



## **Holocene coastal evolution around the ancient seaport of Oiniadai, Acheloos alluvial plain, NW Greece**

Andreas Vött<sup>1</sup>, Helmut Brückner<sup>1</sup>, Armin Schriever<sup>1</sup>, Mathias Handl<sup>1</sup>,  
Mark Besonen<sup>2</sup> & Klaas van der Borg<sup>3</sup>

1 Department of Geography, Philipps-University of Marburg, Germany

2 Department of Geosciences, University of Massachusetts, U.S.A.

3 R. J. Van de Graaff Laboratory, University of Utrecht, The Netherlands

### **Abstract**

The former island of Triardo with the ruins of ancient Oiniadai lies in the midst of the modern Acheloos alluvial plain, one of the largest deltaic areas in Greece. The main objective of this study was to reveal Holocene landscape evolution and its different causes. The ancient seaport of Oiniadai witnessed enormous coastal change during historical times. The site once belonged to the Echinades Islands, most of which have been engulfed by sediments of the Acheloos during the last 6,000 or so years. The present distance to the open sea is between 9 and 11 km. Analysis of literature shows differing interpretations about (i) how the Acheloos delta and alluvial plain formed during the Holocene, and (ii) how ancient Oiniadai was connected to the sea. However, little information about stratigraphy exists. A series of vibracoring were retrieved along selected transects, and lateral and vertical changes in sedimentary facies distribution were used to decipher landscape changes during the Holocene. Results suggest that (i) a vast lagoonal system north and east of Triardo came into existence during the 5<sup>th</sup> millennium BC, (ii) the Acheloos delta front had already passed south of Oiniadai by about 2000 cal BC, and (iii) Oiniadai's shipsheds were connected to the Ionian Sea via a lagoonal system opening to the west. This lagoon finally silted up in the 2<sup>nd</sup> century AD. The southern flank of Triardo, where the southern harbour is assumed to have been located, lay adjacent to a shallow marine embayment which later turned into a lagoon.

### **1 Introduction**

The Acheloos River delta and alluvial plain (Akarnania, northwestern Greece) is situated at the northern margin of the Gulf of Patras. During the Holocene the area underwent enormous environmental change. Oiniadai, an ancient city of the 5<sup>th</sup> century BC, well known for its spectacular shipsheds, was once connected to the sea. Today, the former seaport is surrounded by land; the nearest open water is about 9 km distant (Fig. 1). Using sediments as geoarchives we reconstructed Holocene coastal landscapes of the Acheloos lowlands. This study is part of a regional geomorphological-palaeogeographical project dealing with the landscape history of Akarnania during the last 10,000 years. The analysis of coastal sediments enables us to decipher lateral and vertical changes in sedimentary facies in order to build a detailed scenario for landscape evolution. In this paper we provide new geochronological data which establish a realistic time frame for the evolution of delta progradation and adjacent siltation processes. Special focus is given to the history of Oiniadai and the question of how the landscape looked like in ancient times.

### **2 Methods**

The reconstruction of Holocene landscapes is linked to the study of sedimentary strata. To date, we have carried out 40 vibracoring in the Acheloos delta. In this paper, the interpretation of 10 cores in

the environs of ancient Oiniadai is given. In the field, sedimentary units were photographed and described sedimentologically. The exact position of each coring site was recorded by means of differential GPS measurements. Vibracores were subsampled for further analyses of different geochemical parameters in the laboratory. Information about vertical variations of such geochemical parameters are valuable qualitative as well as quantitative indicators of facies changes (Vött et al. 2003a, b). The most important method for interpreting the sedimentary environment is the analysis of microfaunal assemblages. Ostracod species are sensitive to changes in salinity, water depth and sedimentary input, and therefore are useful indicators of the paleoenvironment (Handl et al. 1999). Organic samples such as plant remains or mollusks were used for AMS-radiocarbon dating.

