Sedimentary Dynamics and Tecto-volcanismin the Venosa Basin (Basilicata, Italia)

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SEDIMENTARY DYNAMICS AND TECTO-VOLCANISM IN THE VENOSA BASIN (BASILICATA, ITALIA)

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Abstract : Direct tecto-volcanism is the main process involved in the sedimentary filling of the Venosa lacustrine Basin. Two formations have been distinguished : the Tufarelle Formation and the Piano Regio Formation. In the sedimentary series exposed at the Notarchirico Middle Pleistocene prehistoric site, several volcanic episodes represented by pumice falls, coarse and fine ash-falls and subsequent epiclastic processes have interrupted the lacustrine sedimentation and induced specific environmental changes. Hominids were present immediatly after every volcanic event to exploit the new environment on an opportunistic basis.

Key-words : Volcanism, Middle Pleistocene, Lower Palaeolithic, Hominids.

Résumé : La Formation de Piano Regio et la Formation de Tufarelle composent le remplissage du Bassin de Venosa. La sédimentation y est contrôlée par l'activité volcanique du Monte Vulture dont il a enregistré les différentes phases d'activité au cours de la fin du Pléistocène ancien et du Pléistocène moyen. A Notarchirico, plusieurs épisodes volcaniques représentés par des ponces, des retombées fines et grossières et leurs différents produits de remaniement ont interrompu la dynamique sédimentaire lacustre et entraîné des modifications environnementales bien particulières. Les occupations successives du site suggèrent une fréquentation opportuniste du milieu volcanique par les Hominidés du Pléistocène moyen.

Mots-clés : Volcanisme, Pléistocène moyen, Paléolithique ancien, Hominidés.

INTRODUCTION

The following data are preliminary results of a chronostratigraphic and environmental research programme we carried out as a joint project with Universita di Napoli and the Soprintendenza Speciale al Museo Nazionale Preistorico L. Pigorini di Roma, as part of the multidiciplinary study of the Pleistocene archaeological complex of Notarchirico-Loreto (Venosa, Basilicata). Field investigations, tephra analysis and sampling for TL age estimates were carried out in 1990, 1991 and 1993 (Lefevre *et al.*, 1991, 1993, Pilleyre, 1991). Relationships between volcanism and sedimentation in the basin were particularily studied.

We present first the Venosa Basin and then focus mainly on the Notarchirico series which illustrates the complexity of volcanic control on sedimentation in the basin.

1 - THE VENOSA BASIN

The Venosa Basin is located at about 20 km NE of the Monte Vulture volcanic complex (plate 1). It is an elongated WNW-ESE depression, 2 to 4 km wide, belonging to the neogene bradanic trough (Boenzi *et al.* , 1987). The Venosa Basin is situated about 50 m below the Piano di Cammera plateau surface which occurs at 400/420 m in the upper part of a Neogene regressive series. The latter consists of polygenic plio-pleistocene conglomerates which contain *Archidiscodon meridionalis* (Segre, 1978). The geometry of the basin and several observed faults indicate that it is a tectonic depression which formed the palaeo-valley of a stream running SE towards the Bradano River (Piccaretta and Ricchetti, 1970; Neboit, 1975). Research on the sedimentary fill of this morphological unit (De Lorenzo, 1906; Picaretta and Ricchetti, 1970) has clearly established that volcanic ejectamenta constitute a major component of the deposits.

Ash-falls originated mainly from the Monte Vulture volcanic system. Several volcanic phases have been identified and dated by the K/Ar method (Cortini, 1975). The oldest ones are dated 860-830 ka. Later lavas from the Vulture are dated 670-660 ka and 500-450 ka. New dates, recently obtained, more or less confirm former interpretations and attest to a long period of Middle Pleistocene activity with several phases, up to the boundary of isotopic stages 6/5 (Villa, 1991; La Volpe et Principe, 1990; Bonadonna *et al.*, 1993; Laurenzi *et al.*, 1993)

Evidence of prehistoric activity has been discovered and excavated at numerous sites in the basin since the nineteenth century (Nicolucci, 1877; Rellini, 1915; Mochi, 1913, 1916; Pinto, 1929); the sites of Venosa-Loreto (Topa, 1932; Rellini, 1932; D'Erasmo, 1932; Blanc, 1953; Chiappella, 1964; Bonifay, 1977; Angelelli *et al.*, 1978; Durante and Settepassi, 1978; Caloï and Palombo, 1979; Barral *et al.* , 1978; Segre, 1978; Baïssas, 1980; Barral et Simone, 1983, 1984) and Venosa-Notarchirico (Piperno and Segre, 1982; Segre *et al.*, 1982, 1984; Piperno, 1987; Piperno *et al.*, 1990; Belli *et al.*, 1991) are the most well known.

The basin exhibits a complex stratigraphy:

- on the basin margin, we have observed a stratigraphy with fluvial deposits and red paleosols at the base, coarse detrital lenses interbedded upwards with volcanic deposits (ignimbrites et co-ignimbrites, pumices). These deposits belong to a single formation, temporarily named the Piano Regio Formation.

