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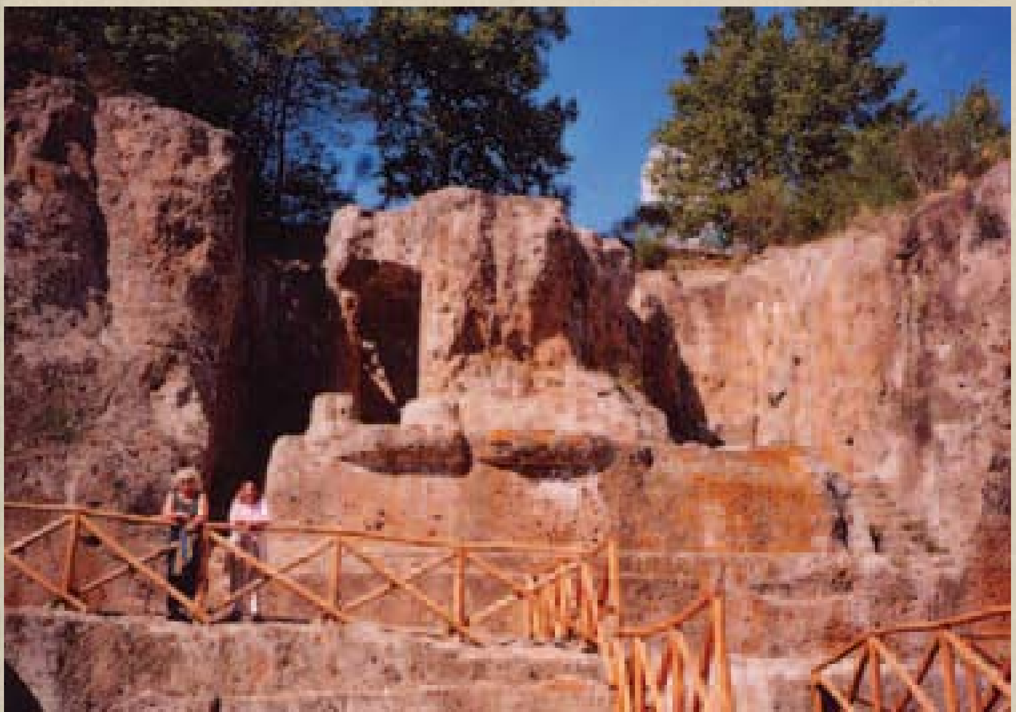
32nd INTERNATIONAL GEOLOGICAL CONGRESS

Field Trip Guide Book - P09

IGNIMBRITIC DEPOSITS IN CENTRAL ITALY: PYROCLASTIC PRODUCTS OF THE QUATERNARY AGE AND ETRUSCAN FOOTPATHS



Leader: G. Nappi

Associate Leaders: L. Valentini, M. Mattioli

Florence - Italy
August 20-28, 2004

Post-Congress **P09**

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Series Editors:
Luca Guerrieri, Irene Rischia and Leonello Serva (APAT, Roma)

English Desk-copy Editors:
Paul Mazza (Università di Firenze), Jessica Ann Thonn (Università di Firenze), Nathalie Marléne Adams (Università di Firenze), Miriam Friedman (Università di Firenze), Kate Eadie (Freelance indipendent professional)

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AUTHORS:
G. Nappi, L. Valentini, M. Mattioli (Università di Urbino - Italy)

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Front Cover:
Necropolis of Sovana, Tomba Ildebranda.

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1 - Introduction

This three-days field trip will cover three important volcanic districts in central Italy: the Vulsini and Vico Volcanic Districts, which belong to the Roman Comagmatic Province, and the Cimini Volcanic District (Figure 1). The field trip will provide participants with an opportunity to examine some of the most studied pyroclastic flow deposits in the world in their most significant exposures. The pyroclastic flow deposits in this area are characterized by a broad spectrum of peculiar features in terms of composition, component distribution, grain-size, degree of welding, structures, depositional sequences, geometries, and their relationships to eruptive and depositional mechanisms. The planned itinerary will enable participants to observe first hand the structural and textural characteristics of these products, and of their main depositional facies within the relative stratigraphic sequences. One of the main goals of the field trip is to stimulate discussion on the possible mechanisms developed during the respective transport and depositional phases.

Some stops will also allow us to gain insight into the relationships between the geology of the area and the history of its towns. Many of these pyroclastic flow deposits have been intensively quarried and shaped by man. Several examples will be visited, starting from Etruscan graves, through Roman monuments up to modern buildings.

2 - Geological setting

The Quaternary ignimbrite-forming eruptions are related to the post-collisional volcanism of the eastern Tyrrhenian border. This potassic-alkaline volcanism developed during the Quaternary period along the Tyrrhenian margin of Italy, from the northern Vulsini District to the southern Vesuvio-Phlegrean Fields' volcanic structures. The area of southern Tuscany and Latium has been affected since the Plio-Pleistocene period by intense magmatic activity, with a migration in time and space of the feeding fissures from west to east, and important changes in the nature of the erupted magma. The Pliocene magmatic activity began along the Tyrrhenian border, with emplacement of intrusive bodies and extrusions of crustal anatectic magmas. During the Pleistocene period some volcanic

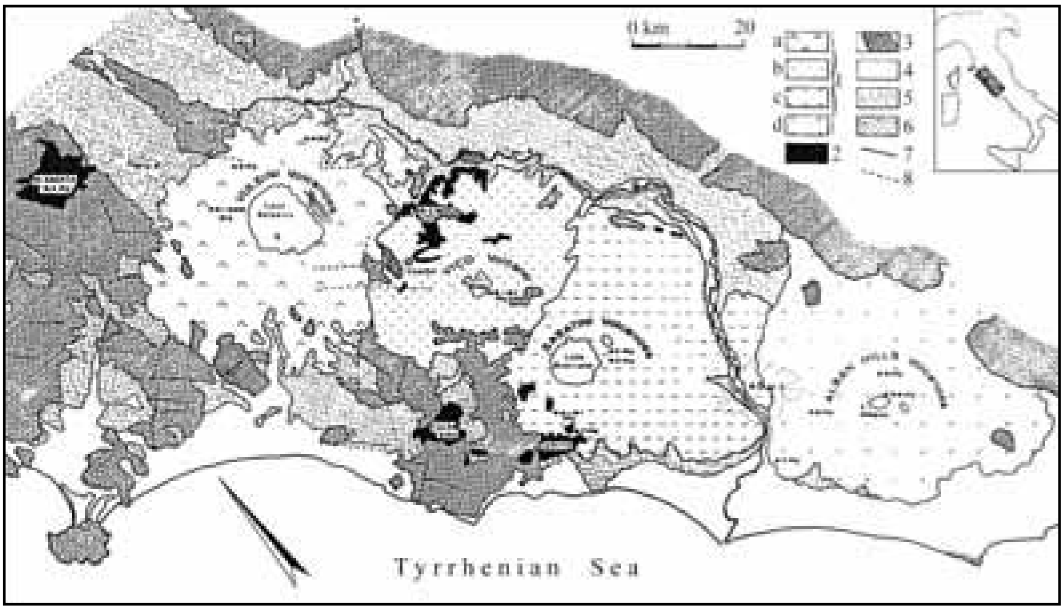


Figure 1 - Geological sketch of the northern Roman Comagmatic Province in Central Italy (modified after Locardi and Molin, 1974). Symbols: 1 = Alkaline potassic volcanics (Pleistocene to Recent): a) Vulsini volcanoes, b) the Vico volcano, c) Sabatini volcanoes, d) Alban Hills volcanoes; 2 = acidic volcanics (Plio-Pleistocene); 3 = travertine; 4 = Recent (continental and coastal sediments); 5 = Upper Miocene-Lower Pleistocene (clay and sand); 6 = Carboniferous-Lower Miocene (sedimentary sequences); 7 = faults; 8 = buried faults.

