) and others – concluded that Melite, compared to the former swamps of Lesini, must have been a freshwater lake situated on the opposite side of the Acheloos river. Fouache's geoarchaeological studies (1999) support the idea that Oiniadai with its shipsheds had a direct connection to the sea and that the Acheloos river was not directly responsible for the siltation of the Lesini swamp area. Finally, similar to the conclusion of Philippson (1958), Grove and Rackham (2001) emphasized that the last phase of considerable deltaic sedimentation must have taken place before the time of the ancient writers, at the latest during the 5th century B.C., due to an increase in sediment transport or a temporary decrease of subsidence rates.

All the cited studies are exclusively based on the interpretation of written reports, maps and remote sensing data; at the most, Piper and Panagos (1981) undertook some superficial sediment samplings. Only Villas (1984) conducted sedimentary investigations in the third dimension (e.g. sediment cores). Unfortunately, her study and facies interpretations were based on only a few core profiles of insufficient depth to provide a complete picture of the Holocene environmental evolution of the alluvial plain.

METHODS

To find out more about lateral and vertical facies correlation in the Acheloos alluvial plain we carried out several vibracorings up to a depth of 20 m below the surface, using a vibracoring device by Stitz and Atlas Copco for cores with a diameter of 6 cm or smaller. The exact position and elevation of coring locations were obtained by means of a Leica differential GPS. The strata were described sedimentologically on site; the samples taken underwent a detailed geochemical analysis in our laboratory. Dr. M. Handl (Marburg) and M. Besonen (Amherst) were responsible for microfaunal analyses and facies interpretation based on the occurrence of ostracod species assemblages (cf. Handl *et al.*, 1999; Besonen *et al.*, 2003). Absolute age determinations by radiocarbon analysis were arranged by Dr. K. van der Borg (Utrecht). For each sediment core profile we established a database for further descriptive and analytical statistical procedures. Based on linear discriminant analysis we have already developed a new methodological approach to facies interpretation using geochemical data (cf. Vött *et al.*, 2002, 2003a).

THE FORMER SWAMPS OF LESINI

The former swamps of Lesini are located north of Oiniadai and Kounovina, and south of the mountain of Kalubitsa (see Fig. 2). Until now it was unclear how far they once extended to the north. At the beginning of the 20th century they were still characterized by a widespread lake during winter flooding (cf. Lolling 1876/77: 285; Philippson 1958). In 1930 the first amelioration measures were undertaken (Fels 1944). The vibracore transect discussed here runs from the coast north of Kounovina (OIN 5) via the central lowland (OIN 4, 8, 9) to the Acheloos river (OIN 10, see Fig. 2). OIN 8 and OIN 9 show similar profiles so that we concentrate on the description of OIN 9 only.

Fig. 3 illustrates the facies profiles of the above mentioned cores. The vertical arrangement of the profiles corresponds to their altitude relative to modern mean sea level. Currently, only strati-

