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Sedimentary Deposition Rates and Carbon-14: the Epi-paleolithic Sequence of Öküzini Cave (Southwest Turkey)

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A series of radiocarbon dates systematically obtained from bone and charcoal samples from the stratigraphic sequence of Öküzini Cave has been analyzed in conjunction with stratigraphic and archaeological data to interpret the rates and processes of deposition and human occupation of the cave during the Epipaleolithic of southwest Turkey. AMS dates obtained on the charcoal series reveal the existence of three stratigraphic gaps. Sedimentation rates for the deposits are evaluated in relation to radiometric determinations, the nature and origin of sediment accumulation, the structure of the faunal and lithic assemblages and the changing nature of human occupation of the cave. A hypothesis is proposed to explain the processes and rates of sedimentation, including the three gaps revealed by the radiometric series. One of our aims is to caution against interpretations of cultural evolution directly linked to sedimentary rates for which the variation is not immediately evident during excavation, but which requires a more critical analysis, as we have had the opportunity to do at Öküzini.

Keywords: RADIOMETRIC DATING, DEPOSITION RATES, OKUZINI, TURKEY.

Introduction

Öküzini is a small cave located at the base of the foothills of the Katran Mountains and opens onto a broad plain overlooking Antalya in southwestern Turkey (Figure 1). Diverse landscapes are present: an alluvial plain situated some 300 m above sea level which continues until it reaches the coastal Mediterranean cliffs; and a mountain chain with summits of more than 2000 m (Burger, 1985). The site was first discovered and excavated by Prof. Kökten (University of Ankara) in the 1950s (Kökten, 1963). Subsequent excavations were conducted by a joint team from Turkey and Germany in the mid-1980s (Albrecht, 1991; Albrecht *et al.*, 1992). Since 1988, excavations have been directed by the current team which includes archaeologists from Turkey, Belgium,

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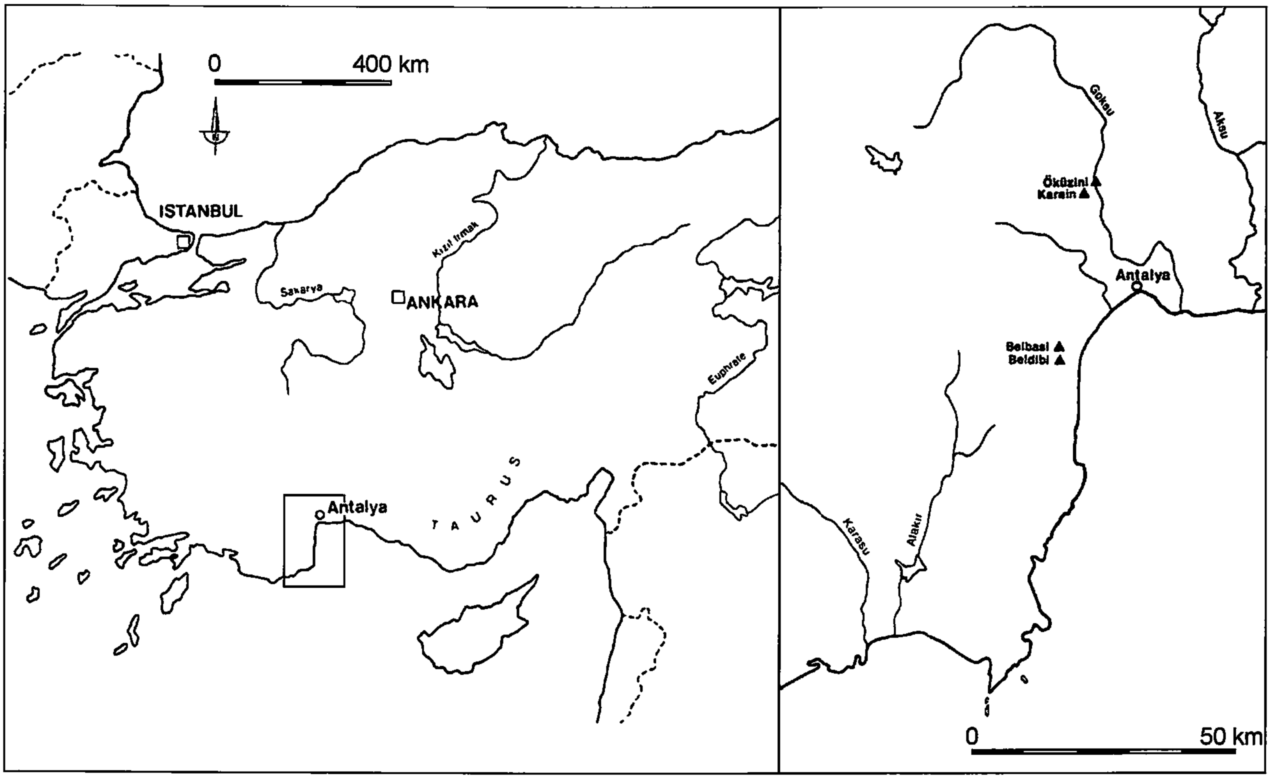

Figure 1. Map of the region showing the location of the site of Öküzini.

the United States and Poland (Léotard *et al.*, 1996, 1998; Otte *et al.*, 1995, 1998; Yalçinkaya *et al.*, 1995; Yalçinkaya, 1998) (Figure 2).

The deposits in Öküzini are composed of loose, friable sediments deposited by water draining through the karstic system, the rate of which varied through time according to the humidity of the region. The sedimentation rate tended to decrease over the course of the Holocene.

The archaeological sequence includes a long series of Final Paleolithic occupations, starting around 18,000 years BP, followed by the transition to the Mesolithic. A series of Neolithic burials is found at the top of the sequence, cut into the underlying deposits (Figure 3).

The apparent homogeneity of the sedimentary system and the recurrence of human occupation of the cave provoked interest in obtaining a large number of radiometric dates covering the range of the stratigraphic sequence. Bone and charcoal samples were systematically collected from two different columns (squares K-L5, I7-8) of *in situ* deposits within the cave, excavated in 10 cm thick spits, as well as from certain other locations (Figures 4 and 5). With data available from the geological strata and archaeological assemblages, the addition of a complete series of radiometric determinations made it possible to identify subtle correlations between archaeological change and sedimentary change through time.

The series of dates permits analysis of the nature of sedimentation processes operating at Öküzini over a period of human occupation lasting around 10,000 years. The precision attained by the AMS dates permits an attempt to explain sedimentation rates with more clarity. Sedimentation rates are evaluated in relation to radiometric determinations, the nature and origin of sediment accumulation, the structure of faunal and lithic assemblages and the changing nature of human occupation of the cave. A hypothesis is proposed to explain the processes and rates of sedimentation operating at Öküzini.

In units containing large quantities of charcoal, the samples recovered were divided in two in order to perform anthracological analyses in the same column and to verify the nature of organic materials used for combustion. Other anthracological samples (a small portion of the organic material, mainly branches and twigs) were dated in addition to samples collected specifically for dating.

This article presents a summary of the stratigraphic sequence and archaeological occupation phases, followed by analysis and interpretation of the series of radiometric dates obtained for the site.

Part I: Stratigraphic Sequence

In the main chamber, the deposits attain a thickness of 3·5 m from bedrock to the current surface. Containing abundant lithic and faunal remains, the geological deposits were formed by internal erosion of the cave (local processes) and superficial montane dismantling

