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THESPROTIA EXPEDITION II ENVIRONMENT AND SETTLEMENT PATTERNS

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Cover: Megalo Karvounari seen from the northeast. Courtesy of the 32nd Ephorate for Prehistoric and Classical Antiquities

Layout: Esko Tikkala

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A Lithological Analysis of Holocene Lake Sediments in the Kalodiki Fen

Ruben Lelivelt

Introduction

In landscape archaeology, palaeoenvironmental reconstruction is essential to the study of topics such as landscape and climate change, human-climate interactions, and the introduction and subsequent development of certain agricultural crop species. The present palaeolandscape study from the Kalodiki basin focuses on the interval ranging from the end of the Last Glacial to the present, using information from sediment cores.[1]

An important prelude to the present research occurred in 2007 when a geoarchaeological study of three lacustrine environments in Thesprotia was carried out.[2] The Kalodiki Fen appeared to be the most promising basin in terms of Holocene pollen preservation. However, the pollen (an important proxy in the palaeolandscape reconstruction) that was recovered from the Kalodiki basin dated to the Early Weichselian,[3] i.e., to the Middle to Upper Palaeolithic archaeological framework. Therefore, a second fieldwork campaign was carried out in 2008 with the aim to retrieve Holocene sediments containing pollen.[4] The results of this fieldwork, which formed part of the Thesprotia Expedition, are presented here.

Research questions

The objectives of this study are to: 1) Reconstruct the environmental history during the Holocene period, 2) Understand human-climate interactions, 3) Detect evidence of human influence in the Kalodiki Fen by studying the sedimentation characteristics in the Kalodiki basin, and 4) Detect evidence of the appearance of new crop species (i.e. olive, grape and cereal cultivation).

The third objective focuses on the local situation in the Kalodiki basin, especially the southeastern part, whereas the other objectives are formulated at a regional scale, for the southern part of Thesprotia. An important proxy that provides such a regional environmental signal is pollen. The pollen data bear a climate signal and are expected

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[1] This research is part of the master programme Landscape Archaeology at the Institute for Geo- and Bioarchaeology, VU University Amsterdam (the Netherlands) and is carried out within the framework of the Thesprotia Expedition. The complete results of this research together with an extensive literature review will be published in Lelivelt forthcoming. Fig 1. was drawn by Esko Tikkala on the basis of maps supplied by the author. All other illustrations are by the author.

[2] Graven *et al*. 2009. For the work carried out by Inge de Kort, Jan Graven and Myrsini Gkouma, cf. also Kluiving *et al*., this volume.

[3] The Weichselian is the last glacial period (116,000-11,500 BP) and forms the last stage of the Pleistocene. The Weichselian is followed by the Holocene.

[4] The field work was conducted in June 2008 by Jan Graven and myself.

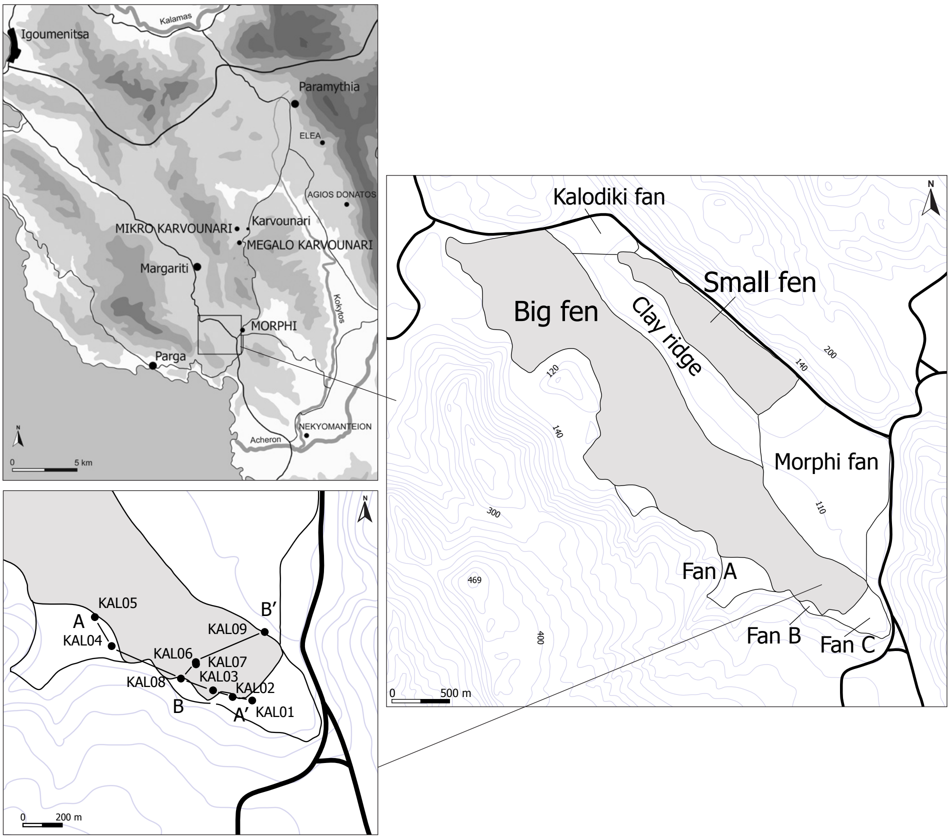

Fig. 1. Map of the Kalodiki Fen with the major geomorphological features (Fan: alluvial fan) and the boreholes located in the south-eastern part of the Kalodiki Fen.[6]

to be representative of the vegetation of the (wide) surroundings of the Kalodiki basin. How large the surrounding area is depends on different factors such as how pollen are dispersed, climate and topography.