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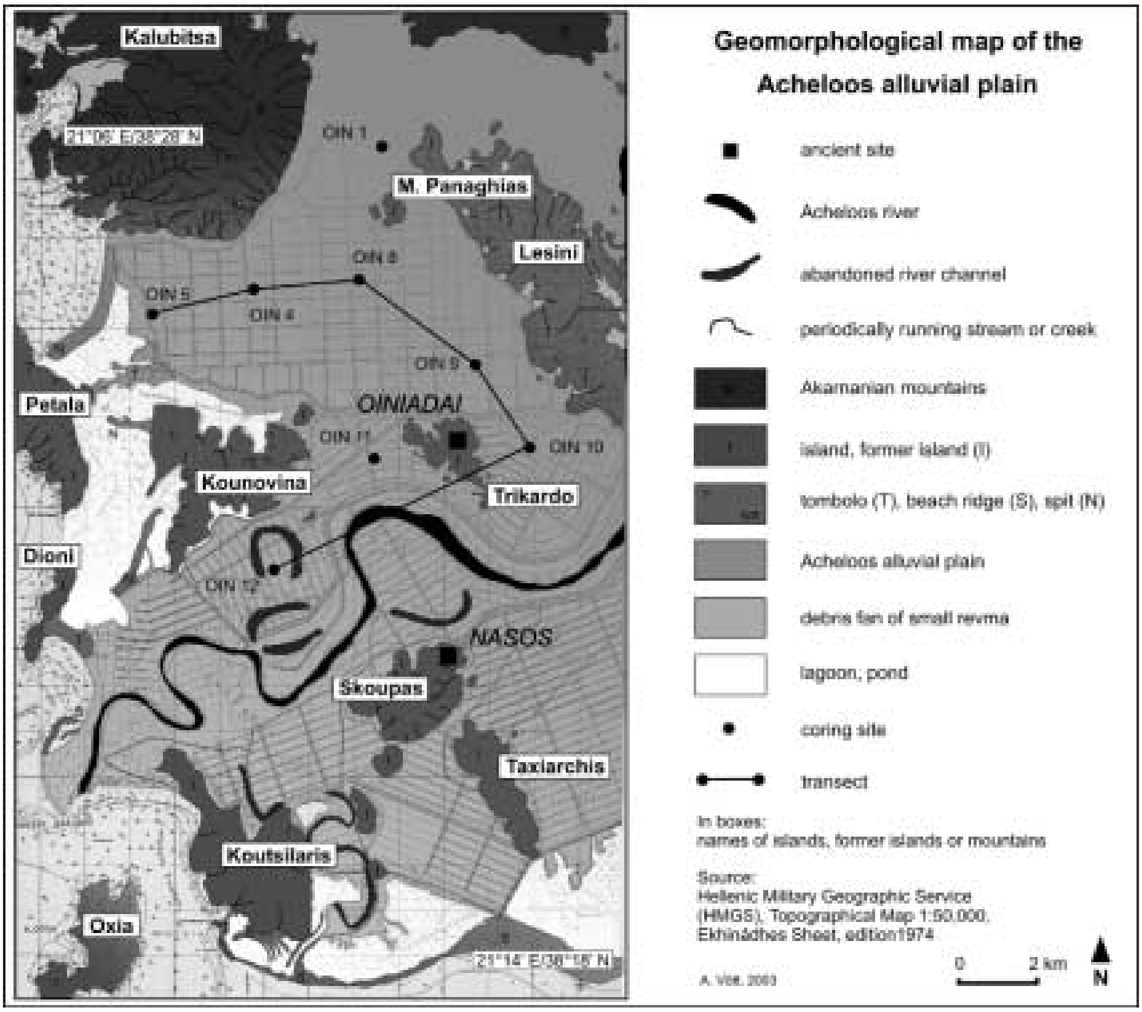

Fig. 2. Geomorphological map of the Acheloos alluvial plain with locations of coring sites and transects.

graphic comparisons are possible as radiocarbon dates are still being processed. Similar sedimentary facies at comparable depths do not necessarily represent synchronous sedimentation; however, they can help to document the lateral arrangement of sedimentary environments. Comparing depths of different strata is bound to the assumptions that (i) there are similar neotectonically induced subsidence rates for all coring sites, (ii) post-ameliorative compaction of sediments is limited to the uppermost parts of the profiles.

The fact that the surface at OIN 4 and OIN 5 lies below the current sea level is caused by the decrease in sediment delivery from the hinterland due to water storage in river barrages for hydroelectric power plants, hydro-ameliorative measures in the Acheloos lowland itself combined with widespread groundwater lowering, and subsidence due to neotectonic processes.

Generally, the profiles show features typical of a marine regression. For the first phase, fully marine environments were detected in vibracores OIN 4, 9, and 10. Provided that they are more or less synchronous, the water depths of the marine embayment must have been deepest somewhere around OIN 4 (see position of marine strata in Fig. 3). The subsequent phase was characterized by the appearance of sediments of a shallow marine environment in the western part of the area at OIN 4 and OIN 5. In core OIN 9 deposits from a fully marine environment were observed up to 8.30 m b.s.l. which means that up to this time there were still open marine conditions at this site. On the contrary, the comparable sediments of OIN 10 are already indicative of a lagoonal environment. This suggests, as a consequence, that a narrow marine embayment must have reached the area from the W or SW, passing over to a lagoonal system in the east. The bay as well as the lagoon were closed off by sandy bars or spits.

