MINERALOGICAL INVESTIGATIONS AT ÖKÜZINI CAVE

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INTRODUCTION

Öküzini cave developed at the base of the Katran Dagı mountains as a stream cave. It was formed at an exit for the outflow of karstic waters from the limestone massif (Pawlikowski 1995). The cave functioned for a long time as a rock spring of the small river and was then blocked by limestone blocks falling down from the cave roof. At this moment, the cave was dry and useable for human occupation. The karstic waters previously flowing through Öküzini changed direction and began to exit from a second cave of similar origin some 20-30 meters away.

The top of the stratigraphic sequence gives a unique opportunity for precise determination and understanding of climatic change and human activity during the Pleistocene-Holocene transition.

I. METHODS OF INVESTIGATION

1.1 *Sampling*

Samples were collected from the southern profile of the trench in Öküzini cave (Fig. 1). The relationship between sediments (sediment number), mineralogical samples (sample number) and archaeological layers (AL) is shown in Figures 2 and 3.

1.2 *Methods*

1.2.1 *Preparation of samples*

Samples were mixed with diluted HCl (1:10) for the dissolution of fine calcite cementing clay substance. After dissolution of carbonates, samples were washed with distilled H_2O for removing the newly formed $CaCl_2$. The remaining material was then screened with 0.1 and 0.5 mm sieves and the 0.1-0.5 mm fraction was used for the preparation of microscopic slides.

1.2.2 *Microscopic analysis*

Samples were examined with two microscopic methods: a) scanning electron microscope (SEM) and b) polarizing light microscope.

SEM observations were performed for preliminary, precise identification of the components tested. Grains of selected material were then covered with gold and tested. Observations were made using a STEREOSKAN S4 microscope of English production.

Polarizing light microscopy was used for the determination of mineral composition of the prepared samples. About 1000 grains were identified in each sample (i.e., for a total of about 34,000 grains) from all samples. Results of these analyses were recalculated in percents and are listed in the tables and shown in the figures.

1.3 *Mineral compounds*

The following mineral compounds were identified and calculated: rock fragments (limestones not dissolved in acid), rounded radiolarite fragments, rounded quartz grains, sharp quartz grains, concentrations of Fe-Mn oxides.

Rock fragments (limestone)

The surface of these fragments is not natural because of the reaction with the diluted HCl. Most of these grains are of light color but some are gray and most were burned. Rare sandstone grains were also identified.

Rounded radiolarite fragments

These grains before deposition in the cave were present on the surface of limestones (slopes of hills) in secondary position in sands. Radiolarite grains present in these sands are connected with radiolarites present in primary position under Cretaceous limestones (Pawlikowski 1995). Radiolarite grains in the sands were introduced into the cave in two ways, via the karstic system and holes as well as directly from the surface above the cave, through the roof.

Rounded quartz grains

This type of grains has a polished shiny surface and indicates features typical for water transport of the material into the cave. They were transported from detrital sediments deposited on the morphological surface of the limestones or were transported into the cave by man (i.e., on food).

Sharp quartz grains

These grains are very rare in the cave sediments and are inticator of short distance transport.

Fe-Mn oxides

These oxides are the result of concentration of Mn-Fe oxides in the residum developed secondarly on limestones as the product of natural weathering of these rocks during the carstic processes of their destruction. They are present in the form of small concretions and nodules. They were introduced into cave sediments by

Sample no.	Component				
	1	2	3	4	5
4	82.4	6.7	0.9	-	0.4
1	81.2	2.0	1.0	-	0.3
0	83.0	4.8	1.6	-	-
2	57.2	3.9	3.2	0.3	-
3	50.0	5.0	1.2	-	0.4
3a	64.7	4.4	1.5	-	0.1
4a	52.4	6.7	0.9	-	-
4b	74.9	5.9	0.2	0.1	0.3
10	88.6	3.0	1.5	-	0.5
5	59.4	4.3	0.8	-	-
6	44.6	7.6	0.8	-	-
7	37.6	6.3	0.9	-	-
8	36.6	2.9	2.8	-	-
9	68.7	3.8	1.7	-	-
11	67.3	6.3	1.0	-	1.0
12	84.0	4.9	-	0.3	-
13	53.7	7.4	4.1	-	0.8
14	82.1	9.6	0.9	-	0.5
15	78.4	4.6	-	-	0.7
16	75.5	5.7	-	-	0.5
17	76.6	3.3	1.1	-	1.1
18	78.3	7.5	3.6	-	-
19	68.8	5.4	2.7	-	-
20	76.5	3.6	2.1	-	1.2
21	80.3	5.3	1.8	0.1	1.2
22	79.1	5.3	1.1	-	1.4
23	72.2	5.9	1.7	-	-
24	94.7	4.1	1.3	-	1.3
25	72.6	3.4	2.1	-	1.7
26	82.5	5.1	1.0	-	2.0
27	76.4	6.3	1.4	-	1.7
28	88.5	6.7	2.2	-	1.9
29	86.8	5.7	2.1	-	0.9
30	72.2	4.9	1.1	-	0.2