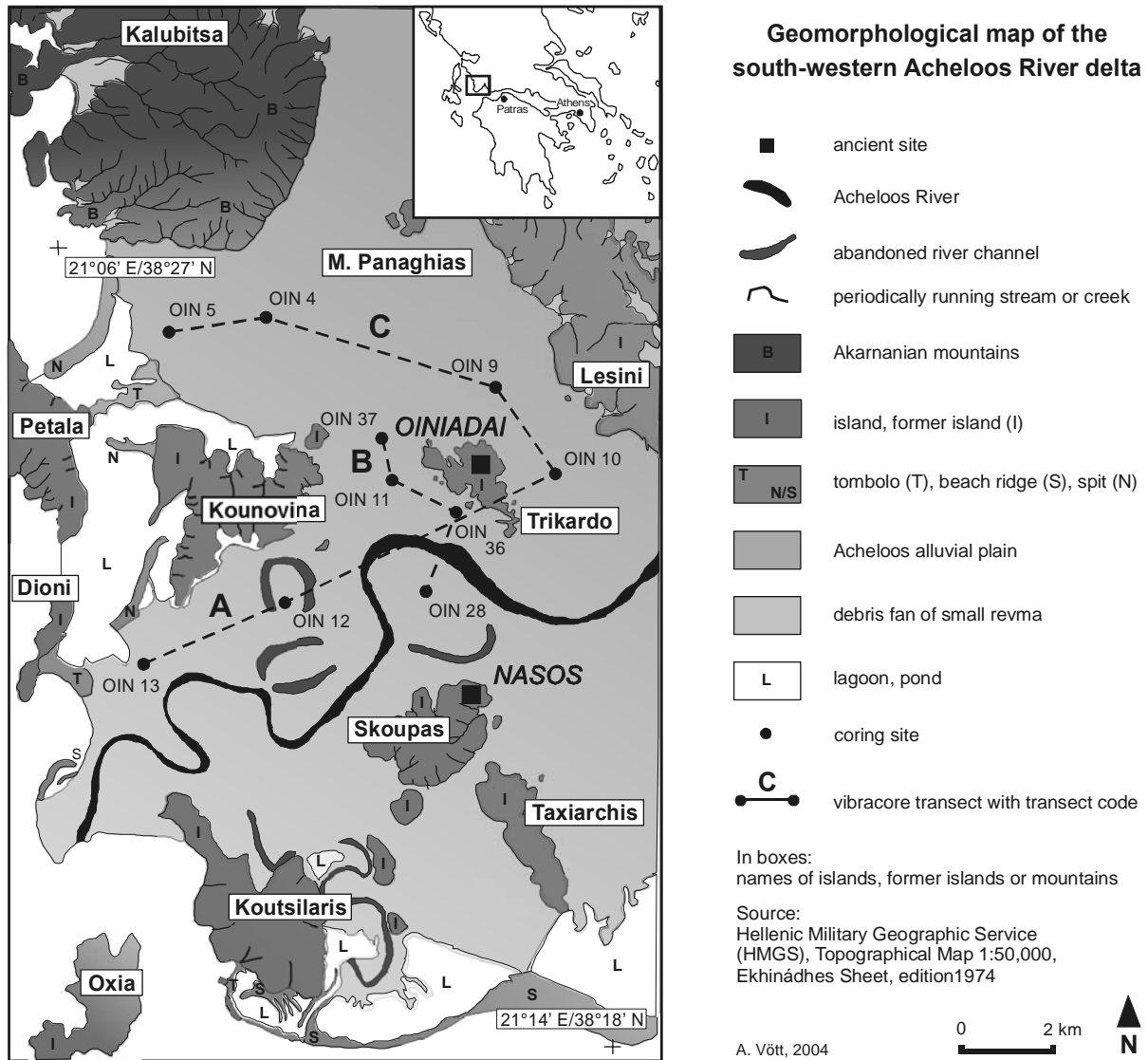


Fig. 1: Geomorphological map of the Acheloos River delta and alluvial plain with vibracore transects A, B and C. Source: Research by authors.

### 3 Literary data

Herodotus, Thukydides (both 5<sup>th</sup> century BC) and Pausanias (2<sup>nd</sup> century AD) are among those ancient writers who realized that the Acheloos River had ‘caught’ the former Echinades Islands by its sediments and connected them to the mainland. Until now, research has focused on the description and interpretation of historical sources (Freitag 1994) or was restricted to the detection of (sub-)recent sedimentary units in order to produce detailed geomorphological maps (Piper & Panagos 1981, Fouache 1999). Based on a few shallow sediment cores, Villas (1984) presented the only scenario for

delta progradation existing so far. According to her results the Acheloos first prograded to the south and southeast. Later, delta growth shifted to the southwest and reached the area around Oiniadai at around 3600 – 2700 years BP (conventional  $^{14}\text{C}$  ages, Villas 1984: Fig. 33). For further details about literary sources see Vött et al. (2003b) and Brückner et al. (2004). Based on new sedimentary data we are now able to establish a detailed scenario for the Holocene evolution of the Acheloos area.

#### 4 Sedimentary facies patterns in the Acheloos lowlands

The description and interpretation of landscape changes around the ancient seaport of Oiniadai is based on 10 selected vibracoring profiles from the western and southwestern parts of the Acheloos lowlands. Vibracore transect A (OIN 10, 12, 13) runs from northeast to southwest along the Acheloos River. Transect B (OIN 28, 36, 11, 37) is oriented in an almost north-south direction between Triardo and Kounovina. Transect C (OIN 10, 9, 4, 5) is connected to transect A east of Triardo, but runs north of it towards the coast north of Petala (Fig. 1). The vibracore description herein is restricted to the interpretation of lateral and vertical sequences of different sedimentary environments.

The following facies were distinguished in the presented cores. Marine deposits of a sublittoral environment are usually composed of homogeneous light grey mud indicating quiescent sedimentation. There are four different types of shallow marine environments: (a) silt of a low energy setting with almost no wave action (abbreviation Fl in Figs. 2-4), (b) littoral sand with abundant fragments of marine mollusks (S), (c) sandy-silty sand bar deposits with fragments and articulated specimen of marine mollusks, seaweed, and a microfauna assemblage rich in species (B), and (d) laminated silty and sandy prodelta deposits adjacent to deltaic distributary arms (P). Lagoonal deposits are characterized by bluish grey mud with abundant brackish-marine fauna, in some cases even with mollusks in living position (L). Periodic flooding by seawater leads to the deposition of laminated reddish dark grey mud in a shallow marine to mostly brackish environment (M). Dark grey sandy silt of coastal swamps contains plant remains and represents brackish conditions (K). Fluvio-marine sediments of delta distributary arms show brownish grey medium to coarse sand with fragments of marine macrofauna (D), whereas grey river channel sand is well-sorted and void of marine faunal indicators (R). Fluvial sediments deposited under subaerial conditions are mostly brown. Sand is associated with levees or crevasse splays (F); clay and silt are related to overbank freshwater marshes (H). At several coring sites semiterrestrial black peat was found (T).