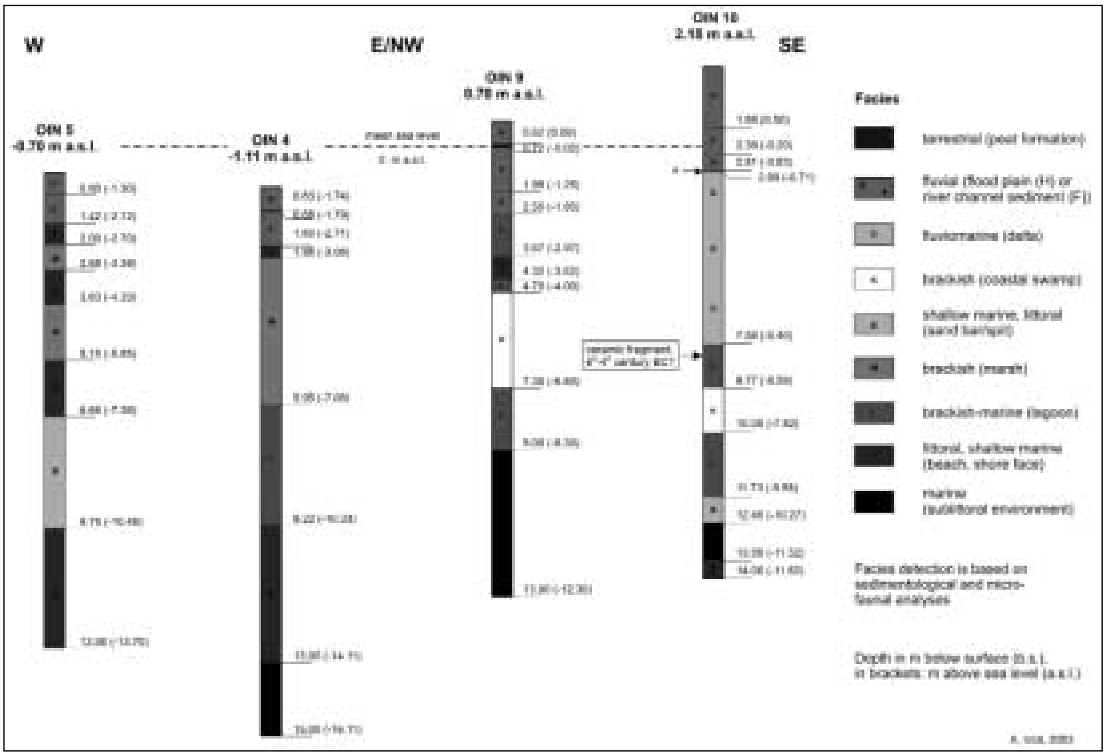

Fig. 3. Summary view of facies profiles for vibracores OIN 5, 4, 9 and 10.

During the third phase the sandy bars in the W reached 5.85 m b.s.l. (see OIN 5 in Fig. 3). Consequently a widespread lagoon came into existence; the sediments of this lagoon were retrieved in cores OIN 4 and OIN 9. As shown by the sediments, the lagoon persisted longest at the site of OIN 9. Sand bar formation east of OIN 10 led to the initiation of a regressive sequence at OIN 10 at an early stage (sandy bar followed by coastal swamp). Assuming that the archaeological dating of the ceramic fragments found in core OIN 10 is correct, lagoonal environmental conditions reappeared along the northern hillside of Oiniadai around the 5th century B.C., whereas siltation of the westernmost part of the lowland had already begun. This is confirmed by marsh deposits found at comparable depths in core OIN 4. Meanwhile, sediments of a coastal swamp environment at OIN 9 indicate the beginning of infilling of the central part of the water bodies from N to S. Passing through of the Acheloos delta next to OIN 10 definitely cuts off the lagoon of Oiniadai; subsequently there is an acceleration of siltation processes at OIN 4, OIN 5, and OIN 9 (marsh sedimentation or coastal swamp formation).

The fourth phase is characterized by two independent marine incursions recorded in core OIN 5 (4.33 - 3.38 m b.s.l., 2.70 - 2.12 m b.s.l.). The sediments of OIN 4 clearly show the influence of the second incursion (3.06 - 2.71 m b.s.l.), whereas the older incursion could only be detected by geochemical analyses (at approx. 3.75 m b.s.l., cf. Vött *et al.*, 2003b). Sedimentary features of OIN 4 and OIN 9 indicate that there still was a narrow bay alongside the hills of Kounovina and Trikardo at the southern margin of the modern plain. We suppose that this area had a considerable freshwater supply from karstic springs sheltering the remaining bay from rapid siltation. Philippson (1958) reports two springs at the northern flank of Trikardo which, today, are almost dry. In addition, it is striking that at OIN 9 the youngest marine incursion is followed by a lagoonal environment with sediments that extend up to 1.85 m b.s.l. in the core. This means that the lagoon of Oiniadai was longest lived in the vicinity of OIN 9.

Taking into consideration the transition to fluvial sediments at the presented coring sites, it should be stated that their base decreases from OIN 10 via OIN 9 to OIN 4. Obviously, these sediments are due to flooding events of the Acheloos in the eastern part of the area. The comparatively deep position of the fluvial sediments at OIN 4 may be due to local subsidence connected to modern anthropogenic ameliorative measures.