Sample no.	Component				
	6	7	8	9	10
4	0.9	9.4	2.0	4.6	-
1	0.5	12.7	0.7	1.1	-
0	-	10.0	0.3	-	-
2	0.3	32.8	1.0	-	-
3	0.4	35.7	2.5	2.3	-
3a	0.1	25.0	1.1	2.8	-
4a	0.1	30.6	2.0	5.4	-
4b	0.1	11.3	1.9	4.7	0.3
10	0.3	4.8	-	0.4	-
5	0.8	22.1	3.9	7.3	0.8
6	-	49.1	-	1.7	-
7	-	57.0	-	2.1	-
8	0.7	42.6	1.4	12.6	-
9	1.0	21.3	0.5	4.0	-
11	-	14.8	4.2	3.1	-
12	0.3	6.1	0.5	4.0	-
13	-	14.0	1.1	14.8	-
14	-	3.8	-	2.0	-
15	-	12.4	-	3.8	0.7
16	-	5.2	-	10.5	-
17	-	7.8	-	10.1	-
18	-	6.4	1.0	3.2	-
19	-	13.6	-	8.2	-
20	-	12.5	1.0	2.1	-
21	-	4.1	0.9	4.9	-
22	-	6.1	-	5.7	-
23	-	9.4	0.8	8.1	-
24	-	1.3	-	1.1	-
25	-	15.8	0.5	2.8	-
26	-	7.0	-	1.7	-
27	-	8.3	0.3	4.2	-
28	-	0.7	-	-	-
29	-	2.1	-	1.1	-
30	0.2	11.1	2.9	4.3	0.2

Sample no.	Component				
	11	12	13	14	15
4	1.8	-	0.9	-	-
1	-	-	0.5	-	-
0	-	-	0.3	-	-
2	1.0	-	0.3	-	-
3	-	1.2	-	-	1.3
3a	-	0.3	-	-	-
4a	1.0	-	0.9	-	-
4b	0.2	0.1	-	-	-
10	-	-	0.7	-	-
5	0.6	-	-	-	-
6	-	-	0.8	-	-
7	-	-	-	-	-
8	-	-	-	-	0.4
9	-	-	-	-	-
11	1.0	-	-	-	0.3
12	0.5	-	-	-	-
13	2.4	-	0.8	0.3	-
14	-	-	1.1	-	-
15	1.4	-	0.7	0.7	-
16	2.1	-	-	-	0.5
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	1.3	-	-
20	-	-	0.9	-	-
21	-	-	0.7	-	-
22	0.7	-	0.3	-	-
23	0.7	-	0.3	0.2	0.2
24	-	-	-	0.2	-
25	1.1	-	-	-	-
26	-	0.7	-	-	-
27	-	-	0.3	-	-
28	-	-	-	-	-
29	0.3	-	-	-	-
30	0.7	-	0.3	0.7	0.2

Tables 1 to 3.

1 - Mineral composition of analyzed samples (vol. %). Components: 1) rock fragments (mainly limestone), 2) rounded radiolarite grains, 3) rounded quartz grains, 4) sharp quartz grains, 5) Fe-Mn oxides.

2 - Traces of human activity in analyzed samples (vol. %). Components: 6) grains of burned quartz, 7) charcoal, 8) bone fragments, 9) burned clay (from hearths), 10) small flakes of white radiolarite.

3 - Traces of human activity in analyzed samples (vol. %). 11) small flakes of red radiolarite, 12) small flakes of green radiolarite, 13) small flakes of gray radiolarite, 14) small flakes of laminated radiolarite, 15) grains of hematite.