##### 4.1 The prograding Acheloos River delta

Vibracores OIN 10, 12 and 13 were directly influenced by the growing Acheloos deltaic system (Fig. 2). The base of profile OIN 10 is characterized by a marine environment established in the leeward position of the Lesini mountains. Nevertheless, the delta prograding from the eastern direction led to the formation of a sand bar, probably due to the lateral transport of fluvio-marine sediments. After the delta front passed south of OIN 10 and dammed the area north of it, a lagoon came into existence. Coastal swamp deposits indicate that water depth was not very deep at this time. Later, the lagoonal environment was abruptly disturbed when a distributary arm of the delta shifted northwards depositing several metres of delta sands. Deltaic sedimentation at OIN 10 was succeeded by river channel deposits which were subsequently overlain by levee and flood plain sediments.

In its lower part vibracore OIN 12 shows deposits of a shallow marine environment possibly due to laterally drifted sediments of the Acheloos River delta. Later, as an expression of regressive conditions, marsh sedimentation took place. The marsh sediments are covered by thick sandy fluvio-marine deposits from a distributary arm of the delta which must have abruptly changed its direction and moved towards OIN 12. Similar to OIN 10, the delta sediments turn into river channel deposits and are followed by riverborne sand and mud deposited under subaerial conditions.

The basal sediments of vibracore OIN 13 show an early influence by drifted delta sediments before the delta itself passed and led to the sedimentation of several metres of fluvio-marine sand. As soon as subsequent river channel sedimentation was complete, a local regressive sequence was established:

coastal swamp deposits were overlain by marsh sediments and covered by flood plain and freshwater marsh sediments.

In a summary view, the earliest indirect influence of the Acheloos River delta is clearly visible at OIN 10 when it initiated the formation of shallow marine littoral or sand bar environments. During that time fully marine conditions prevailed at OIN 12 and 13. In the subsequent phase a lagoon existed around OIN 10. This site was directly affected by delta sedimentation shortly after 3482-3372 cal BC when delta sediments broke into the lagoon and silted it up (Tab. 1). The Acheloos subsequently must have prograded in a southwestern direction as shown by the bases of the delta sediments of OIN 10, 12 and 13. A distributary arm of the delta reached OIN 12 some 4100 years later (681-721 cal AD) resulting in a mean delta growth rate of 1.5 m/y. It cannot be excluded that the Acheloos, after having passed OIN 10, first took its way to the sea directly to the south between Skoupas to the east and Koutsilaris to the west before it turned to the southwest reaching OIN 12 and 13. Deltaic sedimentation at OIN 13 stopped around 1469-1626 cal AD.

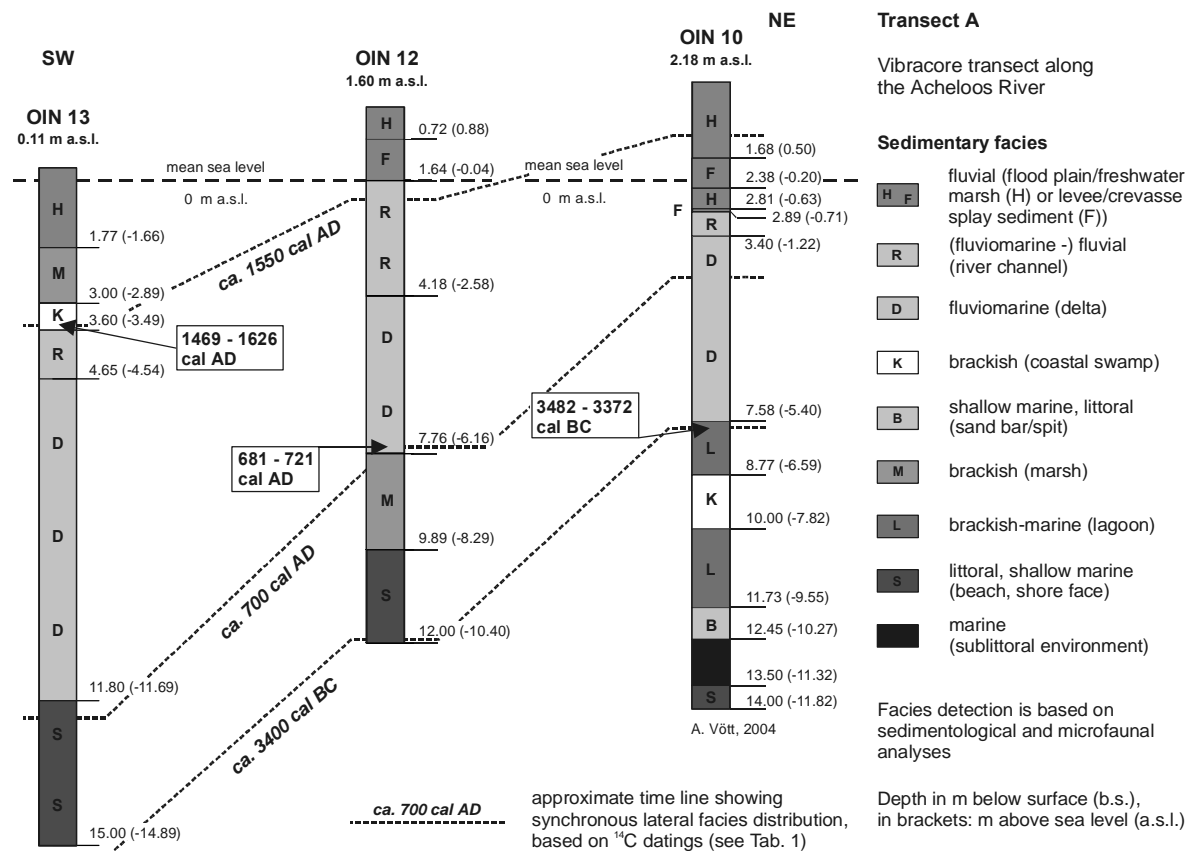


Fig. 2: Summary view of facies profiles of selected vibracores along the Acheloos River (transect A). Source: Research by authors.