- the series described by Picaretta and Richetti (1970) characterize a lithostratigraphic unit named the Tufarelle Formation. It forms most of the medial part of the basin. Some tephra beds exhibit syneruptive geochemical variations. The sequence observed on natural exposures at the prehistoric site of Loreto is typical of the Tuffarelle Formation (plate 2). After Baïssas (1980), the Brunhes-Matuyama limit is supposed to occur in layer 37. In layer 32, we have recognized Tephra R1, a major tephrostratigraphic marker of the Tufarelle Formation. The chemical analysis of selected scorias (table 1, 93054, 93055) indicates a basaltic magma in the diagram of Le bas *et al* (1985) (figure 5, n° 5 and 6).

Sediments indicative of a fluvial environment (gravel bars of braided channels) form the base of the sequence. The volcanic load increases upward in the series to a lahar/epi-lahar facies, overlain by a succession of intercalated pumices, lacustrine limestone beds and coarse detrital beds of more or less reworked tephra.

Volcanic control can be inferred from this series. This is deduced from the increase of the volcanic load, changes in the fluvial dynamics and sedimentation, disorganisation of the drainage pattern, damming and lacustrine dynamics, filling of the paleovalley as a result of concomitant volcano-sedimentary input and a progressive rise in water level.

2 - THE NOTARCHIRICO SERIES

At the prehistoric site of Notarchirico, several archaeological horizons have been excavated. Artefacts belong to a Middle Acheulian phase of the Italian Lower Palaeolithic. Faunal remains are mainly represented by *Elephas antiquus*, cervids and bovids and a fragmentary human femur was discovered in 1985 (Segre *et al.*, 1982; Piperno and Segre, 1982; Segre and Piperno, 1984; Piperno, 1987, 1990; Belli *et al.,* 1991).

The series exposed at the site was accumulated on the margin of the depression, at the foot of a slope cut into coarse Pliocene clastic sediments.

The Notachirico series represents either a margin facies as old as the upper lacustrine part of the Tufarelle Formation (Loreto), or a younger one. Tentative absolute dating of the Notarchirico series obtained previously by various methods, including TL dating (*infra* 2.3), indicate a Middle Pleistocene age (plate 4). Micromammals from upper bed 2.5 also indicate a Middle Pleistocene age (SALA, 1991).

2.1 - Lithostratigraphy.

Our observations were made on the visible part of the site which is now protected as a museum. They confirm the previous stratigraphic data (Belli *et al.*, 1991; Lefevre *et al.*, 1991). From the bottom to the top, the following data have been observed on sections excavated in the upper part of the series, between soil F at the visible base and the top surface (plate 3). The lowermost units are not accessible at present.

Unit 3 - Lower volcanosedimentary unit, 0.5 m thick, with slightly encased metric cross-bedded stratification outlined by volcanic elements (free minerals and scorias). Scorias are rare and rounded. The free minerals do not carry volcanic glass on their surfaces. They are more or less rounded or in prism fragments and include green clinopyroxenes and a few orthopyroxenes. This tephra is an important ash-fall bed, reworked and water-concentrated (TL sample 9002). The unit is capped by a gravel bed. Erosional disconformity F: this is marked at the top of Unit 3 by a cobble lag whose clasts are apparently packed in gravel.

Unit 2 - Intermediate volcano-sedimentary complex:

2.1 Grey fine ash-rain bed: this is marked by a high concentration of free minerals and a few scorias. The free minerals and prism fragments are green pyroxenes. This volcanic sand is a direct ash-fall which has been water-concentrated (TL sample 9003). This layer shows load-casts enclosing a white tephra (2.2).

2.2 White fine ash-rain bed. This silty bed contains rare fragments of pyroxenes, quartz and felspars and exhibits microbubbles and shard structures. It may represent an acid ash-fall.

2.3 Pinky-red fine ash-rain bed, with free minerals and small scorias. Chemical analysis on selected scorias (table 1, 93001) indicates a basaltic magma in the diagram of Le bas *et al* (1985) (figure 5, n° 7) These three beds, 0.20 m in total thickness are deformed by involutions, hood structures and injected load structures. Most of bed 2.3 is incorporated in the deformations. On the frontal sections the thin upper zone has frequent microdepressions and overlies the deformations.

2.4 Fine white micaceous ash-rain, 0.20 m thick, mantle bedded and locally thicker over the microdepressions at the top of 2.3. Beds are thinner towards the top and separated by carbonate concreted laminites. Chemical analysis on selected scorias (table 1, 93002) determines either a basaltic andesite type magma (figure 5, n° 8) or a basaltic magma (figure 5, n°15), although analysis of glass (Juvigné, *in litteris*) falls in the trachyte field of the diagram of Le bas *et al* (1985) (figure 5, n°15v).

2.5 Thick bed (0.1 m) of volcanic light grey sand with abundant pyroxenes in a carbonated cement, with centimetric lens and cones of coarser reworked tephra and abundant cobbles, artefacts and bones up to the top.

Erosional disconformities E and E1 occur at the top of this unit.

2.6 1 m thick: a lower, sandy silt bed and overlying clayey silt bed itself overlain by fine sands which are interbedded with abundant fine light grey volcanic deposits including fibrous pumice. These deposits are occasionally concentrated in small rills and show load structures.In the western part of the site, the upper part of 2.6 consists of a pumice layer.

At the top, the coarse elements of disconformity D are stuck in a more clearly stratified and coarser matrix than in the underlying 2.6 beds. This matrix is rich in melanocratic volcanic minerals.

2.7 Leucocratic volcanic sand, 0.40 m thick, includes pumice. Grain size decreases upwards. This unit is only preserved in the western part of the site.