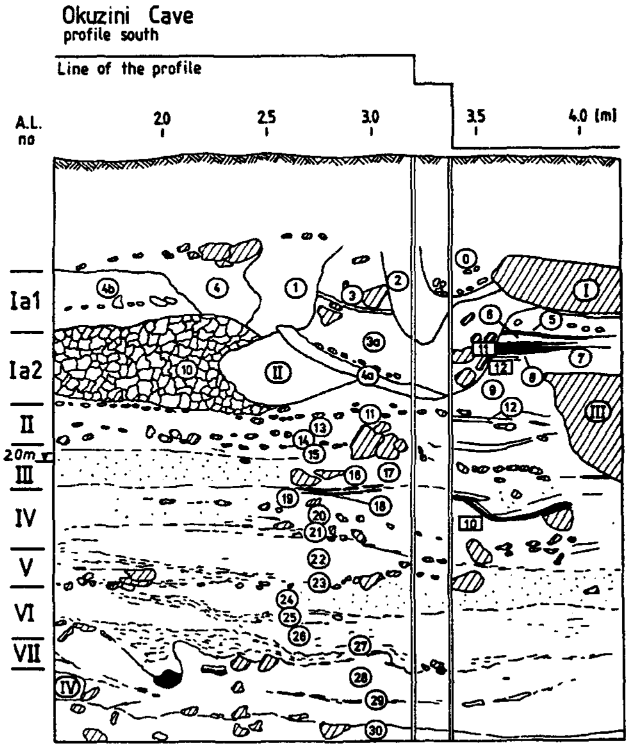


Figure 1. Geological profile of the trench. A.L. no. – number of archaeological layer (by J.-M. Léotard). In circles – numbers of mineralogical samples.

waters penetrating carstic system.

1.4 *Traces of human activity*

The following anthropogenic components were tested: burned quartz grains, charcoal, small bone fragments, fragments of burned clay and small grains of hematite.

Burned quartz grains

These grains have a characteristic surface and are not transparent. The color is gray, pinkish or reddish, depending on the zone of oxidation in the hearth.

Charcoal

Fragments of burned wood are easy to determine due to clearly visible organic tissues.

Bone fragments

Bone fragments are easy to determine as well because of the characteristic porous structure (spongea) or litic structure characteristic of the bone cortex. Two types of fragments were observed: natural and burned. Natural fragments are sharp and yellowish in color. Burned fragments are dark gray and show traces of heating, sometimes even of melting. Both types of fragments were calculated together.

Fragments of burned clay

These fragments constitute elements of burned clay present under or around the hearths.

Small radiolarite flakes

They are clearly seen under the microscope as sharp, thin fragments of microflakes. Color varies and includes white, red, green, gray, and laminated of various colors.

II. RESULTS OF INVESTIGATION

2.1 *Sedimentation*

The sequence of the sediments (Fig. 1) documents many phases of sedimentation, erosion and human occupation of the cave (Fig. 8, Table 1).

Sediment no. 35, sample no. 30 (Figs. 1-3)

This sediment is dark in color due to admixture of small charcoal grains. It is composed of clay minerals (redeposited terra rossa – poorly crystallized kaolinite) containing small grains of limestone as well as radiolarite grains.

Sediment no. 34-33, sample nos. 30-29 (Fig. 4)

After deposition of sediment no. 35 and before no. 34, limestone block no. IV fell (Fig. 4, left side). Nos. 34 and 33 are represented by red clay (redeposited terra rossa) containing intercalation of traces of human activity (sample 29). The clay was soft and wet during deposition and because of this, the top of the sediment is undulated. The clay was introduced into the cave from the morphological surface of the limestone present just above of the roof of the cave. Redeposited terra rossa migrated down through the fissures and holes of the cave roof. This way of transport documents higher humidity and stronger rains outside the cave than at the time of deposition of older sediment no. 35.

Sediment nos. 32-26, sample nos. 27-21 (Fig. 5)

These sediments document a reduction in intensity of introduction of terra rossa into the cave through roof of the cave together with increased intensity of human occupation. This sequence indicates lower humidity out of cave , i.e., small rains.

Sediment nos. 20-10, sample nos. 20-5 (Fig. 3, Fig. 5)

This sequence is a continuation of the earlier deposition and migration of natural mineral materialinto the cave, mainly via fissures in the roof (Fig. 6). The intensity of the process is similar to that observed earlier (for sediments 32-21), but the intensity of human occupation is much higher. As a result, between samples 21 and 20, the color changed from gray-reddish to gray (due to a high admixture of powdered charcoal). After deposition of sediment no. 20, limestone block no. III fell (Fig. 5). Sediment no. 10 is the last sediment of silent conditions in the cave.