## 4.2 The southern and western flank of Triardo

Vibracores of transect B show the decreasing influence of the Acheloos River towards the north (Fig. 3). Vibracore OIN 28 is characterized by a similar sequence as the profiles from transect A. The profile's base is already dominated by fluviomarine sediments of the Acheloos delta. More than 6 m of delta sand with plenty of plant and macrofaunal remains are overlain by well sorted river channel sediments free of any fossil content. The top of the profile is made up of a thick package of levee and floodplain sediments.

Vibracore OIN 36 is situated in the leeward position of Triardo. In the lower part of the profile, sediments of a fully marine environment prevail though a temporary influence by the mouth of the

nearby Acheloos exists. The marine sediments are covered by clearly laminated lateral prodelta deposits with an intercalated phase of stronger deltaic influence. As soon as the delta front passed south of OIN 36 a lagoon came into existence which, subsequently, silted up and turned into marsh. Later, fluvial processes overtook marsh sedimentation and led to the deposition of several metres of levee and overbank freshwater marsh deposits during flooding events.

The base of vibracore OIN 11 consists of sand bar sediments of a shallow marine environment rich in macro- and microfaunal remains. Abundant seaweed suggests a moderate energy environment with moderate sedimentation rates. The stratigraphy indicates that the Acheloos River delta did not directly reach OIN 11. Sand bars were accumulated by lateral drifting of fluviodeltaic sand from areas further in the south. Subsequently, there was a quiescent phase of shallow marine sedimentation followed by a lagoonal environment. Later, the lagoon silted up and was succeeded by a marsh. The marsh deposits partly show influences of younger river channel sedimentation. The profile's top is made up of floodplain sediments from the Acheloos.

Vibracore OIN 37 is situated between Triardo and Kounovina (Photo 1). Its lowest portion is characterized by sediments of a fully marine environment followed by deposits from a shallow marine sand bar setting. As at OIN 11 there are abundant seaweed remains, overlain by lagoonal and marshy deposits. It is striking that the marsh deposits are covered by a 2.5 m thick layer of fluvial channel sediments. The latter, in turn, are covered by subaerially deposited levee or crevasse splay sediments and topped by floodplain deposits.

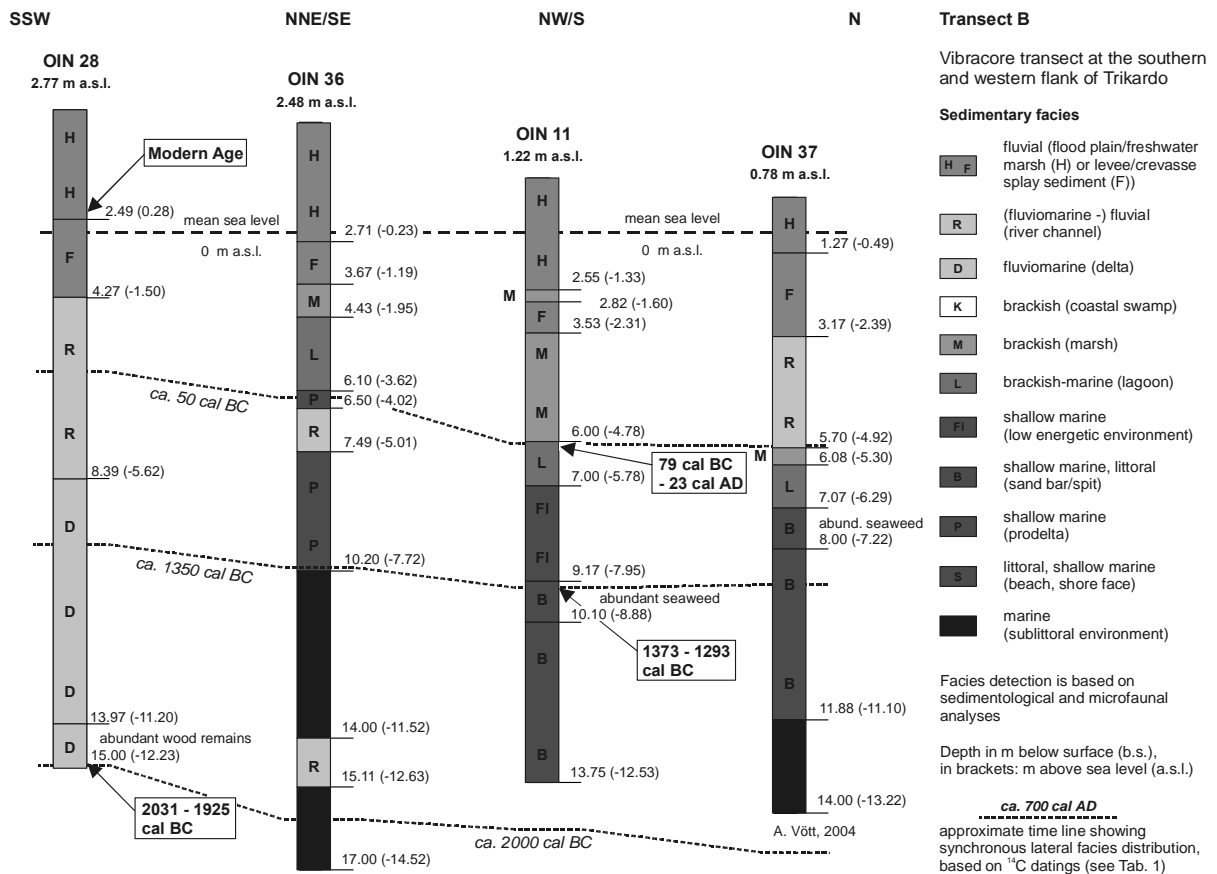


Fig. 3: Summary view of facies profiles of selected vibracores along the southern and western flank of Triardo (transect B). Source: Research by authors.

