



Quaternary river sedimentary sequences of the Voidomatis basin

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Vol. 2: Klithi in its local and regional
setting

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Dr Jamie C. Woodward, School of Geography, University of Leeds, Leeds, LS2
9JT, UK. E-mail: jamie@geog.leeds.ac.uk TEL/FAX: 0113 233 6838 / 3308

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Chapter 17

Quaternary River Sedimentary Sequences of the Voïdomatis Basin

Mark Macklin, John Lewin & Jamie Woodward

Quaternary river deposits both in the Old World (e.g. Huntington 1910; Higgs & Vita-Finzi 1966; Vita-Finzi 1969) and the New World (e.g. Bryan 1941; Hack 1942) have long been recognized by archaeologists and geomorphologists alike as being particularly important sources of evidence for elucidating interrelationships between environmental change and prehistoric human activity. They provide data which complement those from lake and rockshelter sediments, with an additional attribute in that river terraces and alluvial fills may be major landscape features which change over time to provide a varying setting for human activity and exploitation. River systems in the Mediterranean region during Quaternary times, in common with many others in central and northern Europe (Starkel 1985), responded in a sensitive manner to variations in sediment delivery rates to valley floors and also changes in hydroclimatological regimes (see Macklin *et al.* 1995 for a recent review). Episodes of alluviation in the Mediterranean have been attributed both to climatic controls (Bintliff 1975; 1977), epitomized by Vita-Finzi's (1969) now classic subdivision of valley sediment sequences in the region into 'Younger' and 'Older' Fills, and also anthropogenic influences (Davidson 1980). Later workers (Gilbertson *et al.* 1983; Gomez 1987; Lewin *et al.* 1991; Pope & Van Andel 1984; Van Andel & Zangger 1990; Wagstaff 1981), however, have questioned the applicability of Vita-Finzi's model to regionally diverse and stratigraphically complex alluvial chronologies, whilst neotectonic activity is now seen as an important factor (King *et al.*, Chapter 28; Harvey & Wells 1987), as Vita-Finzi's own later work has underlined (Vita-Finzi 1986).

The Upper Palaeolithic coincided with the climatic fluctuations of the last major glacial-interglacial cycle, when the development and decay of glaciers, and the effects of cold-climate periglacial processes transformed the erosion/deposition

systems of many Mediterranean rivers. Whilst Late Würm glaciation of mountains in the Mediterranean is now quite well established (Lewin *et al.* 1991; Sibrava *et al.* 1986; Woodward *et al.* 1995), with cirque glaciers down to 1500–1900 m in southern Italy for example (Palmentola *et al.* 1990), the exact timing of glacial conditions in relation to human activities is not well understood. The examination of Palaeolithic sites in Epirus by the Klithi project provided an ideal field setting in which to use modern geomorphological, sedimentological and geochronological techniques to examine prehistoric archaeological sequences within the context of changing Quaternary riverine environments in a key area for European Palaeolithic studies. Fieldwork in the Voïdomatis was carried out by the authors between 1986 and 1988. A series of papers have already been published on the relationship between Pleistocene glaciation and human settlement (Bailey *et al.* 1990; Woodward *et al.* 1995), river response to Late Quaternary climate change (Lewin *et al.* 1991), and long-term variations in alluvial sediment sources (Woodward *et al.* 1992) and soil chronosequences on river terraces (Woodward *et al.* 1994). This chapter summarizes this work within the broader context of the Klithi project, presents a new interpretation of the Late Pleistocene river record of the Voïdomatis in the light of recent palaeoclimate reconstructions from the GRIP and GISP2 ice cores drilled through the Greenland ice sheet at Summit (Johnsen *et al.* 1992; Taylor *et al.* 1993), and focuses on the implications of these environmental and climatic changes for human occupation of the Voïdomatis basin.

The Voïdomatis basin

Geomorphological investigations have centred on the Voïdomatis basin (drainage area 384 km²) and in particular on a 17.8 km reach of the Vikos and Lower

Vikos Gorge (Fig. 17.1). In broad terms, this catchment is developed in hard limestones overlain by folded and deformed flysch strata, the latter being thin-bedded alternations of fine-grained clay/silt and coarser-grained siliceous sandstones (Bailey *et al.*, Chapter 16). Some of the limestones contain bands of chert, but for the most part they are extremely pure calcium carbonates. There are also some limited areas with igneous rock outcrops, the Pindus

Ophiolite. This is found more widely further to the east of the Voidomatis basin itself.

On the basis of geology and topography, five separate physiographic zones can be recognized in the Voidomatis basin (Table 17.1) (Lewin *et al.* 1991; Bailey *et al.*, Chapter 16). There is, first, a mountainous limestone region in the eastern and northeastern part of the catchment close to the village of Tsepelovon. Here, fresh glacial landforms (cirques, cirques,

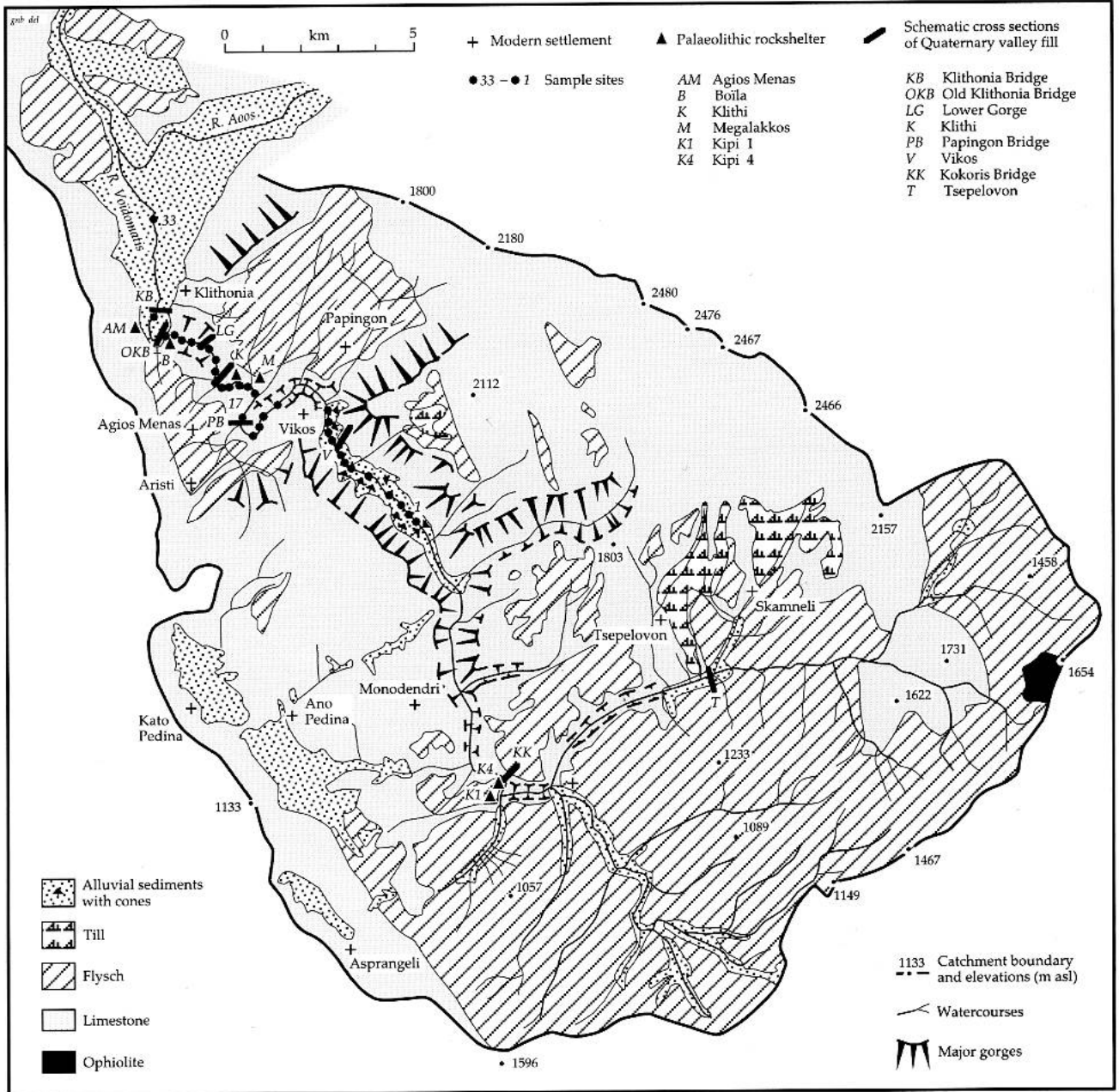


Figure 17.1. The Voidomatis River basin, showing its drainage network, solid geology, location of major Palaeolithic rockshelters and location of study and sample sites. (Redrawn from Lewin *et al.* 1991.)