THE ACHELOOS DELTA *SENSU STRICTO*

The evolution of the Acheloos delta sensu stricto can be revealed comparing vibracores OIN 10 and OIN 12, both of which are strongly influenced by deltaic sedimentation. The facies profile of OIN 10 was already described above; quite similar, OIN 12 reflects the evolution of a shallow marine environment in front of the delta to a delta top marsh. Marsh sedimentation was abruptly terminated by delta sand deposition. Fig. 4 shows the summary view of the two core facies profiles. Due to the fact that the core of OIN 12 is not so deep, fully marine sediments could only be detected at OIN 10; they are free of any direct deltaic influence. Later, close to OIN 10 a sand bar came into existence and initiated the formation of a lagoon. At comparable depths in OIN 12 shallow marine conditions still exist (lagoon at OIN 10: 9.55 - 7.82 m b.s.l., shallow marine environment at OIN 12: 10.40 - 8.29 m b.s.l.). This evolution was due to the Acheloos delta prograding from the NE to the SW.

A later phase was characterized by coastal swamp deposits at OIN 10, followed by a second lagoon which, according to the ceramic fragment found at 7.90 below surface (5.72 m b.s.l.), can probably be dated to the period between the 6th and the 4th century B.C.. Marsh and deltaic sand sedimentation dominate OIN 12 at comparable depths. This seems to support the idea that the late lagoon of Oiniadai reached the Lesini area from the W – north of Kounovina – and did not touch the area around OIN 12. Since core profile OIN 11 (see Fig. 2) shows lagoonal sediments at a corresponding depth, this lagoon might have had a short secondary branch bordering the southwestern flank of Trikardo.

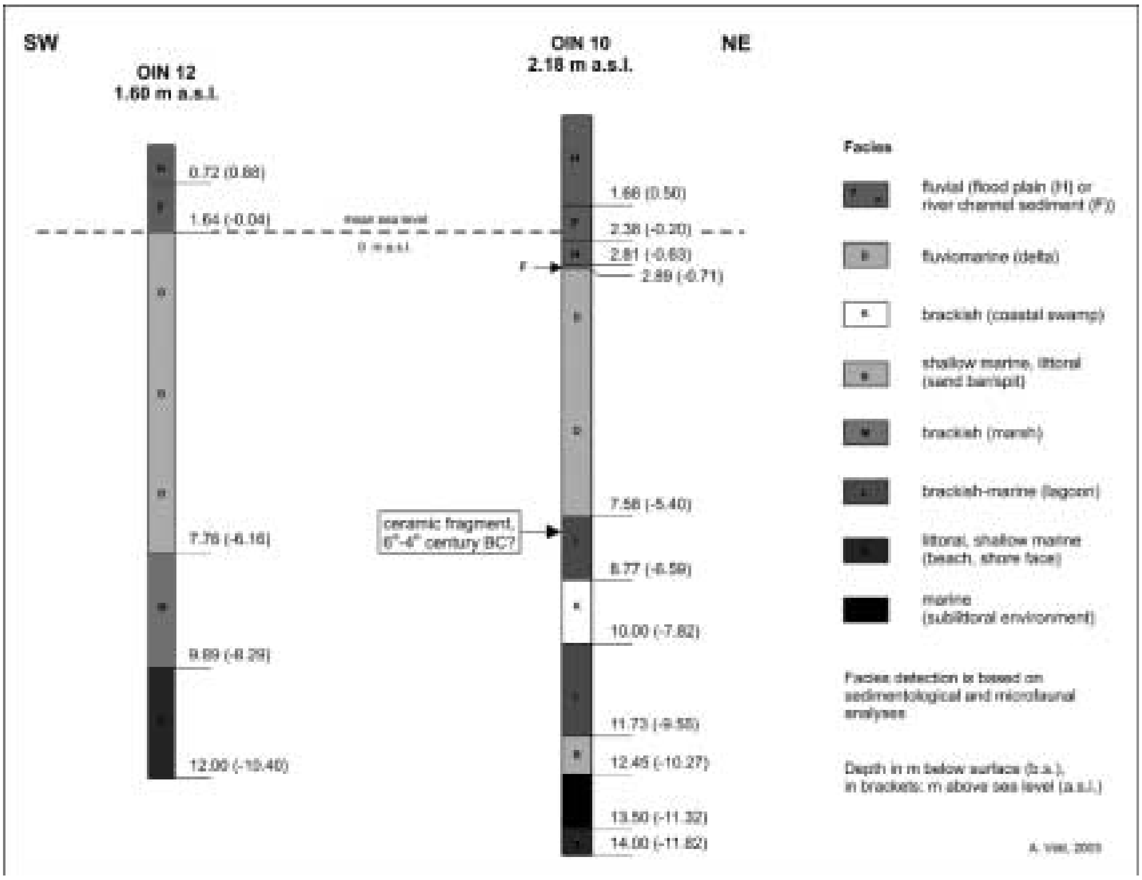

Fig. 4. Summary view of facies profiles for vibracores OIN 10 and OIN 12.