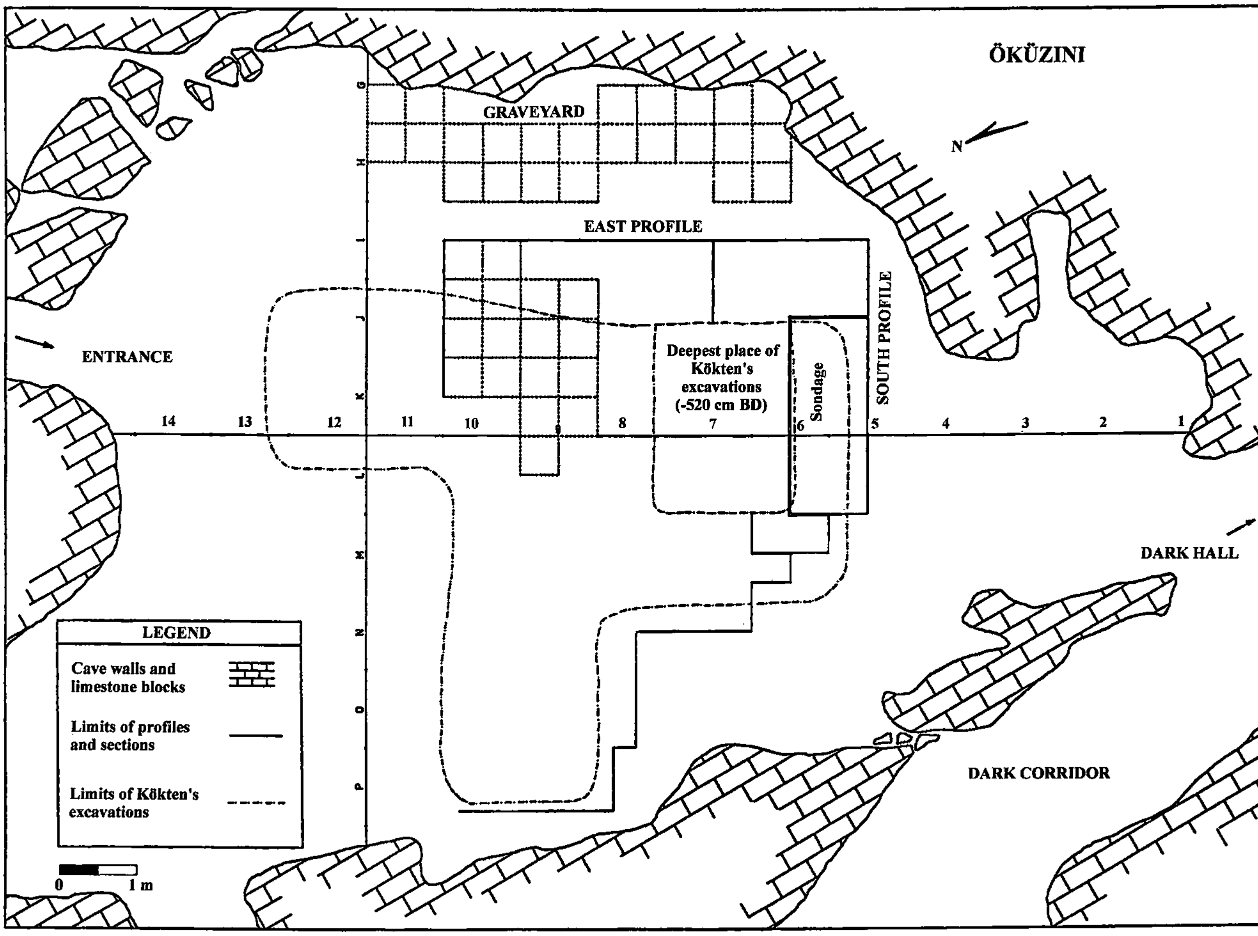

Figure 2. Plan of the site of Öküzini (after Kartal & Erek, 1998: 553, Figure 1).

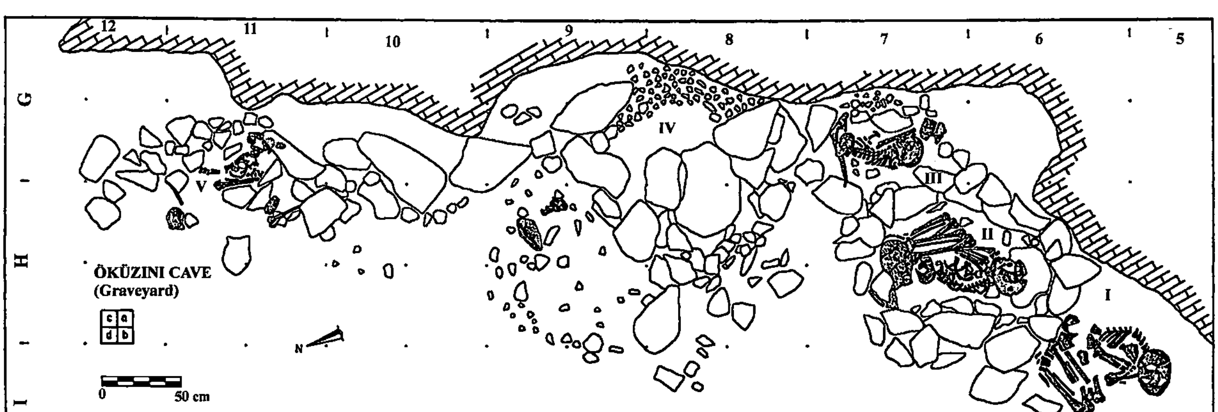

Figure 3. Öküzini. Neolithic burials (after Kartal & Erek, 1998: 554, Figure 2).

(non-local processes). Deposits are composed primarily of limestone fragments and blocks and terra rossa sediment coming from the plateau and slopes above the cave via a natural chimney at the back of the cave and numerous fissures, as well as degradation of the cave walls and roof.

A large series of radiocarbon dates was obtained on bone and charcoal samples from the sedimentary sequence at Öküzini, calibrated with OxCal 3.3 (Stuiver *et al.*, 1998). This series clarifies the variation in deposition rates of the deposits. Dates range from 16,560 ± 180 BP to 7880 ± 80 BP (18,200–17,400 BC

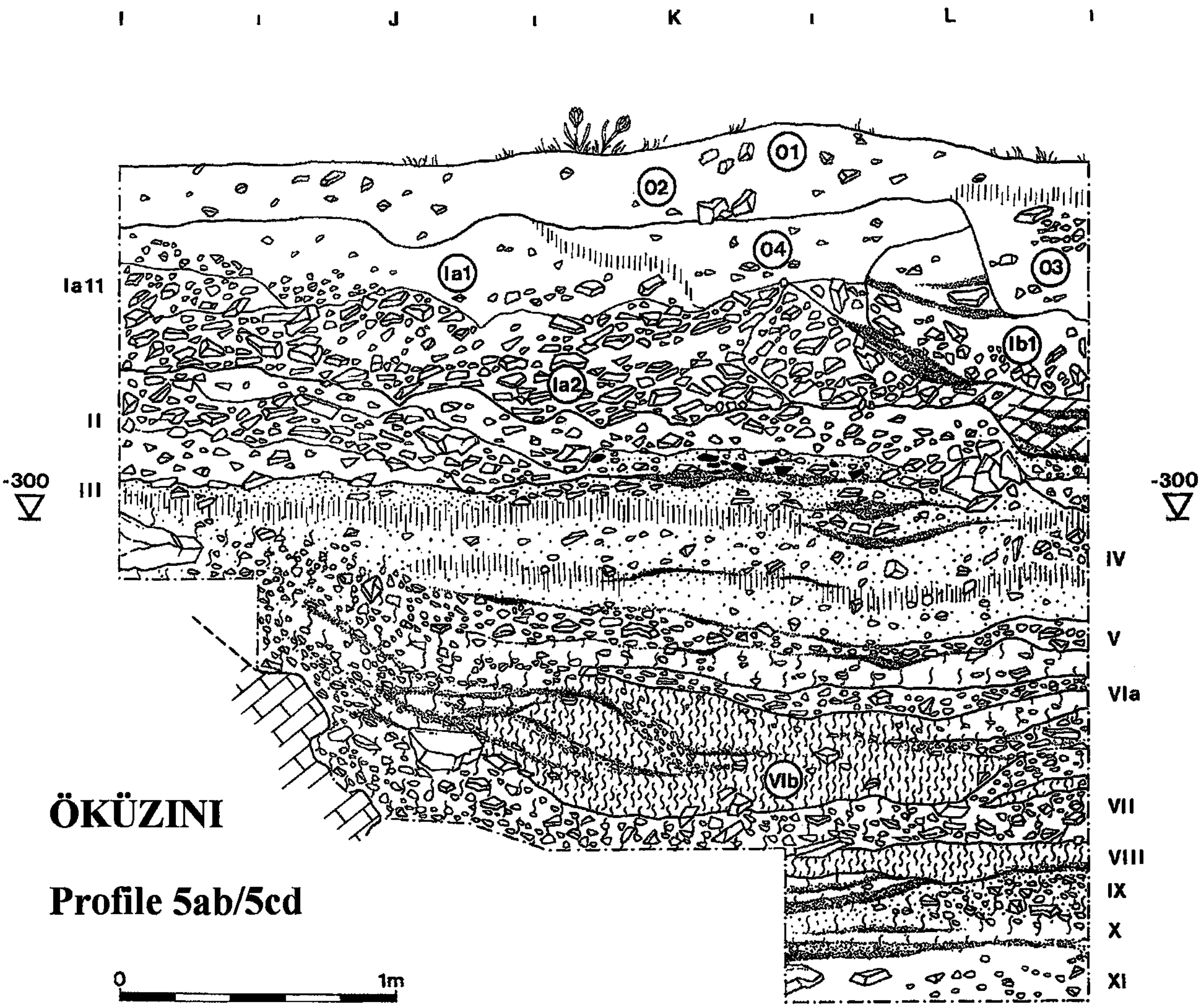

Figure 4. Öküzini. South or Main Profile. Row 5, squares I–L.