U-shaped valleys, lateral moraines, and kame terraces) are well developed, and extensive glacially-related sediments (tills, glaciofluvial deposits) indicate recent glaciation. Mountain elevations exceed 2400 m along the crests of the Gamila range. Second, a dissected flysch basin (of Late Eocene–Miocene age) is to be found upstream of Kipi; this lay beyond the limits of glaciation and displays many of the classic ‘badland’ slope forms typical of semi-arid regions elsewhere in Greece and the Mediterranean (Woodward 1995). The third subregion is the Upper Vikos Gorge, between Monodendrion and Vikos, which is judged to be one of the most spectacular in the whole of the Balkans. The gorge is cut in Eocene and Jurassic limestone and has near vertical sides which are in places >800 m high, although the gorge itself is only about 2.5 km across at its widest point. Talus cones (>40 m thick) and aprons mantle the walls of the gorge and locally cover or interdigitate with coarse-grained alluvial sediments (>20 m thick) that infill the gorge floor. The fourth physiographic unit is the Lower Vikos Gorge that contains the majority of the Palaeolithic rockshelter sites. This is separated from the main Vikos Gorge at a point, 2 km southeast of Papingon, where the Voïdomatis leaves the confines of the Gamila Massif. It extends downstream as far as Old Klithonia Bridge where its narrow limestone walls, up to 150 m high, open out onto the Konitsa basin. Alluvial fans are well developed at the mouths of a number of tributary streams in the lower gorge that drain areas of flysch bedrock (e.g. 2 km northeast of Aristi), which outcrop on the upper slopes of a considerable part of the Lower Vikos Gorge. Where the floor of the gorge widens, dissected colluvial sediments (>15 m thick), and terraced alluvial deposits (>25 m thick), are well preserved. The fifth and final physiographic unit is the Konitsa basin. This is a fault-controlled graben of Tertiary age into which the Voïdomatis and Aaos Rivers flow. The active channel and floodplain of the Voïdomatis are rarely more than 200 m wide in the Konitsa basin, but on both sides

there are extensive Quaternary alluvial deposits whose surfaces lie 1–5 m above river-bed level.

These five physiographic units have all delivered sediment to the river though each area has operated differentially over time. The upper part of the Voïdomatis catchment has also provided material whose characteristics are diagnostic of source area. These lithologically distinctive headwater sub-basins are underlain either by a single rock type, for example, the flysch basin upstream of Kipi and the Eocene and Jurassic limestone in the Upper Vikos Gorge and Tsepelovon district, incorporate a small area of petrographically distinctive bedrock, e.g. the ophiolite complex in the most eastern corner of the catchment — or contain localized glacial deposits. Analysis of the lithological composition of Quaternary alluvial deposits in the middle and lower reaches of the Voïdomatis has allowed these sediment sources to be readily identified (Lewin *et al.* 1991; Woodward *et al.* 1992).

The rockshelters of the Voïdomatis basin are all located in close proximity to areas of Quaternary alluvial sedimentation, even though later dissection has eroded and lowered the valley floor deposits. Alluvial and colluvial units are well exposed on both the sides and floor of the Vikos Gorge, and in conjunction with the archaeological material, they provide a very useful basis for environmental reconstruction. Fluvial sedimentation is inherently episodic in nature, with periods of cut and fill, erosion and deposition episodes following one another, and for that reason they provide a less continuous record than that available from other sorts of deposits, for example lacustrine ones. Locally, however, alluvial units can cover a more extended timespan than is available from either rockshelter or lake deposits (see Chapters 18–20), and this is certainly true of the Voïdomatis. The environmental changes recorded also reflect an intermediate *spatial* scale, integrating environmental effects in the 384 km² of the river catchment, which is somewhat larger than that of the main rockshelter sediments (though some

Table 17.1. *Physiographic units in the Voïdomatis basin.*

	Area	Geology	Drainage density	Local relief
Glaciated region	19.2 km ²	Palaeocene to Eocene limestone	0.16 km/km ²	≈500 m
Headwater flysch terrain	153.6 km ²	Late Eocene to Miocene flysch	0.84 km/km ²	≈150 m
Vikos Gorge and adjacent karst plateaus	117.2 km ²	Jurassic to Eocene limestones	0.26 km/km ²	≈1000 m
Lower Vikos Gorge & adjacent flysch exposures	57.6 km ²	Palaeocene to Eocene limestones & Late Eocene to Miocene flysch	0.76 km/km ²	≈200 m
Konitsa plain	38.4 km ²	Quaternary alluvial sediments	0.24 km/km ²	<20 m

fine-grained aeolian material may have blown in from outside the basin: Woodward, Chapter 19), and probably the lake pollen evidence, but less than the regional scale discussed in Chapters 28–30.

Methods of investigation

Morphostratigraphic relationships between Quaternary alluvial and colluvial fills in the Voïdomatis basin were established by extensive field reconnaissance and detailed morphological mapping. In addition, at 33 sites within the Vikos Gorge and the Konitsa basin, from a point 5 km north of Monodendrion, to a point 1 km northeast of Klithonia (Fig. 17.1), an aneroid barometer was used to measure the height of river terraces and fans (to the nearest 0.3 m) above a fixed local datum. The heights of the rockshelters, measured at present floor level, were also determined. At 8 locations along the Voïdomatis (shown and listed in Fig. 17.1) exceptionally good exposures of valley fill sediments, mostly in currently eroding river bank sections, allowed detailed examination of Quaternary alluvial and colluvial deposits in all of the 5 major physiographic units described above. At these sites the sedimentary properties, sequence and architectures of all Quaternary units were recorded. Sediment logs from a further 32 sites, at which sections were rather less extensive laterally or vertically, were used to supplement and in places refine lithostratigraphic relationships (see Lewin *et al.* 1991).

Lithological and mineralogical analyses of both the gravel (8–256 mm) and fine sediment (<63 µm) fractions were carried out on a range of fluvial, colluvial and glacial Quaternary deposits. More than 50 samples of the fine-grained sediment that forms the matrix of the coarse-grained Quaternary deposits were examined for their mineralogical composition with XRD techniques (Woodward *et al.* 1992). The lithologies of 21 gravel-size sediment samples, including present day river bed material and all Quaternary alluvial units hitherto identified in the study area, have also been analyzed (Lewin *et al.* 1991). Field procedure for

analyzing gravel lithologies consisted of marking-out a one metre square on the section to be sampled, removing all clasts exposed on the surface, and then establishing their size over the range 8–256 mm using templates graduated at 0.5 Ø intervals (Fig. 17.2). The weight and number of clasts in each size fraction were counted and all were assigned to one of four predetermined lithological classes — limestone, flysch, flint or ophiolite rock types. This entailed hand sieving 4.75 tonnes of gravel and measuring 16,263 clasts.

The degree of soil development on the major terrace surfaces was also investigated, with analysis of CaCO₃ and organic content, particle size, magnetic susceptibility and iron content (Woodward *et al.* 1994). Though not the primary means of age sequencing of alluvial units (*cf.* Pope & Van Andel 1984), this analysis has been used to confirm and extend conclusions reached through other dating and lithostratigraphic procedures.