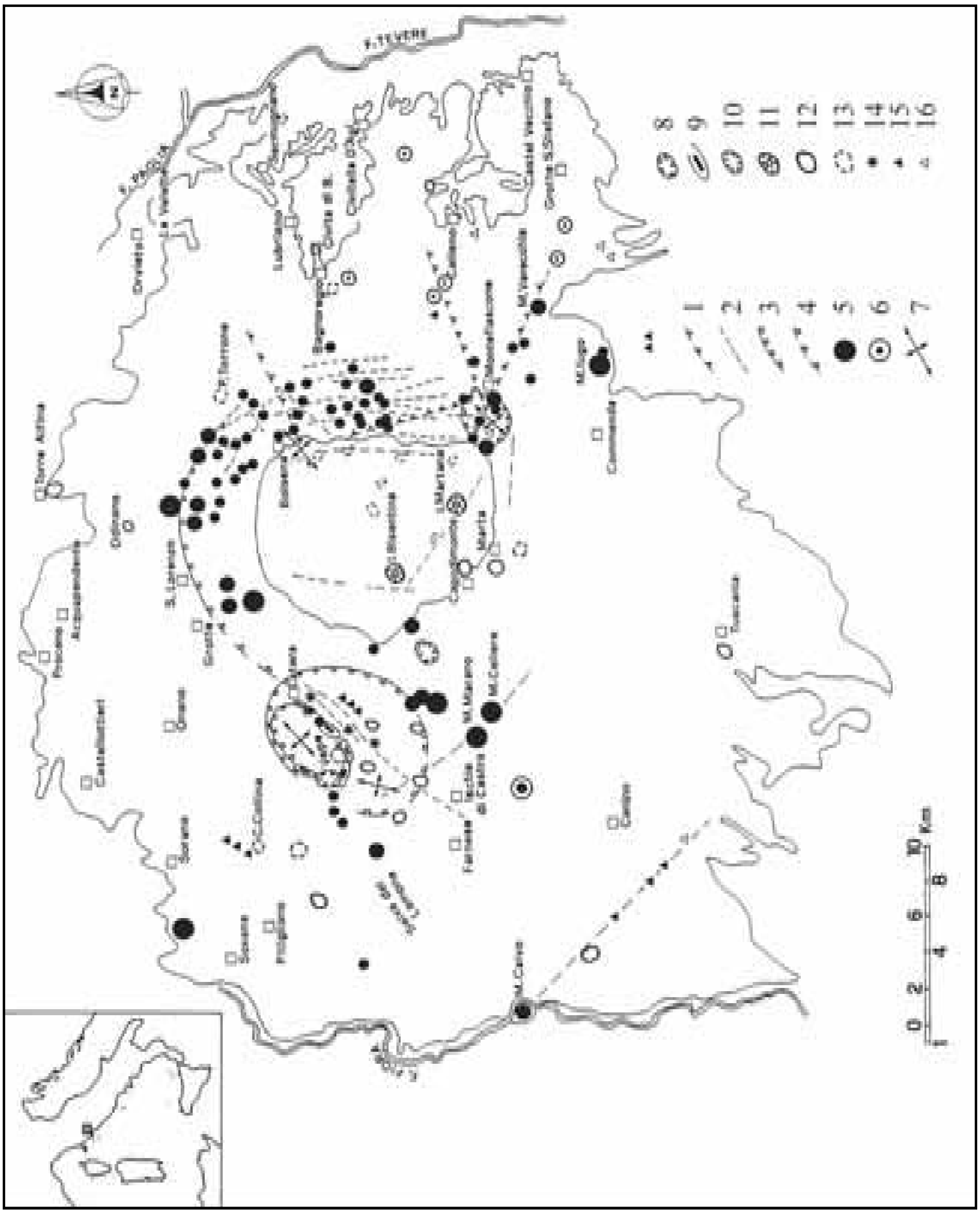


Figure 2 - Structural map of the Vulsini Volcanic District (modified after Nappi et al., 1991). Symbols: 1 = deep faults; 2 = faults; 3 = caldera rims; 4 = buried caldera rims; 5 = cinder cones; 6 = buried cinder cones; 7 = central explosive eruption; 8 = maars; 9 = dome-like structures; 10 = explosion craters; 11 = surtseyan activity; 12 = eruptive centres; 13 = buried eruptive centres; 14 = sulphurous activity; 15 = thermal springs; 16 = mineral springs.

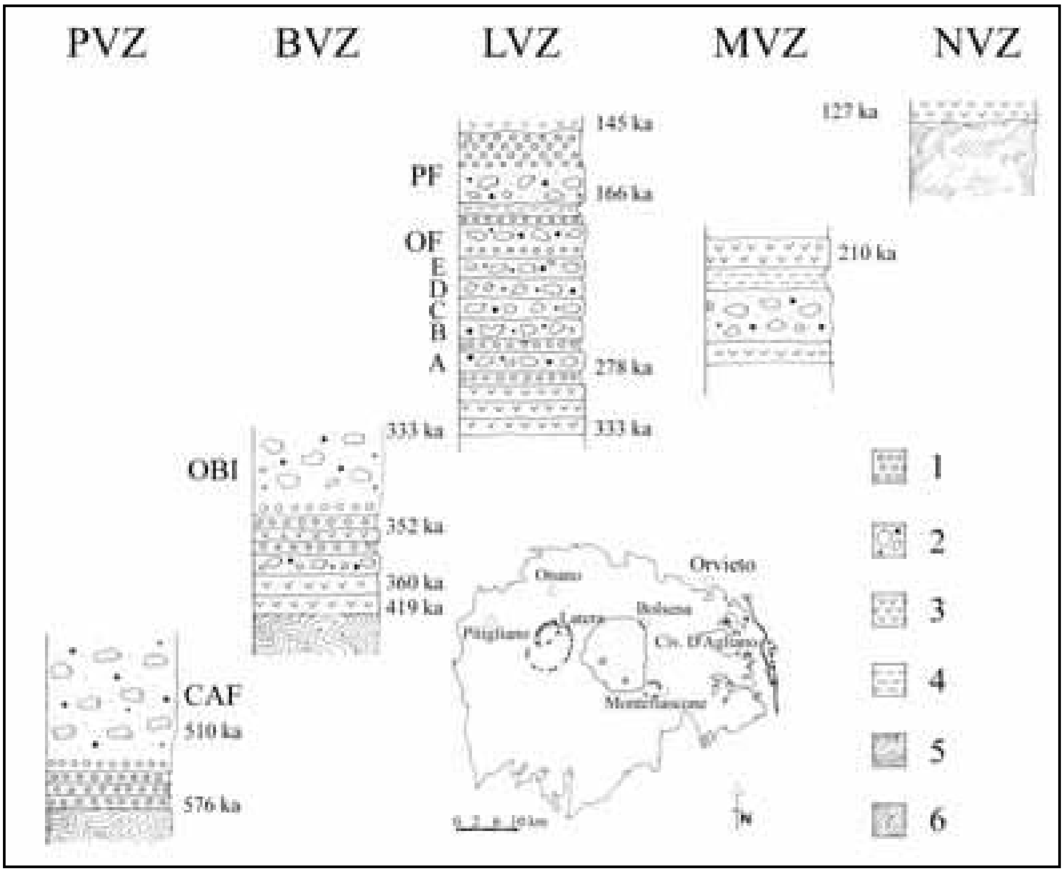


Figure 3 - Chronostratigraphic sketch of the Vulsini Volcanic Zones. PVZ = the Paleobolsena Volcanic Zone; BVZ = the Bolsena Volcanic Zone; LVZ = the Latera Volcanic Zone; MVZ = the Montefiascone Volcanic Zone; NVZ = the Neobolsena Volcanic Zone; CAF = the Civitella d'Agliano Formation; OBI = Orvieto-Bagnoregio Ignimbrite; OF = the Onano Formation; PF = the Pitigliano Formation. Symbols: 1 = pumice fall; 2 = pyroclastic flow; 3 = lava flow; 4 = ash fall; 5 = surtseyan deposits; 6 = sedimentary substratum.

acid products of Tuscan affinity, as well as products with Lamproitic affinity, were erupted (1.3 – 0.9 Ma). The Cimini Volcanic District was formed during 1.35 – 0.95 Ma (Evernden and Curtis, 1965; Nicoletti, 1969), whereas the products of the three main volcanic districts, Vulsini, Vico and Sabatini, were erupted between 0.6 and 0.1 Ma (Figure 1). The volcanic rocks of these districts display a broad compositional spectrum with magmas belonging to the two distinct evolutionary series, called the potassic (KS) and high-potassic (HKS) series (Appleton, 1962; Peccerillo and Manetti, 1985).

According to Beccaluva et al. (1991), the volcanism in the Roman Comagmatic Province can be related to the partial melting of heterogeneously-enriched mantle sources. Serri et al. (1993) suggest that mantle sources of the northern Apennine arc's magmatism can be explained by a geodynamic process which causes a large amount of crustal material to be incorporated within the upper mantle. More recently, Peccerillo (2002) suggests that the variety of magmas in central-southern Italy reflects a mosaic of compositionally-distinct, pre-metasomatic mantle sources that were modified by different metasomatic events.