In this study one pollen core (KAL08-06) was obtained from the southeastern part of the Kalodiki Fen in almost the same location as a pollen core (K-26) had been recovered already by an earlier fieldwork campaign in the mid-1990s.[5] The aim of the current fieldwork project was to extend the pollen sequence produced by the previous study and to achieve a higher resolution in the pollen record. The influence of the alluvial fans on the infilling process of the Kalodiki Fen was studied by positioning sediment cores on the alluvial fans around the central pollen core KAL08-06 (Fig. 1).

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[5] Ioakim and Christianis 1997, 95-104.

[6] Codes are simplified. KAL01 = KAL08-01 (name, year and number). KAL08-01, 02 and 03 and KAL08-04 and 05 are located on two large alluvial fans, KAL08-08 in a small flat alluvial fan, and KAL08-09 on the large Morphi alluvial fan . KAL08-01, 02, 03, 04, 05, and 09 are all placed around KAL08-06 and KAL08-07, which again are situated in the central peat deposits of the basin. KAL08-06 was used for pollen studies and KAL08-07, next to KAL08-06, was used for sediment analysis.

Previous research

In the past, two palaeoenvironmental research projects have taken place in the Kalodiki basin. An extensive geological coring programme was carried out in the early 1990s in the dried out Kalodiki Fen floor. About 20 boreholes were made with a maximum depth of 10 m.[7] This work was followed in 1997 by a palynological study consisting of the analysis of a Holocene pollen sequence dating between 4500 and 23,000 BP. This time a core (K-26) was positioned in the south-eastern part of the fen, as the thickest peat layer was formed here. About 51 pollen samples were taken at regular 20 cm intervals between 0.28 and 10.34 m.[8]

The pollen levels in the core K-26 were sufficient for reconstructing the palynological history during the period stretching from the Late Glacial to the Late Holocene. In the Kalodiki basin and its surrounding area an evergreen temperate forest, dominated by oak, developed during the Holocene at the expense of grass communities. In the upper part of the pollen diagram an increase of the *Taraxacum* type and the *Centaurea nigra* type can be observed.[9] According to Bottema the appearance of these types of pollen in a pollen diagram can be interpreted as possible human influence on the landscape because they are associated with open ground vegetation and cultivated plants (mainly cereals).[10] The increase in pollen numbers of the *Taraxacum* type and *Centaurea nigra* type occurs at a depth of less than 2.65 m in K-26. The interval 2.60-2.65 m beneath the fen surface is dated and has a radiocarbon date of 4498±80 BP (ca. 3250 cal BC). Taxa that are associated with maquis (*Olea*, *Phillyrea*, *Pistacia*, *Ericaceae*, *Cistaceae* and *Ephedra*)[11] and phrygana vegetation (*Pistacia* and *Liliaceae*) also appear, or become more abundant after approximately 4498±80 BP (ca. 3250 cal BC). Maquis and phrygana are regarded as typical degradation-vegetation types in the Mediterranean and thus also indicate human influence.[12]

In 2007 Inge de Kort, Jan Graven and Myrsini Gkouma, as part of the Thesprotia Expedition, focused on the clay ridge and the Morphi alluvial fan. They applied different techniques to their sediment cores, such as macroscopic description and sediment analysis. Pollen analysis, oxygen ($\delta^{18}O$), carbon ($\delta^{13}C$) stable isotopes and magnetic susceptibility of the sediment were performed on a sediment core (KAL07-04) on the clay ridge. The sediments appeared to contain pollen from the Early Weichselian, preserved in calcareous gyttja.[13] The same study also revealed evidence that a tectonic event created the boundary conditions for the increased activity of both the Kalodiki alluvial fan and the Morphi alluvial fan. Similarly Ioakim and Christianis in 1997 attributed the presence of clay layers within the peat deposits mainly to tectonics which control the basin morphometry. The tectonic movements led to phases of temporary extension and contraction of the lake. When water levels are too deep, peat formation cannot occur and thin layers of limnic sediments are deposited (clay and calcareous muds) in the basin.

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[7] Botis *et al*. 1993, 27.
[8] Ioakim and Christianis 1997, 97.
[9] For the pollen diagram, see Ioakim and Christianis 1997, 98-99.
[10] Bottema 1974.
[11] The ecological interpretation of the vegetation type is based on Atherden 2000, 62-78, table 5.2.
[12] Tivy 1993, 194.
[13] Graven *et al*. 2009, 71-72.

Stage	Lithology	Geomorphological unit	Tectonics	Geological period[16]
1	Interfingering layers of organic calcareous gyttja and calcareous gyttja	Clay ridge and Morphi alluvial fan		Early Weichselian
2	Calcareous gyttja and organic calcareous gyttja	Clay ridge and Morphi alluvial fan		Early Weichselian
3	Clay	Clay ridge	Tectonic event	Early Weichselian
4	Minerogenous calcareous gyttja and organic gyttja	Clay ridge and Morphi alluvial fan		Early Weichselian
5	Minerogenous calcareous gyttja/few organic layers	Clay ridge and Morphi alluvial fan		Early Weichselian
6	Silty clay/clay	Clay ridge and Morphi alluvial fan	Succeeding tectonic event	Holocene
7	Clay loam and sandy silt gravel	Clay ridge and Morphi alluvial fan		Holocene

Fig. 2. Modified and simplified table with the stages of development that are defined for the clay ridge and the Morphi alluvial fan (after Graven *et al.* 2009).