[1σ=68·20%] to 6840–6640 BC [1σ=49·20%]). Three gaps are observable in the series, corresponding to three phases characterized by little or no sediment deposition. Eluviation, intentional truncations, periods of no deposition and/or absence of human occupation are possible factors explaining these gaps. Regardless of the cause, the increase in sedimentation rate in the sequence clearly evidences the importance of human contribution to the accumulation of sediments.

While altered at the summit by a series of pits, the main profile (i.e., the South Profile) along the edge of Kökten's original test pit is the most representative for interpretation of the deposition processes acting in the cave. From the base to the summit of the sequence, all strata contain a large anthropogenic component, making it at times difficult to distinguish distinct archaeological levels. A secondary profile (i.e., the East Profile) completes the analysis.

Description of Strata and Archaeological Units

Stratum XII

Stratum XII contains worn rocks and terra rossa sediment darkened by the underlying weathered bedrock. Archaeological material is relatively rare.

Stratum XI

Stratum XI is composed of a brown-black sediment containing large rocks up to 60 cm in diameter, associated with the weathering of the substrate. Traces of ash and charcoal are present, particularly at the top of the stratum.

Stratum X

Stratum X is a fairly compact layer of red-brown clay with much less rock debris than in stratum XI. Large

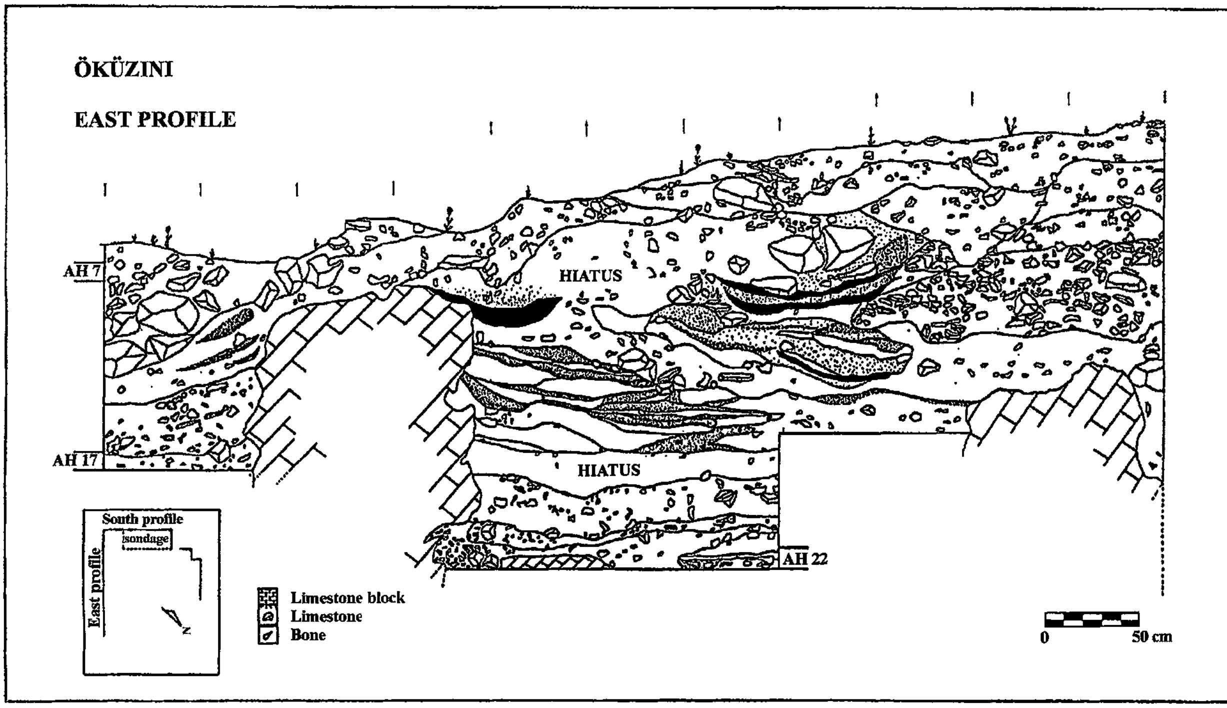

Figure 5. Öküzini. East or Secondary Profile. Row I, squares 5–10.

charcoal fragments are localized very clearly at the base. This unit terminates the first phase of deposition.

The first assemblage, observable only in the Main Profile, thus contains strata XII, XI and X, and is dated to around 16,400–16,560 BP (18,200–17,200 BC [1σ=68·20%]).

First sedimentary gap

Stratum IX

Stratum IX is characterized by the presence of a brown sediment containing many small pebbles. It is present as a lens resulting from an epiphenomenon partially visible in the Main Profile (squares K5 and L5). The matrix includes hearths submerged by water (indicated by ash and reddened balls of sediment in the terra rossa). The horizon developed around 15,460 ± 160 BP (16,900–16,150 BC [1σ=68·20%]).

Stratum VIII

Stratum VIII corresponds to the richest archaeological phase. The matrix is a well-settled red clay with rare stones. The most valid dates are situated around 14,820 ± 150 and 14,940 ± 140 BP (16,100–15,450 BC [1σ=68·20%] and 16,250–15,600 BC [1σ=68·20]). This unit is visible in both the main and secondary profiles.

"Methodological stratum" VII–VIII

The transition between strata VIII and VI has been dated to 14,550 ± 130 BP (15,800–15,150 BC [1σ=68·20%]). The methodological stratum VII–VIII is not a stratum *sensu stricto*, but has been defined as a result of the excavation strategy in which arbitrary 10 cm spits (AH) were dug in 50 × 50 cm squares.

Stratum VII

Stratum VII conserves, in its upper portion, abundant archaeological remains and is clearly visible in both profiles. The brownish-red deposit—highly compact clay—also contains worn limestone blocks. Small pebbles are rare at the base. This lower part of the stratum is dated to 14,610 ± 150 BP (15,850–15,200 BC [1σ=68·20%]). The date obtained at the top of the stratum is 14,610 ± 150 BP (15,850–15,200 BC [1σ=68·20%]). In the Main Profile, the stratum is uniform with prolific small and medium-sized detritus; a darker brown sub-unit is visible locally in square L5. In the lateral profile, the dispersed presence of large charcoal fragments are observed as well as lenticular phenomena associated with stabilization episodes and derived from soliflucted sediments. Detritus is rare.

Second sedimentary gap following an episode of erosion

"Methodological stratum" VI–VII

The transition between strata VII and VI is characterized by the presence of sub-units of fragmented bone, small pebbles and terra rossa. It has been dated to around 14,200 ± 130 BP (15,400–14,750 BC

[1σ=68·20%]). Again, this stratum has been defined as a result of the excavation strategy employed.

Stratum VIb

Stratum VI developed after a long gap (14,200–13,210 BP) and has been divided into two phases. The first, stratum VIb, represents a break in the nature and structure of the deposits; displaced or truncated sediments are observed. The stratum consists of a red clay similar to that in stratum VIII. However, it is more homogeneous, resulting from a greater sedimentary dynamic coming from roof fissures and the central chimney, followed by *in situ* settling in the centre of the chamber. The deposit is compact; charcoal fragments are rare. Dates for this stratum range from 13,210 ± 120 BP. (14,250–13,600 BC [1σ=68·20%]) at the base, to around 12,580 ± 110 BP (12,900–12,300 BC [1σ=50·40%]) at the top.

The detritic component of stratum VIb is sorted in a quite particular manner. In the Main Profile, the lateral presence of lenticular pea gravel (square J5) is observed. In L5, the structure is similar but the pea gravel is accompanied by a blackened sediment that defines a small sub-unit (displacement). At the centre of the profile, in square K5, pea gravel is rare with some medium-sized elements.

In the secondary profile, the pea gravel is practically nonexistent in square I8 and this lack is even more marked in I7 where a lens of nearly pure terra rossa is visible.