2.1 The Vulsini Volcanic District

The Vulsini Volcanic District (hereafter VVD) was developed around 600-100 ka, between Tuscany and Latium, covering an area of about 2000 km^2 (Figure 1). The Bolsena and Latera calderas represent the two main polygenetic structures which developed during the activity of the whole VVD (Figure 2). The volcano-tectonic caldera of Bolsena (16 km in

Figure 4 - Space-time evolution of the Vulsini Volcanic Zones visualized through a schematic cross section from W to E of the District (modified from Nappi et al., 1995). Symbols: 1 = clayey-sandy and conglomeratic sediments of marine and brackish environments; 2 = mainly back-fall lithic breccias; 3 = conjectural effusive activity older than the dated plinian pumice falls; 4 = Basal plinian pumice falls; 5 = pyroclastics and lavas; 6 = the Civitella d'Agliano Formation; 7 = mainly back-fall lithic breccias; 8 = pyroclastics and lavas; 9 = Vietena lavic plateau; 10 = Ponticello pumice fall; 11 = Orvieto-Bagnoregio Ignimbrite; 12 = Monterado lava flows; 13 = Montefiascone pyroclastics; 14 = Bisentina Island surtseyan activity; 15 = pre-caldera effusive phase; 16 = Vulci and Monte Calvo lava flows; 17 = ignimbrites; 18 = the Pitigliano Formation; 19 = post-caldera effusive phase; 20 = post-caldera phreatomagmatic eruptions.

average diameter) is the result of incremental growth due to subsidence, with the caldera floor hinged on the SW side, as well as to some volcanic collapses (Nappi et al., 1991). The Latera caldera, located in the western sector (Nappi, 1969 a, b; Nappi et al., 1995), was formed by partially-coalescent collapses which occurred after several moderate-sized ignimbrite-forming eruptions (Figure 2). In the evolution of the VVD the Paleobolsena, Bolsena, Montefiascone, Latera and Neobolsena Zones have been distinguished (Figs. 3 and 4). These zones developed with alternating effusive, strombolian, plinian and ignimbrite-forming eruptions. Their products are characterized by a wide range of compositions belonging to the leucitite, basanite and shoshonite magmatic suites.

Near-primary magmas and differentiated products are present within each series. The vast majority of differentiated products occurs in the Bolsena and Latera Volcanic Zones, where pyroclastics were erupted during plinian-type and ignimbrite-forming eruptions. On the other hand, abundant, rather undifferentiated magmas are present in the Montefiascone Zone. Such magma distribution has to be related to the structural setting of the sedimentary substratum. In the Latera, Paleobolsena and Bolsena Zones, where a front of over-thrust sheet of the Tuscan sequence is present, relatively large magma bodies only a few kilometres deep can be inferred. The shallow magma chamber position at the top of the fractured carbonate basement in the Montefiascone Volcanic Zone would have facilitated the uprising of less evolved magma (Figure 4).

2.1.1 The Paleobolsena Volcanic Zone

The oldest products of the VVD directly overlie Plio-Pleistocene neoautochthonous sediments and are represented by three plinian pumice-fall layers (576 ± 6.5 ka) and a widespread ignimbrite (Nenfro auct., Nappi, 1969a, b; the Civitella D'Agliano Formation, Aurisicchio et al., 1992; 505 ± 5.7 ka), which represents the result of the largest ignimbrite-forming eruption in the VVD (Figure 5). The inferred average thickness and the areal distribution of this area of about 1500 km^2 suggest a minimum estimated volume of 10 km^3 for this ignimbrite. It can be observed only in the most peripheral area of the VVD, where it either overlies a centimetric-thick pumice-fall layer, or directly lies upon the Plio-Pleistocene sediments.

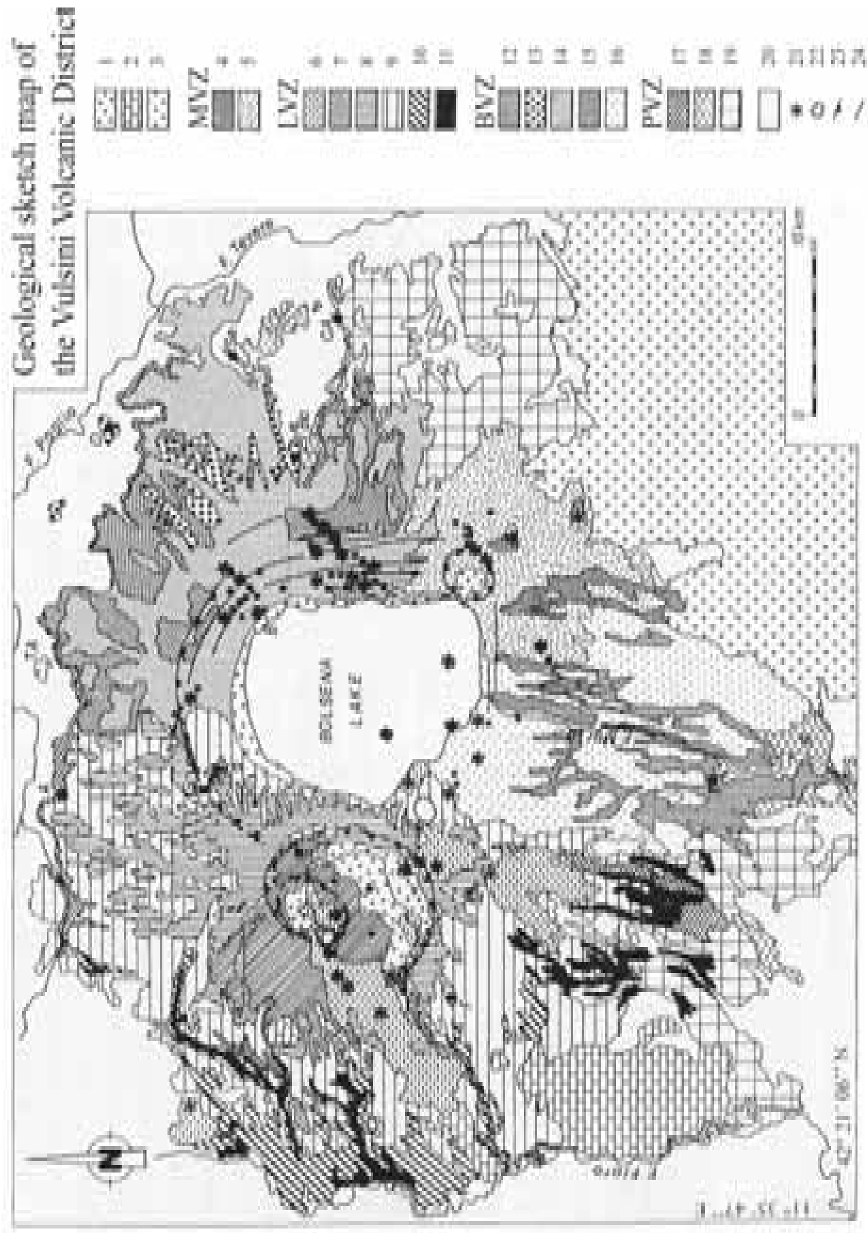


Figure 5 - Geological sketch map of the Vulsini Volcanic District (modified after Vezzoli et al., 1987). Symbols: 1 = Quaternary sedimentary deposits; 2 = travertine; 3 = products of the Torre Alfina center and Vico Volcanic District; 4 = lava flows; 5 = pyroclastic successions; 6 = effusive and strombolian activity products; 7 = the Pitigliano eruption unit; 8 = the Poggio Pinzo succession; 9 = F, E, e and D Ignimbrites; 10 = C Ignimbrite; 11 = B and A Ignimbrites; 12 = lava flows; 13 = Orvieto-Bagnoregio Ignimbrite; 14 = pyroclastic succession; 15 = lava flows; 16 = pyroclastic succession; 17 = lava flows; 18 = Nenfro Ignimbrite; 19 = pyroclastic and volcano-sedimentary successions; 20 = Mesozoic to Quaternary sedimentary substratum; 21 = scoria cones; 22 = craters; 23 = caldera rims; 24 = faults and fractures; A = Acquapendente, B = Bolsena, Ba = Bagnoregio, C = Canino, CA = Civitella d'Agliano, F = Farnese, G = Grotte di Castro, L = Latera, M = Montefiascone, O = Orvieto, P = Pitigliano, PS = Piano della Selva, R = La Rocca, S = Sovana, Se = Sermugnano, So = Sorano, T = Tuscania, TA = Torre Alfina.