Sediment no. 9, sample no. 10 (Fig. 3, Fig. 5)

After a long period of continuous deposition, an extremely strong inflow of karstic waters destroyed the sediments. Sediment no. 9 represents limestone pebbles introduced into the cave by these waters. This means that after a long period during which Öküzini cave was dry, the karstic system was reactivated. Sediment no. 9 (sample no. 10) documents catastrophic, heavy rains in the region during the deposition of this layer or just before block no. II fell. The location of this block is seen as an empty hole in the central part of the profile (Fig. 5).

Sediment nos. 8-3, sample nos. 4b-0 (Fig. 1, Fig. 6)

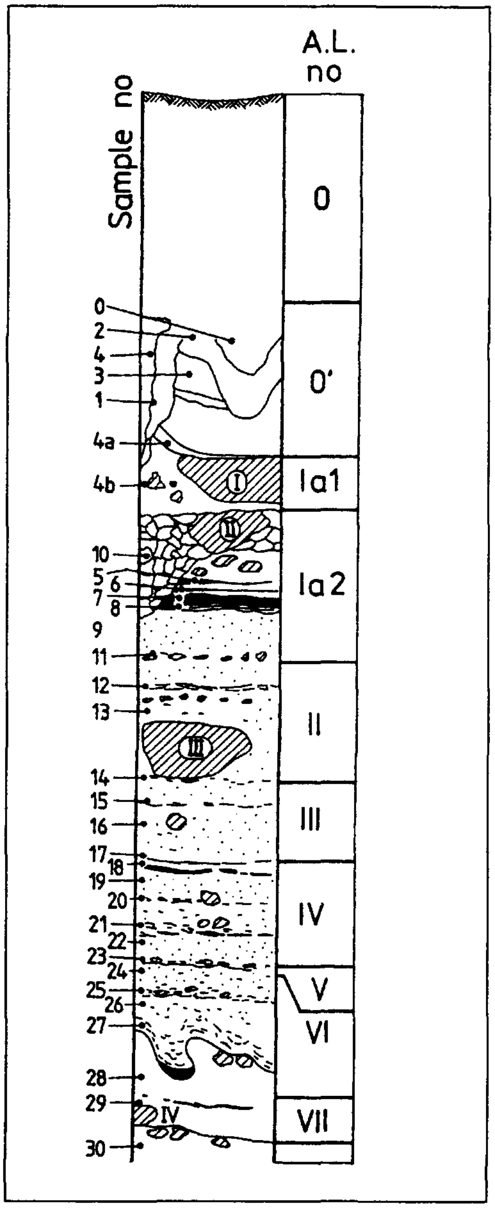
This sequence of sediments documents a gradual reduction in karstic water activity in the cave. After deposition of sediment no. 7 (sample no. 4b), a smaller water channel was formed which was then filled with sediments 6 and 5. These sediments were cut by another small water channel which was filled with sediments 4 and 3 (sample nos. 2 and 0).

Sediment nos. 2-1, sample nos. 4, 1 (Fig. 1)

These sediments are probably artificial holes filled with redeposited material.

Sediment no. 0, not sampled (Fig. 1-2)