2.8 Green fine sand, interbedded with clay laminations. Rests unconformably on 2.7 as a wedge 0.45 m thick at the most. Fine sediments are progressively more abundant toward the top where the clay beds are thinning and interbedded with carbonates and where desiccation structures, such as vertical and horizontal cracks, and small reworked balls are observed. There is a gradual change to Unit 2.9.

2.9 Pink brown clay, 0.3 m thick, with a prismatic structure and some desiccation cracks. Loading deformations are present under unconformity C.

2.10 Heterometric sand, 0.60 m thick, incorporating abundant volcanic material. Several sub-units fill a palaeo-depression. Disconformity B is an undulating lag of contiguous cobbles.

Unit 1 - Upper volcano-sedimentary complex:

1.1 In the northern sector, there is a 0.30 m thickness of stratified gravel and sand in which the grain size decreases upward to clayey sand. In the southern sector, there is a clayey and silty massive sand, with cobbles scattered through the unit but more abundant at the base.

1.2 Brown clay, 0.50 m thick, with a variable content of sand with some soft cobbles of sapropel as well as rock cobbles.

1.3 Greenish grey pumice complex, 0.60 m thick an consisting of: 1.31, fine pumice; 1.32 coarse pumice with channel structures; 1.33 fine, 1.34 coarse and 1.35 fine pumice.

1.4 Bedded gravel and cobbles, maximum thickness: 0.50 m. Artefacts are found in the uppermost gravel bed related to unconformity Alpha.

1.5 In the eastern part of this sector, there are several beds of reworked tephras overlain at the base by fine sand interstratified with thin detrital clay beds and carbonaceous beds; the sand becomes more clearly stratified and more clayey upward. Channel structures with packing faults and load structures have been observed. Thickness of unit 1.5: 1.25 m.

1.6 More or less melanocratic coarse tephra and some cobbles, 0.50 m thick. Load structures occur at the base. Numerous volcanic free minerals (pyroxenes) and various more or less rounded scorias are present. This volcanic sand results from the reworking and concentration of ash-falls by water (TL sample 9010). The uppermost part, directly deposited as ash-rain, is consolidated and more regularly stratified in cones. Chemical analysis on selected scorias (table 1, 93026) indicate a basaltic magma in the diagram of Le bas *et al* (1985) (figure 4, n° 9). One must notice the similarity with a major tephrostratigraphic marker of Tufarelle Formation, Tephra R1, recognized at Loreto (Cf *supra*).

Unit 0:
(0.1) Channels filled by fine colluvium with pedogenesis.
(0.0) Ploughed horizon.

2.2 - Sequence analysis.

The main facies are related to lacustrine, slope and volcanic dynamics. Lacustrine units such as fine detrital sediments or even organogenic sediments (sapropel) are interstratified with volcano-detrital coarse sediments (more or less reworked tephra) of variable grain size.

Overall, it may be said that the deposits of Notarchirico record the deposition of volcanically controlled sequences related to a continuous or strongly fluctuating rise in lake level. This level rise was caused by a volcanic obstruction. As demonstrated by the mineralogical research, some of the tephra are only slightly reworked.

The overall stratigraphy is interpreted as showing the superposition of initially positive grading sequences which failed because of a general trend towards negative grading deposition caused by the volcanic activity. Six superimposed sequences have been observed in the preserved excavated locality. The five lower ones indicate the repetition of two processes : slope destabilization and cobble beach formation.

The sequences are separated by stone pavements which are lag cobble beds interpreted as the remnants of detrital slope deposits originally clast supported and subsequently washed out. After elutriation, the residual stone pavement has developed a joint structure, the polygenic surfaces of which represent a stratigraphic hiatus or diastems between the sequences (Cassoli *et al.*, 1991). Thus, the recorded series on the lake margin is not a continuous one. The duration of these hiatuses has to be evaluated by other methods.

The slope and beach processes are directly related to the highest phases of the volcanic activity and subsequent high lacustrine level stands.

2.3 - TL Dating.

2.3.1 - Principles.

The method is based on the existence of the natural radioactivity. This radioactivity is due, for its largest part, to radioelements of the thorium and uranium series and to potassium-40. Some of the natural minerals are able to "record" this radioactivity. A "reading" of this record can be obtained by heating the mineral to temperatures as high as 500°C and then measuring an emission of light called thermoluminescence (TL). One of the most commonly used minerals is quartz due to its abundance and relatively well-known physical properties but a lot of minerals are thermoluminescent. The essential features of TL are as followings ones:

- the greater the received irradiation (called the absorbed dose), the higher the TL intensity,
- heating the mineral erases the received irradiation; so since this "zero time", thermoluminescent minerals begin to record natural radioactivity.

So, if we are able to evaluate the two following parameters:

- the total absorbed dose received by the sample since the signal was zeroed. This is called the palae or equivalent dose and,
- the absorbed dose rate, for instance the annual one which is supposed constant,

we can write the fundamental relation of TL dating:

$$\text{TL age (years)} = \frac{\text{palaeodose (rads)}}{\text{annual dose (rads/year)}}$$

The palaeodose is determined in the laboratory by TL measurements and the annual dose by field and/or laboratory dosimetry.