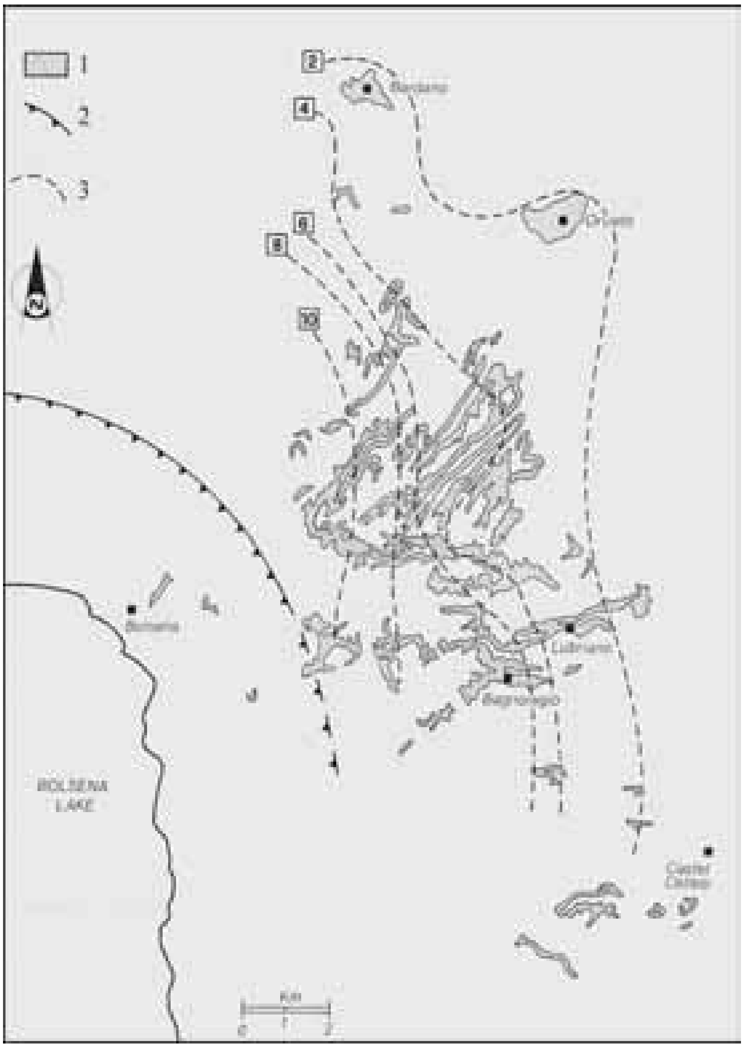


Figure 6 - Areal distribution of the main OBI deposits with the isopleths of the average diameter (in cm) of the five largest lithic clasts in the uppermost unit (modified from Nappi et al., 1994b). Symbols: 1 = areal distribution; 2 = Bolsena caldera rim; 3 = isopleths (equidistance 2 cm).

The deposits of the Nenfro eruption are characterized, from bottom up, by the following facies: a) plinian basal fallout made up of a widespread pumice level only a few centimetres thick; b) a pyroclastic flow deposit consisting of a basal pale-grey level of reversely-graded fine ashes with a maximum thickness of 6 cm, followed by a dark-grey welded deposit (maximum thickness of 6 m) with fine-grained micropomiceous matrix and vitrophiric "fiamme". An unwelded grey deposit, characterized by a coarse-grained matrix containing light sanidine-bearing pumices and dark analcimized leucite-bearing pumices, is also present in the upper part of the Nenfro sequence.

2.1.2 The Bolsena Volcanic Zone

During the Bolsena caldera formation, there was widespread volcanic activity along or within the inner sector of the caldera (Figs. 3 and 5). Lava flows and pyroclastic products, trachytic in composition, were emplaced. A large volume of welded-scoria fall was diffusely emplaced in the area around Bolsena village from about 390 to 360 ka. Immediately afterwards, this area was affected by a large explosive activity that gave rise to the Ponticello plinian eruption, followed by the Orvieto-Bagnoregio Ignimbrite eruption. The Ponticello fall deposit is exposed in the north-eastern sector of the Vulsini area; it reaches a maximum thickness of 2.5 m about 2 km east of Bolsena village. The juvenile fraction of the Ponticello deposit is made up of prevailing white trachytic pumice clasts, and shows a normal grain-size grading; grey and banded (mixed) pumices occasionally occur toward the top of the deposit (Nappi et al., 1994a).

The Orvieto-Bagnoregio Ignimbrite (hereafter OBI) spreads across the north-eastern sector of the VVD (Nappi et al., 1994b; Figure 6) and its primary areal distribution, inferred from the observed outcrops, is about 200 km^2, extending from Bardano, in the north, to Castel Cellesi, in the south. This eruption was the result of the emptying of the compositionally-zoned latite to trachyphonolite magma chamber (Table 1), and represents the largest explosive event of the Bolsena Zone.

The OBI eruption took place 333 ± 3 ka (Santi, 1990; Gillot et al., 1991; Figure 3), during the final

Rock type	*trachyte*	*trachyte*	*phonolite*	*trachyte*
SiO_2	59.04	60.86	58.62	57.89
TiO_2	0.48	0.51	0.45	0.53
Al_2O_3	18.92	19.27	18.50	20.30
Fe_2O_3	0.39	0.39	3.28	0.43
FeO	2.36	2.36	-	2.60
MnO	0.14	0.14	0.12	0.15
MgO	0.29	0.22	0.46	0.25
CaO	2.38	2.21	2.77	2.21
Na_2O	2.93	2.70	3.53	2.89
K_2O	8.90	9.72	9.71	8.11
P_2O_5	0.04	0.04	0.02	0.03
LOI	4.12	1.59	2.54	4.60

Table 1 - Chemical analyses of major elements (%wt.) and classification of the OBI juvenile fragments.

paroxysmal explosive activity of the Bolsena zone, and gave rise to the emplacement of several pyroclastic deposits. The stratigraphic series of the OBI can be summarized in (1) a basal plinian pumice-fall deposit and (2) a main ignimbrite deposit. The latter is made up of: (a) a ground-surge which always underlies the ignimbrite throughout its areal distribution, (b) a near-vent lithic-breccia deposit, (c) a series of thin and highly-dispersed pumice flow units (lowermost unit) and (d) a thick, topographically-controlled pyroclastic flow deposit (uppermost unit).

The OBI is the largest ignimbrite-forming eruption of the eastern Vulsini area and it can be considered the most useful chronostratigraphic marker for separating Bolsena volcanics from the deposits of the upper Montefiascone Zone (Nappi et al., 1994b).

2.1.3 The Latera Volcanic Zone

The history of the Latera Volcanic Zone (Figs. 3 and 5) can be subdivided into three distinct phases.

The first phase produced mostly lava flows. The second phase produced a large volume of ignimbrites and subordinate pyroclastic fall and surge deposits; it was in this phase that the caldera of Latera was formed. During the third phase, hydromagmatic and strombolian activity took place on the rim of the Latera caldera. Sparks (1975) proposed that the Latera volcano be considered an ignimbrite shield volcano, with its low profile so similar to those of many basaltic shield volcanoes. In fact many ignimbritic units have been identified and studied in the Latera Zone (Nappi, 1969a, b; Sparks, 1975; Varekamp, 1980; Metzeltin and Vezzoli, 1983; Capaccioni et al., 1994; Nappi et al., 1994b; Palladino and Valentine, 1995; Palladino and Simei, 2002). The first complete and careful study of the Latera ignimbrite sequence was carried out by Sparks (1975). This author, in a comprehensive study on the Latera caldera, named the major (0.3 - 2.2 km^3 each) and most widespread ignimbrites sequentially with capital letters (A, B, C, D, E, F, from the oldest to the youngest, Figure 7). Smaller ignimbrites (a, b, c, d, e) also occur within the sequence. The A, B, C and D Ignimbrites were generated by the collapse of very high eruptive columns outpoured by central vents and followed by the formation, in the central zone, of the present caldera. On the contrary, the final explosive phases (E, F Ignimbrites and the "Pitigliano Formation") added source vents in the northern sector.

The A Ignimbrite is the oldest ignimbrite and is exposed widely over all sides of the volcano. This deposit ranges from poorly-coherent to coherent and is formed by several layers, which are made up by decimetric, grey, trachytic pumices with sanidine phenocrysts in a crystal-rich matrix containing sanidine, biotite and clinopyroxene. The lithic clasts are represented by both sedimentary and igneous types. The A Ignimbrite reaches its maximum thickness of 45 m far away from the vent.

The B Ignimbrite crops out in the western and north-eastern sector of the Latera caldera (Figure 5). It appears as a light-brown deposit with an ash matrix, poor in pumice clasts but very rich in rounded lava bombs and sedimentary lithic fragments, olocrystalline nodules and rare accretionary lapilli. The juvenile fraction consists of two types of pumice-clasts varying in colour from white to dark-grey. The B Ignimbrite normally shows one or two flow units, and it reaches a maximum thickness of a few meters.

The C Ignimbrite is the most widely distributed of the Latera ignimbrites in the south-western sector, overlying epiclastic lacustrine deposits (Figs. 5 and 7). This ignimbrite, which consists of two pyroclastic flow units, always shows a pyroclastic surge level at the base. The basal surge is formed by a horizon of white ashes and accretionary lapilli. The lower unit consists of decimetric, white pumices, containing leucite and sanidine phenocrysts. The upper is a sillar-type deposit with a red ash-matrix and blackish pumices. The lithic clasts occur both concentrated at the base and dispersed throughout the deposit.