Fig. 3 illustrates that at OIN 36 marine conditions were still predominant even when the Acheloos had already reached OIN 28 at around 2031-1925 cal BC (Tab. 1). This is due to leeward and therefore sheltered position of the site. When the deltaic influence increased, a prodelta environment was estab-

lished. Further to the northwest deposits of the Acheloos triggered the formation of sand bars. At OIN 11 a quiescent shallow marine environment was established around 1373-1293 cal BC. Later, this marine embayment was sealed off from the sea and a lagoonal system developed. The latter disappeared at OIN 11 shortly after 79 cal BC – 23 cal AD. Because of the different stratigraphical situations of the lagoonal sediments at OIN 11 and OIN 36, we assume that in a subsequent phase the ongoing delta sedimentation silted up the prodelta environment at OIN 36 and led to the formation of an until now unknown, younger lagoon at the southern flank of Trikardo. Similar to the situation at OIN 11, laterally drifted delta sand initiated sand bar formation at OIN 37. It appears that the subsequent lagoon was the same as that found at OIN 11. The lagoonal deposits are overlain by marshy ones. Of particular interest in vibracore OIN 37 is the fact that river channel sediments appear at a moment when siltation is at its peak further south. This suggests that these sediments might belong to a channel branching off from the Acheloos east of Trikardo. The waters prevented the remaining lagoonal bay – e.g. the connection of Oiniadai's northern harbour to the sea (see below) – from further siltation. As indicated by the sediments of vibracore OIN 11, this channel did not reach OIN 37 from a southern direction. It appears to have been the (probably man made) precursor of the modern Trikardo canal which nowadays runs along the northern flank of the hill.



Photo 1: Panoramic view from the western edge of Trikardo to the west towards the former island of Kounovina (156 m a.s.l.). South of Kounovina lies the present mouth of the Acheloos River, and north of it the western part of the Lesini swamp (see Fig. 1). The lagoonal system between Dioni, Petala and Kounovina is located west and north of Kounovina. Its narrow northern branch once extended further to the east and guaranteed the connection of Oiniadai's shipsheds to the Ionian Sea. In the right background the southern flank of the Kalubitsa hills are visible (photos taken by A. Vött, 2001, assembled by H. Nödler, 2004).

### 4.3 The former swamps of Lesini

Transect C lies north of Trikardo and crosses the former swamps of Lesini. The facies sequence of vibracore OIN 10 was already discussed above. The base of vibracore OIN 9 is composed of sediments of a fully marine environment indicating that a marine embayment existed at this site (Fig. 4). This was subsequently followed by a long-lasting lagoonal phase which was partly replaced by deposits of a coastal or, in this case, lagoonal swamp. In their upper part, the lagoonal sediments are intercalated with well-sorted sand void of macrofaunal remains; this sand was probably deposited in a river channel. The uppermost part of the profile is made up of crevasse splay and freshwater marsh sediments related to flooding events of the Acheloos in the southeast.

Similar to OIN 9, there are sediments of an open marine embayment at the base of vibracore OIN 4. However, they are covered by deposits from a littoral environment, followed by sediments indicative of a lagoonal setting. Due to ongoing siltation processes the lagoon became marshy. A thin layer of

sterile sand in the upper part documents the later existence of a river channel. As at OIN 9, there is a thin peat intercalation in the uppermost alluvial strata.

Vibracore OIN 5 lies next to the present shore of today's lagoon. The lower part of the profile shows sediments of both littoral and sand bar environments covered by marsh deposits of a later phase. These deposits are succeeded by two different layers of sterile sand which possibly are of fluvial nature. They are overlain by crevasse splay and floodplain sediments.

In a summary view, Fig. 4 shows that an open marine embayment once extended to the north and east of Triardo. The sediments of transect C indicate that this bay disappeared due to siltation initiated by the Acheloos River. In a first phase, delta progradation led to the formation of sand bars at OIN 10, somewhat later in the area between Kounovina and Kalubitsa around OIN 5. Consequently a large lagoonal system came into existence. The marine embayment as well as the subsequent lagoon had its deepest parts around vibracore OIN 4. However, the lagoon existed longest at OIN 9.