Based on the results of these previous studies, the thickest Holocene peat sequence[14] (and thus an expected higher temporal resolution in the pollen record) was expected to be present in the south-eastern part of the Kalodiki basin. In this part of the basin the peat layer is interrupted by two thin clay layers. The presence of Holocene pollen records in the peat deposits was furthermore to be expected in the southwestern part of the Kalodiki Fen.[15] Older pollen records from the Early Weichselian are found in calcareous gyttja deposits on the clay ridge. The clay ridge consists of sequences of clastic material and (organic) calcareous gyttja (Fig. 2). The upper part of the clay ridge sequence is of Holocene age.

The stratigraphical sequence of the alluvial fans A, B and C (Fig. 1) was unknown before the fieldwork in 2008. In view of the previous studies the alluvial fans were expected to consist of clastic material (clay/loam), possibly covering (calcareous) gyttja and/or peat deposits.

Technique	Field/Lab	Number	Technique	Scale
Macroscopic description	Field	9	Texture, organic matter, inclusions, oxidation/reduction, $CaCO_3$	Local
Pollen analysis	Lab	48	Vegetation	Regional
Grain size analysis	Lab	145	Texture, sorting	Local
Thermo Gravimetric analysis (TGA)	Lab	170	Organic matter, $CaCO_3$, clastics	Local

Fig. 3. The techniques used for the determination of environmental proxies, classified by scale. Sediment analyses were performed on core KAL08-01, -04, -07, -08 and -09. Pollen slides were prepared on KAL08-06 from the interval 255-490 cm.

[14] Botis *et al*. 1993, Ioakim and Christianis 1997.
[15] Ioakim and Christianis 1997, sediment core K-26.
[16] The dating of stages 1-5 is based on pollen data, that of stages 6-7 on stratigraphical characteristics (Graven *et al*. 2009, 71-72).

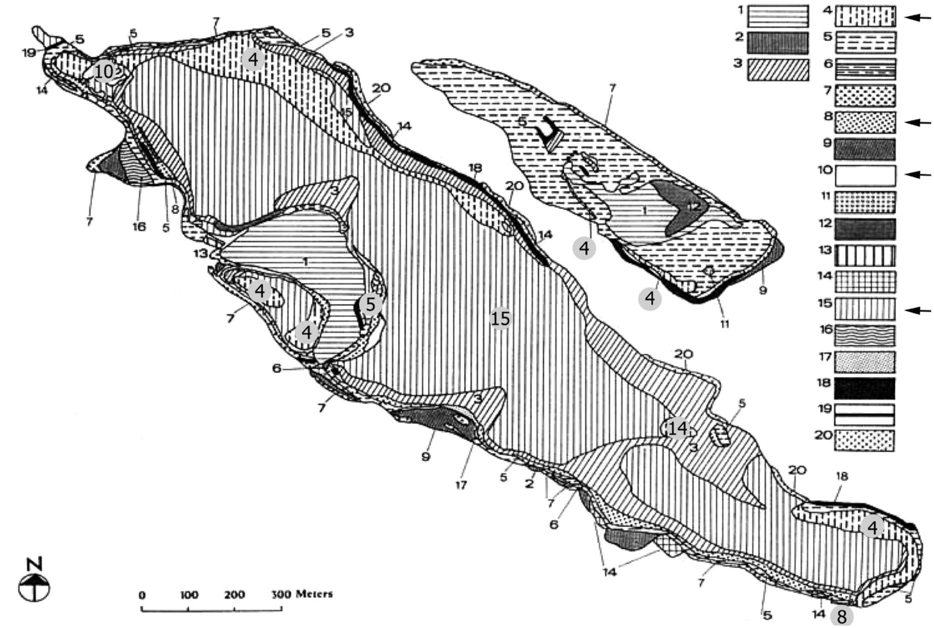

Fig. 4. Adapted vegetation map of the Kalodiki Fen (after Dimopoulos *et al*. 2005, 71, fig. 1). The vegetation mapping units indicated with arrows correspond to plant communities that occur in the deeper parts of the fen (black circles): mapping units 4, 8 and 15: mean water depth 200-250 cm and 10: mean water depth 350-400 cm. KAL08-06 and KAL08-07 are located in mapping unit 15.

Method

To test the research objectives, a combination of environmental proxies was determined, as shown in Fig. 3. The south-western part of the Kalodiki Fen was selected close to the location of core K-26.[17] Two cores were retrieved from the big fen: KAL08-06 was used for pollen studies and KAL08-07, positioned directly next to KAL08-06, was used for sediment analysis. Both cores were placed in the deepest part of the lake where pollen preservation conditions are expected to be relatively benign (Fig. 4). The waterlogged and thus reduced circumstances in these sediments inhibit microbial decay of the pollen grains. On the alluvial fans and the clay ridge, cores KAL08-01, -02, -03, -04, -05, and -09 were positioned around KAL08-06 and KAL08-07 (Figs. 1, 4).

All cored sediments were described in the field. In the laboratory, sediment analysis was performed on 315 sediment samples. The samples were taken from five sediment cores (KAL08-01, -04, -07, -08 and -09), located on five geomorphological units (alluvial A, B and C, the Morphi alluvial fan and the big fen). On the basis of ^{14}C-dates (Fig. 5), pollen slides

Sample number	Material	Sample weight
Thesprotia 350 ^{14}C	Peat (gyttja-like)	10 g
Thesprotia 610 ^{14}C	Peat (gyttja-like)	10 g
Thesprotia 760 ^{14}C	Peat (gyttja-like)	10 g
Thesprotia 615 ^{14}C	Peat (gyttja-like)	15 g

Fig. 5. Sample numbers, material and weights from KAL04 and KAL06 selected for AMS ^{14}C dating. The ^{14}C dating was performed in 2009 by the Tandem Laboratory (University of Uppsala) ^{14}C laboratory.