The D Ignimbrite is a fine-grained ignimbrite with a large areal distribution. In the southern sector only one flow unit occurs; on the contrary, in the northern and

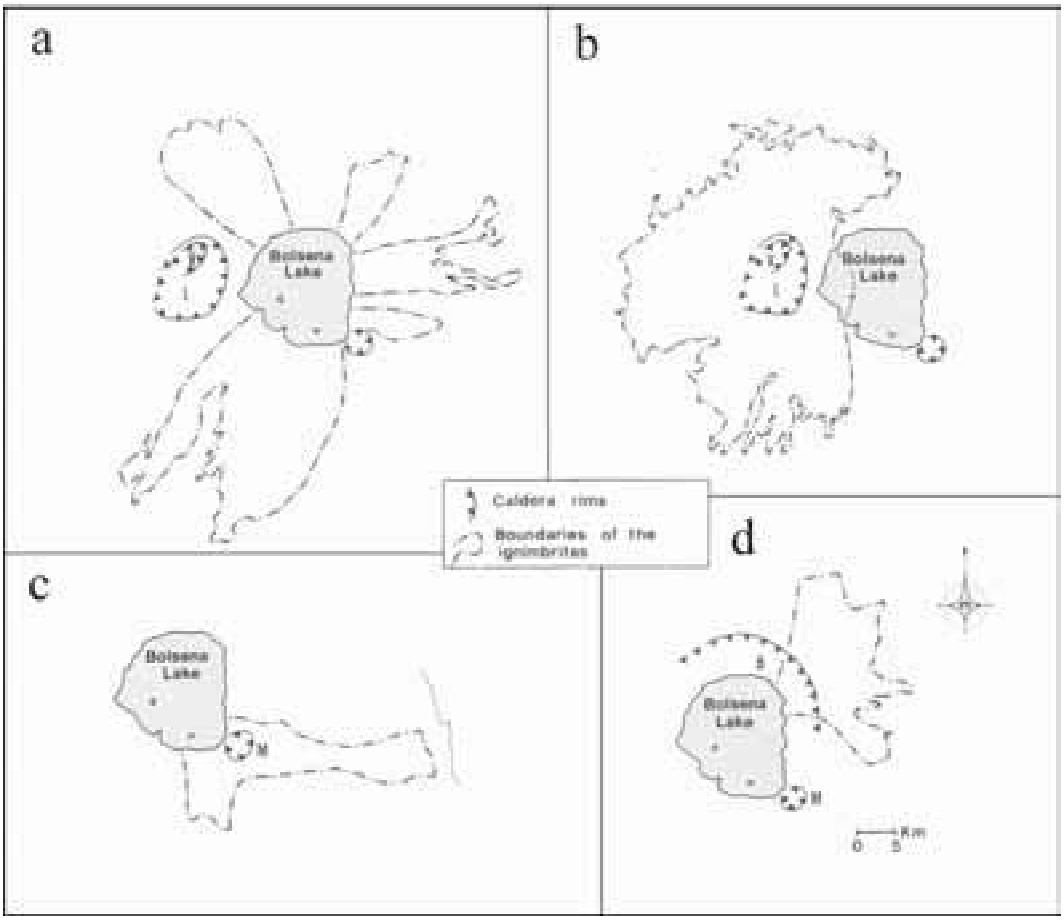


Figure 7 - Areal distribution of the main ignimbrite deposits related to the Vulsini calderas (modified after Nappi et al., 1991). a = Basal Ignimbrites; b = Latera Ignimbrites; c = Basal Montefiascone Ignimbrite; d = Orvieto-Bagnoregio Ignimbrite. B = the Bolsena caldera; L = the Latera caldera; M = the Montefiascone caldera; V = the Vepe caldera.

western sectors, many flow units are present (Figs. 5 and 7). The colour ranges from pale-yellow (coherent sillar deposits) to white (incoherent facies). The lower flow unit shows a repetition of beds, with reversely-graded, coarse pumices. An orange lithified deposit in sillar facies, containing sanidine and analcimized leucite crystals, occurs in the upper part.

The E Ignimbrite is a well-lithified sillar deposit, which can be found on both the northern and southern sides of the Latera caldera. Many flow units can be distinguished on the northern side (Figs. 5 and 7). According to Sparks (1975), this is a complex ignimbrite produced by a mixed magma, as shown by the presence of both pale tubular pumices (5 cm of length) and black scoria clasts (15 cm of length). A distinctive characteristic of this pyroclastic deposit is the presence of large tree holes at its bottom. Sparks also indicates the presence of several ignimbrites which occur at the same stratigraphic level as the E Ignimbrite.

The tephriphonolitic F Ignimbrite represents the final phase of the eruption that gave rise to the "Vulcanite Complessa di Onano" (Nappi, 1969a, b). The beginning of this activity is represented by lava fountaining along a NW-SE eruptive fissure, mostly coinciding with the NE border of the present caldera. Products of such activity produced a welded air-fall deposit, exposed on the northern and eastern sectors of the Latera caldera (Figure 5). The overlying pyroclastic flow deposit (F Ignimbrite) is a sillar-type deposit, light-yellow to reddish in the upper part, and incoherent, grey to black with breadcrust bombs in

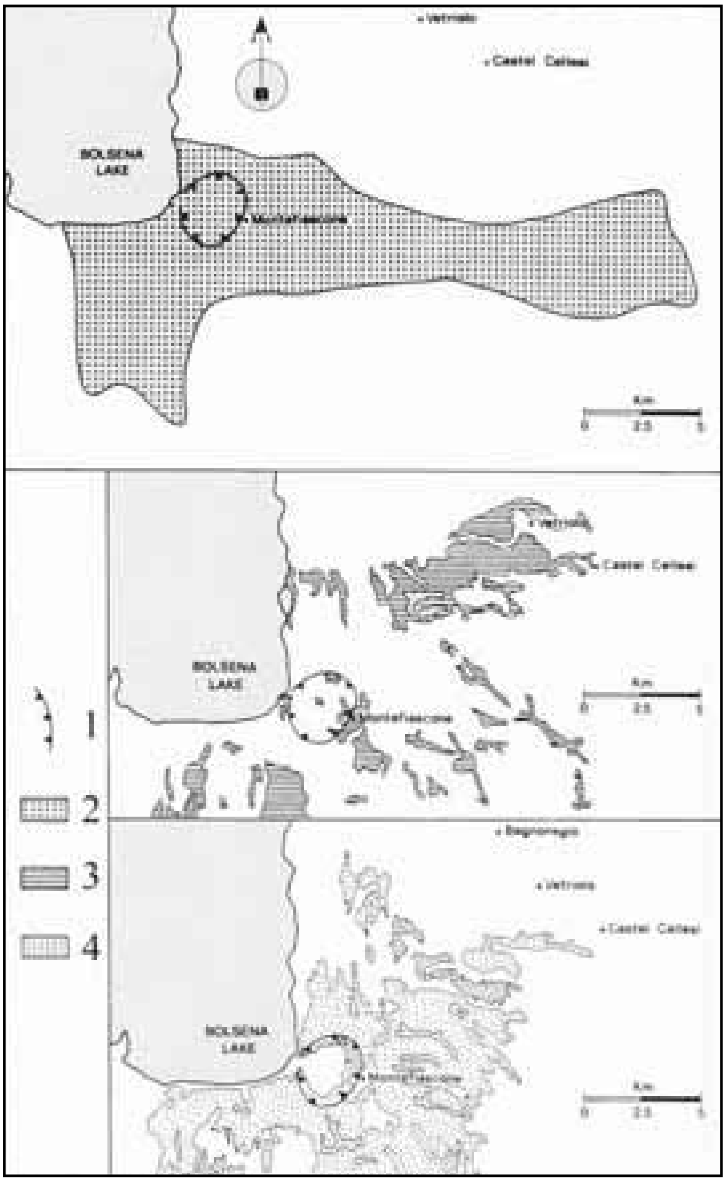


Figure 8 - Evolution of the Montefiascone caldera. Symbols: 1 = caldera rim; 2 = areal distribution of the Basal Ignimbrite; 3 = lava flow; 4 = hydromagmatic deposits and spatter cones.

the lower part. The ash matrix contains leucite and pyroxene crystals, while feldspars are absent.
The depositional sequence of the "Pitigliano Formation" (Nappi 1969a, b) is composed of: (a) basal pumice flow deposits (unwelded sequence), (b) rheomorphic welded air-fall tuffs (welded sequence), which locally transition into lava-like deposits, and (c) lava flows that form low-angle exogenous domes. In the more distal outcrops, polygenetic layers are interbedded within the welded sequence, whose variations in physical properties, textural characteristics, and other field evidence suggest an important fallout component followed by rheomorphism. Furthermore, the occurrence of variations in the relative proportions of the different kinds of near-surface and deep-seated rocks of the polygenetic breccia layers supports the hypothesis of a progressive opening of several source vents localized around the NW rim of the Vepe caldera (Nappi 1969a, b; Figure 5). Collapsing eruptive columns, followed by lava fountains, respectively produced the lowermost welded sequence (rheomorphic air-fall tuffs) and the un-welded sequence (pumice flow deposits). Nevertheless, during the final stage of the eruption, lavas outpoured quietly from a caldera ring fracture. The eruptive styles were regulated by the degree of magma fragmentation and the rapid subsidence of a "piston-like" block, which mostly occurred when the magma chamber had been nearly completely tapped, and the residual melt of the deeper part of the magma reservoir was squeezed out, forming low-angle exogenous domes. In the final stage of the Latera Volcanic Zone, strombolian eruptions took place within the caldera ("Mt. Becco", "Mt. Spinaio" and "La Dogana" centres) and along the caldera rim ("Valentano" scoria cones).