This sediment is represented by mixed material and has



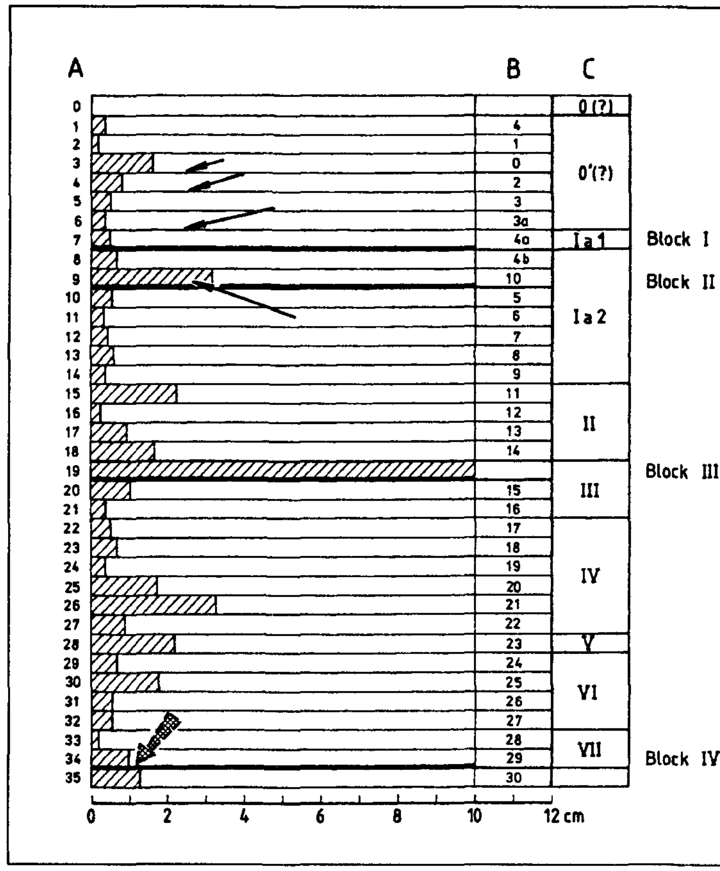


Figure 3. Medium grain size of tested samples.
A - sediment number.
B – mineralogical sample number.
C – archaeological layers.
Upper arrows – vector of intensity of karstic water flow across the cave.
Lower arrow – beginning of deposition of wet, red clay.

Figure 2. Locations of samples in the profile.

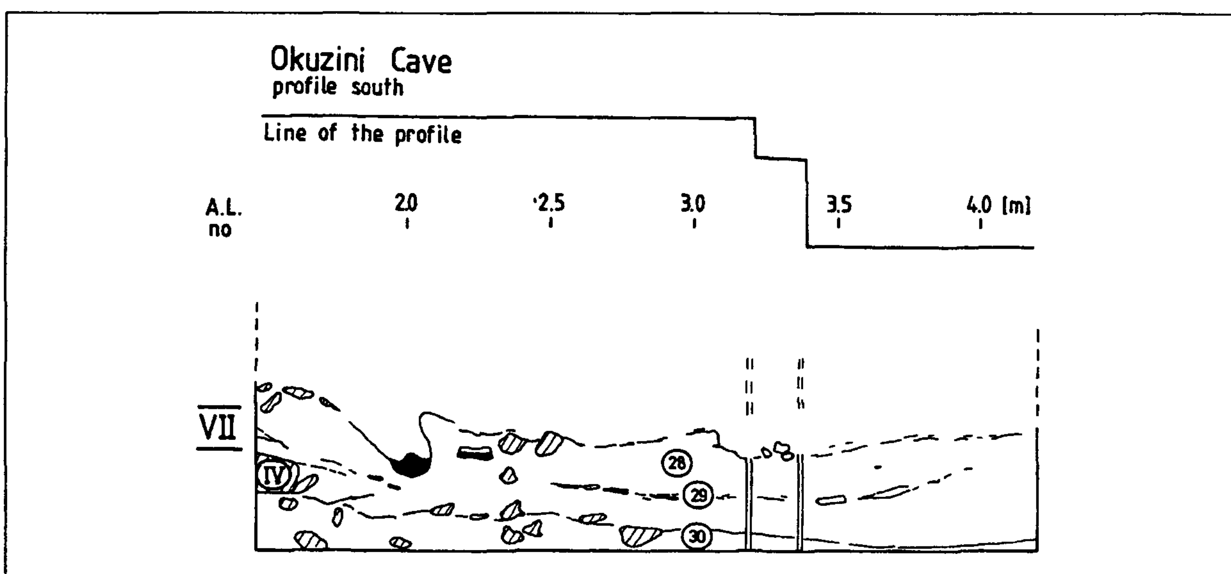


Figure 4. Deposition of sediments in Phases VIII and VII.

not been mineralogically tested.

2.2 *Human activity*

A diagram of traces of human activity (Tables 2-3, Fig. 8) shows many phases of occupation in the cave. Sedimentological and mineralogical data, as well as traces of human activity, suggest the following climatic and occupation phases for the cave:

Phase VIII (end of Older Dryas?). This earliest phase is represented by sediment no. 35 (sample no. 30). The layer documents intense occupation of the cave, which is confirmed by the high amount of bone fragments (up to 3%), fragments of burned clay (about 10%) and small flakes of different types of radiolarite microflakes, and grains of hematite (Fig. 9). This is a phase of relatively little sedimentation and suggests a relatively dry, and probably slightly colder, climate.

Phase VII (Alleröd?). This phase is documented by red clay (sediment nos. 35 and 34) containing horizons of human activity (sample no. 29). Deposition was relatively fast. Terra rossa from the hill slope was transported into the cave as wet, soft mud via the cave roof. This indicates a wet climate, with much more rain than in Phase VIII. The floor of the cave, covered as such with soft, red mud, was not conducive to human occupation, and traces of human activity are only found in sediment no. 34 (sample no. 29).