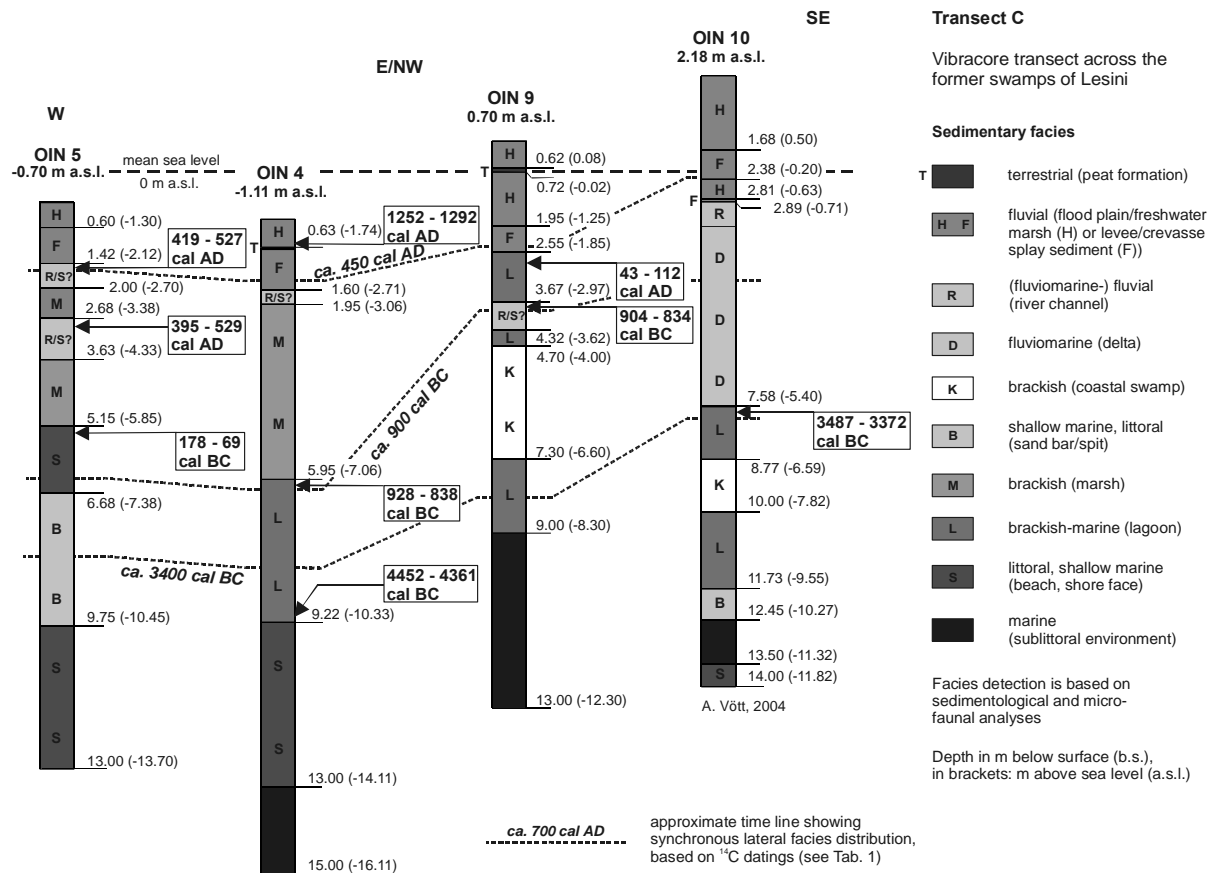


Fig. 4: Summary view of facies profiles of selected vibracores in the area of the former swamps of Lesini (transect C). Source: Research by authors.

A radiocarbon date places the beginning of lagoonal sedimentation at OIN 4 at 4452-4361 cal BC (Tab. 1). At OIN 10, almost 1000 years later, this vast Lagoon of Oiniadai was abruptly filled by delta deposits (3487-3372 cal BC). Whereas the lagoonal environment at OIN 4 already ceased to exist by 928-838 cal BC, it lasted until 43-112 cal AD at OIN 9. At OIN 5 shallow marine conditions were replaced by marsh sedimentation after 178-69 cal BC. A significant age difference was not noted between the two layers which are possibly river channel sediments. They both date back to the 4<sup>th</sup>-6<sup>th</sup> centuries AD. Therefore it seems impossible that the mentioned sandy intercalations in the upper parts of vibracores OIN 5, 4 and 9 indicate synchronous sedimentation processes. At OIN 9 this layer dates from 904-834 cal BC. During this time span the lagoon at OIN 4 had almost completely disappeared. This supports the hypothesis that considerable freshwater supply from the Acheloos prevented the

remains of the lagoonal system next to OIN 9 from further siltation. Whether this is due to anthropogenic intervention or to natural fluvial dynamics remains an open question. The first considerable human impact at Oiniadai dates from the 5<sup>th</sup> century BC (Oberhummer 1887, Philippson 1958). Provided that the <sup>14</sup>C dated plant remain found within the sand layer at OIN 9 is not reworked older material, the age for the river channel therefore seems several hundreds of years too old. The youngest phase of Holocene landscape evolution is characterized by the deposition of freshwater marsh sediments interrupted by a temporary peat formation. At OIN 4 this occurred around 1252-1292 cal AD. This inaccessible swampy landscape is responsible for the naming “Swamps of Lesini”. The swamps were drained in the 1930s and are nowadays intensely used for irrigation farming.