2.1.4 The Montefiascone Volcanic Zone

The structural study of the entire VVD has revealed the presence of a main caldera structure (the Montefiascone caldera; Marini and Nappi, 1986),

which has a volume of 1 km^3 and is located south-east of Bolsena Lake (Figure 8). Its sub-circular rim has a diameter of 3 km with a base diameter of 1.5 km; the average rim height is 200 m over the Bolsena Lake level. The Montefiascone caldera lies in an area of convergence of several fault systems, with dominant N-S and NE-SW directions. Such tectonic lines have controlled the eastern Vulsini volcanic activity since the early phases, with continuous reactivations until the most recent episodes (Nappi and Marini, 1986a). A third regional tectonic discontinuity, a fracture oriented NW-SE, divides the Montefiascone caldera into two parts.
The evolution of the Montefiascone caldera can be summarized in the following volcano-tectonic phases: a) emission of the basal Montefiascone Ignimbrite, followed by the caldera's collapse, b) hydromagmatic activity and a new collapse, followed by circum- and intra-calderic strombolian activity.

2.1.5 The Neobolsena Volcanic Zone

The Neobolsena Volcanic Zone (Figure 3) developed within the present Bolsena Lake during the final stage of the evolution of the Bolsena caldera. The activity is represented by sub-lacustrine eruptions of surtseyan-type which produced the Martana and Bisentina Islands. Although most of the products are represented by phreatomagmatic tuffs, the final activity of Bisentina Island is entirely effusive, with the outpouring of leucite-bearing lava, which shows the youngest radiometric age among all the Vulsini volcanic products (127 ± 1.8 ka; Santi, 1990; Gillot et al., 1991).

2.2 The Cimino Volcanic District

The evolutive history of the Cimino Volcanic District (hereafter CVD; Figure 1) can be subdivided into three eruptive phases (Lardini and Nappi, 1987). During the first phase, endogenous and exogenous domes formed along NW-SE feeding fissures; explosive activity followed the domes' growth, and pyroclastic flows (which gave rise to the Cimina Ignimbrite) were generated along the same fissures (Figure 9a, b). The Cimina Ignimbrite spread out essentially along the eastern side of the feeding fissures, and covered an area of about 300 km^2, with a maximum thickness of about 200 m. During the second phase, a few domes developed along NE-SW fissures, followed by hydromagmatic activity generating pyroclastic surges. According to their distribution they seem to have been generated by explosions inside the domes' feeding fissures on the eastern part of the present Cimino Mount. The hydromagmatic products are characterized by a prevalently planar structure with reverse grading.
Such products crop out only in the eastern part of the CVD and show a regular distribution. After hydromagmatic explosions, another large magmatic explosive eruption generated a second pyroclastic flow deposit, which covers an area of 20 km^2, with an average thickness of 10 m. The matrix and the coarse pumices of the younger pyroclastic flow deposit show a more marked vesiculation than the older one. Furthermore, the lithic fragments are smaller in the younger ignimbrite. In the third and final cycle a central volcano developed.

2.3 The Vico Volcanic District

The Vico Volcano (hereafter VV; Figure 1) can be considered a central strato-volcano with a caldera depression at its summit. The VV developed on complicated regional structures, consisting of a graben elongated NW-SE and a very important tectonic fracture directed NE-SW (the Orte-Vico fault). The VV activity extended between 419 ka and 95 ka, and its volcanic history can be summarised in four phases: (1) a prevalently explosive plinian-type activity, (2) a predominantly effusive activity, with the formation of the strato-volcano, (3) ignimbrite-forming eruptions and caldera genesis, and (4) circum-caldera hydromagmatic and strombolian eruptions.
The products of the first phase consist of several plinian fall deposits with wide areal distribution, which are spread out northward and eastward from the inferred central crater. The second phase is characterized by the building of the cone by lava flows, from 300 to 200 ka. The lava flows crop out along the inner caldera walls and can be subdivided into leucite-bearing and sanidine-bearing groups. The leucite-bearing lavas show chemical and mineralogical characteristics typical of HKS rocks, whereas the sanidine-bearing lavas are generally weakly silica under-saturated. From 200 to 100 ka a main explosive activity gave rise to the emplacement of several pyroclastic flows (third phase). The first three ignimbrites (A, B and C; Locardi, 1965) show a symmetric distribution around the caldera, whereas the D Ignimbrite is only found on the W side (Figure 10).
The A Ignimbrite (Figure 12a, d) is characterized by a basal plinian-fall deposit followed by three

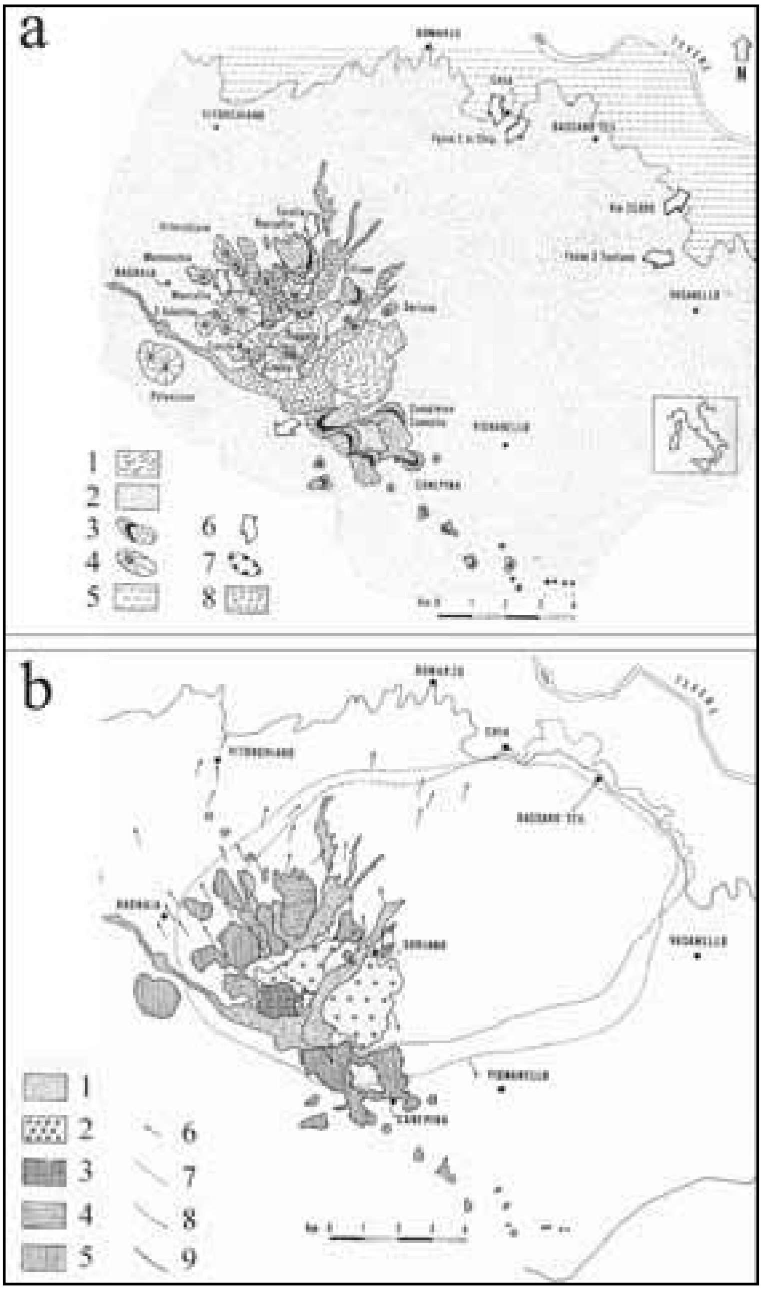


Figure 9 - Sketch map of the Cimino Volcanic District. a) Symbols: 1 = latitic lava; 2 = ignimbrites; 3 = collapsed lava dome; 4 = lava dome; 5 = Quaternary sediments; 6 = pyroclastic surges; 7 = lateral eruptive centres; 8 = olivine latitic lava.
b) Symbols: 1 = olivine latitic lava flow; 2 = latitic lava flow; 3 = 3rd cycle dome; 4 = 2nd cycle dome; 5 = 1st cycle dome; 6 = flow direction of the lower ignimbrite; 7 = boundary of the pyroclastic surge deposits;
8 = boundary of the upper ignimbrite; 9 = boundary of the lower ignimbrite.

flow units. Each flow unit is formed, in proximal sectors, by flattened, grey and black scoriae in highly-welded, ash-sized matrix. The black scoriae are coarse-grained and contain leucite, plagioclase, clinopyroxene, sanidine and biotite crystals. On the contrary, in the distal sectors, lithification is caused by zeolitization processes. This ignimbrite is mainly distributed in the W, E and S sectors, with a maximum thickness of about 10 m.