For practical reasons, only one part of the TL signal is measured: a wavelength (a colour) of analysis is chosen. The most employed colour with quartz is the blue one. The reason comes from the weakness of the black body emission (thermal background) in the blue range at our working temperatures; the prominent black body emission is in the red and infrared wavelength region. As a drawback, the blue TL signal is generally not convenient for long range TL dating (above around 100 ka). A more appropriate colour is the red one (see for instance Hashimoto and Habuki, 1987 or Miallier et al., 1991) although the signal is more difficult to measure because of the thermal background.

2.3.2 - Application.

TL dating is possible for well-heated materials if they contain TL minerals. So the technique is appropriate for the chronology of eruptive events either directly (dating of eruptive products) or indirectly (dating of objects heated by eruptive products). Our choice was to date volcanic products directly by means of the red TL emission of quartz grains they contain. We have already done such dating successfully in the French Massif Central (Pilleyre et al., 1992); the red TL seemed to be appropriate for the chronological period of interest in this Italian context.

Three samples have been dated: VNS 90-03, VNS 90-10, VNS 90-02 (ditto 90-01). Two of them came from close stratigraphic levels: i.e. VNS 90-02 et VNS 90-03; the sample VNS 90-10 being much higher in position. The corresponding TL age for VNS 90-10 was 230 ± 50 ka and is compatible with its stratigraphic position (above alpha soil). The ages obtained for the two other samples are incompatible with each other. The results were 640 ± 70 ka for VNS 90-03 and 304 ± 50 ka for VNS 90-02, it must be stressed that VNS 90-02 is beneath VNS 90-03 in the stratigraphy.

2.3.3 - Errors and consequences.

One error among others can be related to the quality of absorption of the natural radioactivity by the TL mineral. If the absorption happened to be partially erased (fading phenomenon) over geological time, the intensity of the corresponding TL signal will be less than in non-erasing cases. This will also decrease the palaeodose and the final estimate age. This phenomenon, depending on physical properties of the TL mineral itself, could explain an underestimation of age. Nevertheless, the red TL of quartz is generally insensitive to fading so incompatibility is unlikely to be explained by such a behaviour.

Another source of error is the presence of TL minerals zeroed at a different time than the bulk of the sample. In this case, mixing of minerals of "different ages" leads to underestimation ("younger minerals") or overestimation ("older minerals") of the age. However, such pollution can be detected when the TL signals are scattered and this means that several tens (sometimes around a hundred) of calibrated amounts of quartz have to be measured for one TL age. No significant scattering has been noticed with our measurements.

Another problem concerns the annual dose rate. When the age is calculated, the annual dose rate is supposed to have been constant during geological time. However, this may be a false assumption because of the presence of water for instance. However, the consequences in much cases are likely to be the same for

VNS 90-03 and VNS 90-02 due to their proximity, so uncertainty remains.

The more likely explanation could be an insufficient zeroing of TL for the sample VNS 90-03. If zeroing was not complete, a residual signal could have been present in the quartz at the time of the eruption. This signal may have been superimposed on the signal registered since the eruption causing an overestimate of the palaeodose and, consequently, of the age. In this case, the real age would be the younger one: 304 ± 50 ka. Unfortunately, insufficient zeroing cannot be recognised before measurements and comparisons with other available data. At the time of writing, it is actually quite impossible to know what age (of the two) should be preferred. However, Falguères et al. (1994) have suggested a test to show if erasure has been totally efficient. It is based on the presence or absence of the E' centre signal of quartz in ESR measurements. If this test is reliable, it might be possible to find out "a priori" which sample has to be chosen for dating investigations.

3 - CONCLUSIONS.

The study has demonstrated that direct tecto-volcanism is the main process involved in the sedimentary filling of the Venosa lacustrine Basin. Former interpretations had insisted on sedimentary processes and underestimated the distal volcanic facies , sometimes residual. This made correlation attempts more difficult.

At Notarchirico, several volcanic episodes represented by pumice falls, coarse and fine ash-falls and subsequent epiclastic processes have interrupted the lacustrine sedimentation and induced specific environmental transformations. Hominids were present immediately after every volcanic event and this can be considered as an opportunist exploitation of or, adaptation to, the volcanic environment. The search for fresh meat could have been easier in such conditions. This would have been caused by the destruction of vegetation, the concentration of animals at water-holes, the existence of muddy swamps, sudden deaths of animals, particularly birds, animals weakened after carbon dioxide and sulfuric dioxide emission, animals trapped in debris flow etc. Historical and contemporaneous parallels exist for such phenomena and have been evoked several times for prehistoric settlements in the French Massif Central (Daugas et Raynal, 1989, 1991 a and b; Raynal et Daugas, 1984, 1989, 1991; Raynal et Sanzelle, 1989).

Further investigations will be focused on :

- Characterization of the volcanic facies in the whole basin,
- New attempts at dating tephra,
- Detailed correlations with the Monte Vulture activity,
- Hominid adaptation in volcanic areas.

