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THE UPPER PLEISTOCENE IN THE PAGLICCI CAVE (GARGANO, SOUTHERN ITALY): LOESS AND TEPHRA IN THE ANTHROPOGENIC SEQUENCE

Abstract - Paglicci Cave (SE Italy) represents undoubtedly one of the reference cave sequences for Southern Italy, both for archaeological and palaeoenvironmental implications. The aim of the present paper is the study of the basal portion of the deposit (Interpleniglacial-first phases of Last Pleniglacial). For this purpose, standard sedimentological methods were applied, together with heavy mineral determination and micromorphology. In lower units, sediments result from transportation of weathered volcanic material from the surrounding areas, connected with the Vulture volcanic activity. At *c.* 34,000 y BP, Campanian Ignimbrite fresh pyroclastic material is recognised. Above this unit, glacial conditions predominate, as indicated by cryoclastic deposits. Beside gelifraction, arid phases of loess deposition are recognised. Loess exhibits the same mineralogical assemblage of Campanian Ignimbrite deposits, confirming the persistence of western winds in the area.

Key words - soil micromorphology, Campanian Ignimbrite, Aurignacian, Gravettian, Paglicci Cave, Italy.

Riassunto - *Il Pleistocene superiore della Grotta Paglicci (Gargano, Italia meridionale). Loess e tephra nella sequenza antropica*. La Grotta Paglicci (Italia sud-orientale) è indubitabilmente una delle sequenze di grotta di riferimento per l'Italia meridionale, sia dal punto di vista archeologico che paleoambientale. Lo scopo di questo lavoro è lo studio della parte basale del deposito (Interpleniglaciale-prime fasi dell'Ultimo Pleniglaciale); a questo fine sono stati applicati metodi sedimentologici standard, determinazioni di minerali pesanti e micromorfologia. Nelle unità inferiori, i sedimenti sono originati dal trasporto di materiale vulcanico alterato proveniente dalle aree adiacenti, connesso con l'attività vulcanica del Vulture. A circa 34.000 anni BP si riconosce la presenza di materiale piroclastico fresco dell'Ignimbrite Campana. Al di sopra di questo predominano condizioni glaciali, come indicato dai depositi crioclastici. Oltre alla gelifrazione si riconoscono anche fasi aride di deposizione di loess; questo mostra la medesima composizione dei depositi dell'Ignimbrite Campana, confermando la presenza di venti occidentali nell'area.

Parole chiave - Micromorfologia del suolo, Ignimbrite Campana, Aurignaziano, Gravettiano, Grotta Paglicci, Italia.

INTRODUCTION

Paglicci Cave (Rignano Garganico, Foggia) is located in south eastern Italy, in the western side of the Gargano promontory, at about 100 m a.s.l. (Fig. 1).
The cave was discovered at the end of the 1950s and archaeological excavations were performed in the 1960s. The systematic excavation of the site started only at the end of the 1970s, under the direction of Prof. A. Palma di Cesnola who invited the Authors to investigate the sequence from sedimentological and palaeoenvironmental points of view.
The site is composed of a rockshelter and an underground cave. The rockshelter fill includes archaeological artefacts spanning from the late Acheulean to Mousterian. In the cave the whole stratigraphy is about 8 m thick and subdivided into 26 units. The archaeological stratigraphy spans from Aurignacian (unit 24) where the oldest radiocarbon date was obtained (34,000+900/-800 y BP), to Late Epigravettian (unit 2, 11,440 ± 180 y BP).
This paper focuses on the basal portion of the stratigraphy (units 22 to 26) where significant sedimentological and mineralogical changes are recorded. Radiocarbon datings of these units span from 34,000+900/-800 y BP to 26,800 ± 300 y BP, while the archaeological evidences range from Aurignacian to Early Gravettian.

METHODS

The whole stratigraphic sequence was described according to Hodgson (1976) and Courty *et al.* (1989). From each unit were collected both bulk samples and undisturbed and oriented samples for thin section preparation.
Particle-size analysis for gravel and sand fractions was performed by wet sieving (sieves with 1/2 Φ interval). Percentages of silt and clay fractions were determined by hydrometric analysis.
Organic carbon content was determined using the Walkley and Black method (Ministero delle Risorse Agricole, Alimentari e Forestali, 1994), by oxidation of organic matter.
Heavy minerals were separated in the fine sand fraction (180÷63 μm), using sodium metatungstate (density: 2.9 g/cm^3) and mounted on slides with Canada Balsam. In each slide, 150 transparent granules were counted under the petrographic microscope, with the aid of Parfenoff *et al.* (1970) and Mange *et al.* (1992).
Micromorphological description was carried out according to Bullock *et al.* (1985), with some integration from Stoops (1998) and, as far as concerned to interpretation, with the reference of Courty *et al.* (1989).

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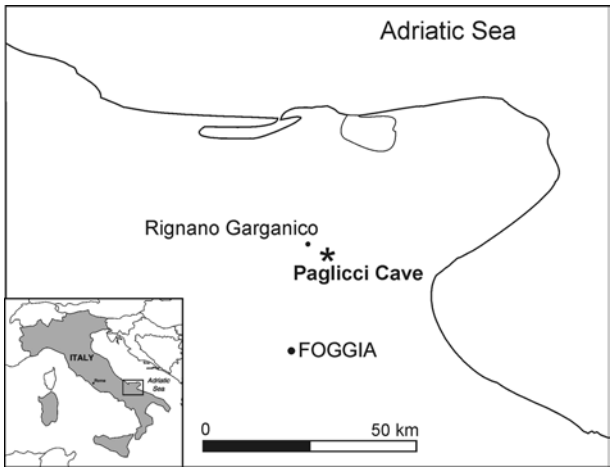

Fig. 1 - Location of Paglicci Cave.