The distribution is probably linked to a mechanical sorting during a stabilization phase of soliflucted terra rossa deposits. This phenomenon would have only slightly affected the centre of the chamber, but would be more clearly active towards the internal corridor of the cave. The narrowing of the width of the cave at this area would have produced (i) a loss of speed followed by settling and lateral deposition of the pea gravel, and (ii) recurrent and progressive eluviation affecting the central square (K5).

"Artificial stratum" VIa–VIb and "methodological stratum" VIa–VIb

The transition between VIb and VIa is without chronological discontinuity: the dates obtained from the secondary profile oscillate between 12,540 ± 110 BP (13,000–12,300 BC [1σ=53·30%]–13,500–13,200 BC [1σ=14·90%]) and 12,390 ± 110 BP (12,550–12,150 BC [1σ=35·80%]–13,100–12,600 BC [1σ=32·40%]). In the Main Profile, unit VIa–VIb seems to be out of place; this is the result of the excavation strategy based on arbitrary AH units.

In contrast, an artifical stratum was defined on the basis of data from the secondary profile. Stratum VIa–VIb, in places 17–20 cm thick, was defined because the density and position of combustion zones (in squares I7 and I8), in conjunction with fire-reddened clays, limit clear observation of the transition between the two existing strata. Stratum VIa–VIb is thus characterized by the presence of fire-reddened clay and several superimposed combustion zones charged with charcoal and blackened, grey and white ash.

Stratum VIa

The second half of cycle VI, stratum VIa, consists of a cracked reddish clay with small pebbles and abundant charcoal fragments. A long rocky lens is visible in the Main Profile at the base of VIa (squares L5 and K5), which, by its structure and composition, resembles the lateral sub-unit found in VIb. In the secondary profile, a vertical alternation of ash, hearth residues and terra rossa can be observed.

The change in the sediment composition in VIa is probably due to filling from microfissures in the roof of the cave; in this way; the majority of the sediment contribution would have arrived via the chimney, incorporating a greater percentage of detritus (small- and medium-sized worn rock fragments). From this moment on, the clay contribution is reduced and one observed the presence of open-spaced limestone blocks. This trend continues from VIA to II.

Methodological stratum V–VI and stratum V–VI

Resulting from the application of an excavation technique based on arbitrary spits, a non-congruent stratum was defined in the Main Profile: methodological stratum V–VI. The problem of arbitrary spits is also found in the secondary profile where, in addition, one observed the presence of a fairly unique stratigraphic unit associated with stratum V–VI. This unit is found in squares I7 and I8, at the top of stratum VIa and below strata IV and Ia2–II. It is positioned chronologically after the development of VIa and before the deposition of stratum IV.

At the beginning of this study, the Main Profile was preferred because it represents the two chrono-sedimentary extremities of the deposits, beginning with the weathering of the bedrock and terminating with near-modern sediment at the summit. In the secondary profile, the pit dug into stratum IC—in square I7—prevents direct association of stratum V in the two profiles (preserved in I6 and I5 and in the Main Profile). The fact that it developed between the end of VIa (*data post quem*) and the beginning of IV (*data ante quem*) is the reasoning for calling this stratum "V–VI".

The characteristics of this stratum are as follows: (i) progressive reduction in size of detritus as the deposit was formed and (ii) reddish colour of the matrix, composed of a fairly compact sediment.

Stratum V

Stratum V is formed of a highly compact sediment containing small stones and archaeological remains;

the mixed assemblage is enclosed by a mass of larger stones in sub-horizontal position and of thermoclastic origin. In the secondary profile, the stratum is truncated by combustion pits attributed to stratum IV (in squares I6 and I7); a sedimentary unit absent in the Main Profile is present here. In the Main Profile, the subsequent units show traces of soils and diffused ash.

Stratum IV

Stratum IV is composed of the same matrix as V: a highly compact reddish sediment. Charcoal fragments and small stones worn by circulating water are found within this matrix. The presence of such pebbles causes interstitial gaps in which a large number of snails are found (*Helix pomatia levantina*). A few very large boulders, probably roof-fall resulting from tectonic activity, are also found in this stratum. It has yielded a date of 12,260 ± 90 BP (12,450–12,100 BC [1σ=46·90%]) (RT-1442).

Methodological stratum III–IV

The transition between strata IV and III is laterally characterized by a beige colour (due to ash) which is progressively emphasized to the top of the stratum. This discoloration is likely due to post-sedimentary processes of percolation in conjunction with the presence of both circulating and stagnant water. Beginning with this episode, the strata are sloping. They are characterized by a more powdery lateral structure.

Stratum III

These diffused soils are associated with a much larger quantity of archaeological material. Stratum III consists of a succession of hearths (packed ash), accompanied by grey or brownish-red lenses. In brief, the stratum is quite heterogeneous. In the secondary profile, the matrix is a beige ash-charged soil with lateral—in square I8—narrowing and disappearance. Overall, stones are scarce in this stratum.

Stratum II

The following strata are constituted of stones with numerous interstitial gaps; no horizons are discernible in this context.

Stratum II is characterized by a brownish-ochre coloured sediment containing angular stones and rare cobbles. It is fairly rich in archaeological material. The lateral presence of stony lenses again contain gaps which could have permitted a certain degree of percolation. This stratum is dated to 12,130 ± 100 BP (12,400–11,800 BC [1σ=56·50%]). In the Main Profile, the stratum is truncated by a pit (IB1); in the secondary profile, it has been eroded by strata Ia2–II and Ia2.

Third sedimentary gap

Stratum Ia2

Stratum Ia2 is composed of aerated slightly worn stones and abundant archaeological material. It is enriched by the presence of *Helix promatia* and anthropogenic debris. The presence of non-rolled gravels at the summit of Ia2 indicates the reactivation of the karstic system in relation to the eolian system. The stratum is locally incised by a series of pits (units O3, O4, O5 and Ib1) attributed to Neolithic and Chalcolithic periods based on the ceramics present.

Anthropogenic unit Ib1

Unit Ib1 corresponds to the fill of a pit dug into strata Ia2 and II. It is characterized by the presence of a brownish sediment with grey shades, a darker component (Ib2) at the base, and abundant archaeological material.

Stratum Ia1

Stratum Ia1 is a colluvium of clay particles mixed with a blackish sediment (small charcoal and bone fragments) which conform to the soil. Brechia formation and the presence of backfill are also noted. In square I5, a stratified deposit anthropogenically stabilized in relation to funeral practices contains two sub-units: (i) lower Ia1 is more aerated and reddish and (ii) upper Ia1.1 is brown-beige and more compact. At its summit, this stratum contains horizontally oriented bones and flint.

Unit O5-Ia1 and stratum O5

Unit O5-Ia1, found in square I6 in the secondary profile, corresponds to a pit dug into Ia1 and Ia2 and its fill (a burial). Stratum O5 is localized in a secondary stratum. Chronologically more recent than Ia1 and the digging of pit O5-Ia1, stratum O5 underwent several phases of redigging during the lateral placement of a series of burials corresponding to a change in cave function. The powdery, mixed matrix—secondary fill—contains stones, human remains, pottery sherds and a few osteological elements coming from domestic ovicaprine livestock.

Stratum O4

Stratum O4—visible only in the Main Profile—erodes stratum Ia1 and supports the digging of pit O3. The matrix is a brownish-ochre coloured sediment, very powdery and with little detritus. It likely results from eolian sediments mixed with dust contributed by livestock (ovicaprines). The activity of these animals would be the cause of the erosive contact with Ia1, resulting from the use of the cave as a pen.

Unit O3

Pit O3 contains a loose sediment that fills a trench with sub-vertical walls.