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FORMATION	TUFARELLE FORMATION				OTHER TEPHRA	
LOCALITY	NOTARCH.	TUFARELLE	LORETO		NOTARCHIRICO	
LAYER	1.61	R1	R1 top	R1 bottom	2.3	2.4
SAMPLE	93026	93044	93055	93054	93001	93002
*COMPOSITION**						
SiO2	46,05	44,20	44,56	41,00	36,72	41,49
Al2O3	15,26	21,76	15,69	17,14	14,43	26,91
Fe2O3	8,61	10,72	8,97	7,86	3,26	4,10
MgO	3,51	2,40	4,12	2,32	1,18	0,28
CaO	11,41	5,32	11,75	11,75	19,25	2,40
Na2O	0,93	1,46	1,42	1,09	0,52	0,46
K2O	2,73	0,47	1,73	0,79	0,98	1,14
TiO2	1,05	1,07	1,00	0,82	0,45	0,64
P2O5	0,00	0,00	0,00	0,00	0,00	0,00
MnO	0,13	0,17	0,18	0,17	0,10	0,14
H2O+	7,51	10,04	7,96	11,14	18,15	12,24
H2O-	2,16	3,17	2,46	2,16	5,84	10,32
Total :	97,19	97,61	97,38	94,08	95,04	89,80
**On selected scorias*						

Table 1: Chemical composition of tephras from the Tufarelle Formation and from the site of Notarchirico. X-Fluorescence analysis, Centre de Recherches Volcanologiques, Clermont-Ferrand.

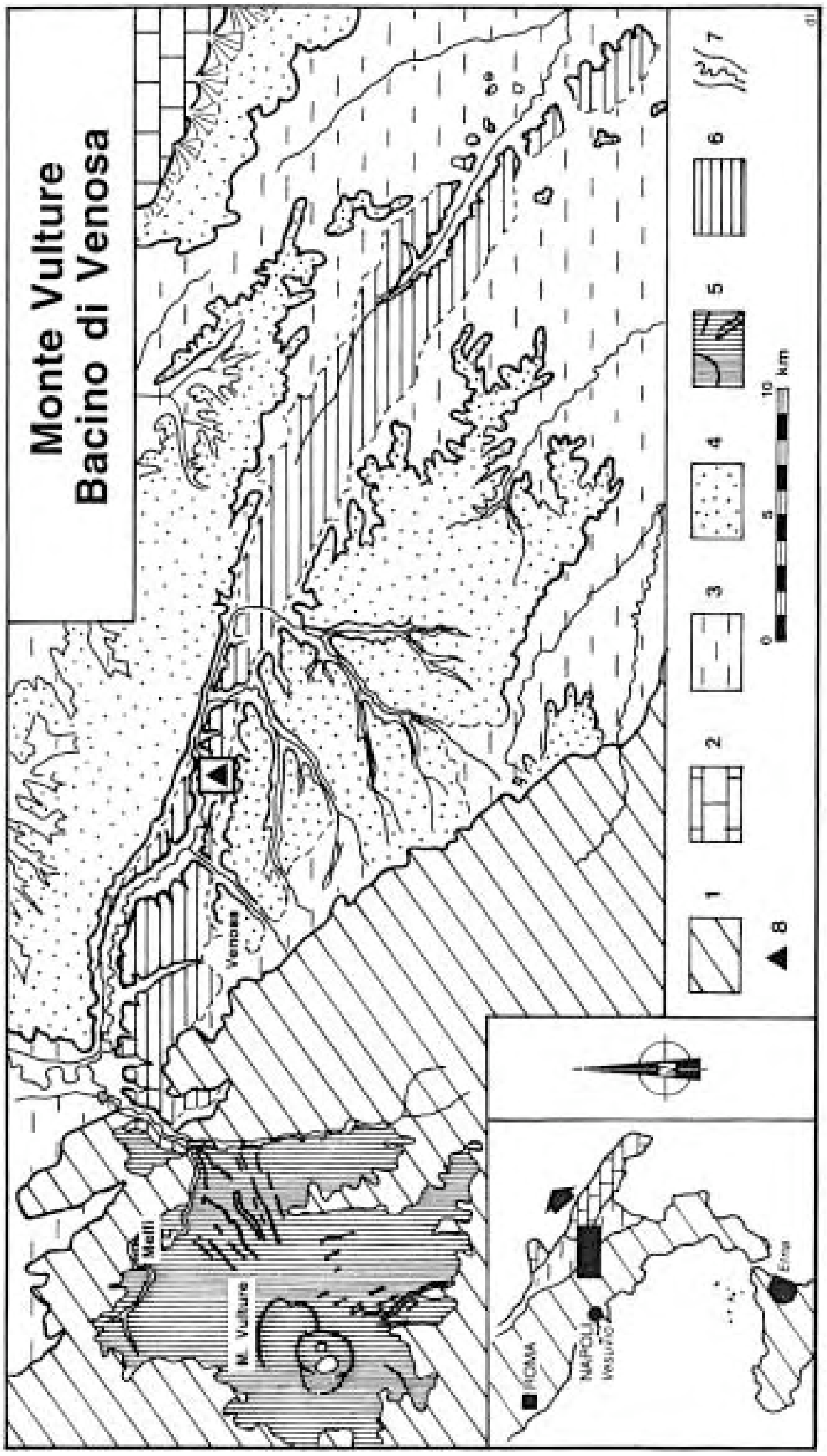

Figure 1: Morphostructural map of Venosa - Monte Vulture area.
1: Southern Apennines.
2: Murge limestones Plateau (carbonated platform of Apulian foreland).
3: Bradanic Trough. Blue clays from Gravina and Monte Marano sands. Pliocene.
4: Bradanic Trough. Irsina conglomerates. Upper Pliocene / Lower Pléistocene.
5: Monte Vulture volcanic complex. Middle Pleistocene.
6: Volcano-sedimentary, fluvial and lacustrine deposits from Venosa.Middle Pleistocene.
7: Alluvial deposits of valley floors.
8: Studied area.