Comparing the bases of delta sediments at OIN 10 (5.40 m b.s.l.) and OIN 12 (6.16 m b.s.l.), there is a weak sedimentation gradient to the southwest. This corresponds with the main flow direction of the modern Acheloos river. The profiles show that there still was deltaic sand sedimentation at OIN 12 when subaerial flood channel sediments prevailed at OIN 10.

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CHRONOLOGICAL RECONSTRUCTION OF HOLOCENE LANDSCAPE CHANGES FROM RADIOCARBON DATES

Until now very few radiocarbon dates from the Acheloos alluvial plain have been published. Selected samples from the above mentioned sediment core profiles have been submitted for AMS ^{14}C age analysis. Here we present radiocarbon dates for sediment core OIN 1 which is situated approx. 4.6 km northeast of OIN 4 and approx. 1 km north of the former island of Monasteria Panaghias (see Fig. 2). Fig. 5 shows the simplified facies stratigraphy. The profile is characterized by a clear regressive sequence. Sediments of a marine environment are succeeded by brackish-lagoonal deposits, the latter being covered by peat layers and limnic sediments. Three independent phases of marine incursion occur from 12 m below surface up to the modern land surface. Three peat layers represent three phases of comparatively quiet sedimentary conditions (4.92 - 4.82 m b.s.l., 2.38 m b.s.l., 1.66 - 0.43 m b.s.l.).