Finally, the alluvial deposits in the basin have been dated by a range of isotopic (radiocarbon) and radiogenic (TL, ESR) dating techniques. Organic materials have been dated at two sites in the Konitsa basin and at one in the Lower Vikos Gorge. Three TL sediment dates, and three ESR dates from a deer tooth incorporated into alluvial sediment at Old Klithonia Bridge, have also been obtained.

Quaternary river deposits in the Voïdomatis basin

Four Quaternary alluvial units that pre-date the contemporary floodplain have been identified in the Voïdomatis basin. Their sedimentary properties, height relationships, depositional environments and estimated ages are summarized in Table 17.2, and Figures 17.3 & 17.4. The names used for all alluvial units are informal and they are described below in order of apparent age.

(i) Kipi Unit

This is the oldest alluvial fill yet identified in the study basin. To date it has been recognized only at one site near Kokoris Bridge, 1.5 km west of Kipi, in a road cutting where 22.9 m of the unit was exposed (Fig. 17.5). A TL date of >150,000 ka (BM ref VOI26, Appendix A) was obtained from silts close to the base of the section, and this gives a minimum age for the deposition of the unit.

The Kipi alluvial fill is highly weathered and comprises flat-bedded, imbricated sandy gravels which grade down valley into cross-stratified sands. The contact between vertically contiguous gravel units is generally non-erosional and frequently marked by thin beds (<0.2 m) of laminated silts. Coarser sediments within the Kipi Unit are interpreted as longitudinal/mid channel bar-forms deposited in an aggrading, low-sinuosity river system, with sands and silts representing bar-tail fines and bar-surface drapes, respectively. The surface of the Kipi terrace lies 56 m above present river-bed level, is underlain by Late Eocene–Miocene flysch, and was clearly deposited before the formation of the limestone gorge in which the Voïdomatis now

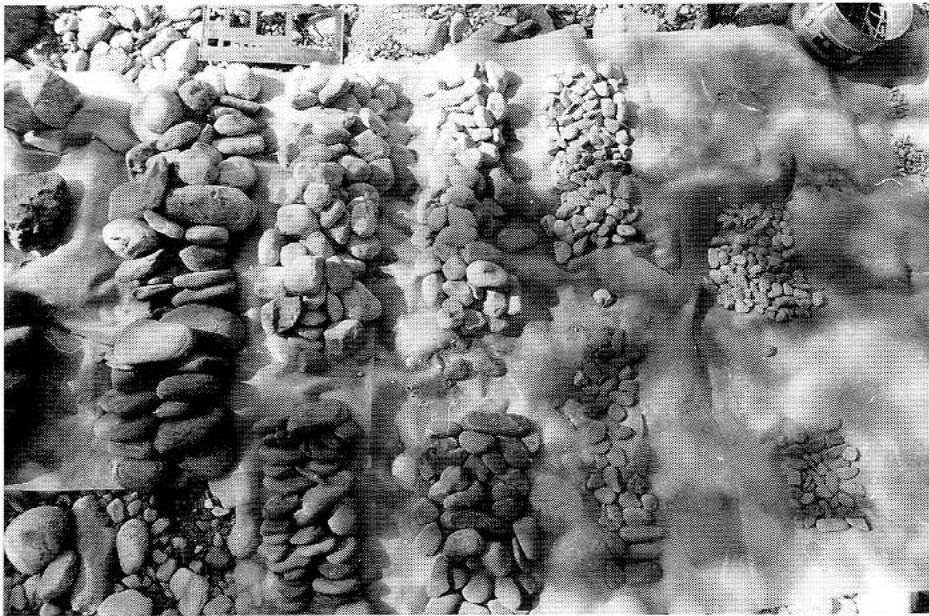


Figure 17.2. Particle size and lithological analyses of Voïdomatis River gravels. Well-rounded limestone gravels above, flatter and rounded flysch gravels below.

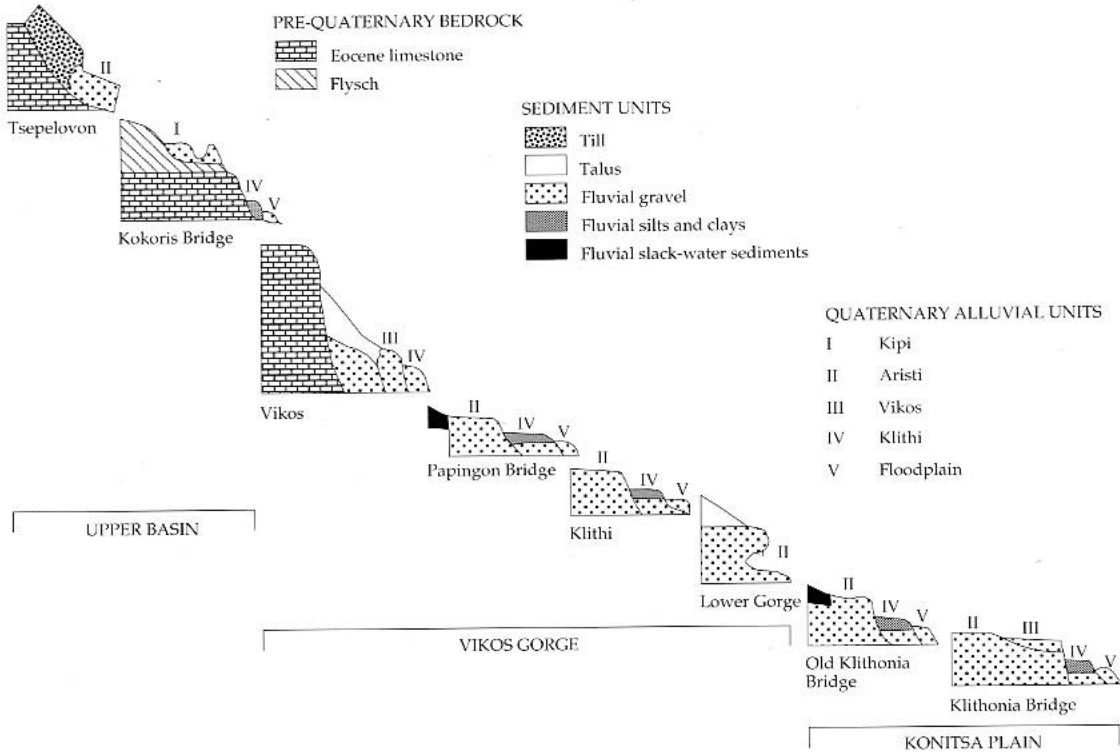


Figure 17.3. Quaternary valley fill sequence in the Voidomatis basin. Locations of schematic cross sections are shown in Figure 17.1.