## 5 Holocene coastal evolution of the Acheloos River delta and alluvial plain

The results of our geomorphological-geological research clearly prove that Trikardo once was an island surrounded by a marine environment. It is still unclear exactly when the prograding Acheloos River delta first influenced the area. Lateral drifting of delta deposits must have begun very early and led to the formation of sand bar and sand spit systems at OIN 5 and west of it. This initiated the formation of a vast lagoon in the western and southwestern parts of today’s lowlands of the Acheloos. Nevertheless, our data show that the lagoonal system is a very old and long-lasting feature. OIN 4 captured the beginning of the lagoonal phase at 4452-4361 cal BC. When delta growth reached OIN 10 around 3487-3372 cal BC, the northern, eastern and southeastern flanks of Trikardo still faced a lagoonal environment. The river then prograded in a southwestern direction and reached the area around OIN 28 at 2031-1925 cal BC leading to the formation of sand bars along the southern and southwestern flank of Trikardo. However, open marine conditions prevailed south of Trikardo at least until 1373-1293 cal BC when a long linearly shaped distributary arm of the delta had already passed south of OIN 11 and caused low energy conditions in a shallow marine environment. As deltaic influences appear very late at OIN 12, we assume that the Acheloos prograded first in a southern direction and reached the Ionian Sea between Skoupas and Koutsilaris (Fig. 1). This time span is also characterized by the gradual shrinking of the Lagoon of Oiniadai. At OIN 4 lagoonal sedimentation was replaced by a marsh environment shortly after 928-838 cal BC. The channel fill found at OIN 9 in the upper part of the profile lies some 4 m higher but shows the same age; this indicates that the dated plant remains might represent reworked older material.

Marsh sedimentation started at OIN 5 after 178-69 BC. Further siltation led to the end of the lagoonal environment west of Trikardo, at OIN 11, at 79 cal BC – 23 cal AD (Photo 1). The Lagoon of Oiniadai existed longest around OIN 9. In the last phase, a narrow lagoonal bay extended in west-east direction adjacent to the northern flank of Trikardo. This lagoon was the prolongation of today’s lagoonal arm north of Kounovina (Fig. 1, Photo 1) and was continuously threatened by further siltation. Comparing profiles OIN 9 and OIN 37 shows that the lagoonal sediments found at OIN 9 lie at the same depth as the river channel sediments at OIN 37. This suggests that a river channel – diverging from the Acheloos southeast of Trikardo – supplied the remaining waterbody with freshwater and guaranteed the connection to the sea in the Petala area. Additionally, strong karstic springs at the northern hillside of Trikardo had a comparable effect (see also Fouache 1999: 72). Lagoonal conditions definitely disappeared at OIN 9 sometime during the late 2<sup>nd</sup> century AD.

Later, the Acheloos turned towards the southwest and reached OIN 12 at 681-721 cal AD. We have no evidence for further shifts in direction until 1469-1626 cal AD when deltaic sedimentation stopped at OIN 13. In the western Lesini area there are signs of fluvial sedimentation from northern or eastern directions during the early Middle Ages. These sediments possibly caused the formation of large swamps east of Kalubitsa as found in other profiles (not shown here). A second phase of peat formation in this area dates back to the early 13<sup>th</sup> century AD. The fact that coring sites OIN 4 and 5 lie below present sea level can be explained by subsidence due to tectonics and sediment loading on the one hand and by drainage measures on the other.



In comparison to previous studies this research provides new and more detailed information about landscape evolution during the last several millennia. Villas (1984), for instance, assumed that delta progradation in a southwestern direction occurred some 1000 years later than in our scenario (see also Brückner et al. 2004). Furthermore, the radiocarbon dates for vibracores OIN 12 and 13 prove that fluviodeltaic sedimentation had not already ceased by 1 BC, as anticipated by Philippson (1958). Intensity of coastal changes and siltation processes in the vicinities of the delta area are also underestimated by Piper & Panagos (1981) who discounted significant changes in the area of today's river mouth within the last 2300 or so years. On the contrary, we can confirm Fouache's assumption (1999) that the northern harbour of Oiniadai was connected to the sea via a lagoonal system and that there was not a direct access to the sea during historical times.

Sample Name	Depth (m b.s.)	Depth (m b.s.l.)	Sample Description	UtC No.	$\delta^{13}\text{C}$ (ppm)	M.R.C.	$^{14}\text{C}$ Age (BP)	$1\sigma$ max.; min. (cal BP)	$1\sigma$ max.; min. (cal BC)
OIN 4/2 PR	0.66	1.77	peat, organic material	12311	-27.5	n	748 ± 36	698 - 658	1252 - 1292 AD
OIN 4/15 M	6.05	7.16	<i>Dosina exoleta</i> , articulated spec.	12310	1.3	y	3085 ± 40	2878 - 2788	928 - 838
OIN 4/22 M	8.79	9.90	<i>Cerastoderma glaucum</i> , artic. spec.	12309	-4.5	y	5962 ± 47	6402 - 6311	4452 - 4361
OIN 5/3 PR	1.82	2.52	unidentified plant remain	12314	-27.6	n	1604 ± 34	1531; 1423	419 AD; 527 AD
OIN 5/5 PR	2.81	3.51	unidentified plant remain	12313	-27.1	n	1623 ± 34	1555; 1421	395 AD; 529 AD
OIN 5/10 M	5.30	6.00	<i>Nucula nucleus</i> , articulated spec.	12312	1.9	y	2443 ± 45	2128 - 2019	178 - 69
OIN 9/9 M	2.84	2.14	<i>Dosina exoleta</i> , single valve	12352	2.4	y	2270 ± 33	1907 - 1838	43 - 112 AD
OIN 9/12 PR	3.82	3.12	unidentified plant remain	12319	-26.1	n	2740 ± 40	2854 - 2784	904 - 834
OIN 10/19 M	7.80	5.62	<i>Dosina exoleta</i> , articulated spec.	12320	1.7	y	5032 ± 48	5432 - 5322	3482 - 3372
OIN 11/19 M	6.20	4.98	<i>Nucula nucleus</i> , articulated spec.	12322	0.9	y	2363 ± 44	2029 - 1927	79 BC - 23 AD
OIN 11/28 PR	9.34	8.12	sea weed remain. marine	12321	-15.9	y	3406 ± 37	3323 - 3243	1373 - 1293
OIN 12/18 M	7.70	6.10	fragment of <i>Dosina exoleta</i>	12368	0.7	y	1687 ± 26	1269 - 1229	681 - 721 AD
OIN 13/10 PR	3.54	3.43	unidentified plant remain	12323	-27.9	n	365 ± 37	481; 324	1469 AD; 1626 AD
OIN 28/4 PR	2.35	-0.42	unidentified plant remain	12332	-29.0	n	152 ± 42	278; 10	1672 AD; 1940 AD
OIN 28/28 PR	14.72	11.95	wood fragment	12331	-21.7	n	3628 ± 40	3981 - 3875	2031 - 1925