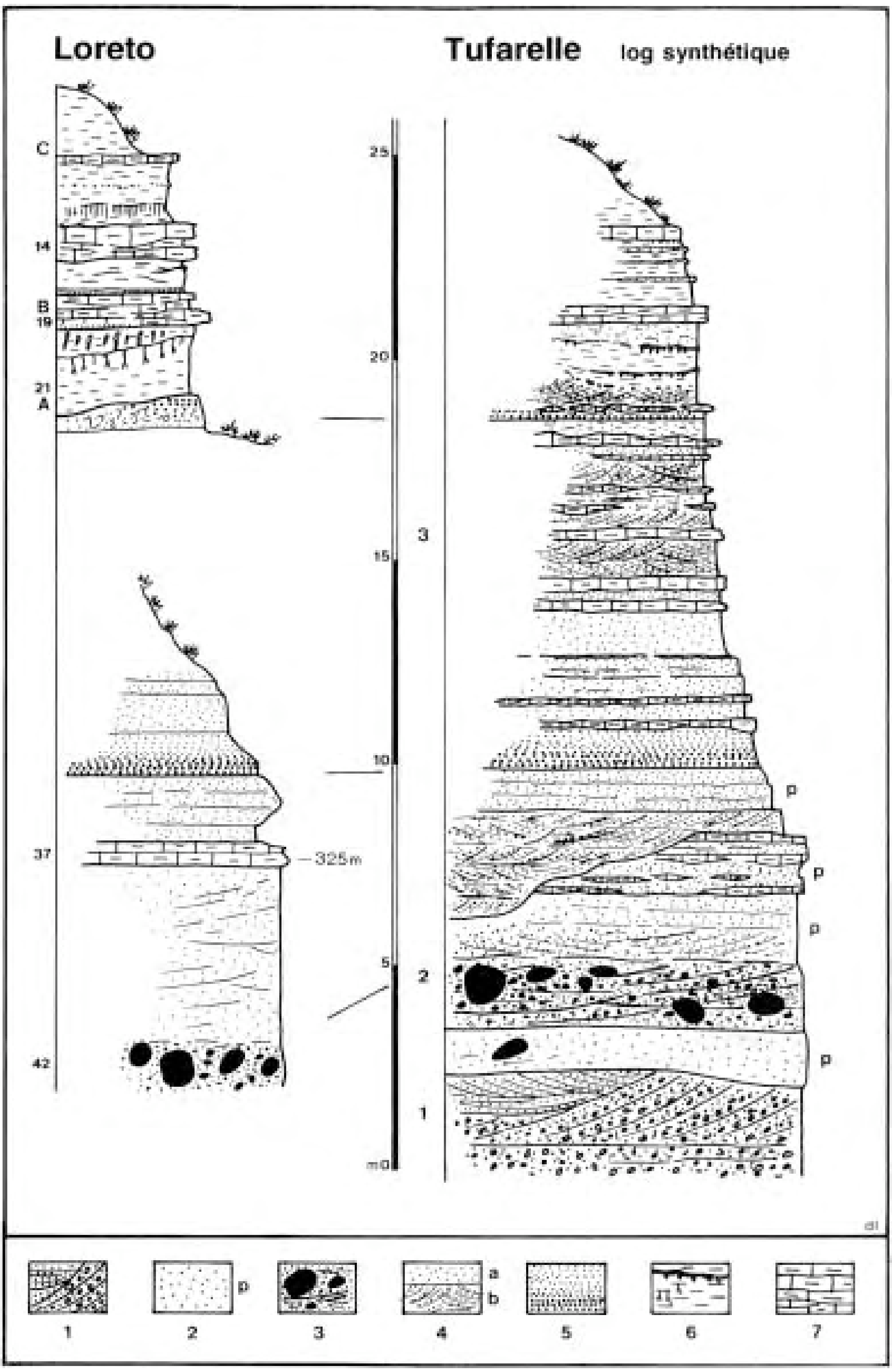

Figure 2: Logs of Tufarelle Formation and at Loreto prehistoric locality.
1: Coarse fluvial deposits.
2: Pumice.
3: Lahar and epi-lahars.
4: Tephra and epiclastites.
5: Direct ash-fall.
6: Silts and calcitic hard-grounds and roots.
7: Calcareous beds.