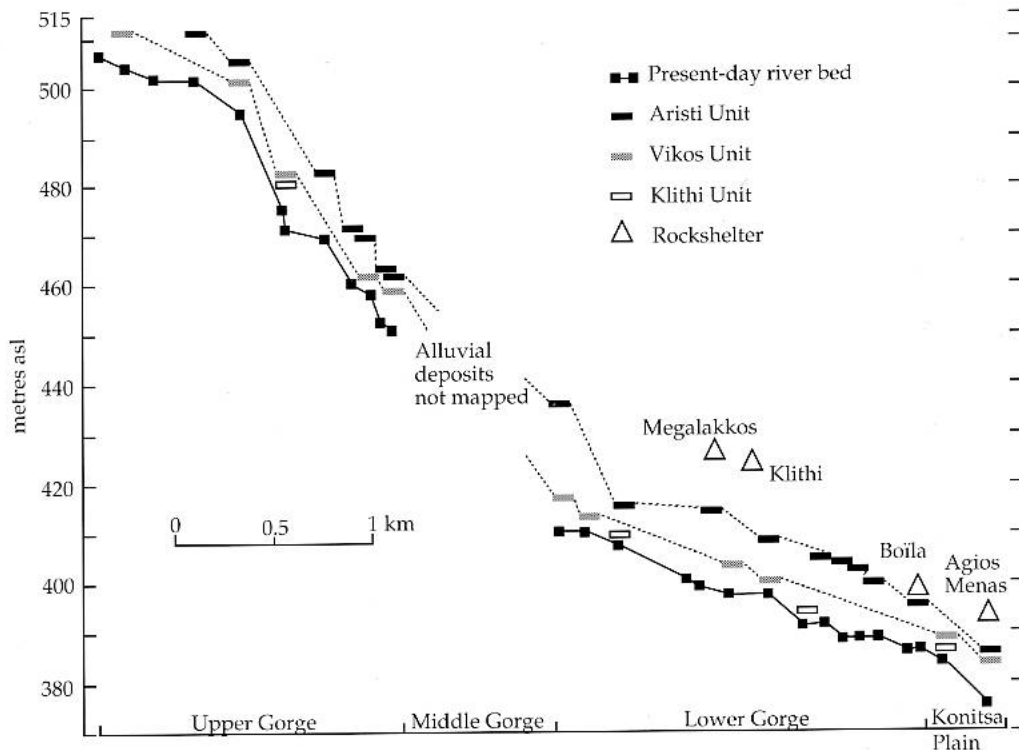


Figure 17.4. Quaternary river terrace surfaces in the Vikos Gorge and Konitsa basin. The heights of major rockshelters above present river bed level are also shown.

flows in this part of the basin. High proportions of ophiolite and flysch rock types and low amounts of limestone (Table 17.2 & Fig. 17.6) distinguish the Kipi Unit from other Quaternary alluvial fills in the Voidomatis basin. This strongly suggests that in Kipi times the Voidomatis catchment extended further to the east and drained a much larger area of ophiolite terrain than at present. This sub-basin was subsequently captured by the Aaos River.

(ii) *Aristi Unit*

This is the major alluvial fill in the catchment and it can be traced almost continuously from the Tsepelovon moraine complex (Figs. 17.1 & 17.3), where it interdigitates with glacial till, to the present Aaos-Voidomatis junction in the Konitsa basin, more than 40 km downstream. It forms a prominent terrace (Fig. 17.4) whose surface lies on average 12 m above river-bed level. In places the Aristi Unit is more than 26 m thick and consists almost entirely of flat-bedded or massive matrix-rich cobble gravels with occasional boulder-sized clasts (Figs. 17.7 & 17.8). Imbrication of clasts is locally well developed where there is a lower proportion of silt-sized matrix. XRD analysis of the <63 µm (silt and clay) size fraction in the Aristi Unit (Fig. 17.9) shows a mineralogical composition very similar to glacial till at Tsepelovon from which, at least in part, it appears to have been derived. The gravel size fraction of the Aristi alluvial fill also has a similar lithological

composition to the till, containing up to 95 per cent limestone and significant amounts of flint (Fig. 17.6).

The Aristi Unit is believed to be the terraced remnant of a formerly extensive glaciofluvial outwash system that was deposited by an aggrading, low-sinuosity pro-glacial stream which drained a series of valley glaciers in the Tsepelovon region. In common with many contemporary and Pleistocene glacially-fed river systems, suspended sediment loads of the Voidomatis were high during full glacials, as shown by the large proportion of silt and sand-size matrix in the Aristi gravels. The combination of high suspended sediment loads during these periods with the backing-up of tributary streams by the Voidomatis during major floods also resulted in the deposition of several metres of fine-grained slack water sediment (*cf.* Baker *et al.* 1983) at a number of tributary and main valley junctions (e.g. at the Papingon Bridge and Old Klithonia Bridge: Figs. 17.1 & 17.3).

Towards the base of gravels underlying slack-water sediments at Old Klithonia Bridge, part of a red deer jaw bone and a number of Palaeolithic flint flakes were discovered in a small palaeo-channel infilled with sandy silts (Fig. 16.19). The fragility of the bone and the unmodified condition of the flints attest to minimal river transport. A tooth from the mandible was submitted for enamel dating by ESR, using the linear, continuous U-uptake model (Grün *et al.* 1987), and yielded ages of $24,300 \pm 2600$,



Figure 17.5. Kipi Unit sediments exposed in a road cut section near Kokoris Bridge.

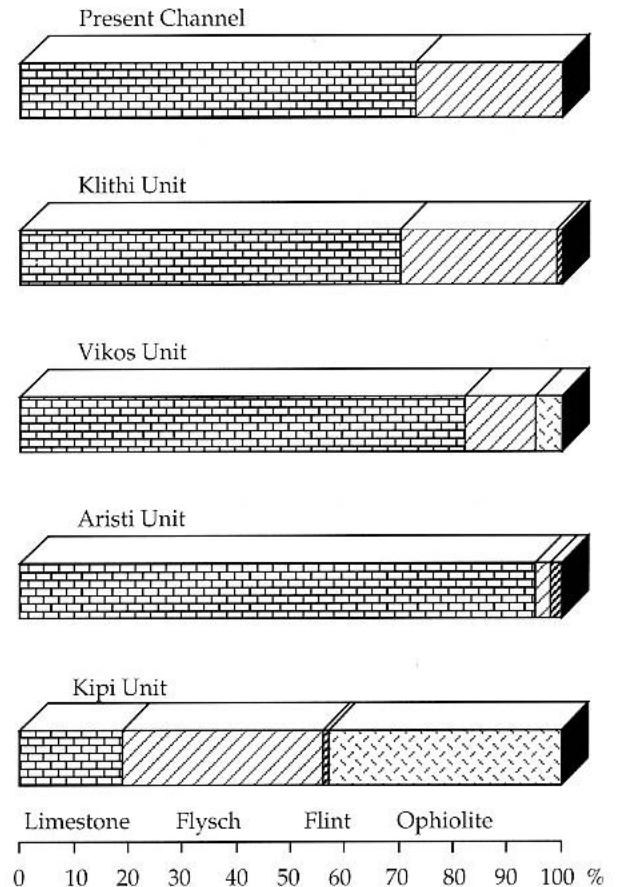


Figure 17.6. The lithological composition of the coarse-grained sediment (8–256 mm) in each of the Quaternary alluvial units.

Table 17.2. Alluvial units in the Voïdomatis basin. See text for the different dating methods used to obtain ages.

Alluvial Unit	Height of terrace surface above river bed level (m)	Maximum observed thickness of alluvial unit (m)	Lithological composition (8–256 mm)				Coarse (C)/ fine sediment (F) member ratio	Fluvial sedimentation style	Age (BP)
			% Limestone	% Flysch	% Flint	% Igneous			
Present channel	–	–	72.7	26.6	0.5	0.2	C > F	Incising, confined meandering gravel bed river. Low suspended sediment load.	< 30
Klithi	x = 3.2 s = 0.7 Range = 1.8–4.5	4.5	69.3	29.6	1.0	0.1	C < F	Aggrading, high sinuosity gravel bed river. High suspended sediment load.	1000 ± 50
Vikos	x = 6.8 s = 1.7 Range = 3.9–9.7	8.3	82.3	12.8	0.6	4.3	C > F	Incised wandering gravel bed river. Low suspended sediment load.	24,300 ± 2600– 19,600 ± 3000
Aristi	x = 12.4 s = 3.9 Range = 6.7–25.9	25.9	94.6	3.1	2.2	0.1	C > F	Aggrading, low sinuosity, coarse sediment river system. High suspended sediment load.	28,200 ± 7000– 24,300 ± 2600
Kipi	56	22.9	18.7	36.7	0.9	44.0	C > F	Aggrading (?) low sinuosity, coarse sediment river system.	>150,000

25,000 ± 500 and 26,000 ± 1900 from three separate dating assays. These ages, together with a TL date of 28,200 ± 7100 (British Museum ref. VOI23, Appendix A) from fine sediments at Old Klithonia Bridge suggest a Late–Middle Würm date for the Aristi Unit, and for the glaciation to which it relates. The alluvial unit was also at least in part being deposited whilst there was Upper Palaeolithic human activity in the Konitsa basin.