17 Ioakim and Christianis 1997, 95-104.

were prepared from the interval between 255 and 490 cm. This interval was expected to represent the time interval 6200 to 2050 BP (4900 to 30 BC). This corresponds to the Atlantic to Subatlantic period, or in the archaeological time division to the interval between the Final Neolithic and the Hellenistic period.

Results

The lithology based on field observations and sediment analysis in the laboratory is briefly summarized in Fig. 6; the ^{14}C-dates are shown in Fig. 7. The correlation between the lithological data will be discussed per geomorphological units in the next section. Although organic material was present in KAL08-06 and KAL08-07, pollen appeared to be practically absent in KAL08-06 (further, see Pollen preservation below).

Sediment core	Geomorpho-logical unit	Lithological division	Lithology[18]	Depth top of layer (cm)	Max. thickness (cm)
KAL08-01 (L)	Fan C	Clastic layer 1	Silty clay loam/Silt loam	0	450
KAL08-02					
KAL08-03		*Sandy layer 1*	*Sandy layer*	50	50
KAL08-04 (L)*	Fan A	Clastic layer 1	Silty clay loam/Silt loam	0	850
KAL08-05		*Sandy layer 3*	*Sandy layer*	70	40
		Sandy layer 2	*Sandy layer*	170	40
		Sandy layer 1	*Sandy layer*	330	40
		Organic layer A	Peat	850	225
KAL08-06* (pollen core)	Big fen	Organic layer D	Floating peat layer	0	100
KAL08-07 (L)		Organic layer C	Peat	250	160
		Clastic layer 2	Clayey layer with sand grains	410	60
		Organic layer B	Peat	470	60
		Clastic layer 1	Clayey layer with sand grains	530	10
		Organic layer A	Peat	540	490
KAL08-08 (L)	Fan B	Clastic layer 1	Silty clay loam/ Silt loam	0	830
		Sandy layer 1	*Sandy layer*	50	80
KAL08-09 (L)	Morphi alluvial fan	Clastic layer 2	Silty clay loam	0	350
		Sandy layer 2	*Sandy layer with small grains*	50	80
		Sandy layer 1	*Sandy layer with small grains*	170	150
		Clastic layer 1	Silty clay loam	350	75

Fig. 6. The sediment cores, geomorphological units and simplified lithological layers (description from down to up). The sandy layers within the clastic layers are best observed in the cores that are analysed in the lab (L). Peat levels in the cores that are marked with a * are dated by the ^{14}C method (AMS) (see Fig. 7).

[18] Based on field observations and laboratory results.

Sample number	Lab no.	^{14}C age BP	δ13C‰ PDB
Thesprotia 350 14C KAL06	Ua-38400	3736 ± 50	-27,0
Thesprotia 610 14C KAL06	Ua-38401	8434 ± 64	-26,8
Thesprotia 760 14C KAL06	Ua-38403	11269 ± 76	-27,8
Thesprotia 615 14C KAL04	Ua-38402	12528 ± 84	-27,2

Sample number	Calibrated age 1σ (68.2%)	Calibrated age 2σ (95.4%)
Thesprotia 350 14C KAL06	2204-2116 BC (41.5%) 2099-2038 BC (26.7%)	2291-2016 BC (93.7%); 1997-1980 BC (1.7%)
Thesprotia 610 14C KAL06	7578-7472 BC (68.2%)	7587-7354 BC (95.4%)
Thesprotia 760 14C KAL06	11280-11149 BC (68.2%)	11339-11043 BC (95.4%)
Thesprotia 615 14C KAL04	12966-12495 BC (68.2%)	13082-12272 BC (95.4%)

Sample number	Holocene subdivision	Archaeological time period	Lithological division
Thesprotia 350 14C KAL06	Subboreal	Bronze Age	Organic layer C
Thesprotia 610 14C KAL06	Boreal	Mesolithic	Organic layer A
Thesprotia 760 14C KAL06	Preboreal	Mesolithic	Organic layer A
Thesprotia 615 14C KAL04	Preboreal	Mesolithic	Top Organic layer A

Fig. 7. Dating report of one peat sample from KAL08-04 and three peat samples of KAL08-06. The ^{14}C dating (AMS) was performed by the Tandem Laboratory (University of Uppsala) ^{14}C laboratory

Alluvial fans A, B and C

The sediments in the alluvial fans A, B and C differ slightly in texture, organic matter and $CaCO_3$ content and in the presence of inclusions. The sediments consist mostly of silty clay loam/ silt loam. The material is poorly to moderately sorted, which is typical for alluvial fans.[19] Small sandy peaks do occur in KAL08-01, -04 and -08 (Fig. 8) at around 90 cm, and at deeper levels in KAL08-04 at around 190 cm and 350 cm.

The top of the peat layer underlying fan A (KAL08-4) dates from around 13,000 BC (Late Weichselian) (Fig. 6). The silty clay loam/silt loam layer that covers the peat layer was thus deposited after 13,000 BC. Apparently, the activity of the fan starts, or increases around the Late Weichselian (at the location of KAL08-4) resulting in the deposition of the silty clay loam/silt loam layer. In the clastic layer no peat layers are observed, which means that at the location of alluvial fan A the sedimentation was never interrupted after the Late Weichselian by temporal marsh conditions. The increased alluvial fan activity is due to a complex combination of karstic processes, tectonics, climate and in the last

[19] Summerfield 1991, 222-223.