Units O2, O1 and current surface

These units, even more powdery and mixed, complete the Öküzini sequence. Unit O2 consists of a light

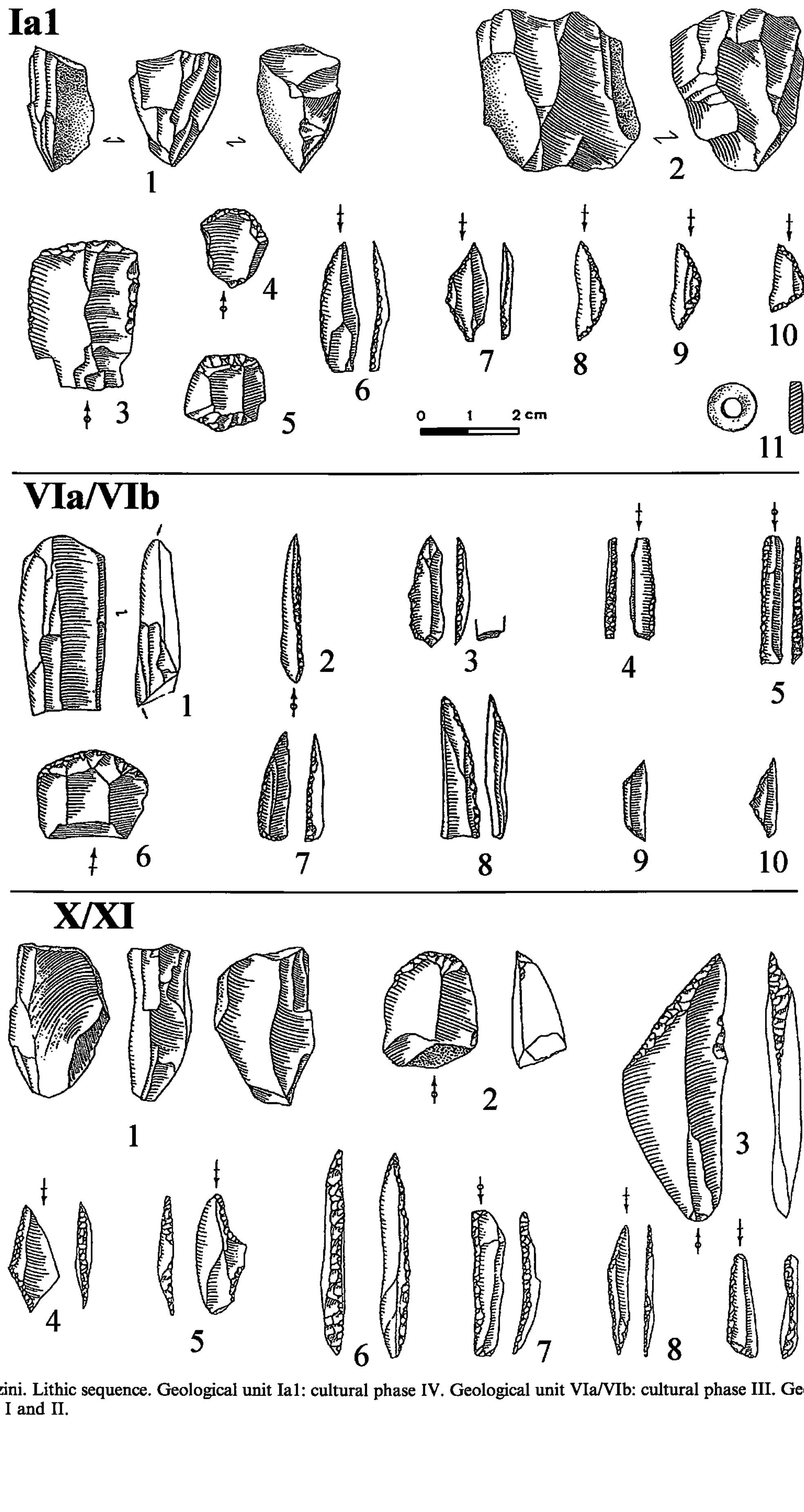

Figure 6. Öküzini. Lithic sequence. Geological unit Ia1: cultural phase IV. Geological unit VIa/VIb: cultural phase III. Geological unit X/XI: cultural phases I and II.

brown sediment charged with terra cotta fragments. Unit O1 is characterized by a darker brown, loose sediment again containing terra cotta fragments; it is attributed to the backdirt of Kökten's excavations. The current surface is extremely powdery.

Interpretation

The structure of the cave facilitated "steady" deposition by different agents, either natural or anthropogenic. By percolation and via fissures in the roof of the cave, sediments reddened by oxidation (terra rossa) on the plateaux were deposits in the centre of the chamber. Various humid phases seem to correspond to these sedimentary movements (warm phase: unit VIII and Bölling: unit VI). Other sedimentary contributions—brownish-black—appear to be associated with intense human activity. For example, hearthstones, extremely abundant lithic material and floral and faunal debris are found throughout the entire stratigraphic sequence. Ash and cinders, sometimes considerable, demonstrate the intensity both of human occupation and its contribution to the cave fill. Red lenses and combustion horizons (white, grey and black ash) evoke the diversity of materials burned.

The base of the sequence is of natural origin, composed of angular blocks and stream sediments in which the first human occupation took place (stratum X). Next, the overlying deposits contain abundant anthropogenic elements, which seems to have been the principal agent for this deposition phase (stratum VII). The middle part of the sequence (stratum VI) is characterized by an important sedimentary disruption, with the activation of the chimney and the arrival of a substantial quantity of clayey sediments (terra rossa) that indicate an increase in humidity (and a lesser human presence). Processes of different nature and rate thus appear to be acting simultaneously at this phase to produce rapid deposition of cave fill. The following phase is again clayey (still humid), but this time of brownish coloration due to human activity, sealed by a rocky layer (stratum IV). Curiously, the group of processes is brusquely interrupted in the upper part of the sequence, to create a regular and smooth surface that apparently—in the Main Profile—remained intact (stratum Ia2). Finally, more recent occupations (Neolithic and Chalcolithic) are in a sense "negative": their presence is indicated by burial pits dug into the stabilized surface.

Human Activity

Lithic and cultural sequence

Based on analyses of the archaeological assemblages, six phases of human occupation can be distinguished (Figure 6).

Phase I. In the first assemblage (phase I), dated to around 16,560 BP, straight-backed armatures, often pointed, and slightly angular backed armatures are associated with endscrapers on blades and truncated blades. This toolkit is based on the production of laminar blanks obtained from bipolar cores. Hunting is primarily oriented towards goat and fallow deer.

Phase II. After an interruption of more than 1000 years, human activity is again attested around 15,460 BP (phase II). The hunter is equipped with elongated triangles and backed bladelets and concentrates almost exclusively on ovicaprines—with a clear preference for goat—(herbivores which could adapt to a generalized diet, woody plants, grasses) and ignoring cervids (with a diet based on leaves and humid herbaceous plants). A priori, this observation seems to be in opposition with the more humid character observed in stratum VIII (formation of terra rossa). This inconsistency seems to indicate an increase in estival aridity which would have led to selective behaviour more emphasized by the seasonal character of hunting which occurred during the humid period. If phase II is compared with the LGM (phase I) with the establishment of a local microclimate, this second phase would be characterized by the presence of warmer waters, favouring in winter the Mediterranean cyclogenesis; in contrast, in summer (see López Bermúdez, 1984) the rate of evaporation would have increased following the general rise in temperature and the activation of a preferential system of estival circulation (intermediary vein of water of Levantine origin, *sensu* Rodríguez, 1982 and Mateu Belles, 1984).

Phase III. After another important gap, phase III develops around 13,200 BP. Numerous inflections are found in the deposits of this period, suggesting possibilities of mixing and perhaps explaining the mixed nature of the archaeological assemblage. The exploitation of bipolar cores continues, with blanks used to produce backed bladelets, multiple-notched blades, endscrapers on blades, burins and irregular microliths. While the presence of fallow deer and red deer indicate diversification in subsistence resources exploited as well as an increase in vegetal cover, ovicaprines remain dominant, but with a greater presence of sheep, which indicates a progressive increase in humidity.