DESCRIPTION OF THE STRATIGRAPHIC SEQUENCE

The detailed description of the stratigraphy (Fig. 2) is proposed in Table 1. The base of the sequence (unit 26) consists of a carbonatic crust, overlain by a thick, reddish, silty loamy laminated unit, containing abundant pedorelicts (*sensu* Brewer, 1964) and lithorelicts. Over an erosive surface, the upper portion of unit 26 consists of a light brown silty clay loamy laminated unit.
Unit 25 consists of red laminated silty clay and is covered by a discontinuous carbonatic lens.
Unit 24 is subdivided into several subunits with different sedimentological characteristics: at its base reddish brown silty clay loam sediments are recorded, as in the underlying units 25 and 26.
In units 24b2 and 24b1, a remarkable sedimentological change occurs: silty clay laminated sediments are recorded, containing abundant subrounded weathered lithorelicts (pyroclasts). This unit is radiocarbon dated to 34,000+900/-800 y BP.
A new change in the nature and dimensions of sediments occurs in the upper part of unit 24: from unit 24a4, strongly weathered limestone fragments (breccias and boulders) are found inside laminated sediments.
Toward the upper part of unit 24, breccias and boulders become increasingly admixed with silty loam light brown sediments. Unit 24a1 gave a radiocarbon date of 29,300 ± 600 y BP.
In unit 23, breccia is common, although less than in unit 24, filling spaces left in between big boulders of the lower unit. Fine fraction is similar to the one of unit 24 (dark brown silty loam), except for the sandy laminated sediments of the lowest portion. A radiocarbon date of 28,100 ± 400 y BP is available for unit 23c.
In the upper portion of unit 23, limestone fragments are still present, together with silty matrix. In this portion, coarser elements show planar fabric. A radiocarbon date of 26,300 ± 400 y BP was obtained from unit 23a.
Unit 22 is essentially anthropogenic, as it is composed of ash layers, organic and organic origin material, alternated with planar layers, where mineral fraction predominates. Dates for this unit span from 28,300 ± 400 y BP (unit 22f4) to 26,800 ± 300 y BP (unit 22b).

RESULTS

Textural analysis

Results of textural analysis are summarised in Figure 3 and 4. In Figure 4, the textural diagram plotted with depth shows that coarse (> 2 mm) fraction is very scarce in basal units and increases toward the top, reaching a peak of 38.66% in the higher unit (22a). On the contrary, sand and silt do not show strong variations. Clay fraction is more abundant toward the lower portion of the profile.
Among fine fractions, sand content is essentially constant all along the profile, with percentages ranging between 2.85 and 22.34%. Silt is abundant, especially in unit 24b1, where it reaches 78.84%. Clay occurs in considerable amounts with a first maximum between units 24b5 and 25, where it reaches 37.79% and two lower maximums, in units 24a3-2 (22.95%) and 23b (29.12%).
Cumulative curves show significant trends and they can be subdivided into two main groups (Fig. 4). The first group (Fig. 4A) includes the upper units (22antr, 23b, 23c, 23 base and 24b1) and the lowest one (26h), and contains 6.16 to 29.12% of clay, with a variable amount of sand. These curves show a single-mode trend with median value comprised between 5 and 6 Φ, corresponding to medium silt size.
Second group (Fig. 4B) (24b2, 24b5, 25 and 26e) is more heterogeneous and contains higher amounts of clay, with a moderate sand content. Inside this group, units 24a3-2 and 25 contain an even higher clay content, especially in unit 25 (37.79%), where sand fraction is negligible (2.85%).

Organic matter content

Organic matter has more or less similar values throughout the stratigraphic sequence (Fig. 5), with the exception of an abrupt increase in unit 22 (2.9%). Organic carbon percentage spans between 0.5 and 1.22% in the other units.

Heavy minerals

Heavy minerals extracted from fine sand fraction show significant variations with depth (Tab. 2 and Fig. 6). They are essentially pyroxenes and amphiboles, but in the lower portion (from unit 24a3-2) a strong increase in garnets, sphene and spinels is recorded.
In the upper portion of the stratigraphy (from unit 22a to 23 base), transparent species strongly dominate (Fig. 6A), ranging between 86.81 and 97.50%. On the contrary, in lower portion (from unit 24b2), although transparent species still dominate, opaque minerals increase, spanning from 37.14 to 57.06%.
Ultrastable species (zircon, tourmaline and titanium oxides) are always present in low percentages in the upper portion of the stratigraphy (1.04-5.68%) and