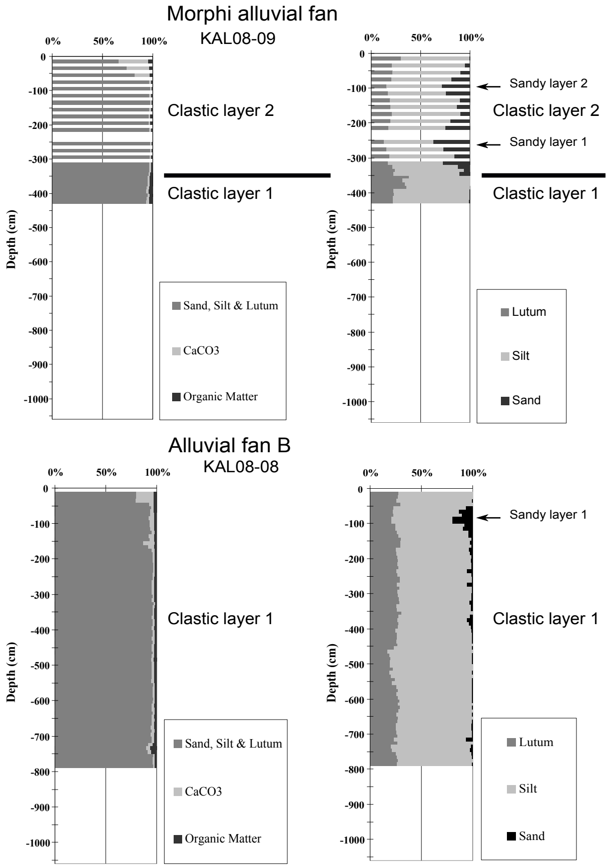

Fig. 8. Lab results of core KAL08-09 (Morphi alluvial fan) and KAL08-08 (alluvial fan B). In core KAL08-09 a sudden coarsening of the sediments is visible at a depth of around 350 cm below the surface (boundary clastic layers 1 and 2). The arrows indicate intervals where coarser intervals occur in the sediment characteristics (sandy layers 1 and 2). The division in clastic layers and sandy layers is determined per geomorphological unit and does not necessarily correspond between the units.

part of the Holocene, probably also by humans disturbing the natural vegetation. This human impact on the vegetation in the Kalodiki basin can be suggested on the basis of palynological evidence from the basin itself[20] and from Lake Ioannina, around 50 km northeast of the Kalodiki Fen.[21] Deforestation and traditional burning[22] of the natural vegetation in the Kalodiki basin may have led to (severe) erosion and therefore to an increased availability of sediments. Strong evidence of the human-induced destruction of the slope vegetation is the presence of maquis and phrygana vegetation[23] on the southern slopes. The degradation of the natural vegetation in the surroundings of the Kalodiki Fen took place at some stage approximately after 4498±80 BP (ca. 3250 cal BC).[24]

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20 Ioakim and Christianis 1997, 95-104.
21 Gerasimidis *et al*. 2009, 29-37.
22 Traditional burning practices result in fresh young shoots for sheep grazing.
23 Widely regarded as a typical degradation-vegetation type in the Mediterranean (i.e. Tivy 1993, 194).
24 Ioakim and Christianis 1997, 98-99.

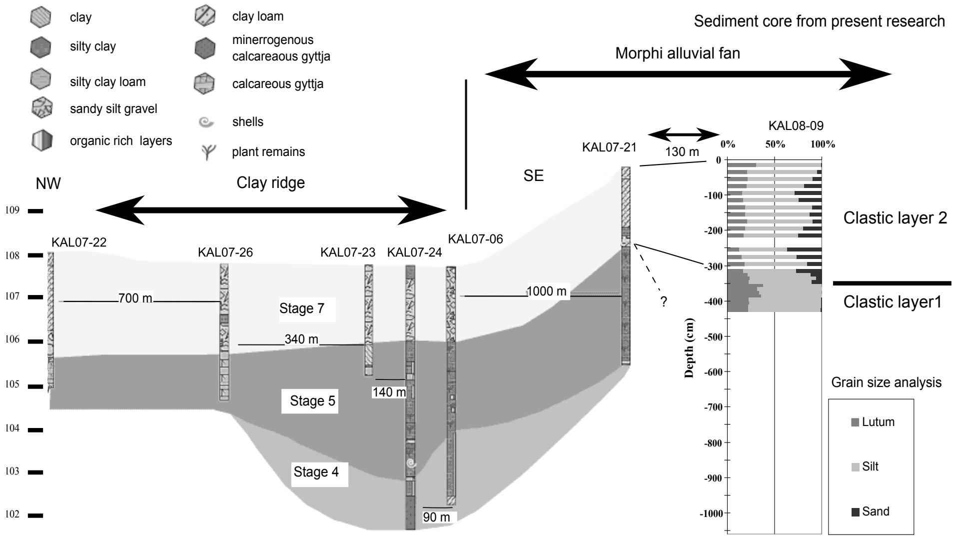

Fig. 9. Correlating clastic layers 1 and 2 discerned in KAL08-09 (Morphi alluvial fan) with the stages of development[26] defined for the clay ridge and Morphi alluvial fan by Graven *et al.* 2009. Given the lithology, clastic layer 2 in KAL08-09 corresponds to stage 7. Clastic layer 1 possibly matches stage 6 (silty clay/clay) or an undefined stage (see also Figs. 7 and 10). KAL08-09 is situated at around 130 m south-east of KAL07-21. Modified after Graven *et al.* 2009. Appendix C6.