Phase IV. At the contact with the following assemblage (phase IV), the emergence of artistic or symbolic productions is observed (lines engraved on bone and stone, animal representations on cobbles). Moreover, abrupt changes are observed in the lithic industry. Cores are for the most part polyhedral and sometimes pyramidal; flaking surfaces are multiple and often overlapping. Short, often irregular, blades were produced, useful for the preparation of microliths. In addition to this technological change, the fourth group, dated to around 12,200 BP, is characterized by geometric microliths, the appearance of micro-endscrapers and grinding stones. The animals hunted are distinguished by their variety:

Table 1. Öküzini ^{14}C datings

Average depth (m)	Square	Geological horizon	Sampled material	B.P. datings	Calibration limits Lower	Calibration limits Upper	Laboratory reference	Cultural phase
1·97	L5	Ib1	Charcoal	8595 ± 90	7504	7696	HD-14363-13884	
2·27	K5	Ia2	Charcoal	10,440 ± 115	10,225	10,550	RT-1441	
2·27	L5	Ib1	Charcoal	8800 ± 80	7702	7944	ETH-8031	
2·27	I6	Ia1	Bone	12,410 ± 140	12,375	12,775	GIF A-92389	
2·47	K5	1a2	Bone	11,440 ± 100	11,300	11,525	Lv-1895	
2·47	K5	1a2	Bone	11,880 ± 530	11,300	12,600	GX-16283	
2·47	L5	1a2	Charcoal	11,730 ± 90	11,620	11,830	ETH-8032	
2·57	L5	Ib1	Charcoal	9650 ± 50	8670	9002	HD-13364-13887	
2·57	I8	Ia1	Charcoal	10,150 ± 90	9272	10,120	OxA-5213	
2·67	L5	2	Charcoal	12,020 ± 90	11,960	12,180	ETH-8026	
2·67	I8	VIa	Charcoal	12,130 ± 100	12,075	12,350	OxA-5214	IV
2·77	L5	II	Charcoal	11,920 ± 190	11,725	12,200	HD-13334-13211	
2·77	I8	VIa	Charcoal	12,500 ± 110	12,075	12,350	OxA-5215	IV
2·87	L5	Ib1	Charcoal	7880 ± 80	6558	6994	HD-13345-12983	
2·87	L5	Ib1	Charcoal	9480 ± 80	8420	8848	ETH-8029	
2·87	I8	VIa	Charcoal	11,900 ± 70	11,840	12,010	RT-2335	
2·87	I8	VIa	Bone	12,480 ± 160	12,450	12,925	Lv-2078	
2·97	L5	III	Charcoal	12,210 ± 90	12,190	12,425	ETH-8033	
2·97	I8	VIa	Charcoal	12,390 ± 110	12,375	12,700	OxA-5216	III
3·07	L5	III	Charcoal	11,900 ± 90	11,815	12,030	ETH-8030	
3·07	I8	VIb	Charcoal	12,540 ± 110	12,575	12,925	OxA-5217	III
3·07	J6	IV & V	Bone	12,810 ± 180	12,900	13,475	Lv-1998	
3·17	K5	IV	Charcoal	12,260 ± 90	12,250	12,490	RT-1442	
3·17	J5	V-VIa	Bone	12,680 ± 210	12,650	13,300	Lv-1997	
3·17	I8	VIb	Charcoal	12,580 ± 110	12,650	13,000	OxA-5218	III
3·27	I8	VIb	Charcoal	12,700 ± 110	12,825	13,175	OxA-5219	III
3·37	L5	IV	Charcoal	11,565 ± 110	11,425	11,675	HD-13347-13341	
3·37	I8	VIb	Bone	13,430 ± 180	13,850	14,350	Lv-2079	
3·37	I8	VIb	Charcoal	13,060 ± 120	13,400	13,775	OxA-5220	III
3·47	I8	VIb-base		13,210 ± 120	13,625	14,000	OxA-5221	III
3·57	L5	IV	Charcoal	12,420 ± 80	12,475	12,700	HD-13348-12984	
3·57	I8	VIb-base	Charcoal	14,200 ± 130	14,925	15,250	OxA-5222	II
3·67	L5	VIa	Charcoal	12,190 ± 120	12,125	12,450	HD-13349-13373	
3·67	I8	VII	Bone	13,740 ± 200	14,250	14,775	Lv-2080	
3·67	I8	VIb-base	Charcoal	14,320 ± 130	15,075	15,375	OxA-5223	II
3·77	L5	VIa	Charcoal	12,500 ± 75	12,590	12,810	HD-13351-12985	
3·77	I8	VII	Charcoal	14,550 ± 130	15,325	15,625	OxA-5224	II
3·87	K5	VIb	Bone	12,585 ± 280	12,425	13,250	GX-16284	
3·87	K5	VIb	Bone	13,060 ± 360	13,025	14,100	Lv-1896	
3·87	L5	VIa	Charcoal	12,610 ± 180	12,600	13,150	HD-13352-13343	
3·87	I8	VIII	Charcoal	13,670 ± 175	14,200	14,650	RT-2334	
3·87	I8	VIII	Bone	13,910 ± 120	14,575	14,875	Lv-2081	
3·87	I7	VIII	Bone	14,380 ± 190	15,050	15,500	Lv-2077	
3·97	I8	VIII	Charcoal	14,940 ± 140	15,750	16,050	OxA-5225	II
4·07	L5	VIb	Charcoal	12,850 ± 310	12,775	13,725	HD-13353-13381	
4·17	K5	VII	Bone	14,570 ± 150	15,325	15,675	Lv-2074	
4·17	K5	VII	Charcoal	14,610 ± 150	15,375	15,725	OxA-5175	II
4·17	L5	VIb	Charcoal	12,190 ± 270	11,925	12,650	HD-13354-12989	
4·27	K5	VIII	Charcoal	14,820 ± 150	15,600	15,925	OxA-5176	II
4·27	L5	VIII	Bone	13,620 ± 180	13,975	14,725	Lv-1999	
4·27	L5	VIII & IX	Bone	13,380 ± 190	13,775	14,325	Lv-2000	
4·37	K5	VIII & IX	Charcoal	15,460 ± 160	16,250	16,575	OxA-5177	II
4·47	K5	IX	Charcoal	16,420 ± 180	17,150	17,600	OxA-5178	I
4·47	L5	IX & X	Bone	15,740 ± 290	16,400	16,975	Lv-2057	
4·57	K5	X	Charcoal	16,440 ± 240	17,125	17,700	OxA-5180	I
4·67	K5	XI	Bone	15,020 ± 550	15,375	16,525	Lv-2075	
4·67	K5	XI	Charcoal	16,560 ± 180	17,325	17,800	OxA-5181	I
4·77	K5	XI & XII	Bone	13,520 ± 640	13,300	15,025	Lv-2076	
4·77	K5	XI	Charcoal	16,440 ± 160	17,200	17,600	OxA-5179	I
4·77	K5	XI	Charcoal	16,400 ± 160	17,150	17,550	OxA-5182	I

fallow deer, ovicaprines, roe deer, wild boar, with a clear preference for sheep and fallow deer. The environment is more humid and increasingly forested, as indicated by palynological (Emery-Barbier, in press), anthracological (Thiébault, in press) and zooarchaeological (Léotard, *et al.*, 1998) analyses.

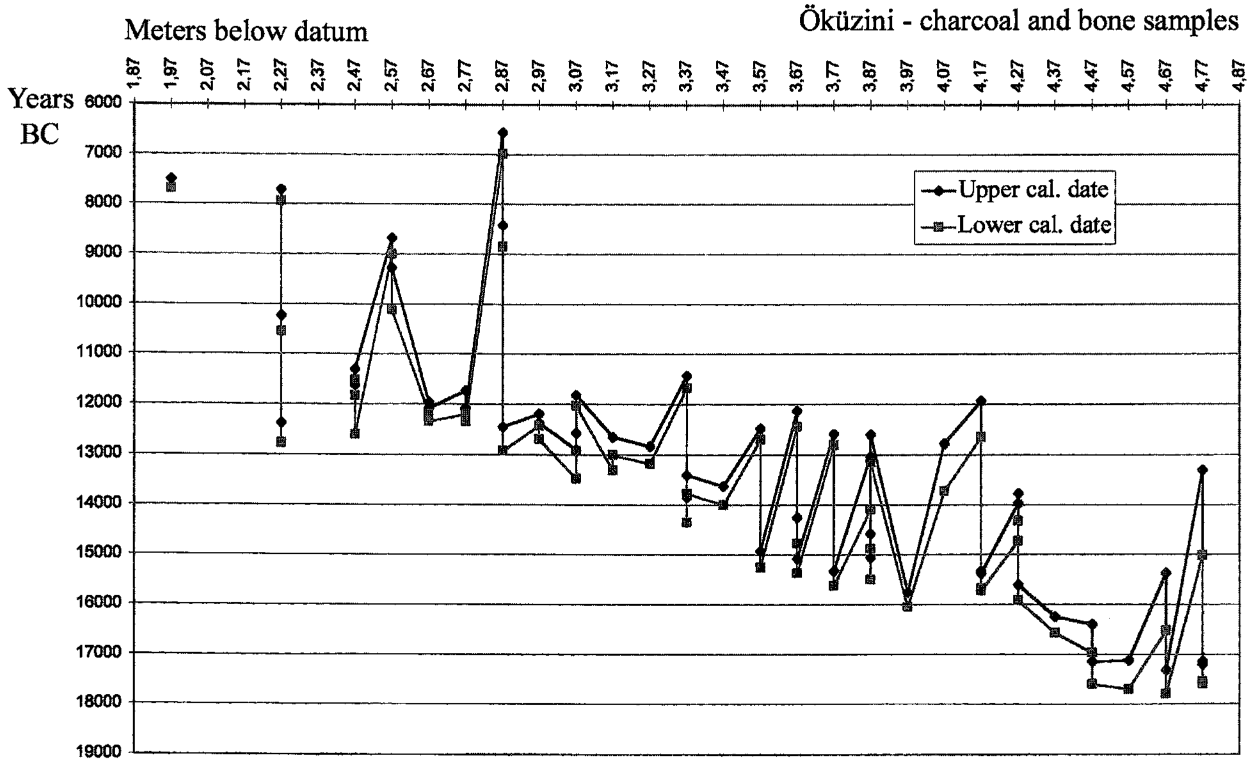

Figure 7. Öküzini. ^{14}C dates (both charcoal and bone samples).