Phase VI (Younger Dryas?). This phase is documented by sediments. 32-26 (sample nos. 27-21). At the beginning of this phase, occupation developed on the soft surface of red clay. Because the top of this surface was not stable, the first archaeological horizon (sample no. 27) is strongly folded and destroyed. During Phase VI, occupation intensified. The proportion between naturally introduced and anthropic sediments continually changed. In Figure 7, one can see an ever increasing contribution from human activity. There were likely many occupation events during this phase. The amount of terra rossa introduced into the cave is less than in Phase VII and indicates decreased humidity.

Phase V (Late Preboreal?/Boreal?). This phase is documented by sediments 25-10 (sample nos. 20-11, 9-5). There are no significant differences between this phase and phase VI regarding intensity of natural sedimentation rates (again via the cave roof) but human activity is much more intensive. It is clearly observable in the very high concentration of charcoal, burned clay, bone fragments, etc. (Fig. 7). This suggests that the only difference is of intensity of occupation in Phases VI and V with only slight changes in climate.

Phase IV. This phase is documented by sediment no. 9 (sample no. 10) and is a phase of very intensive destruction of the cave sediments. Limestone pebbles were introduced intro the cave by karstic waters from the reactivated karstic system. At this point, limestone block no. II fell from the rood. Catastrophic rains are indicated. Small admixtures reflecting human activity are present in secondary position. This is supported by the presence of slightly rounded radiolarite microflakes. Because of this, radiocarbon dates of the charcoal will be older than the actual age of the sediment.

Phase III. This phase is documented by sediment no. 8 (sample no. 4b), which indicates that conditions were similar to those in Phase V. Archaeological material is again in primary position, but in comparison to Phase V, only in small quantity, suggesting a reduction in intensity of human activity in the cave.

Phase II. This phase is documented by sediments 7-3 (sample nos. 4a-0) and represented by a sequence of channels eroded by karstic streams flowing across the cave and their infilling. Sedimentation and erosion processes during this phase are similar to those in Phase IV (intensive rains and reactivation of the karstic system), but the intensity is gradually reduced, evidenced by smaller and smaller channels as rainfall decreases in intensity. Traces of human activity are mainly in secondary position. For objective determination of human activity during this phase, it is necessary to take samples from other, undisturbed, profiles.

Phase I. Sediments 2 and 1 (samples 1, 4) represent artificial holes which were filled with secondary material.

Phase O. Sediment 0, which was not sampled, is an artificial mixture of sediments and is probably backdirt from earlier excavations.

2.3 *Discussion*

The mineralogical and sedimentological phenomena observed at Öküzini cave correlate well to the description of climatic changes in southern Turkey (Beyeshir, Sogut, Ora; Bottema 1991) but should be confirmed by palynological and archaeological data as well as radiocarbon dates.

ACKNOWLEDGMENTS

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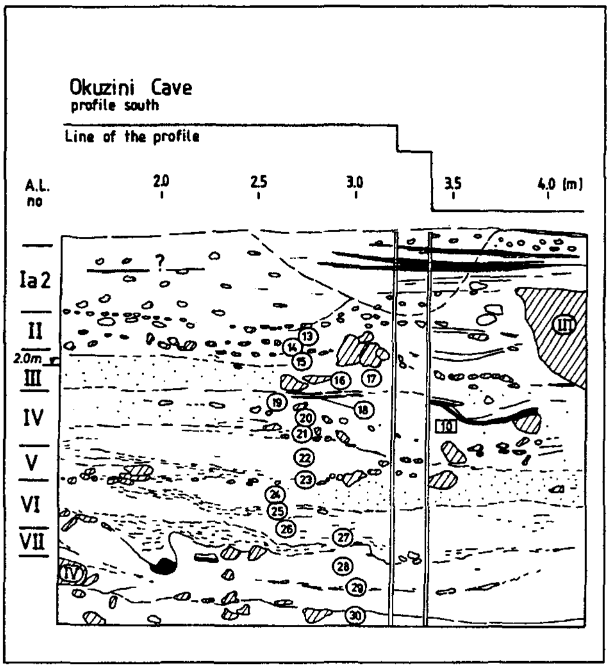

Figure 5. Deposition of sediments in Phases VI and V. Discontinuous line - future channels.