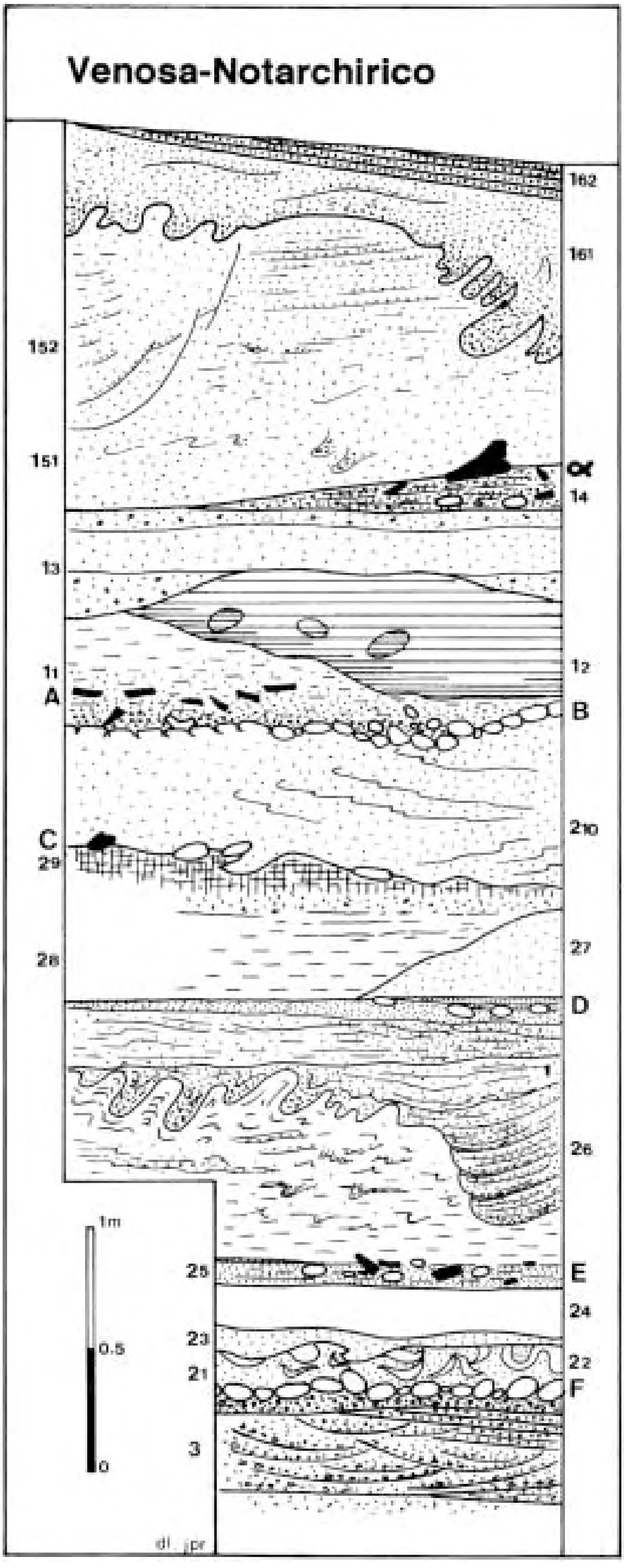

Figure 3: Log at Venosa-Notarchirico prehistoric locality. See text for key.