Recent analysis of soil profiles developed on the Aristi Unit (Woodward *et al.* 1994) has revealed significant variations in the degree of pedogenic weathering (Fig. 17.10). This suggests that it comprises at least two alluvial fills which relate to different glacial episodes. The youngest of the alluvial fills with Aristi-type sedimentary characteristics can be assigned, as outlined above, to the Late–Middle Würm substage. The older unit obviously pre-dates this, but at the moment, in the absence of independent dating control, it is unclear whether it is of Early Würm age, or, quite possibly, was deposited during a pre-Last Interglacial glaciation.

(iii) Vikos Unit

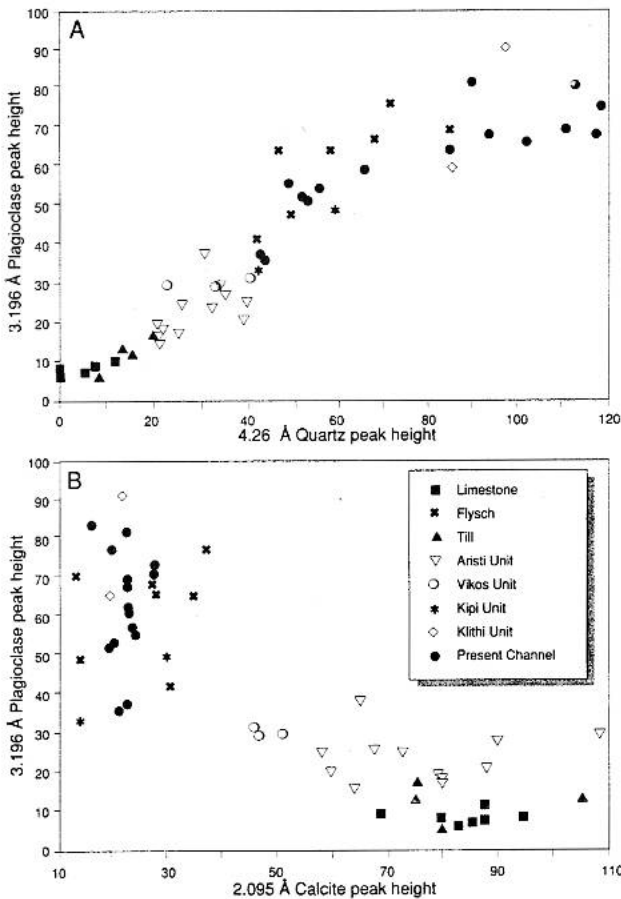
Considered on the basis of the proportion of valley floor that it occupies at any one site, this is a minor unit, but a lithologically and sedimentologically distinctive alluvial fill (Fig. 17.11). Its terrace surface lies 4 m to 10 m above river-bed level and it has a maximum thickness of just over 8 m. It consists of contact-


Figure 17.7. Aristi Unit sediments exposed in a road-cut section near the Papingon–Aristi road bridge on the right bank of the Voïdomatis.

imbricated sandy gravels with a significantly lower matrix content than the Aristi Unit. A fine-grained sediment fill in a channel in the upper part of the Vikos Unit, at sample site 13, 1 km west of Vikos village, has been dated by TL to 19,600 ± 3000 (British Museum ref. VOI24, Appendix A), and gives a minimum age for the unit. Although the fill cannot be traced upstream to the Tsepelovon glacial deposits, the predominance of limestone clasts in its coarse fraction, which is much higher than in more recent alluvial sediments, together with the intermediate mineralogical composition of the fine fraction, suggests input of glacial materials



Figure 17.8. Close-up of Aristi Unit matrix.



(Fig. 17.9). The high percentage of ophiolite rock types, and the flysch-derived matrix fines, also indicate significant erosion of the non-limestone areas of the catchment.

(iv) Klithi Unit

The Klithi Unit (Fig. 17.3) represents the only important episode of valley floor alluviation of demonstrable Holocene age in the catchment. It has many of the sedimentary characteristics of alluvial deposits that have been described in many parts of the Mediterranean basin by Vita-Finzi (1975) and subsequent workers (Wagstaff 1981) as 'Younger Fill'.

The Klithi Unit forms a terrace c. 3 m above present river-bed level and is composed of two distinct lithofacies: an upper unit of thick (up to 2.5 m) crudely bedded sandy silts which fine upwards, and a lower unit of

flat-bedded, contact-imbricated, sandy gravels (Fig. 17.12). This coarse/fine couplet with upward fining is a 'type' example of a sedimentary sequence produced by lateral migration and associated sedimentation in a high sinuosity meandering river (Jackson 1978). The sandy-silts are interpreted as overbank fines and the sandy gravels as within-channel sediments resulting from river bed/bar accretion. The Klithi Unit appears to have been deposited by an aggrading, meandering river system with suspended sediment concentrations in flood waters significantly higher than those of the present day. Comparatively low rates of lateral channel movement during this period allowed the development and subsequent preservation of thick sequences of vertically accreted fine sediment. The fine-grained lithofacies of the Klithi Unit attains its maximum thickness in the Lower Vikos Gorge where mineralogical analyses (XRD) show that it has been derived from erosion of local flysch rocks and soils (Fig. 17.9). Clast lithological analyses also show the Klithi fill to have a high proportion of flysch rock types in its gravel size fraction (Fig. 17.6). Flysch outcrops extensively in this part of the basin and is dissected by

Figure 17.9. Peak height data from X-ray diffraction traces showing the broad mineralogical composition of the <63 μm component of the Voïdomatis glacial and alluvial sediments. (A) Plot showing the strong positive correlation between quartz and plagioclase in the basin sediments ($r^2 = 0.86$). (B) Plot showing calcite and plagioclase relationships (after Woodward et al. 1992). Aristi Unit sediments contain low amounts of plagioclase and quartz and are rich in calcite reflecting their derivation from limestone-rich glacial sediments. Klithi Unit fine sediments are dominated by flysch-derived materials. The fine fraction of the Vikos Unit sediments is intermediate between these two extremes.

numerous gully systems that feed directly into the Voïdomatis, many of which are partially stabilised by vegetation (see Bailey *et al.*, Chapter 16).

Sheets of colluvium consisting entirely of flysch lithologies mantle many parts of the Lower Vikos Gorge and slopes surrounding the Konitsa basin. When seen in section at the margins of the valley floor, colluvial sediment frequently interdigitates with the fine member of the Klithi Unit. Charcoal recovered from the upper part of a sequence of colluvial sediments 200 m downstream from the road bridge at Klithonia (Fig. 17.1) has been dated to between 800 ± 100 BP (OxA-192) and 1000 ± 50 BP (OxA-191), and suggests that this major period of hillside erosion and coeval deposition of the Klithi alluvial fill ended at about 1150 cal AD (Gowlett *et al.*, Chapter 2, Table 2.2). Near the Klithi rockshelter, however, organic deposits radiocarbon-dated as modern (OxA-1747) underlie more than 2 m of flysch-derived alluvial and colluvial sediments, and indicate the continued and rapid development, at least locally, of the Klithi Unit until quite recent times.

There is a close similarity between the thick sequences of overbank fines and colluvium that characterize the Klithi Unit and the widespread 'haugh loams' of central and northwest Europe (Butzer 1980; Macklin & Lewin 1986) and 'Post-settlement alluvium' of North America (Knox 1977), which formed in response to anthropogenically related deforestation and the advent of cultivation. It is probable that deposition of the Klithi Unit followed disturbance of the catchment vegetation by human agency, especially the readily erodible soils on the flysch terrains (Woodward 1995).