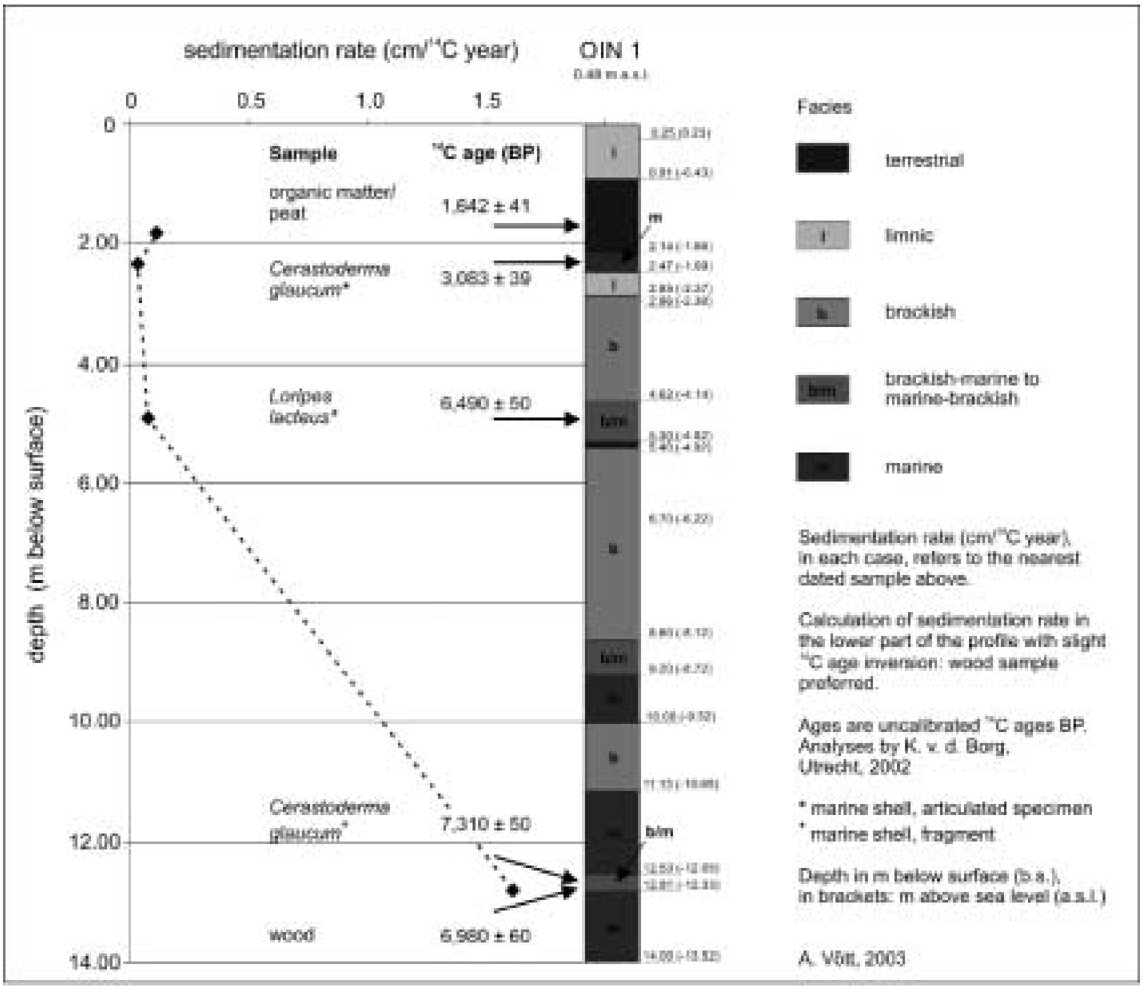


Fig. 5. Facies profile, ^{14}C dates and sedimentation rates for OIN 1.

Chronologically, we were able to discern four different changes in sedimentary conditions. Between 12.33 and 12.05 m b.s.l. there is a phase of freshwater input in a marine environment leading to a relative sweetening. A wood fragment (OIN 1/29 H) from this level yielded an AMS ^{14}C age (all ^{14}C ages are conventional ages, i.e. uncalibrated ages) of 6,980 ± 60 BP. A single valve of *Cerastoderma glaucum* (OIN 1/28) which was found at an inconsiderably higher position gave 7,310 ± 50 BP as a ^{14}C age. In spite of the risk of a large “old wood effect” we prefer the first sample to break up the slight age inversion. As to OIN 4 and OIN 5 there are no sedimentological features corresponding to this first dated event at OIN 1.

The marine incursion present at OIN 1 at 4.82 - 4.14 m b.s.l. shows a ^{14}C age of 6,490 ± 50 BP (single valve of *Loripes lacteus*, OIN 1/12). This incursion corresponds to the one we found at OIN 5 from 4.33 - 3.38 m b.s.l.; at OIN 4 it seems to be identical to the marine incursion at 3.75 m b.s.l. which we were able to detect geochemically. A complete specimen of *Cerastoderma glaucum* (OIN 1/7) yielded 3,083 ± 39 BP for the youngest marine incursion. This corresponds to a calibrated age of 1404 - 1310 cal B.C. (already corrected for marine reservoir effects). Again, the neighbouring cores show corresponding events: OIN 5 at 2.70 - 2.12 m b.s.l. and OIN 4 at 3.06 - 2.71 m b.s.l.. According to their depth, the marine sediments we found at OIN 9 (3.62 - 2.97 m b.s.l.) should have been deposited during the same marine incursion at about 3,000 B.P. Taking into account the ceramic fragment at OIN 10 at 5.72 m b.s.l. within lagoonal sediments, and its preliminary archaeological dating to the 6th to 4th century B.C., we hypothesize that these sediments correspond to the lagoonal phase following the youngest marine incursion at OIN 9.