Phase V. After a final interruption in occupation of the site, new activities are attested around 9500 BP by pits dug into older levels.

Phase VI. In Phase VI, the cave changes "status": it has become a burial ground, probably in relation with stabilization of the environment and a shift to sedentary occupation. Ceramic sherds and a fragment of polished axe indicate the presence of Neolithic cultures. These levels are sealed by a series of individual burials, perhaps Chalcolithic.

Fauna and hunting strategies

The general "trend" of faunal development is exaggerated by the selective hunting by humans throughout the sequence. Similarly, gaps in deposition give the sequence an impression of abrupt change.

Changes in the faunal spectrum indicate a progressive and continuous tendency for an increase in humidity and the establishment of parklands (lightly wooded). The development of hunting behaviour, at the base of the sequence oriented towards goat (montane landscape), and developing progressively towards diversification with sheep (prairie) and particularly cervids (open forest), is a function of both climate change and seasonal hunting strategies gradually evolving towards a greater stabilization. From a techno-typological point of view, the presence at the base of the sequence of bipolar technology producing microgravettes seems to be correlated with hunting in an open environment. The progressive appearance in the middle part of the sequence of a polyhedral technique, associated with the production of microliths, could correspond rather to new strategies of prey acquisition in a more closed environment.

Part II: Radiometric Analyses

Various methods were applied to identify possible correlations between "radiometric time" and the sedimentary phenomena described above. "Stages" corresponding either to gaps in deposition (due to temporary pauses in the deposition process, truncation of deposits or leaching of sediments) or to differences of slope in the depth correlation curves (indicating differences in sedimentary rates) were thus able to be distinguished.

As a result, the interpretation of such irregularities in the sequence varies and depends on the context in which the gaps occur. For example, we could explain apparent "gaps" observed within technological development (transition from the Upper Paleolithic to the Epi-Paleolithic) or, inversely, explain certain "backwardness" or slowed development proper to particular archaeological periods.

Table 1 gives the complete list of ^{14}C dates available for all strata of the site, and includes both bone and

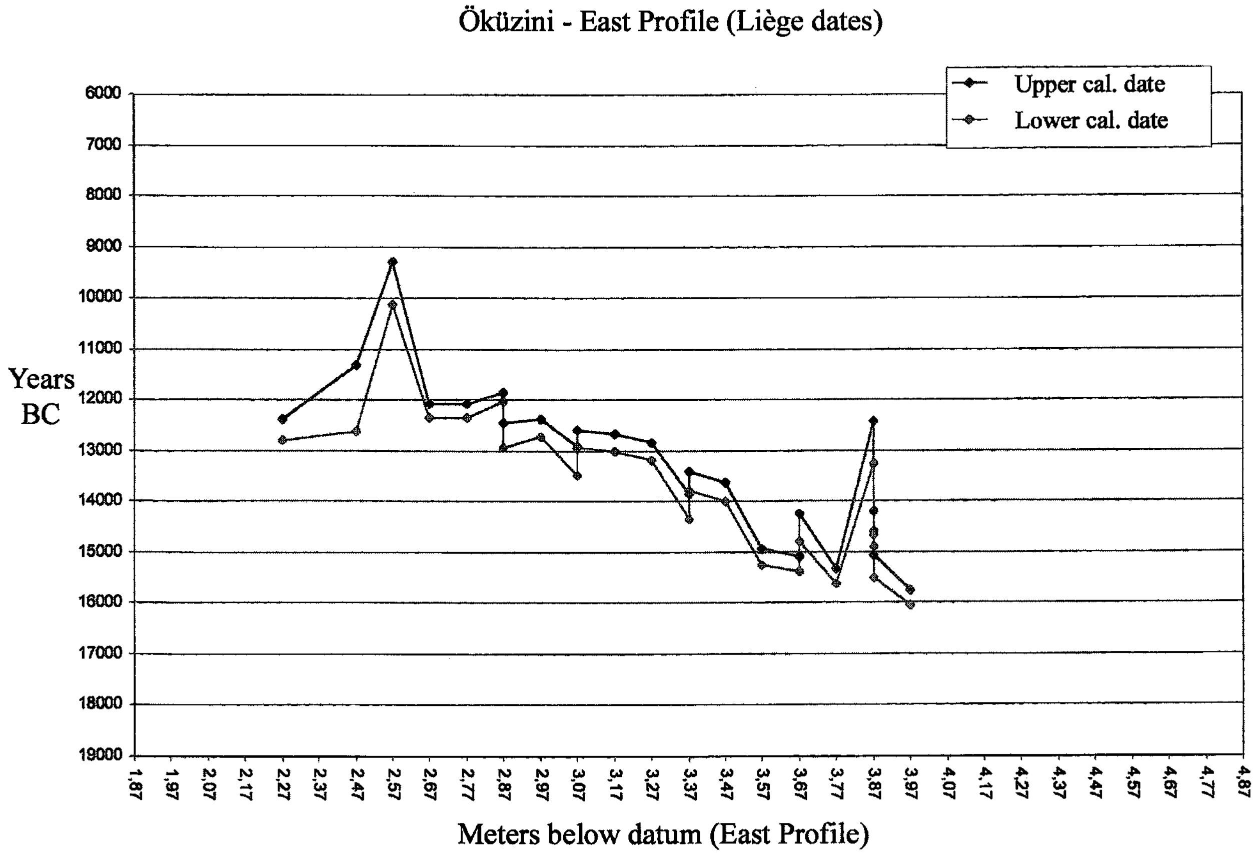

Figure 8. Öküzini. East Profile, Liège dates.

charcoal samples obtained from excavations in the 1980s (Albrecht, 1991) and those of the current team (Léotard *et al.*, 1996).

The series of dates is analyzed with the aid of graphs which address a number of specific issues.

Criteria for Selection of Valid Dates

The results presented in Figure 7 correspond to the entire series of calibrated dates obtained on charcoal and bone ($n=60$). Two different profiles are considered simultaneously. Discrepancies, or dates which lie outside the expected chronological ordering (represented as a serrated curve), are clearly observable. Possible reasons for these discrepancies include depth and location of the samples taken, the type of material dated (bone or charcoal), and finally, the different laboratories which analyzed the samples. In order to evaluate their role, each cause has been isolated.

Considering only the East Profile, if we eliminate dates for which depths do not accurately represent the stratigraphic sequence (e.g., samples taken from pits which yield young dates at lower depths), the curve becomes less disjointed ($n=24$) (Figure 8).

Next, keeping only the dates produced on charcoal samples ($n=14$), all discrepancies are eliminated apart from a single date (produced by the RT laboratory) (Figure 9). It should be noted that in other profiles, dates from the RT laboratory are systematically "younger".

Finally, in Figure 10, only dates obtained by the Oxford laboratory from samples in the East profile, with the addition of samples from the South Profile for the lower part of the sequence, are represented. The physical connection not established between the two profiles, we have here associated them artificially on the basis on similarity in sedimentary units. The selection (or culling) of dates by these successive criteria results in a curve plotting depth versus date that is increased in strength and precision.

The large number of dates obtained at Öküzini makes it possible to observe, and eliminate, discrepancies due to such criteria which may otherwise be overlooked at sites for which only a few dates are available.