Quaternary river environments in the Voïdomatis

It is clear from the evidence presented above that the Quaternary fluvial sedimentary sequence of the Voïdomatis is indeed more complex than the Older/Younger subdivision suggested by the Vita-Finzi model (Vita-Finzi 1969). We have also not found evidence in the local alluvial record for major tectonic activity in the last *c.* 30,000 years, such as faulting within Quaternary river deposits or distortion of river terrace profiles. Over a longer timescale as elsewhere in Northern Greece, tectonics has been important in controlling the pattern of fluvial sedimentation (King & Bailey 1985; King *et al.*, Chapter 28), but within the Voïdomatis basin it appears that climatic fluctuations have had by far the strongest effect on Late Pleistocene river development and the alluvial record.

The Voïdomatis Late Pleistocene alluvial sequence can be usefully assessed in relation to two other palaeoenvironmental records. The first is quasi-continuous long pollen sequences from a number of lake basins in northern Greece. These include the

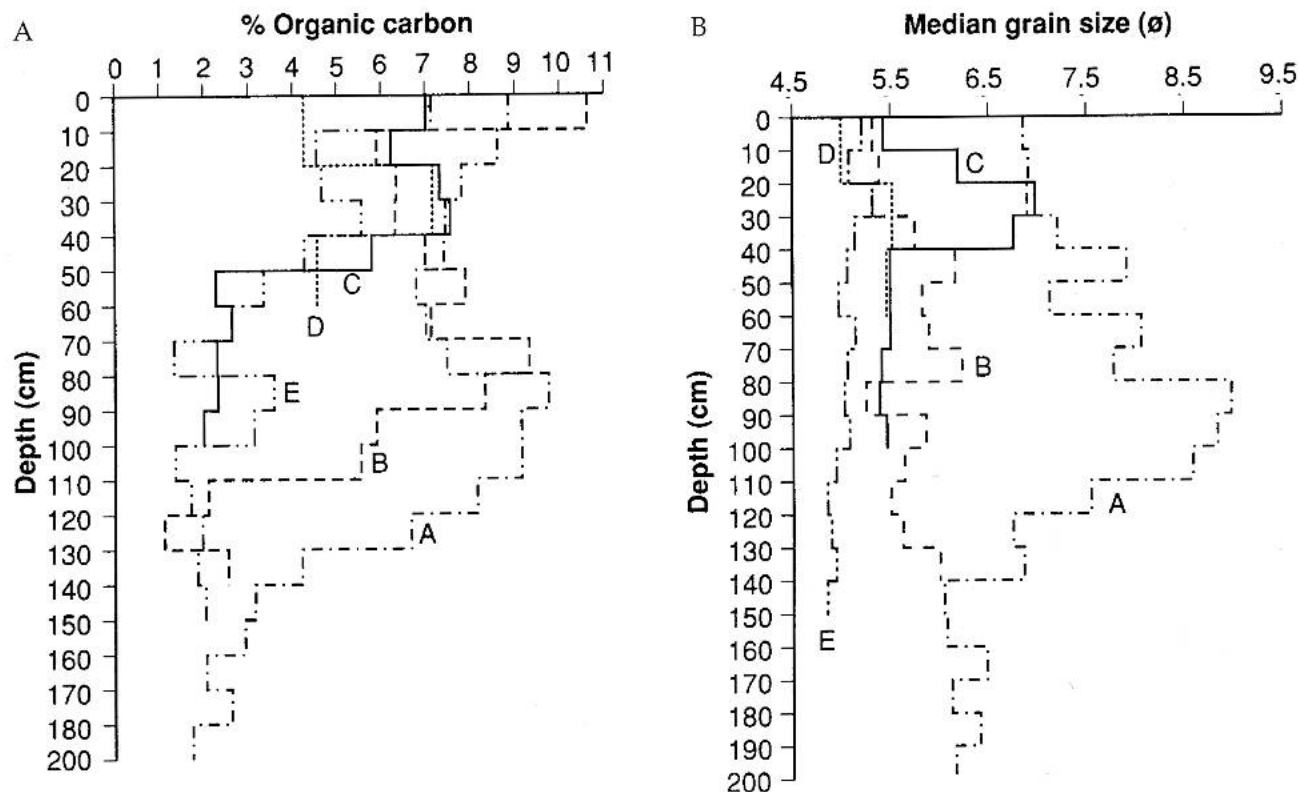


Figure 17.10. Soil profile data from Quaternary alluvial sediments in the Lower Vikos Gorge and Konitsa basin. These plots show (A) changes with depth in organic carbon content and (B) the mean grain size of the fraction $<63 \mu\text{m}$. Profile A = Aristi Unit at site 4, profile B = Aristi Unit at site 7, profile C = Vikos Unit at site 3, profile D = Klithi Unit at site 7, profile E = Klithi Unit at site 5. (After Woodward *et al.* 1994.)

relatively well-dated Tenaghi Philippon site in Macedonia which covers the entire Würm stage (Wijmstra 1969), and also the less well-dated but longer sequence from nearby Lake Ioannina (Bottema 1974; Tzedakis 1993). The second record which can be used as a palaeoclimatological framework is the profile of oxygen isotope ratios from the Summit deep Greenland ice-core Project (GRIP, Johnsen *et al.* 1992). This gives a continuous and very high-resolution record (annual for the most part) of changes in climate and atmospheric circulation for the North Atlantic and adjacent land areas including Europe for the entire period of relevance to the Klithi investigations.

Comparable Late Pleistocene river sequences in Greece, which like the Voïdomatis evidence relate to discontinuous phases of alluviation, have been studied in the Larissa Plain, Thessaly (Demitrack 1986) and, more distantly, in the Southern Argolid

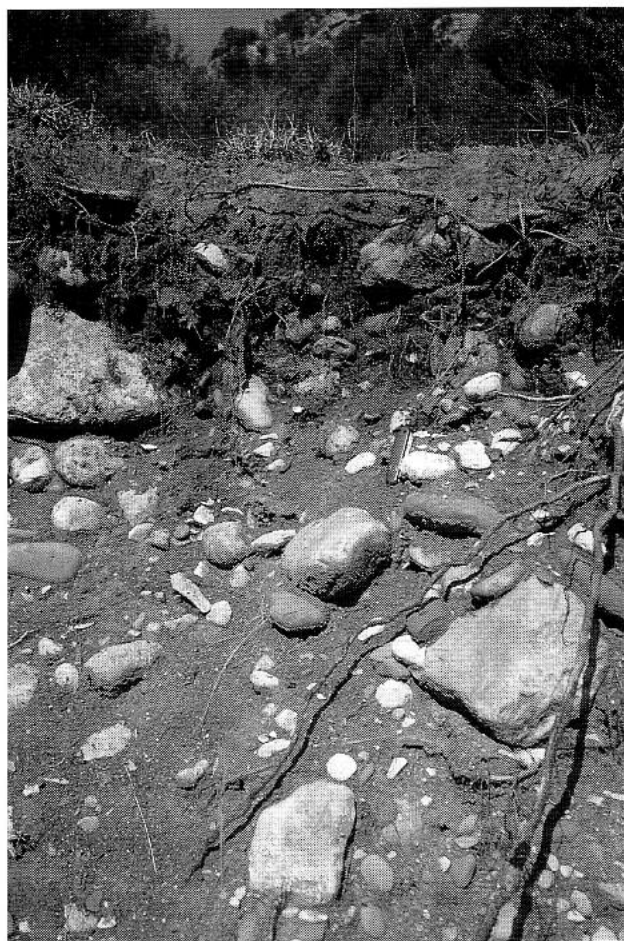


Figure 17.11. *Vikos Unit sediments exposed in a river cut section in the upstream section of the Lower Vikos Gorge.*

(Pope & Van Andel 1984). These studies place greater emphasis on soil mapping and on dating via the age characteristics of soils than do our Voïdomatis studies, but there are also radiocarbon and U-Th dates available. However, correlations between alluvial phases from these studies and those in the Voïdomatis are difficult (Lewin *et al.* 1991).