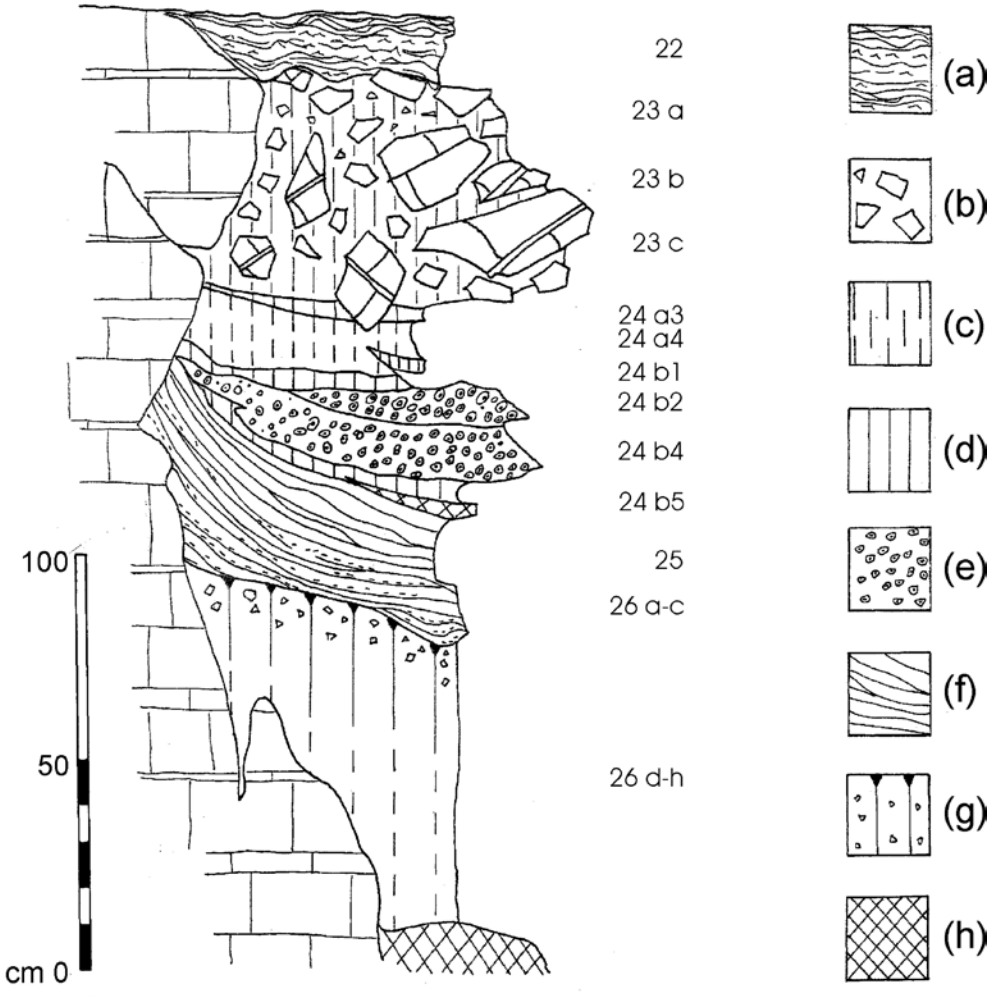

Fig. 2 - Stratigraphic sequence of lower portion of Paglicci Cave deposit. a: units strongly affected by human activity; b; cryoclastic material; c: aeolian matrix and breccia; d: aeolican matrix; e: deposit including high concentration of pyroclastic material; f: laminated deposit containing pyroclastic material; g: strongly weathered pyroclastic deposit; h: stalagmite.

show an increase toward the base of the sequence (Fig. 6B); in units from 25 to 26h, ultrastable species range between 8.64 and 11.11%. The maximum for these minerals (13.16%) is recorded in unit 24b2.
From unit 22 to unit 23 base, dominant species are pyroxenes (41.77-65.36%) and amphiboles (15.91-41.77%), especially of the green varieties, *i.e.* augite for pyroxenes and hornblende for amphiboles.
In unit 24a3-2, mineral assemblage is more varied, showing a strong decrease in pyroxenes (max 40%) and only a relative decrease in amphiboles (max 18.06%). In this portion of the stratigraphy it is also recorded an increase in garnets (max 49.67%), sphenes (58.94%) and, in minor amount, of ultrastable species (max 13.16%).
It is therefore possible to subdivide units into two main groups, denoting a drastic change in the mineral assemblage. The lower portion of the stratigraphy (from unit 26 to 24a) is characterised by a high content in opaque minerals, garnets, sphene and spinels, whilst the content of pyroxenes and amphiboles is low. From unit 24b2 toward the top, pyroxenes and, in smaller amount, amphiboles, both mainly of the green colour, become the most abundant mineral species, marking a strong mineralogical change in the sediments.
The upper units (units 22 a-23 base) are characterised by a low content of opaque minerals, whilst pyroxenes and amphiboles of mainly green colour are the most abundant transparent minerals.

Micromorphology
The main micromorphological characteristics are summarised in Table 3, and some significant features are shown in Plate 5.
Unit 26h exhibits crumb microstructure and porphyric c/f related distribution, as recognised in all the

Tab. 1 - Description of the stratigraphic sequence. Radiocarbon datings after Palma di Cesnola (1992).

Stratigraphic units	**Field characteristics**	**^{14}C datings (y BP)**
22; 0-15 cm	Brown (10YR 4/3) silty loam; common stones some cracked by fire; planar, undulated and centimetric thick *laminae* are alternated to charcoal and ash lenses; abrupt undulated boundary.	26,800 ± 300 (22b); 28,300 ± 400 (22f4)
23; 15-30 cm	Dark brown (10YR 3/3) silty loam; common middle-big size stones; coarse elements (stones, artefacts and bones) show planar distribution; frequent burned pedorelicts; clear boundary.	26,300 ± 400
23b-23c; 30-50 cm	Pale brown (10YR 6/3) silty loam; dominant middle size angular breccia; massive; this unit fills the space between large boulders; clear boundary.	28,100 ± 400 (23c)
23base; 50-70 cm	Light olive brown (2.5Y 5/4) sand, in planar millimetric *laminae*; clear boundary.	
24a1; 70-75 cm	Light yellowish brown (10YR 6/4) silty loam; very dominant angular breccia; massive; gradual boundary.	29,300 ± 600
24a2-24a4; 75-82 cm	Yellowish brown (10YR 5/4) silty clay loam (pyroclastic deposit); from unit 24a4, strongly weathered limestone fragms. surrounded by a reddish brown, finely laminated crusts occur; massive at the top and laminated in the central portion, where darker centimetric *laminae*, containing millimetric concretions, are intercalated; few charcoals; clear boundary.	
24b1; 82-90 cm (lateral to unit 24a)	Dark yellowish brown (10YR 4/4) silty loam; massive, subhorizontal; common subrounded lithorelicts, composed of porous whitish weathered pyroclasts, surrounded by a millimetric orange halo; clear boundary.	
24b2; 90-100 cm	Light yellowish brown (10YR 6/4) silty loam; laminated; frequent subrounded lithorelicts with a millimetric orange halo; clear undulated boundary.	34,000+900/-800
24b4-24b5; 100-117 cm	24b5 is brown (10YR 5/3), while 24b5 is darker, silty clay loam; common pale brown (10YR 6/3) tixotropic lenses, horizontal or slightly undulated; 24b5 is a very porous and friable thin layer; massive; clear boundary.	
25; 117-137 cm	Reddish yellow (7.5YR 6/6) silty clay; planar centimetric and millimetric *laminae*; at the top, a calcite discontinuous and undulated lens represent the upper boundary; clear boundary.	
26a-26c; 137-150 cm	Reddish yellow (7.5YR 6/6) silty clay; planar centimetric and millimetric *laminae*; abrupt, erosive upper boundary.	
26d-26i; 150-200 cm	Yellowish brown (10YR 5/4) silty clay loam; massive, except for 26f, laminated; scarce bioturbation voids, containing centimetric, circular areas, made of light brown material; clear boundary.	
26l-26h; 200-220 cm	Brown (10YR 5/3) silty loam; massive; common dark carbonatic concretions; scarce bioturbation voids, with grayish green coatings; 26h is mainly composed of abundant grey angular pedorelicts, and few light red pedorelicts; lower boundary made of a thick carbonatic concretion.	