Tab. 1: Radiocarbon analysis results for samples from selected vibracores around the ancient seaport of Oiniadai. Note: b.s. – below ground surface; b.s.l. – below sea level; M.R.C. – marine reservoir correction with 402 years of reservoir age (corrected? y – yes, n – no);  $1\sigma$  max; min cal BP/BC – calibrated ages,  $1\sigma$ -range; “;” means there are several possible age intervals because of multiple intersections with calibration curve; UtC No. – laboratory number, University of Utrecht. All  $^{14}\text{C}$  datings processed by K. van der Borg, Utrecht.

## 6 Palaeogeographical aspects of Holocene coastal changes in the environs of ancient Oiniadai

The first considerable evidence for human settlement at Triardo dates back to the 5<sup>th</sup> century BC (Philippson 1958). It seems probable that even in the centuries before Triardo had been occupied by man (Oberhummer 1887: 211). Our study shows that in the middle of the first millennium BC remains of the vast lagoonal system adjacent to the northern flank of Triardo still existed. However, in the northern part of the Lesini area and east of Triardo, the lagoonal environments had already disappeared. A narrow lagoonal embayment guaranteed the connection between ancient Oiniadai's shipsheds – renewed and fortified by Philipp V. in 219 BC (Oberhummer 1887: 162), lying on the northern flank of the hill – and the open sea. This bay probably had a short secondary branch which reached OIN 11 west of Triardo. The lagoon may have been connected to open marine or shallow marine environments south of Triardo as indicated by the facies stratigraphy found in OIN 36. However, because the sandy sediments detected at OIN 9 and 37 seem characteristic of a river channel environment, we hypothesize that there was a river channel (artificial?) running along the northern flank of Triardo which delivered freshwater from the Acheloos to the narrow lagoonal embayment. Using Oiniadai's shipsheds as a sea level indicator (Vött et al. 2004), the architectural remains suggest a former sea level at about 1.20 m b.s.l. for the late 3<sup>rd</sup> century BC; we conclude that the related

sediments lie between 1.95 and 3.20 m b.s.l. This corresponds to the depth interval where the mentioned lagoonal and/or river channel sediments were encountered.

South of Trikardo, in the 5<sup>th</sup> century BC, the Acheloos River delta front was located somewhere southwest of OIN 28 where the first massive deltaic influence had already occurred by 2031-1925 cal BC. The stratigraphic sequence at OIN 36 shows that the conditions remained marine and later shallow marine for a long time. The southern harbour of Oiniadai – located at the southern flank of Trikardo directly north of OIN 36 (see Murray 1982: 43-45) – might have been a sea harbour first. Later, conditions turned it into a lagoonal environment (see also Fouache 1999: 72-73.). According to vibra-core OIN 36, the southern harbour was not a river harbour as suggested in literature (Leake 1835: vol. III, 568, Weil 1903: 344, Philippon 1958: 403, Freitag 1994: 233-234). It is worth mentioning that the highest position of lagoonal sediments around Trikardo were found at OIN 9 and OIN 36. We cannot definitely exclude that there was a narrow canal-like connection between these two lagoons. Further corings will be needed for answering this question.

## 7 Conclusions

The different evolutionary steps in the development of the southwestern delta and alluvial plain can be synthesized to the following scenario:

(1) In the 5<sup>th</sup> millennium BC early delta progradation and lateral drifting of sediments led to the formation of a large and long-lasting lagoonal complex north and east of the former island of Trikardo where ancient Oiniadai is situated. (2) The delta front of the Acheloos – a long linear distributary arm – passed south of Trikardo by approx. 2000 cal BC; it then moved further south reaching the Ionian Sea between Skoupas and Koutsilaris. (3) During the first millennium BC Trikardo's southern flank remained under marine conditions whereas the northern lagoonal system was gradually reduced in size due to siltation processes. (4) From the 5<sup>th</sup> century BC until around 1 BC the Lagoon of Oiniadai narrowed and stabilized at the northern flank of the hill. Sediments of a river channel (possibly artificial) suggest that freshwater from the Acheloos southeast of Trikardo helped keep the lagoonal bay open and navigable. Oiniadai's shipsheds in the northern harbour were connected to the sea west of Kounovina via this lagoonal system. (5) At the same time, the site where the southern harbour of ancient Oiniadai lay had access to shallow marine and, later, to lagoonal conditions. (6) The northern lagoon finally silted up by the 2<sup>nd</sup> century AD. (7) Further delta progradation in southwestern direction took place at least between the 8<sup>th</sup> and the 17<sup>th</sup> centuries.

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## Address

Dr. Andreas Vött  
Fachbereich Geographie  
Philipps-Universität Marburg  
Deutschhausstr. 10  
D-35032 Marburg/Lahn  
Germany

E-Mail: voett@staff.uni-marburg.de