Relationships Between Deposition Processes and Human Occupation

The correlation of the selected calibrated dates with depth shows three clear gaps in the continuity of the stratigraphic sequence. In Figure 11, these gaps are

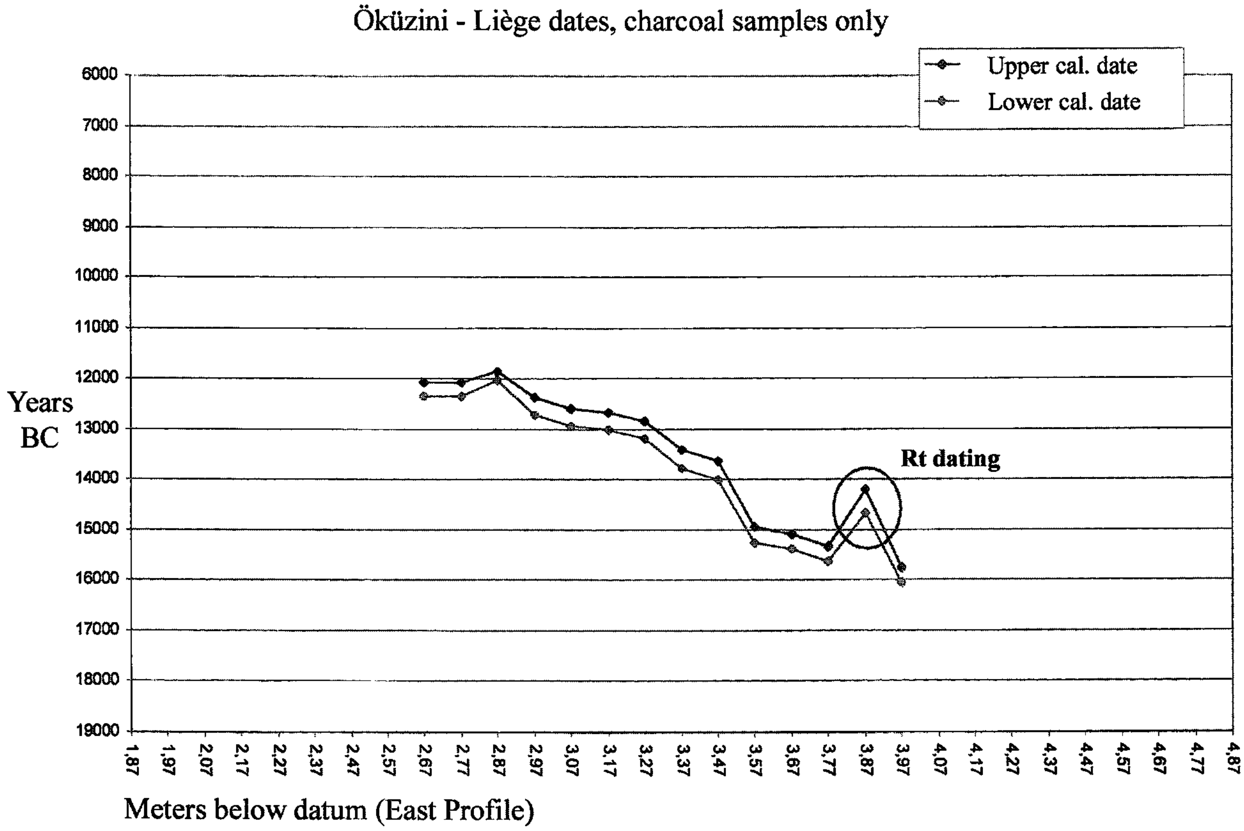

Figure 9. Öküzini. East Profile, Liège dates (charcoal samples only).

indicated by black bands at around 11,000 BP, between 14,000 and 15,000 BP, and at 17,000 BP. Roman numerals indicate the geological horizons from which dates were obtained.

Figure 12 summarizes the cultural phases described above in relation to sedimentary rates. Several comments can be made:

(1) In Phase I (the earliest), sediments were deposited rapidly.
(2) Phase II lasted around 1500 years, but corresponds to a deposition process of average intensity, probably associated with an increase in aridity.
(3) Phase III shows minor human occupation at its base, and is correlated with natural deposition of *terra rossa* over a short period. This is likely attributable to a more substantial pluvial regime.
(4) In Phase IV, thick deposits are again observed, here associated with intense human occupation. The presence of less pure *terra rossa*, brown rather than red, reflects the importance of anthropogenic action.
(5) Phase V is characterized by disruptions linked to gravel deposits and to stabilization of humidity.
(6) Phase VI (not represented here) corresponds to Neolithic and Chalcolithic periods and is characterized by a new stabilization of sedimentary deposition, from now on mainly of anthropogenic origin. Human occupations (pits and burials) are dug into underlying deposits and natural sedimentation processes are no longer active.

Interpretation

The final series of dates (Figures 10–12) was obtained by selection of dates according to the criteria discussed above. Possible hypotheses for the three gaps in the chronological sequence include (1) a temporary halt in sedimentation processes, (2) a break in human occupation of the site, (3) anthropogenic alterations, (4) natural leaching or (5) a combination of these factors. The succession of cultural phases corresponds to the different geological horizons, supporting the first hypothesis as the most probable.

In effect, at the base of the sequence, in stratigraphic units IX, X, and XI, the balance between anthropogenic and sedimentary remains, both within and outside the cave, is gradually established, indicating a stabilization of exchanges. During this phase, the cave was preferentially occupied in summer. Seasonal attribution is based on analyses of attrition, dental eruption and the results obtained from the

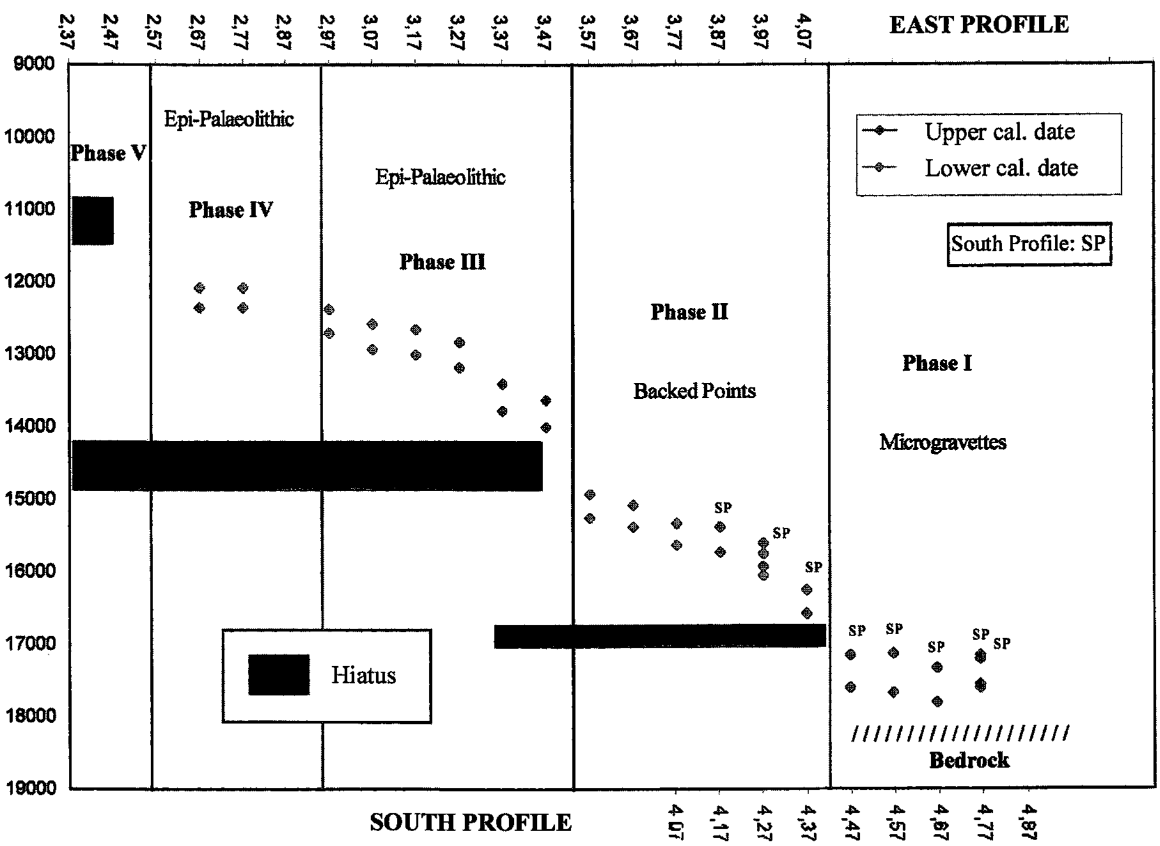

Figure 12. Öküzini. Cultural phases related to ^{14}C dates.

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