A particular problem with both lake and alluvial data lies in the comparability and reliability of different dating techniques. For example, work by Bard *et al.* (1990) using U-Th dating of corals has shown that the radiocarbon timescale may be significantly compressed between 9000 and 30,000 BP, with a maximum difference of around 3500 years at around 20,000 BP (see also Gowlett *et al.*, Chapter 2). As we are especially concerned with environmental reconstruction in precisely this time period, it is important to appreciate that alternative dating techniques may need some reconciliation. In order to achieve this, we have used the Bard chronology to convert radiocarbon dates to 'calendar' ages, so that we can directly compare the archaeological sequence with both the TL- and ESR-dated Voïdomatis alluvial fills and the GRIP ice core record. Establishing a common and consistent timescale for both palaeoenvironmental and archaeological data sets is of critical importance for the correct interpretation of human interactions with environmental change in the Voïdomatis basin during the latter part of the Late Pleistocene.

As far as the Upper Palaeolithic is concerned, the Aristi and Vikos Units are the most significant. The Aristi Unit has been dated to between 24,300–26,000 and 28,200 BP using ESR and TL methods, respectively. Judging by the GRIP oxygen isotope ice core record (Fig. 17.13), sedimentation in Aristi times, and the period of glaciation in the upper Voïdomatis catchment to which it is linked, falls within the severest climatic phase of the Late Würm. This coincided with a massive iceberg release (Heinrich event 3: Bond *et al.* 1992) into the North Atlantic Ocean, dated to 27,000 BP, associated with cold North Atlantic surface water, and cold air over Greenland. Low temperatures would also have accelerated rates of frost weathering and rock breakdown. Much of the thick limestone scree deposits in the Vikos Gorge, including the archaeologically sterile basal scree units of the Klithi rockshelter (Bailey & Woodward, Chapter 4; Woodward, Chapter 18), probably formed during this period. The Voïdomatis dates for glaciation are somewhat older than the often quoted time of maximum glacial extent in Europe for the Last Glacial Maximum at c. 18,000, cor-

responding to 21,500 cal BP. This most likely reflects the more rapid response, and greater sensitivity, of small Mediterranean mountain glaciers to climate change compared to the much larger continental-scale ice sheets of northern Europe.

The broader regional picture given by palynological evidence and lake-level data from Tenaghi Philippon, Lake Ioannina and from elsewhere in the eastern Mediterranean, indicates cold winters, intense winter precipitation and summer drought (Harrison & Digerfeldt 1993; Prentice *et al.* 1992). Markedly reduced winter temperatures resulted from strong westerly advection from the cold North Atlantic and the development of a fixed anticyclone over the northern European ice sheet. The drying and cooling effect of these was most likely counteracted in winter by increased storm frequency under a southward-shifted jet stream. This may account for greater runoff and higher lake levels, while at the same time low winter temperatures and a soil moisture deficit during the growing-season would have maintained an open vegetation dominated by *Artemisia* and *Chenopodiaceae* (see also Turner & Sánchez-Göni, Chapter 29). The river regime of the Voïdomatis under full-glacial conditions would have been different from that of today. At present, from early summer to late autumn stream flow is maintained only in the lower reaches of the river, downstream of a major exurgence in the Vikos Gorge. In central and upper parts of the basin, main channel flows are ephemeral and controlled by late autumn and winter precipitation. During Late Pleistocene and earlier glacials, however, peak river flows would have been associated with spring and early summer glacial meltwater discharges, making access to and movement along the floor of the Vikos Gorge very difficult for animals and humans alike. Indeed, the fact that the only archaeological material of this age so far recovered in the Voïdomatis basin is located downstream of the gorge by the Old Klithonia Bridge, points to a very hostile river environment at this time.

Deposition of the Aristi Unit was followed by a major phase of valley floor entrenchment which, on the basis of the 1 σ error ranges of the TL and ESR dates for the Aristi and later Vikos Unit, can be bracketed to some time between 24,500 and 21,000 BP. This places this interval of erosion within Johnsen *et al.*'s (1992) interstadial number 3 (Fig. 17.14). Climatic amelioration would have reduced sediment supply both from glacial sources (with glacier retreat) and also from those parts of the Voïdomatis basin unaffected by glaciation, which would have witnessed lower rates of mechanical rock weathering

and stabilization of hillslopes by vegetation.

The TL date on the upper part of the Vikos fill indicates that renewed valley floor aggradation had begun before c. 19,000 BP and broadly coincides with a return to full-glacial climatic conditions, dated in the GRIP ice core record to c. 21,000 bp (Fig. 17.13). There is, however, a marked change in lithology between the Aristi and Vikos Units: the later fill has a much higher proportion of flysch-derived material but retains a significant glaciogenic element in its fine-grained sediment fraction (Fig. 17.9). This may relate either to higher rates of erosion from flysch terrains than in Aristi times or to reduced glacial erosion of limestone terrains in the catchment. The decline in the limestone-derived sediment component in the Vikos fill, which is particularly evident in the gravel-size fraction, could be attributed to two principal causes:

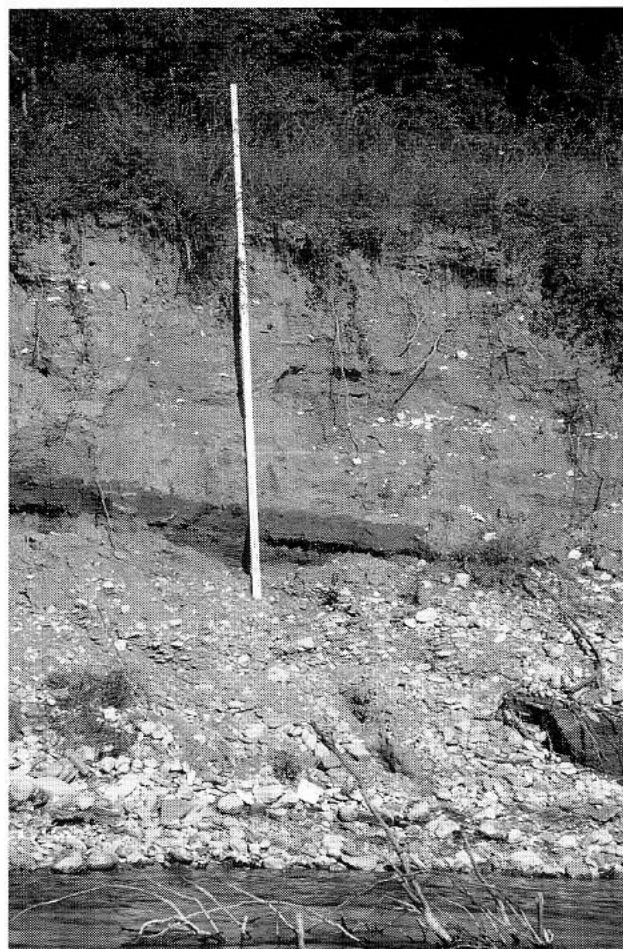


Figure 17.12. Klithi Unit sediments exposed in a natural river cut section approximately 300 m downstream of the Klithi rockshelter. Survey staff for scale.

- A much smaller proportion of the mountain headwaters of the Voïdomatis were occupied by glaciers than during the earlier Late Würm glacial phase at *c.* 27,000 BP. Nevertheless, glacial rock flour still appears to have been the primary source of calcite-rich sediment in the <63 µm size fraction.
- There may have been less active slope processes and mechanical weathering during this period. These, to a large degree, regulate the delivery of coarse rock debris to the Voïdomatis especially in the more confined reaches of the river such as the Vikos Gorge. Erosion of the lower relief flysch terrain, on the other hand, was probably controlled more by vegetation cover which, as discussed above, has been shown to be very sensitive not only to altered temperature and rainfall regimes but also to changes in the seasonality of precipitation. A decline in effective precipitation in the Vikos period, coupled with low temperatures, could have severely affected vegetation growing on flysch bedrock. In some areas this may even have

initiated accelerated erosion and the development of extensive badlands that are one of the characteristic features of these areas today.