The B Ignimbrite begins with a basal decimetric level constituted by dark-grey coarse ashes, uniformly distributed around the VV. This level consists of many laminated ash layers showing reverse or normal grading, and it is overlaid by a plinian pumice fall level. Three flow units can be observed within the ignimbrite body: the basal one is characterized, in the proximal areas, by a “breccia” deposit made up by coarse lithics with a diameter up to 0.5 m. The subsequent units show varying colours and degrees of cohesiveness. They are generally welded, with flattened scoriae and pumices included in a micro-scoriaceous, coarse-grained matrix. Lithic fragments are represented by sub-volcanic rocks and sanidine-bearing lavas; sanidine, clinopyroxene, plagioclase, olivine and biotite are also present as loose crystals.

The C Ignimbrite is the deposit with the largest areal distribution in the VV (Figure 11). It spreads out symmetrically northwards,

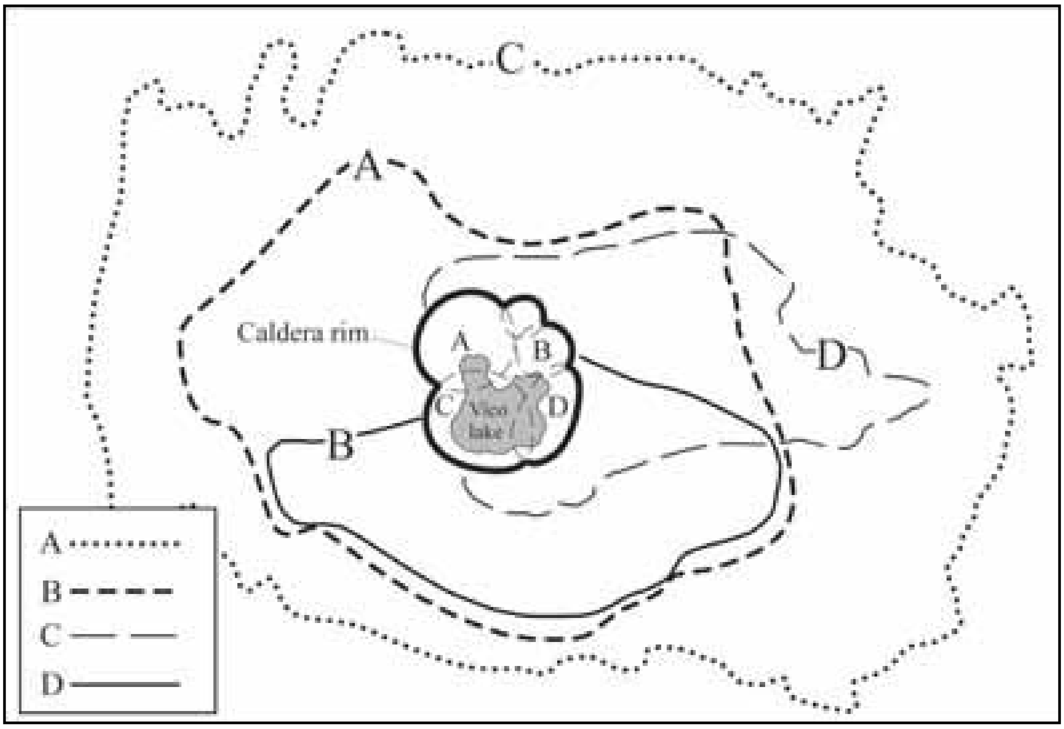


Figure 10 - Vico caldera evolution and areal distribution of the ignimbrites. Symbols: A = boundary of the A Ignimbrite; B = boundary of the B Ignimbrite; C = boundary of the C Ignimbrite; D = boundary of the D Ignimbrite.

where it overlies the Vulsini pyroclastic deposits, and southwards, where it is interbedded within the Sabatini pyroclastic succession (Figure 12). It is the most studied of the Vico ignimbrites (Locardi, 1965; Mattias and Ventriglia, 1970; Bertagnini and Sbrana, 1986; Perini et al, 1997; Nappi et al., 2003). At the base of the C Ignimbrite there is a metric horizon made up by white plinian pumices. The pumices are micro-vesiculated and contain sanidine, clinopyroxene, biotite and rare hauyne crystals. Three pumice flow units, from decimetric (the lower two) to metric (the upper one) in thickness, follow. The matrix consists of pale-grey ashes, containing rounded sub-aphiric pumices. A lag-breccia deposit, with scarce matrix and a maximum thickness of 20 meters in the proximal sector, follows. Towards the distal sectors its thickness decreases abruptly and the matrix appears to be constituted by coarse lapilli. Lithics are represented by lavas, clay fragments and thermo-metamorphic rocks. The sequence goes on with a massive, welded deposit constituted by up-to-metric flattened scoriae, followed by a sillar-type deposit, with a zeolitized matrix containing large, and rare, grey, rounded pumices.

The D Ignimbrite extends mainly in the eastern sector of the VV (Figure 10); it appears as a massive, pale grey or yellow deposit. The depositional sequence is composed of many flow units: a fine-ash lithified level at the base, followed by several flow units with a sharp hydromagmatic character. The basal units are mainly constituted by inverse graded levels, and contain pomiceous lapilli, white coarse-pumices and rare lithics in a micropomiceous or ashy matrix. Massive deposits with a lithified ash matrix containing white pumices, flattened dark pumices and heterogeneous lithic fragments (obsidian fragments are also present), occur as we move upwards. The final units include at least four flow units: they are represented by pale-grey or white deposits, containing white pumices, obsidian fragments, leucitic lavas and sedimentary fragments in an ash or micropomiceous matrix. These units are massive in the proximal areas, and stratified with reversely-graded layers in the distal sectors. A fine-ash level occurs at the top.

2.4 Emplacement mechanisms of ignimbrites: some examples in the visited area

Pyroclastic flow deposits from the Quaternary

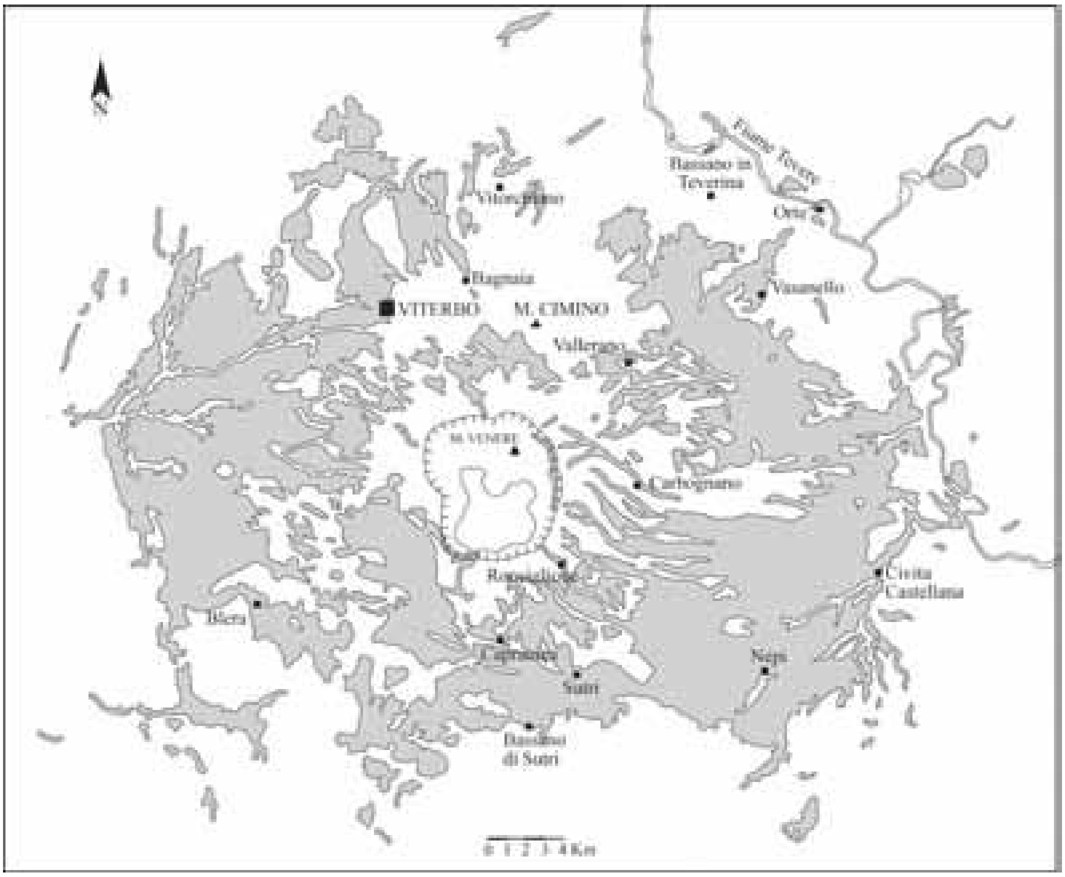


Figure 11 - Vico Volcano: areal distribution of the C Ignimbrite.

volcanism of Central Italy can be ascribed to a broad spectrum of both eruptive and depositional processes. The study of the mechanisms that regulate the transport and deposition of pyroclastic flows has dominated volcanic literature in the last few decades (Sparks, 1976; Wright and Walker, 1981; Fisher, 1986, 1990; Valentine, 1987; Carey, 1991; Branney and Kokelaar, 1992, 1997; Kneller and Branney, 1995; Palladino and Valentine, 1995; Druitt, 1998; Freundt and Bursik, 1998; Valentine and Fisher, 2000; Capaccioni et al., 2001; Palladino and Simei, 2002; Valentini, 2002, 2003). Though numerous authors have tried to shed light on this topic, today it still remains unclear because proposed models are often different and ill-matched.