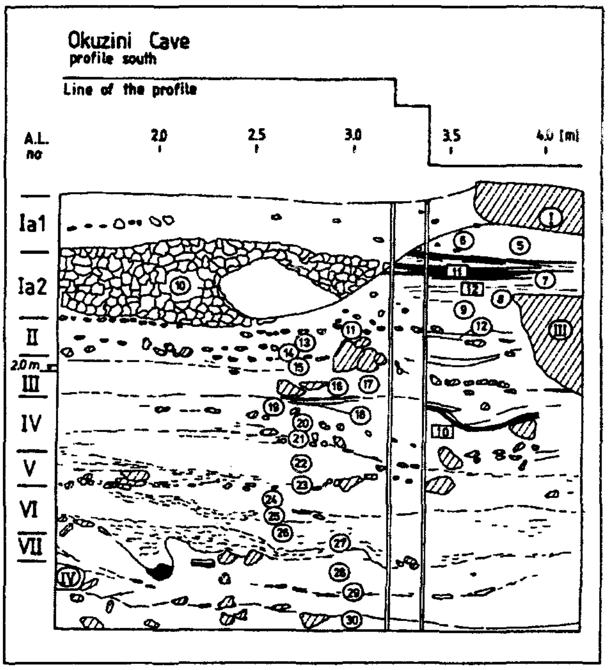

Figure 6. Erosion and deposition of Phases IV and III.

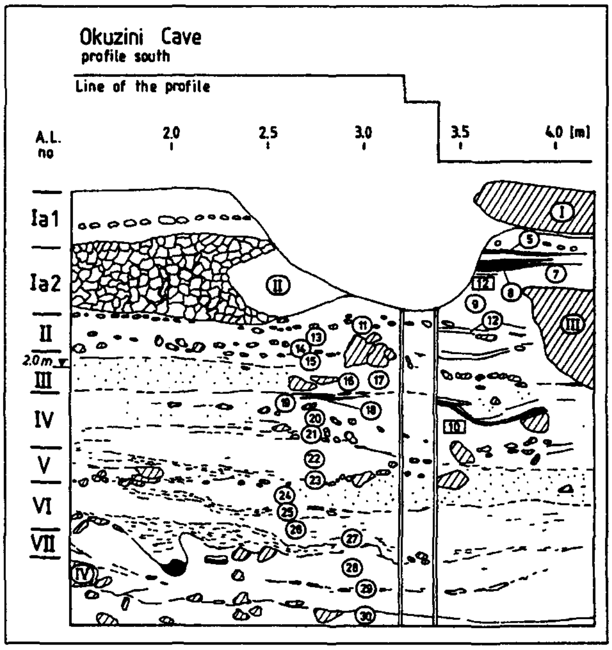

Figure 7. Erosion after Phase III.