described units. Voids are frequent compound packing voids and common channels and planes; in the profile, voids are often organised in a sort of net, less developed going toward the top, until they vanish in unit 24a4. The coarse fraction is scarce and composed of a few grains of feldspar (sanidine), quartz and a few weathered pyroclastic fragments. Fine fraction is reddish with crystallitic b-fabric. Scarce bone fragments are found. Pedofeatures are mainly represented by thick clay coatings and internal crusts (*sensu* Stoops, 1998), phosphates infillings and other scarce pedofeatures interpreted as hyena coprolites (Pl. 5B) (Courty *et al.*, 1989). These

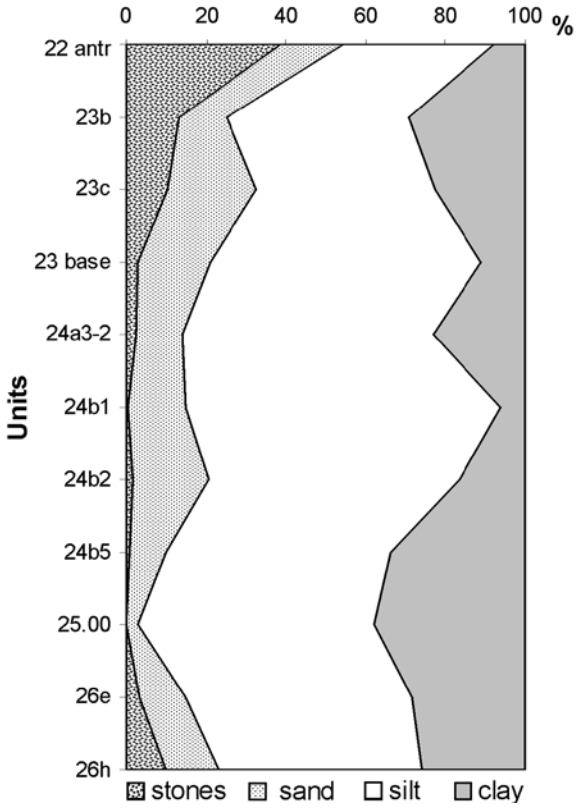

Fig. 3 - Grain-size profile.

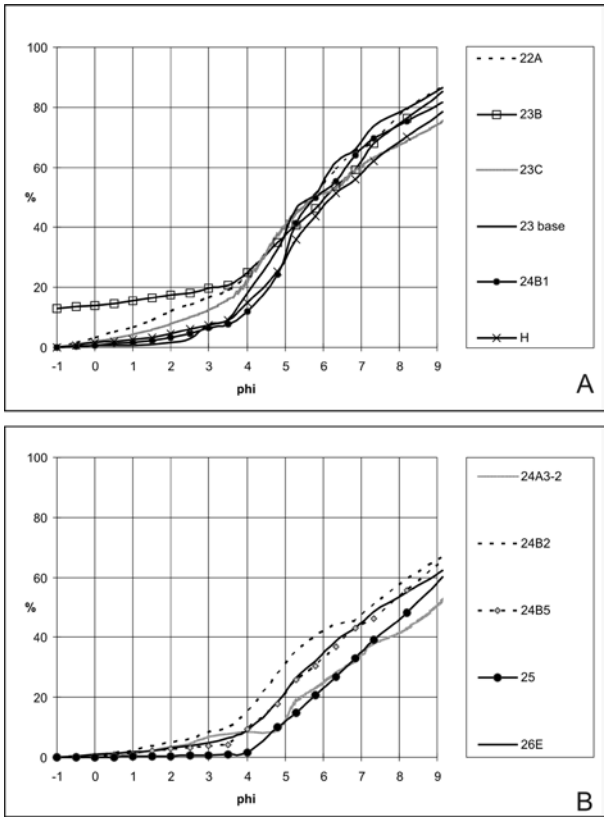

Fig. 4 - Cumulative curves.

pedofeatures have centimetric size and are rounded, pale yellow (only few are red) and contain scarce feldspars and quartz grains of the silt size; groundmass is prevalently made of amorphous organic matter and of abundant black organic punctuations; voids are vughs and others are very elongated pores with smooth walls (resulting after hair decomposition).

Unit 26h sup is comparable to unit 26h. Voids are frequent planes and star-like vughs, and very common vughs. Coarse fraction is here more abundant. Pedofeatures are frequent iron impregnations and scarce pedorelicts (rounded, mainly composed of reddish clay; coarse fraction is composed by scarce feldspars and quartz; they are often surrounded by coatings and weathering halo).

Unit 26f has a vescicular microstructure and the coarse fraction shows planar fabric. Dominant voids are vescicles, together with frequent planes and channels. Beside coarse fraction similar to the one of other sections, scarce pyroclast fragments and frequent phosphates are found. Fine fraction is red, with mosaic speckled and granostriated b-fabric. Bone fragments are frequent, while charcoals are scarce and phytoliths common. Pedofeatures are common pedorelicts, scarce yellowish-red coatings and weak iron elongated impregnations.

Unit 26e is similar to unit 26f, except for crumb microstructure and crystallitic b-fabric. In this unit, bone fragments are scarce. Among pedofeatures, are recognised brown coatings, clay internal crusts, common reddish rounded pedorelicts and scarce canid coprolites.

Unit 25 is characterised by blocky and vesicular microstructure; the upper portion is arranged in alternating *laminae* (Pl. 5F): red (fine silt texture) and brown (coarse silt - fine sand texture), with clear upper boundary and gradual lower boundary. Voids are frequent planes and channels and common vescicles. The scarce coarse fraction also contains micas. Fine fraction, reddish to brown in colour, shows a grano- and porostriated b-fabric. The only recognised pedofeatures are common yellowish-red clay coatings.