During this fieldwork campaign evidence was found that humans did use the flat alluvial fans in the past: a small sherd, coarse and of reddish fabric with a black core (1.5 cm2) was recovered in core KAL08-03 in alluvial fan C at a depth of 210 cm. The sherd is probably of prehistoric (Neolithic/Bronze Age?) date.[25] It was found in an anthropogenic layer, consisting of a clay loam matrix with various inclusions such as small grains, angular rock fragments (dolomite), varying in particle size from several millimeters to a few centimeters, two angular stones (dolomite) and black spots (possibly humics).

Morphi alluvial fan

Core KAL08-09 is located in the Morphi alluvial fan, which is connected to the clay ridge, directly northwest of the Morphi alluvial fan. The dimensions of this alluvial fan are far greater than the smaller alluvial fans located on the opposite side of the basin (Fig. 1). A different depositional pattern developed here than in the southern margins of the basin in alluvial fans A, B and C. Less fluctuations in grain size distributions are recorded in core KAL08-08 (alluvial fan A) than in core KAL08-09 (Fig. 8). In core KAL08-09 up to a depth of 350 cm below the surface, the sediments are relatively fine and deposited under low energy conditions. These silty clay loam deposits are referred to as clastic layer 1 in Fig. 6. In the upper 350 cm of the sequence, clastic layer 2 consists of silt loam, and shows at least two sandy, coarse-grained peaks, described as sandy layers 1 and 2. They are especially well observed in the lab results (Figs. 8, 9 and 12). These levels are interpreted as being the result of increased activity of the Morphi alluvial fan

[25] According to Jeannette Forsén.
[26] Graven *et al*. 2009, 22-23, Appendix C2.

Present study		Graven *et al*. 2009	
Morphi alluvial fan KAL08-09		Morphi alluvial fan and clay ridge KAL07-22, -26, -23, -24 -06 and -21	
Lith. division	Lithology	Stage	Lithology
Clastic layer 2	Loam and clay	Stage 7	Clay loam and sandy silt gravel
Clastic layer 1	Loam and clay	Stage 6	Silty clay/clay
		Stage 5	Minerogenous calcareous gyttja/few organic layers
		Stage 4	Minerogenous calcareous gyttja/few organic layers

Fig. 10. The lithological subdivision of the present study correlated with the stages of development on the Morphi alluvial fan.

with relatively high runoff velocities and erosion energy. The sandy peaks are interrupted by a phase of a gentler runoff and relatively low erosion energy, interpreted as based on finer-grained, but still relatively sandy intervals.

It seems that this phenomenon is local, as it is not observed in the same way in cores on the southern side of the Kalodiki basin. The southern margins of the Kalodiki Fen can be characterised as relatively less active compared to the Morphi alluvial fan (Fig. 8). The sedimentation pattern observed in core KAL08-09 shows similarities with cores located on the clay ridge and the Morphi alluvial fan described by Graven *et al*. 2009. Also here, two relatively coarse peaks were observed in the upper part of the sediment sequence of several cores.

The two clastic layers 1 and 2 (Figs. 8, 9 and 12) that are discerned in core KAL09-09 can be correlated with the lithological units in the sediment cores described in Fig. 2.[27] It seems plausible that the upper part of the sequence, loam and clay of clastic layer 2, can be allocated to stage 7 represented by clay loam and sandy silt gravel in cores KAL07-22, -26, -23, -24, -06 and -21 (Fig. 9). Stage 7 is present all around the eastern shore of the big fen, forming the top of the sequence.

The underlying clastic layer 1 in KAL08-09 is more difficult to correlate. The texture description of silty clay/clay in stage 6 forms the best fits for the loam and clay in clastic layer 1 based on its lithology (Fig. 10). In KAL08-09 stage 5 may be present deeper than 425 cm, or stage 5 may have been (partly) destroyed by erosion at this location.

Big fen

The lithological sequence earlier found in pollen core K-26[28], retrieved from the big fen, is very much comparable to the profile found in cores KAL08-06 and KAL08-07 (Fig. 11). Clay layers were recognized at around the same depth, and the clay layers could therefore (in this part of the basin) be considered isochronous. When combining the radiocarbon dates for K-26 with the levels dated for KAL08-06, we can date the base of clastic layer 2 before 4498±80 BP (ca. 3250 cal BC) and the top before 3736 ± 50 BP (2000 cal BC) (Fig. 12).

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[27] Based on Graven *et al*. 2009.

[28] Ioakim and Christianis 1997, 95-104.