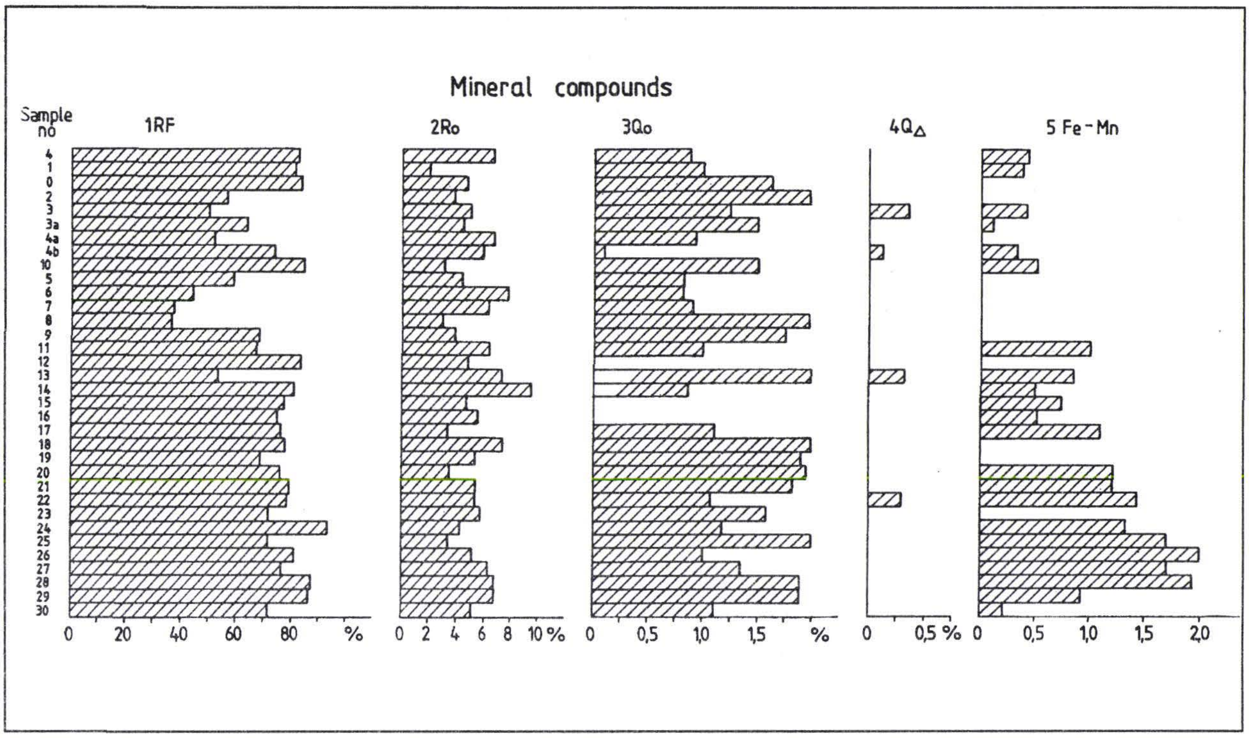

Figure 8. Diagram of the presence of tested mineral compounds (volumetric percent).

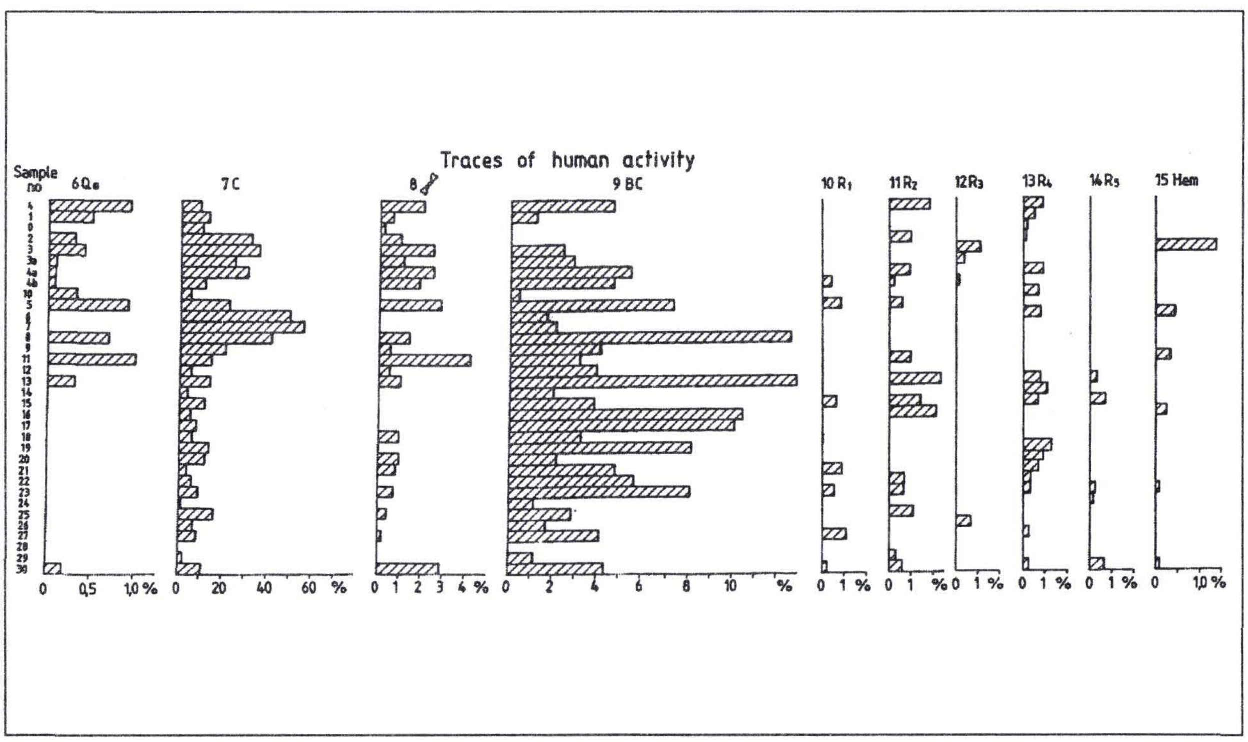

Figure 9. Diagram of the presence of tested traces of human activity (volumetric percent).