It appears that the Klithi rockshelter first started to be used in Vikos times at about 20,000–19,000 cal BP. The river, however, was flowing at about 7 m above present levels, though it is likely that the main phase of occupation at Klithi post-dates the Vikos Unit and took place while the river was incising into its alluvial valley floor. Indeed, the formation of a low terrace above the river, which at this time would still have had a prominent spring/early summer nival flood, may have greatly facilitated access along the gorge both for humans and their ibex and chamois prey.¹

Conclusion

The Late Pleistocene alluvial record of the Voïdomatis river has been used both to reconstruct the local valley floor environment in the Upper Palaeolithic, and, in conjunction with rockshelter and lacustrine evidence, to establish the broader environmental

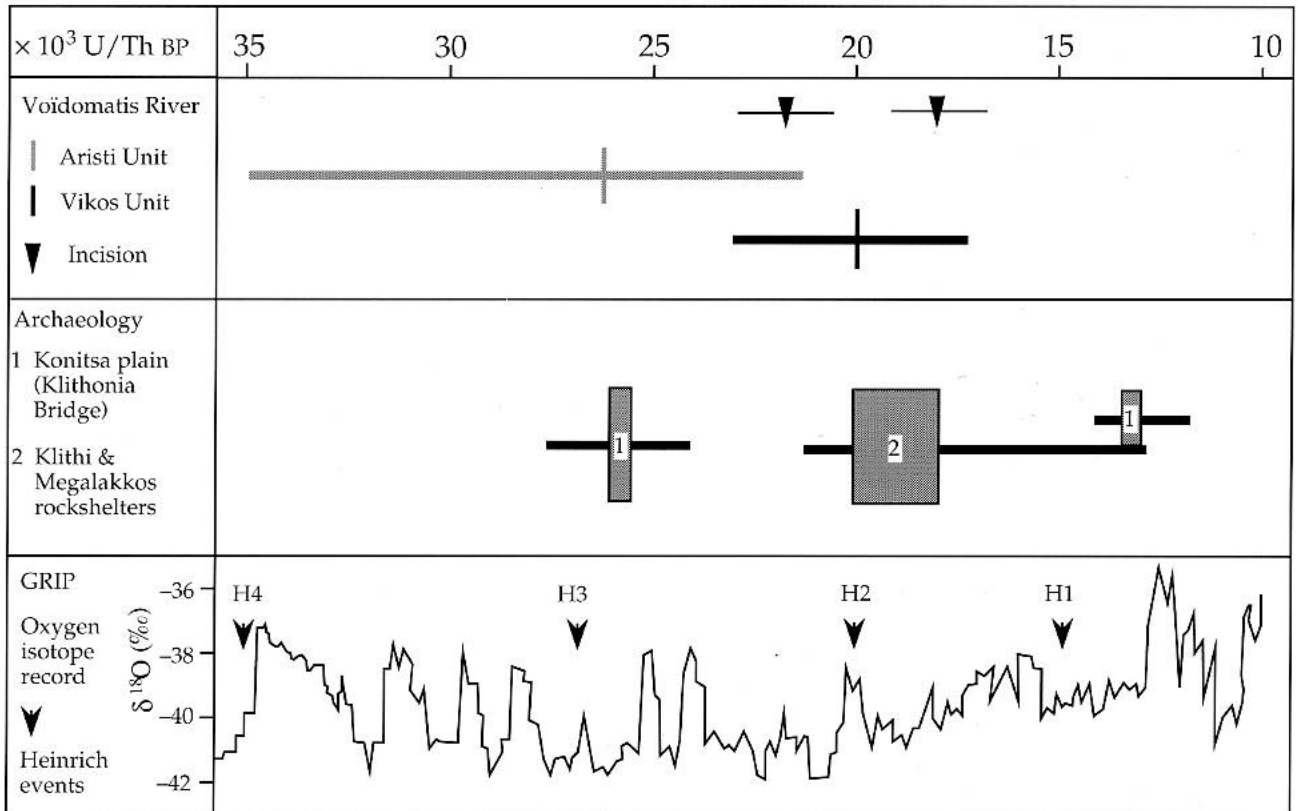


Figure 17.13. Correlation of environmental changes in the Voïdomatis basin with the GRIP oxygen isotope ice core record.

context of human occupation in the basin. It is clear that before 20,000 cal BP the Vikos Gorge must have been a very harsh and uninviting environment. In the spring and early summer, with the river swollen by glacial meltwater, movement along the floor of the gorge must have been particularly difficult and hazardous. The absence of evidence of occupation at Klithi and at Boïla and Megalakkos before 20,000 cal BP strongly suggests that the Vikos Gorge was very infrequently visited. By some time after 19,600 cal BP, river incision and an improving climate appear to have facilitated both physical access to and availability of food resources in the gorge. This marks the beginning of the main phase of occupation at Klithi. Though there is little further local geomorphological evidence to go on, the GRIP ice core record (Johnsen *et al.* 1992) shows that the climatic 'window of opportunity' may have been terminated by a return to colder conditions in the Oldest Dryas at *c.* 15,000 cal BP (Heinrich event 1: Bond *et al.* 1992) rather than at the beginning of the Younger Dryas as originally proposed by Bailey *et al.* (1990).

The Late Pleistocene fluvial sequence of the Voïdomatis basin is probably as well dated and as fully documented lithostratigraphically as any available at present in Greece. Nevertheless, the alluvial record is fragmentary, with no information presently available for the many thousands of years between the Vikos and Klithi Units. Since the late 1980s, when geomorphological fieldwork in the Voïdomatis was completed, there have been important developments in a number of new luminescence dating methods which now offer dating precision for Late Pleistocene and Holocene river sedimentation events which could not have been foreseen even ten years ago (e.g. Fuller *et al.* 1996). In conjunction with the high resolution continuous climate records of the GRIP and GISP2 ice cores, the wider application of optically stimulated luminescence dating methods promises to revolutionize our understanding of human interactions with environmental change, especially for the Late Glacial-early Holocene periods which witnessed important changes in the human economy.

Acknowledgements

We would like to extend special thanks to Geoff Bailey for inviting us to join the Klithi project and also to Jane Lewin, the fourth member of the infamous 'rubble-grading' team. We also thank Rainer Grün, formerly of the Godwin Laboratory, Cambridge, and Nick Debenham and the British Museum Department of Scientific Research for arranging ESR and TL dating respectively.

Note

1. The slack-water sediments at the Old Klithonia Bridge have been radiocarbon-dated to about 13,000–11,000 cal BP (Gowlett *et al.*, Chapter 2; Bailey *et al.*, Chapter 16), or 18,000–19,000 cal BP on the humic acids from the charcoal samples (Chapter 2). This deposit appears to form the topmost part of the Aristi Unit. It is also at the same height as the uppermost level of the typical Aristi Unit gravels which underlie the Boïla archaeological sequence where the earliest archaeological deposits immediately above the Aristi Unit are dated by radiocarbon to 16,000–17,000 cal BP (Gowlett *et al.*, Chapter 2; Kotjabopoulou *et al.*, Chapter 22). This suggests that the TL date of $19,600 \pm 3000$ for the Vikos Unit is too old with respect to the calibrated radiocarbon time scale, although it could be reconciled with the radiocarbon dates by taking the lower end of the 1σ range. It also suggests that the radiocarbon dates from the humic acids of the Old Klithonia Bridge sample are to be preferred to those from the charcoal. The effect of these adjustments would be to make the main period of occupation at Klithi contemporaneous with the period of river incision between the Aristi and Vikos Units, and the occupation at Boïla contemporaneous with the Vikos Unit. Further resolution of these issues must await a more extensive programme of dating including paired luminescence and radiocarbon samples.