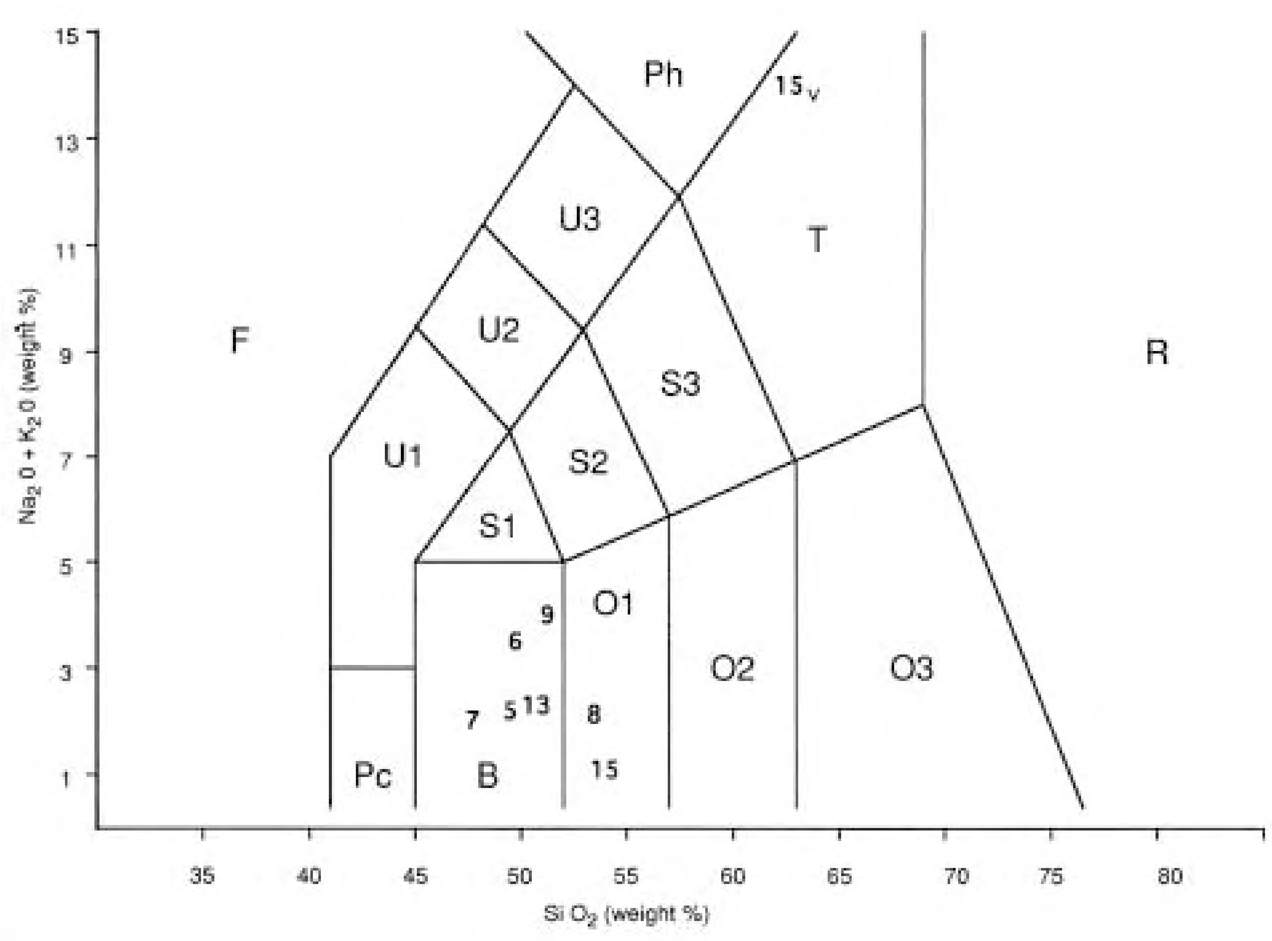

Figure 4: Chemical composition of identified tephra in SiO_2/Na_2O+K_2O (weight%) diagram (LE BAS *et al.*, 1985). 5: Loreto layer 32 Tephra (bottom). 6: Loreto layer 32 Tephra (top). 7: Notarchirico layer 2.3 Tephra. 8 and 15: Notarchirico layer 2.4 Tephra. 9: Notarchirico Layer 1.61 Tephra. 13: Tuffarelle R1 Tephra. 15v: Notarchirico layer 2.4 (on glass).

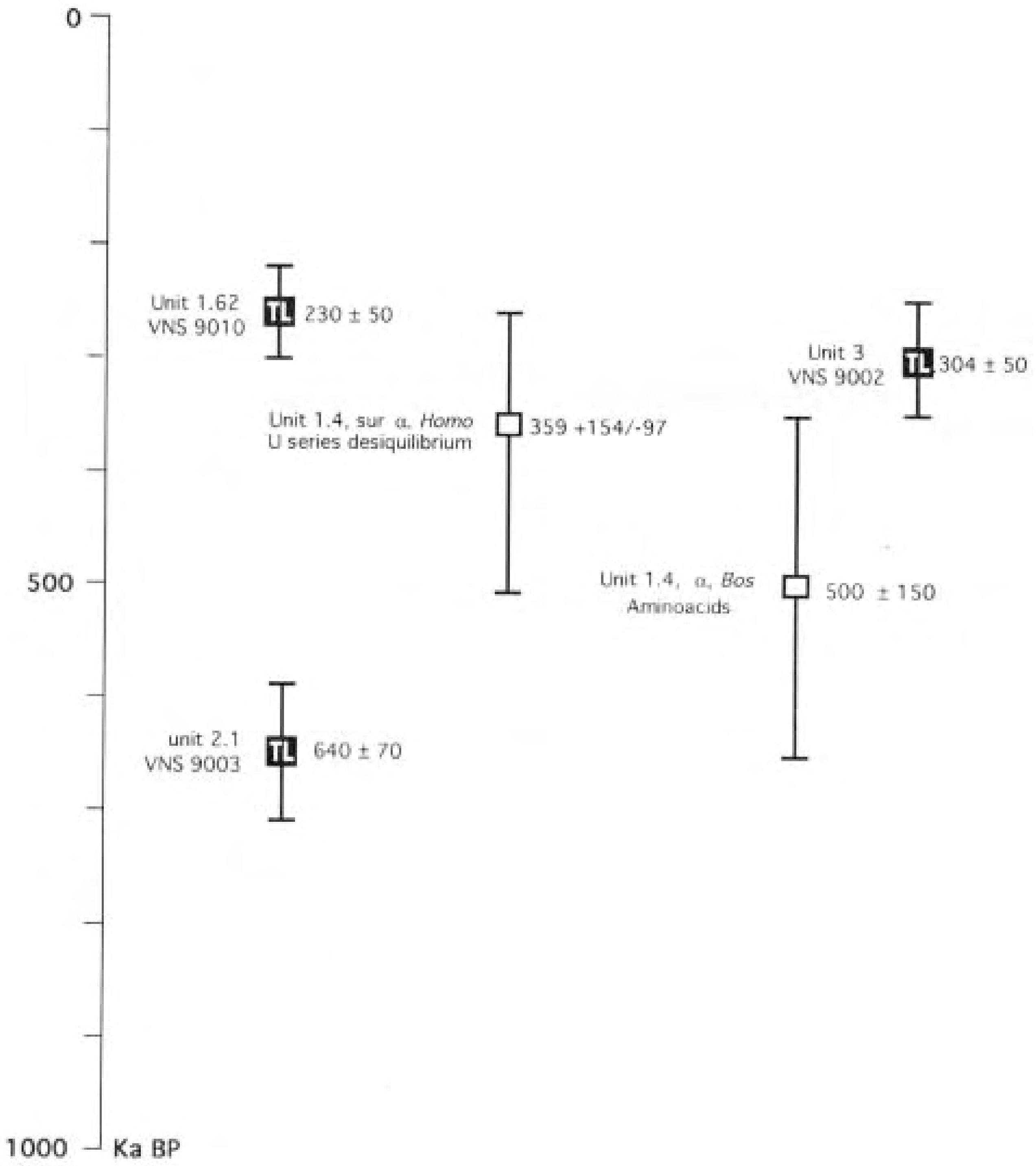

Figure 5: Absolute dates for the Notarchirico sequence.

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