Unit 24b5 is very similar to unit 25, except for a laminated crack microstructure. Beside common planes, frequent compound packing voids are found. As in unit 25, the coarse fraction is scarce, but also rare phosphates and rare weathered pyroclastic fragments are recognised (Pl. 5E). Scarce bone fragments and frequent phytoliths are found. This unit is richer in pedofeatures than unit 25: besides reddish hypocoatings, common reddish pedorelicts are found, often with fine cappings and common coarse cappings.

As unit 24b5, unit 24b4 is laminated and its micro-

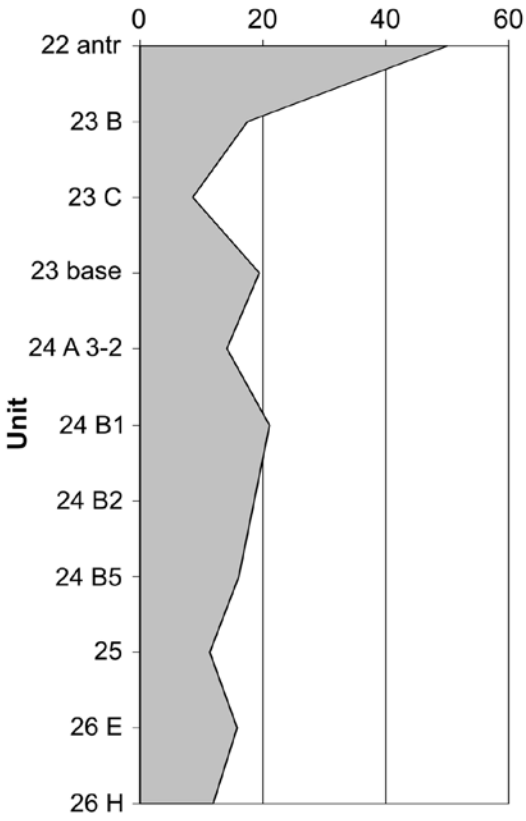

Fig. 5 - Variations of organic carbon content with depth.

structure is of the crumb type. Voids and coarse fraction are as in unit 24b5. Fine fraction is reddish, with crystallitic b-fabric. Pedofeatures are represented by common brown coatings, common pedorelicts and clay internal crusts.

Unit 24b2 differs from the two underlying units, except for a crumb microstructure; vughs are abundant, while starlike vughs and planes are frequent. Coarse fraction is more abundant than in the underlying units. Fine fraction is rather similar: yellowish-red to reddish-brown in colour, with a mosaic speckled and granostriated b-fabric. Charcoals and bones are scarce, while amorphous organic matter is frequent. Pedofeatures are limited to frequent iron impregnations and scarce pedorelicts.

Unit 24b1 is comparable to units 25, 24b4 and 24b5, except for a horizontal disposition of the coarse fraction and voids. Dominant voids are vescicles, while planes and channels are frequent. Coarse fraction is similar to unit 25 but more abundant; phosphates are frequent (Pl. 5D). Fine fraction is red in colour and shows mosaic speckled and granostriated b-fabric. In the groundmass frequent (burned) bone fragments, scarce charcoals and common phytoliths are found. Among pedofeatures, beside scarce yellowish-red coatings (see unit 25), common pedorelicts are found.

In unit 24b1, the void arrangement induces a different aspect; dominant vughs give rise to a spongy microstructure. Coarse fraction is similar to the one of unit 24b5. Yellowish-brown fine fraction exhibits a crystallitic b-fabric. Common (burned) bone fragments are found. The only recognised pedofeatures are small iron impregnations.

Unit 24a4 is similar to other thin sections and exhibits spongy microstructure. Dominant voids are vughs. Coarse fraction is composed of dominant feldspars (sanidine) and quartz and rare pyroclastic fragments. Fine fraction is yellowish-brown with crystallitic b-fabric. Common (burned) bone fragments are present. As in unit 24b1, the only recognised pedofeatures are small iron impregnations.

Unit 24a3/2 is very similar to 24b1, but in coarse fraction are also present scarce limestone fragments and abundant phosphates. Among pedofeatures, beside iron impregnations, common pedorelicts, with strongly iron cemented groundmass, are recognised.

Unit 23 base shows micromorphological characteristics completely different from the other sections. Microstructure is single grain, locally vughy. Voids are dominant simple packing voids and starlike vughs, frequent complex packing voids and channels. Coarse fraction is composed by dominant feldspars (sanidine) and quartz, common pyroxenes and green amphiboles, scarce limestone fragments; the most peculiar feature is represented by abundant fresh pyroclastic fragments (Pl. 5C). These are rounded objects, in which the coarse fraction is made of few sanidine crystals (often with acicular shape) and of other feldspars; the yellowish-light brown fine fraction is composed of a yellowish isotropic glassy material and displays mosaic speckled b-fabric. This unit contains scarce bone fragments, often iron coated. Pedofeatures are represented by common iron nodules and by fine coatings on pyroclastic fragments and mineral grains.

Unit 23c is partially different from the underling 23 base, showing crumb microstructure. Voids are frequent star like vughs and scarce channels and planes. Coarse fraction is composed of dominant feldspars (sanidine) and quartz; in this unit micas are found, increasing in upper units; scarce limestone fragments and scarce pyroclastic fragments are present. Fine fraction, being yellow, is lighter than other units and shows crystallitic b-fabric. Bone fragments and charcoals are frequent. As in unit 23 base, this unit contains iron impregnations, coatings on clasts, pedorelicts and canid coprolites (Pl. 5B).

Similarly, unit 23a exhibits crumb microstructure, voids are frequent compound packing voids, frequent planes and common vughs. Coarse fraction is composed of dominant feldspar (sanidine) and quartz, common limestone fragments, sometimes phosphatised. Fine fraction is yellowish-brown and appears slightly reddened; b-fabric is crystallitic. Bones fragments are abundant and charcoals common. Pedofeatures are the same described for unit 23c; moreover, micritic calcite, in the groundmass and as isolated block, is recognised.