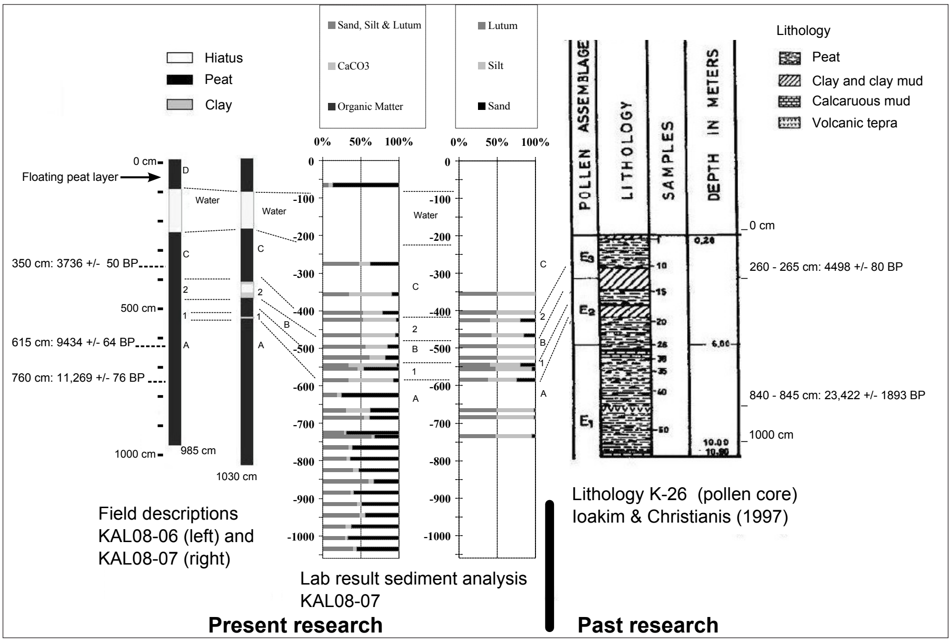

Fig. 11. Correlation. Field (left) and lab (middle) results of KAL08-06 and KAL08-07 compared to the pollen core K-26 by Ioakim and Christianis 1997 (right). Also indicated are the radiocarbon dates. The ground level in K-26 corresponds approximately to the 250 cm level in KAL08-06 en -07: there is no floating peat layer in K-26. Layers A, B, C and D represent organic layers (peat) and 1 and 2 are layers with a relatively low clastic component and an increased clastic and CaO_3 component.

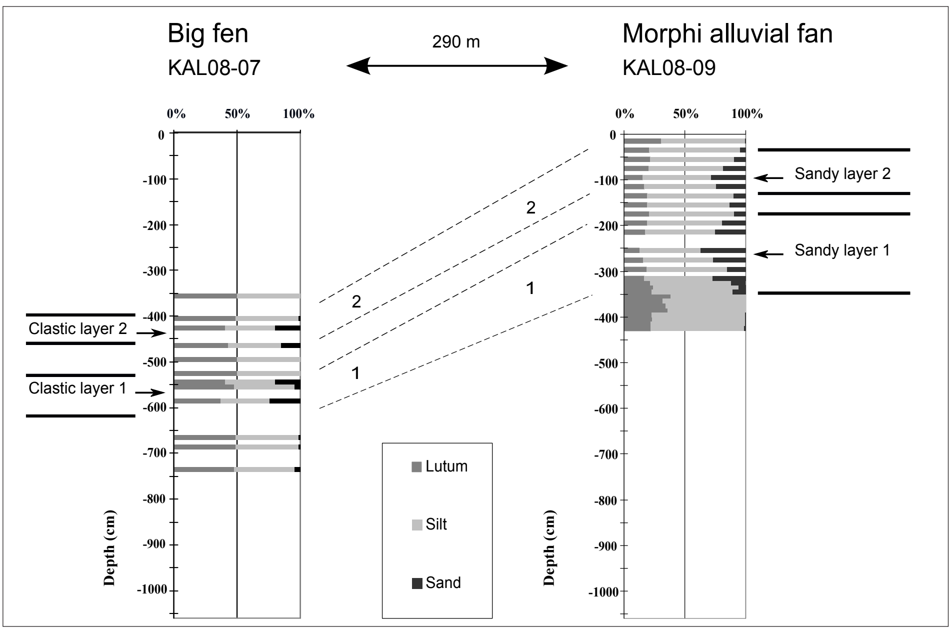

Fig. 12. Correlation of the sediment data (lab sediment analysis) of KAL08-07 (Big fen) and KAL08-09 (Morphi alluvial fan). Clastic layer 1 (KAL08-07) corresponds to Sandy layer 1; clastic layer 2 corresponds to sandy layer 2.

Correlation of sedimentation characteristics of the big fen and the Morphi alluvial fan
When comparing the grain size distributions of core KAL08-07 to the grain size distributions of the Morphi alluvial fan (KAL08-09), similarities in particle size distribution are striking. In both cores, relatively coarse-grained peaks are present in the grain size distributions. In Fig. 6 these coarse-grained peaks are described as sandy layer 1 and 2 for KAL08-09) and *clayey layer 1 and 2* for KAL08-07 (Fig. 11). These *sandy layers with small grains* and *clayey layer with sand grains* respectively can also be correlated with the clayey layers that are detected on several locations in the fen deposits as shown by Ioakim and Christianis 1997 and Botis *et al*. 1993 (for example K-26, Fig. 12). They are also recorded by Graven *et al*. 2009 on the Morphi alluvial fan and the clay ridge which is connected to the Morphi alluvial fan. The youngest of these layers is usually thicker but in composition they are identical.

These data suggest that the largest alluvial fan of the basin, the Morphi alluvial fan, is also the major source of sand and clay material throughout most parts of the fen[29] after a tectonic event took place. This tectonic event (for example an earthquake) can be dated, on the basis of lithological correlation combined with several ^{14}C-dates from the present study and previous palynological study by Ioakim and Christianis 1997 (Fig. 12), to have taken place after 8434 ± 64 (ca. 7500 BC, Boreal/Mesolithic) and before 4489 ± 80 (ca. 2500 BC, Subboreal/Bronze Age).

Human impact in the Kalodiki basin
What exactly caused these two high previously mentioned energy deposition phases to take place is yet unknown. A reduction in the density of the vegetation cover may have increased erosion processes. Plants protect the soil from impacting rain drops, and their root systems prevent further transport of soil particles. Apart from natural explanation such as climate change, it is also possible that humans damaged the vegetation cover on the Morphi alluvial fan, causing the development of the most recent sandy layer with small grains (sandy layer 2) in core KAL08-09 and the clayey layer with sand grains (clastic layer 2) in KAL08-06 and core KAL08-07. This would have taken place approximately in the period between 4498±80 BP (ca. 3250 cal BC) and 3736 ± 50 BP (2000 cal BC). This period corresponds mainly to the Early Bronze Age. The small sandy peaks in cores KAL08-01, -04 and -08 on the other geomorphological units may also correlate with this clayey layer with sand grains (clastic layer 2) in core KAL08-06, KAL08-07 and sandy layer 2 in core KAL08-09.