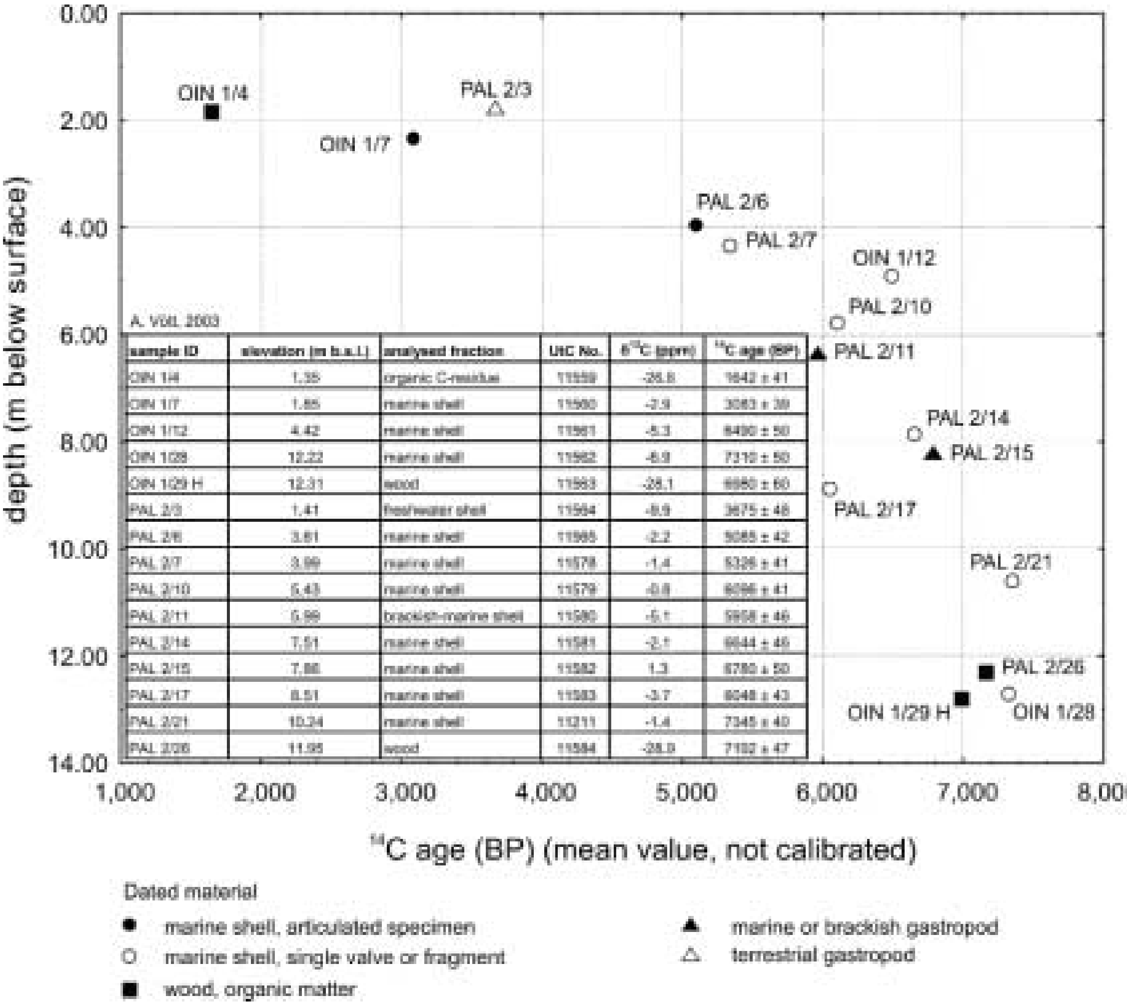
We know from ancient sources that during the time of continuous occupation of Oiniadai (5th to 2nd century B.C.) its shipsheds were actively used and of great strategic importance. Our study shows that at this time a narrow embayment which entered the Lesini area from western direction and which had its central axis south of OIN 5 and OIN 4 must have existed. This embayment was of primarily lagoonal nature. We detected at least two cases when sudden marine incursions affected the water bodies. Originally, the bay must have extended to the E far beyond OIN 10 where the lagoon had its deepest parts. Later, this lagoon was abruptly cut off by abundant deltaic sedimentation. The Acheloos delta which passed northeast of Oiniadai initiated the final siltation processes affecting the Lesini area. The former lagoon of Oiniadai became increasingly narrower, and was concentrated towards the southern part of the lowland around OIN 9, mainly supplied by karstic springs from Trikardo and Kounovina (see above). Our results match well with a course interpretation of the architectural remains of Oiniadai’s shipsheds. We estimate that the slipways could only be used properly when sea level was at -1.70 m below present terrain surface which corresponds to approx. 1.20 m below present sea level. Furthermore, we assume that the ancient ships required a minimal water depth of 0.75 m and a maximum water depth of 2.00m. Consequently, the corresponding sedimentary surface lies between 1.95 m and 3.20 m b.s.l. (compare sediment core profile OIN 9 in Fig. 3) for the time when the slipways were operated.

Following the marine incursion at OIN 1 another change in environmental conditions took place. A peat sample from the youngest phase of quiet sedimentation yielded an age of 1,642 ± 41 BP. In the more central parts of the study area no corresponding features could be found.

Regarding the sedimentation rates calculated for OIN 1, there must have been an extremely strong sedimentation rate until approx. 6,500 BP (see Fig. 5). The reasons are still unclear. After 6,500 B.P. sedimentation rates clearly decrease and show that the landscape became much more stable and appropriate for settlement activities.

Fig. 6 summarizes the results of AMS 14C dates from the Acheloos alluvial plain and the coastal plain of Palairos. The ^{14}C age – depth relations for the outermost southeastern and outermost northwestern parts of coastal Akarnania do not correspond to a curve for the eustatic sea level rise. Uncalibrated ^{14}C ages are compared with sampling depth below terrain surface; results from non-littoral samples were not related to actual water depths. Further, the dates shown in Fig. 6 refer to different materials from different sedimentary environments (see table within Fig. 6). Nevertheless, this relation can give important information about irregularities and/or trends of the sedimentary evolution which is, of course, controlled by sea level.