At the top of the sequence, unit 22a displays channel microstructure and planar fabric: all the components are horizontally oriented. Central portion is laminated, scarcely porous and red in colour. Porosity is less

Tab. 2 - Heavy minerals percentages.

	RP 22antr	RP 23b	RP 23c	RP 23base	RP 24a3-2	RP 24b1	RP 24b2	RP 24b5	RP 25	RP 26e
Transparent	86.81	97.50	93.87	59.63	62.86	42.94	50.17	55.31	60.67	44.41
Opaque	13.19	2.50	6.13	40.37	37.14	57.06	49.83	44.69	39.33	55.59
Zircon	1.90	2.56	3.92	0.00	4.55	3.87	10.53	1.32	5.56	5.30
Tourmaline	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	1.85	1.32
Rutile	0.00	0.00	0.65	1.04	0.57	0.65	2.63	0.00	3.70	2.65
Brookite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anatase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green Amphiboles	36.08	26.92	15.69	12.50	5.11	7.74	2.63	0.66	3.70	1.32
Brown Amphiboles	1.27	2.56	5.23	5.21	7.39	8.39	1.32	1.99	1.23	2.65
Other Amphiboles	4.43	2.56	2.61	1.04	3.41	1.94	0.66	0.66	0.62	0.00
Green pyroxenes	25.95	26.92	40.52	51.04	6.82	30.97	3.29	0.00	0.00	0.00
Pyroxenes	15.82	30.13	24.84	10.42	14.20	9.03	5.92	5.96	4.32	4.64
Epidotes	10.76	6.41	3.27	4.17	9.66	4.52	3.95	5.30	1.85	2.65
Garnets	1.90	0.64	1.31	7.81	31.25	9.03	30.92	49.67	19.75	14.57
Baryte	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
Sillimanite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corundum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andalusite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphene	0.00	0.00	0.00	5.21	7.95	12.90	26.97	15.89	49.38	58.94
Spinel	0.00	0.00	0.00	0.00	0.00	1.94	8.55	12.58	3.70	3.31
Staurolite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Altered	1.90	1.28	1.96	1.56	8.52	9.03	2.63	5.96	4.32	1.99

frequent than in other units and it is mainly due to scarce planes and frequent channels. Coarse fraction is composed of dominant feldspar (sanidine) and quartz, scarce calcite, frequent micas and common limestone fragments. Fine fraction is yellowish-brown and darker in the central portion of the thin section, with stippled speckled b-fabric. Organic and organic origin material is abundant, including common charcoals and (burned) bone fragments (Pl. 5A), abundant phytoliths and vegetal remains and frequent amorphous organic matter. Pedofeatures are dense iron impregnations, calcite coatings and impregnations, and coarse cappings in some voids.

CONCLUSIONS

On the basis of the analysis of the lower portion of Paglicci Cave sequence, the main processes responsible for its deposition can be summarised as follows:

– The base of the stratigraphy (units 26 and 25) is composed of weathered pyroclasts and pedorelicts and under the microscope reveals sedimentary laminated structures. These units mark both the higher clay percentage and, among heavy minerals, a high amount of ultrastable species. Moreover, from the mineralogical point of view, these units are characterised by the predominance of minerals such as sanidine and, among heavy minerals, high content of opaque minerals, sphene, garnets and spinels, suggesting a volcanic origin of the sediments. These units result from the erosion and subsequent transportation, in wet and temperate environment, of soils and sediments of the surrounding areas, originating from the Pleistocene eruptive activity of Vulture volcano, which ended around 130.000 y BP (La Volpe & Principe, 1990; Laurenzi *et al.*, 1993).
– From unit 24b2 a dramatic sedimentological change occurs, as indicated by the deposition of fresh volcanic ashes and pyroclastic material, confirmed by a strong variation in heavy mineral assemblage: ultrastable species increase, while pyroxenes and, in smaller amount, amphiboles, both mainly of the green colour, become the most abundant species. The strong mineralogical variation suggests a change in the source area of the sediments. Moreo-