Evidence for agricultural practices, dating from the Early Bronze Age, was found by the Thesprotia Expedition at the site PS 12, which is located a distance of ca. 15 km to the north of the Kalodiki Fen, more exactly on the lowermost slope of the Liminari hill. At PS 12 chipped stone with sickle gloss and large amounts of bones of cattle, sheep and goat were found.[30] Palynological data from the Kalodiki Fen give further evidence for agricultural practices and indications for the development of maquis and phrygana vegetation in the (wide) surroundings at some stage after approximately 4498±80 BP (ca. 3250 cal BC).[31] Further away, in the area around Ioannina (around 50 km northeast of the

[29] Botis *et al*. 1993, 32.
[30] For the site in general, see Forsén *et al*., this volume, site PS 12, or Forsén and Forsén forthcoming. The animal bones are being studied by Vivi Deckwirth and will be published in *Thesprotia Expedition* III.
[31] Ioakim and Christianis 1997, 98-99. See also previous research above.

Kalodiki basin), palynological evidence suggests that forest vegetation decreased during the period 4500-2400 BC due to human impact.[32]

Pollen preservation

The absence of pollen in KAL06 is interpreted as being the result of the poor preservation conditions in the Kalodiki Fen. The most important processes in this regard are the fluctuating water levels in the fen due to the Mediterranean climate, which may have led to intermittent dry conditions. The fluctuating water levels have caused temporally oxidising circumstances (and subsequent oxidising of pollen grains) and mechanical degradation of pollen due to swelling and shrinking of the pollen grain. The relatively high pH values that prevail in the fen might be of less importance in the degradation process, as pollen were detected in calcareous gyttja in the Kalodiki Fen in 2007.[33]

The pollen core K-26[34] retrieved during a fieldwork campaign by Ioakim and Christianis and KAL08-06 are both taken from the same area of the Kalodiki Fen and share a similar lithological build-up. The difference in pollen preservation may be explained by local variations in hydrological conditions. Another possibility is that pollen destruction increased rapidly in the southeast part of the basin between the mid-1990s[35] and 2008 as a result of a deterioration of the hydrological conditions (i.e. desiccation of the basin). Finally, it cannot entirely be excluded that pollen were destroyed during transportation and/or storage of the sediment samples or during the preparation of the pollen slides

Conclusions and future research

The Kalodiki basin is considered an area with a high archaeological potential. It is a unique natural basin in Thesprotia given its location close to the sea, the availability of fresh water throughout the Holocene and other natural resources associated with the fen. Compared to other basins (Limnoula and Prontani) the Kalodiki Fen also constitutes (and constituted) the largest fresh water supply in the region throughout the Holocene. The relatively flat alluvial fans and the clay ridge provide suitable locations for agricultural practices and (temporary) settlement. In this study, archaeological and lithological evidence is found that may confirm this settlement theory; however, more (archaeological) evidence is necessary.

Landscape reconstruction based on lithological criteria in the southeastern part of the Kalodiki Fen resulted in the following discoveries:

- The hypothesis that the Morphi alluvial fan was activated as a result of a tectonic event (for example an earthquake) in Graven *et al*. 2009 is supported by the lithology found in core KAL08-09 on the Morphi alluvial fen.
- The period of increased activity of the Morphi alluvial fan that occurred after the tectonic

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[32] Gerasimidis *et al*. 2009, 35.
[33] Graven *et al*. 2009, 22-23. Appendix C2. For further information on pollen preservation, see Kars and Smit 2003, 47-49.
[34] Ioakim and Christianis 1997, 95-104.
[35] After 1992, when fieldwork was performed for the article Botis *et al*. 1993.

event is likely to have taken place after 8434 ± 64 (ca. 7500 BC, Boreal/Mesolithic) and before 4489 ± 80 (ca. 3250 BC, Subboreal/Bronze Age).
- After the tectonic event, the sedimentation behaviour of the Morphi alluvial fan shows at least two high-energy deposition phases, resulting in the deposition of two sandy layers with small grains (sandy layers 1 and 2; KAL08-06 and KAL08-07) reaching into the deeper parts of the southeastern part of the basin (clayey layers 1 and 2; KAL08-09).
- The youngest sandy layer with small grains (sandy layer 2), found in the subsurface of the Morphi alluvial fan, was deposited between 3250 and 2000 cal BC. This layer may be (partly) attributed to human impact on the vegetation cover of the Morphi alluvial fan.
- Alluvial fan A (and possibly also fans B and C) gradually expands during the Late Glacial.
- The presence of a sherd (Bronze Age/Neolithic?) in alluvial fan C, found in a context that was interpreted as an anthropogenic layer, may point at the presence of an archaeological site in alluvial fan C.

The archaeological potential of the Kalodiki fen, and the possibilities of multi-proxy analysis (such as lithology, pollen, macro remains and molluscs) on the lake sediments, make the Kalodiki area unique and well suited for further (geo)archaeological research. However, when future palynological research is performed it should be taken into consideration that pollen numbers might be significantly reduced locally. More detailed palaeobotanical research of sediment cores in the fen is suggested in combination with high-resolution information on the sedimentological build-up of the Morphi alluvial fan. This may shed new light on the role humans played in the erosion and sedimentation processes in the Kalodiki basin. Moreover, an intensive coring programme on the alluvial fans may reveal more traces of past human occupation, covered and thus protected by younger sediments. Below the groundwater table, in the distal part of the alluvial fans, organic archaeological material might be well preserved.

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