The sampling points in Fig. 6 do not show any systematic discrepancies in depth for samples of similar age. Both areas seem to be characterized by comparable vertical crustal movements. Possibly, the ^{14}C age yielded by OIN 1/12 is a little bit too old due to reworking processes affecting the shell. The phase of strong sedimentation ends between 6,000 BP and 5,000 BP. It is doubtful that relative sea level in the region has ever had a higher position than today (see also Fouache, this volume) For southern Greece, Kelletat (2002) reported a sea level maximum at 5,200 BP, a subsequent decrease until 3,500 BP and, finally, a gradual rise until the modern day. But for the highly tectonically active Akarnania, things may be different and modern sea level may be the



sample ID	elevation (m b.s.l.)	analysed fraction	UtC No.	$\delta^{13}C$ (ppm)	^{14}C age (BP)
OIN 1/4	1.35	organic C-residue	11559	-26.8	1642 ± 41
OIN 1/7	1.85	marine shell	11560	-2.9	3063 ± 39
OIN 1/12	4.42	marine shell	11561	-5.3	6490 ± 50
OIN 1/28	12.22	marine shell	11562	-6.9	7310 ± 50
OIN 1/29 H	12.31	wood	11563	-28.1	6980 ± 60
PAL 2/3	1.41	freshwater shell	11564	-8.9	3675 ± 48
PAL 2/6	3.61	marine shell	11565	-2.2	5085 ± 42
PAL 2/7	3.99	marine shell	11578	-1.4	5326 ± 41
PAL 2/10	5.43	marine shell	11579	-0.8	6096 ± 41
PAL 2/11	5.99	brackish-marine shell	11580	-5.1	5958 ± 46
PAL 2/14	7.51	marine shell	11581	-2.1	6644 ± 46
PAL 2/15	7.86	marine shell	11582	1.3	6780 ± 50
PAL 2/17	8.51	marine shell	11583	-3.7	6048 ± 43
PAL 2/21	10.24	marine shell	11211	-1.4	7345 ± 40
PAL 2/26	11.95	wood	11584	-28.0	7192 ± 47

Fig. 6. ^{14}C age – depth relations for samples from the Acheloos alluvial plain and the coastal plain of Palairos (modified from Vött *et al.*, 2003b).

highest ever experienced. One possible reason for this could be the subduction of the Adriatic beneath the Aegean microplate not far from Akarnania; it is connected to a clear subsidence of coastal land masses. Future studies should aim for several objectives: (1) to produce more 14C dates from coastal areas in order to separate local from regional tectonic influences, (2) to eliminate or minimize disturbing factors in order to isolate purely eustatic sea level changes, and (3) to document more or less catastrophic or gradual geomorphological events and their effects on ancient human settlements.

SUMMARY

This paper presents selected results from geomorphological-palaeogeographical studies of landscape changes in the area of the Acheloos river delta (northwestern Greece) during the Holocene. Vibracores were used to obtain detailed stratigraphic information about Holocene coastal sediments. Geochemical and microfaunal assemblage analyses gave further information about sedimentological processes. Reconstructions of landscape changes were based on horizontal and vertical changes in sedimentary facies. During the last two field campaigns 29 cores were obtained; here, the results of 6 cores are presented in the context of case studies.

Stratigraphic profiles in the area of the former swamps of Lesini document a regressive cycle. Deposits from a fully marine environment are succeeded by a shallow marine facies, and subsequently by sediments of a lagoonal and/or marshy environment. Siltation of the former marine bay is related to the formation of sand bars or sand spits resulting from longshore sand transport. These barriers sealed off the bay between Kalubitsa and Kounovina preventing open marine con-

BOOK IN STOCK

ditions. We stress the following results: (i) The siltation process is not directly caused by delta channel sediments of the Acheloos; most of the sediments piled up in the Lesini area can be traced back to the sea. (ii) In a later phase a long-lived, narrow lagoonal bay ran from west to east at the southern margin of the Lesini lowland. It possibly corresponds to the former prolongation of the modern bay north of Kounovina. (iii) Sediments representing marine incursions were found in the upper parts of the studied profiles. According to 14C analyses of an adjacent profile the younger incursion dates back to the second half of the second millennium B.C.. In the eastern part of the area this incursion is followed by the presence of a lagoon. It is probably this lagoon which guaranteed a connection between the shipsheds of Oiniadai and the sea. (iv) Sediments of the Acheloos delta sensu stricto are concentrated in the area of the modern river channel.

According to ^{14}C dating results, there was a very high sedimentation rate until 5,000 – 6,000 ^{14}C years BP. slower landscape evolution during the following phase seems to have been more favorable for the colonisation of the area.