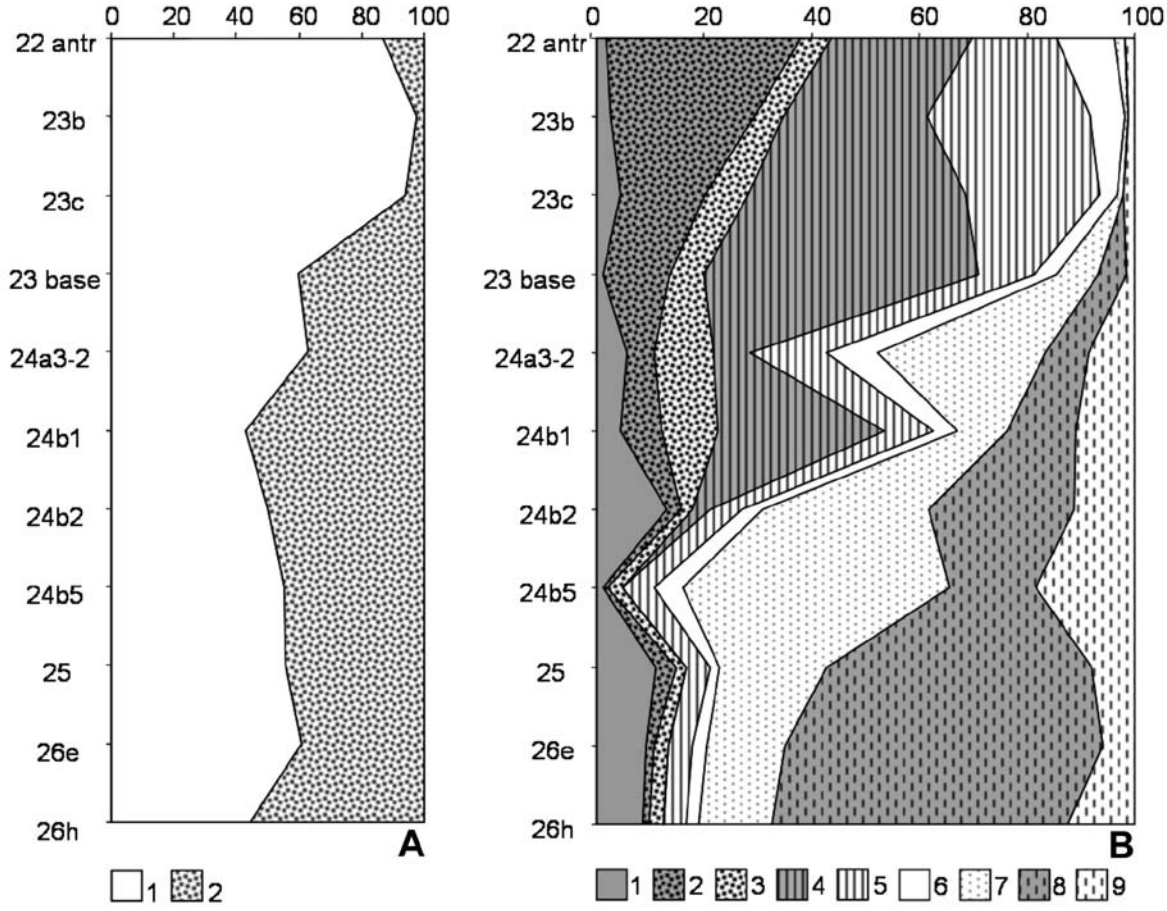

Fig. 6 - Heavy minerals. A: Transparent/opaque ratio: 1: transparent; 2: opaque. B: Transparent species assemblage: 1: zircon, tourmaline and titanium oxides; 2: green amphiboles; 3: other amphiboles; 4: green pyroxenes; 5: other pyroxenes; 6: epidotes; 7: garnets; 8: sphenes; 9: other species.

ver, the strong bioturbation suggests that these units experienced a subsequent phase of pedogenesis in wet and temperate climate.

– A new change in the nature and dimension of sediments is indicated in the upper portion of the unit 24 by the occurrence of cryoclastic limestone breccias and boulders. Such rock slabs were subsequently weathered and/or phosphatised and incorporated in laminated sediments, owing to a renewal of standing water conditions. Toward the top of unit 24, the cryoclastic material is progressively admixed with fine aeolian sediments, suggesting the onset of glacial and dry conditions. From the mineralogical point of view, loess has a mineralogical composition similar to the Campanian Ignimbrite deposits: the persistence of dusts from sources to the west in the stratigraphic record, confirms the persistence in the area of westerly winds.
– Beside the natural processes above described, from the upper portion of unit 24, anthropogenic inputs become more and more important as responsible for the cave infilling: high amount of organic material, charcoals, bone fragments and micritic calcite testify the increase of human frequentation in the cave. From unit 23c upward, a clear trampling lamination occurs and a high amount of phytoliths, with planar disposition, testify to an accumulation of grass inside the cave.

On the base of the archaeological content and of the available radiocarbon datings (Tab. 1), the processes indicated above can be dated as follow.

Unit 24b2 gave a radiocarbon date of 34,000+900/-800 y BP and the archaeological context is referred to Aurignacian. This evidence represents an *ante quem* term for the deposition the lower portion of the stratigraphy (units 26 and 25), that seems to have been deposited during a humid phase of the Interpleniglacial.

The same radiocarbon date of 34,000+900/-800 y BP (24b2) allows one to correlate fresh volcanic ashes and pyroclastic material of this unit with the Campanian Ignimbrite eruption, as also proposed by Fedele *et al.* (2002).

Tab. 3 - Description of thin sections, according to Bullock *et al*. (1985).

Unit	Microstructure	C/f related distribution	Voids	Coarse fraction	Fine fraction	Organic and organic origin material	Pedofeatures
22a	Channel; trampled	Open space porphyric	S planes; F channels; R vughs	D Fld (sanidine) and Qz; S calcite; F micas; C limestone frags	Yellowish-brown; Ss b-fabric	C charc.; A (burned) bone frags; F amorph. OM; A phytoliths and vegetal remains	Dense Fe and calcite impregnations; calcite coatings in pores, on granules and vegetal remains. Coarse cappings in some voids
23a	Crumb	Open space porphyric	F compound packing voids; F planes; C vughs	D Fld (sanidine) and Qz; S calcite, micas and HM; C limestone frags, sometimes phosphatised	Yellowish-brown, slightly reddened; Cr b-fabric	A (burned) bone frags; C charc.	Micritic calcite, in the groundmass and as isolated blocks; Fe nodules; pedorelicts (Fld, Qz and calcite in strongly Fe-impregnated groundmass); C coatings
23c	Crumb	Open space porphyric	F star like vughs; S channels and planes	D Fld (sanidine) and Qz; S Pyr, green Amph and micas; S limestone frags; S pyroclastic frags	Yellow, locally maculated; Cr b-fabric	F bone frags; F charc.	Fe-impregnations; coatings on clasts; pedorelicts (polycrystalline Qz, Fe cemented); canide coprolith
23 base	Single grain, locally vughy	Open space porphyric	D simple packing voids and starlike vughs; F complex packing voids and channels	D Fld (sanidine) and Qz; C Pyr and green Amph; S limestone frags; A pyroclastic frags	Yellowish-light brown; maculated limpidity; Ms b-fabric	S bone frags	C Fe-nodules; Fe-coatings on bones; fine coatings on pyroclastic frags and mineral granules
24a3/2	Spongy	Open space porphyric	F vughs and starlike vughs; S planes and channels	D Fld (sanidine) and Qz; C green Amph; S limestone frags; S pyroclastic frags; A phosphates	Yellow-brown; dotted limpidity; Cr and Gs b-fabric	C bone frags	Weak Fe-impregnations; pedorelicts (with minerals strongly cemented by Fe oxides)
24a4	Spongy	Double space porphyric	D vughs; S planes and channels	D Fld (sanidine) and Qz; S Pyr; R pyroclastic frags	Yellowish-brown, maculated; dotted limpidity; Cr b-fabric	C (burned) bone frags	Small Fe-impregnations
24b1	Vescicles; horizontally organised coarse fraction and voids	Open space porphyric	D vescicles; F planes and channels	D Fld (sanidine) and Qz; S Pyr; R pyroclastic frags; F phosphates	Red; limpid, dotted; Ms and Gs b-fabric	F (burned) bone frags; S charc.; C phytoliths	C pedorelicts; S yellowish-red coatings
24b2	Crumb	Open space porphyric	A vughs; F starlike vughs; F planes; S channels	D Fld (sanidine) and Qz; S HM; A rounded phosphates	Yellowish-red to reddish-brown; Ms and Gs b-fabric	S charc.; S bone; F amorph. OM	F Fe-impregnations; S pedorelicts
24b4	Crumb	Double space porphyric	F compound packing voids; C planes and channels	Few Fld and Qz; R pyroclastic frags and HM; F phosphates	Reddish, maculated limpidity; Cr b-fabric	S bone frags	C brown coatings; C pedorelicts; S canide coprolites; clay internal crusts

Unit	Microstructure	C/f related distribution	Voids	Coarse fraction	Fine fraction	Organic and organic origin material	Pedofeatures
24b5	Crack	Double space porphyric	F compound packing voids; C planes	C Fld (sanidine) and Qz; R phosphates and weathered pyroclastic frags	Reddish-brown, maculated limpidity; Ss and Gs b-fabric	S bone frags; F phytoliths	Reddish hypocoatings on voids; C reddish pedorelicts, often with fine capping; C coarse cappings; S Fe nodules; S canide coprolites
25	Blocky and vesicular; fine laminae in upper portion	Open space porphyric	F planes and channels; C vescicles	R Fld (sanidine) Qz and micas	Red (fine laminae) to brown (coarse laminae); grano- and porostriated b-fabric	Absent	C yellowish-red coatings
26e	Crumb aggregates; crumb	Double space porphyric	F compound packing voids; C circular channels; C accommodating planes	Few Fld (sanidine) and Qz, SA; S pyroclastic frags; S brown HM	Reddish; maculated limpidity; Cr b-fabric	S bone frags	F brown coatings; clay internal crusts; loose and discontinuous phosphate infillings in larger voids; C reddish rounded pedorelicts; S canide coprolites
26f	Vescicles; planar fabric of coarse fraction	Open space porphyric	F planes; F channels; D vescicles	D SA-SR Fld (sanidine) and Qz; S SA-SR Pyr; S pyroclastic frags; F phosphates	Red, limpid, dotted; Ms and Gs b-fabric	F bone frags; S charc.; C phytoliths	C pedorelicts (as unit 24a4); S yellowish red coatings; weak elongated Fe-impregnations
26h sup	Polyhedric aggregates, (sub) angular; crumb	Open space porphyric	S circular channels; F accommodating planes; very C vughs, sometimes interconnected by planes; F starlike vughs	F SA Fld (sanidine) and Qz; S SA-SR Pyr; A rounded phosphates	Yellowish-red to reddish brown; speckled limpidity; Ms and GS b-fabric	S charc.; S bone frags; F amorph. OM	F Fe-impregnations, moderately impregnated; S pedorelicts (as unit 24a4)
26h	Crumb aggregates; pedality moderately developed; crumb	Double space porphyric	F compound packing voids; C circular channels; C accommodating planes	S Fld (sanidine) and Qz, SA, often fractured; R pyroclastic frags; S brown HM	Reddish; maculated limpidity; Cr b-fabric	S bone frags	Brown coatings; clay internal crusts; loose and discontinuous phosphates infillings in larger voids; C reddish rounded pedorelicts; S canide coprolites

D: dominant; A: abundant; C: common; F: frequent; S: scarce; R: rare. Qz: quartz; Fld: feldspar; Pyr: pyroxene; Amph: amphibole; HM: heavy minerals; OM: organic matter; SA: subangular; SR: subrounded; Cr: crystallitic; Ss; stipple-speckled; Ms: mosaic-speckled; Gs: granostriated.

Cryoclastic detachments began after 4,000+900/-800 y BP (24b2) and go on at least until 28,100 ± 400 y BP (23c); from at about 29,300 ± 600 y BP (24a1) prevails microthermoclastism, together with aeolian deposition. This time span corresponds to the last phases of Interpleniglacial or to the first phases of Last Pleniglacial. The radiocarbon date of 26,300 ± 400 y BP (23a) and the Early Gravettian artefacts, put the episodes of severe climate (cryoclastic detachments and loess deposition) during the Last Pleniglacial.

Unit 22, essentially of anthropic origin, gave some dates, spanning from 28,300 ± 400 y BP (22f4) to 26,800 ± 300 y BP (22b), falling in the Last Pleniglacial, when Paglicci Cave experienced a period of intense cold cli-

mate, that led to the deposition of cryoclastic breccia, together with aeolic sediments.
A correlation with the Lago Grande di Monticchio record (Allen *et al*., 1999; Watts *et al*., 1996, 2000) may be established.
The deposition of units 25 and 26 is dated to a humid phase of the Interpleniglacial: its upper portion can be correlated with the interstadial humid phase of Lago Grande di Monticchio, comprised between 36,500 and 35,000 y BP (Watts *et al*., 2000).
The Campanian Ignimbrite deposits, recorded in Paglicci Cave at 34,000+900/-800 y BP, are found in the sequence of Lago Grande di Monticchio at 32,970 y BP (Allen *et al*., 1999).
Units of cryoclastic and aeolian deposition (from 24a4 toward the top) occur during the last phases of the Interpleniglacial or Early Last Pleniglacial. The prevailing cold climate registered for this portion of the stratigraphy agrees with faunal assemblages dominated by *Capra ibex* (Palma di Cesnola, 1992).
During this time span the Lago Grande di Monticchio record indicates a prevailing cold climate; in particular, a cold peak that in its older phase is correlated to the Heinrich Event H_4 recognised around 32,000 y BP (Watts *et al*., 2000). This cold event seems to correspond to the big boulder deposition of unit 24a1.
The higher portion of the cave stratigraphy (23), dominated by aeolic material, can be correlated with a high *Gramineae* content in Lago Grande di Monticchio record, especially for the period comprised between 23,400 and 22,800 y BP (Nimmergut *et al*., 1999).

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