Several authors (Sparks, 1976; Wright and Walker, 1981; Fisher, 1986; Valentine and Fisher, 1986; Valentine, 1987; Carey, 1991; Palladino and Valentine, 1995) believe that pyroclastic flows are partly- or non-fluidized, highly-concentrated density currents that move in a laminar and/or plug style, and stop “en masse” along all the flow body. According to Valentine (1987) and Fisher (1990), transport and deposition systems are one and the same. The highest velocity gradient and shear stress occur in the basal portion of the flow, while almost constant vertical flow velocities (“plug” zone) occur in the upper portion (Palladino and Valentine, 1995). Deposition takes place when the applied shear stress becomes lower than the yield strength of the material. The resulting deposit is then represented by a massive unit with possible shear-induced inverse size-grading at the base (layer 2a; Sparks, 1976), and density-induced normal grading at the top (layer 2b; Sparks, 1976). Therefore, these features are considered strong evidence for deposition from concentrated suspensions (Druitt, 1998).

An alternative model, already envisaged by Fisher (1966), was proposed by Branney and Kokelaar (1992). In agreement with the depositional model

Figure 12 - a) = Vetralla: Vico Volcano, A Ignimbrite. b) = Pitigliano: Vulsini Volcanic District, e Ignimbrite underlying the E Ignimbrite. c) = Sovana Necropolis: "Via Cava" of Cavone, excavated inside the C Ignimbrite, d) = Vetralla: Vico Volcano, matrix of the A Ignimbrite: detail of photo (a).

of the high-density turbidity current (Lowe, 1982), the authors suggest that pyroclastic flows can be considered as sustained and stratified flows which deposit at the base by progressive aggradation. The depositional system is restricted to the basal part of the flow, where the high particle concentration suppresses turbulence, independently and with different rheology from the overriding, more diluted and turbulent transport system. This is also in accordance with the high-velocity, turbulent pyroclastic flow end-member proposed by Palladino and Valentine (1995). In the sustained and stratified flows, the basal zone moves like a shear-induced grain flow, just before deposition by frictional freezing. The basal depositional system is composed of a granular flow zone subdivided into a lower portion in "frictional regime", where particles glide along each other, passing upwards to a portion in "collisional regime", where particle-

particle collisions prevail (Freundt and Bursik, 1998). Before deposition, dispersive pressures due to grain-to-grain frictional and collisional interactions develop inverse size-grading and directional fabric (Rees, 1968). According to Kneller and Branney (1995), the absence of traction-induced structures, together with the development of a poor fabric, result from the occurrence of a gradual transition between transport and depositional system. Otherwise, structures would occur distinctly and a good fabric would develop. Hence, massive beds or layered flow units in ignimbrites may represent the result of a continuous incremental deposition at the base of the flow.

The debate on transport and depositional mechanisms of ignimbrites should now be considered within the framework of the controversy over the distinction between "surge" and "flow" deposits. The concept of these two respective modes of transport as two fundamentally distinct phenomena is eclipsed by the idea that they might represent two end-members of a variable spectrum of possible particle concentrations in between (Wilson and Houghton, 2000). Accordingly, the two end-members are correctly represented in the recently-proposed terms "high- or low-concentration pyroclastic density currents" (Valentine and Fisher, 2000).

In a recent paper by Palladino and Simei (2002), three flow scenarios and corresponding deposits have been identified, within the continuum of pyroclastic currents ranging from diluted to concentrated end members, based on a survey of pyroclastic successions in the Vulsini Volcanic District.

The first is represented by diluted, turbulent pyroclastic currents producing normally or multiple graded beds, for progressive aggradation during the passage of the flow due to direct fallout from the gas-pyroclast suspension. The related deposits are massive to planar/cross laminated, with no fabric development, but a possible clast imbrication.

The second can be represented by density-stratified pyroclastic currents with a concentrated bed-load region, beneath a turbulent, diluted and fine-grained upper part, depositing inversely graded beds by traction carpet sedimentation. Diffuse bedding-parallel clast fabric and other traction features, such as laterally discontinuous trains of clasts, lamination and local imbrication of elongate clasts, are indicative of laminar shear prior to deposition.

The last scenario is represented by self-sustained, high particle concentration, laminar, mass flows developing massive, meter-thick deposits with a possible normal grading for lithic and inverse for pumice clasts, overlaying a fine-grained, inversely graded basal layer. These flows emplace by "en masse" freezing up as the shear rate drops below the yield strength throughout the entire flow height (Sparks, 1976) or by rapid stacking of flow laminae from bottom up (Palladino and Valentine, 1995).

Analysis of structural and textural properties of pyroclastic flow deposits takes on major importance for investigating the genetic mechanisms of deposits. Accordingly, Palladino and Simei (2002) propose facies analysis as the main distinguishing criteria in pyroclastic deposits. The authors indicate, as examples of type 1 deposits in the Vulsini area, part of the basal layer of the "C Ignimbrite" (Sparks, 1976) of the Latera Volcanic Zone (or "Sovana Eruption Unit"; Vezzoli et al., 1987; Palladino and Taddeucci, 1998), and the coarse lithic breccias with the associated spatter flow deposits of the "Onano eruption succession" (Marsella et al., 1987). The type 2 deposit is well represented in the "Orvieto-Bagnoregio Ignimbrite" (Nappi et al., 1994b) of the Bolsena Volcanic Zone. Finally, the authors interpreted much of the Latera ignimbrites as derived from type 3 pyroclastic currents.

Although facies analysis represents the main tool for discriminating between different types of pyroclastic deposits, we believe that it should be supported by other investigative methods. The intensive secondary mineralization that very often affects the ash-sized matrix, and also the superficial alteration, hide structures and textures. Moreover, the lack of traction-induced structures and grading, according to Kneller and Branney (1995), may not only be related with "en masse" deposition, but also with a gradual transition between transport and depositional systems. Massive deposits may, in fact, also originate from progressive aggradation of basal depositional layers (Branney and Kokelaar, 1992), in which the residence time of particles under shear conditions (which ultimately depends on sedimentation rate) is not enough to produce grading, dunes or ripples, but, rather, enough to produce directional fabric. A continuous incremental deposition at the base of a pyroclastic current could then produce, under different conditions, massive beds or layered flow units (Capaccioni et al., 2001; Valentini, 2002, 2003). A careful evaluation of the qualitative and quantitative information about the directional fabric may, therefore, help shed light on the emplacement of ignimbrites (Branney and Kokelaar, 1992). Several fabric studies

in pyroclastic flow deposits have been carried out measuring the orientation of single elongate clasts (Elston and Smith, 1970; Suzuki and Ui, 1982, 1983; Kamata and Mimura, 1983; Potter and Oberthal, 1987; Ui et al., 1989; Hughes and Druitt, 1998). Anisotropy of magnetic susceptibility has also been used as a fabric indicator in ignimbrites (Ellwood, 1982; MacDonald and Palmer, 1990; Hillhouse and Weels, 1991; Seaman et al., 1991; Fisher et al., 1993; Baer et al., 1997; Cagnoli and Tarling, 1997).
Data regarding directional fabric obtained by using a computer-assisted image analysis method from different ignimbrites (Capaccioni and Sarocchi, 1996; Capaccioni et al., 1997; Capaccioni et al., 2001; Valentini, 2002, 2003) have recently been presented and discussed to make inferences on the emplacement processes of pyroclastic currents. The analytical method consists of a computer-aided image analysis system, able to carry out textural investigation (grain size analysis, morphological analysis and direction of lengthened particles) on consolidated and unconsolidated rocks, at different scales. Details of this method are described by Capaccioni et al. (1997).
Orientation data are processed to obtain information about the occurrence of preferred particle orientations and their strengths. Specific statistics are used in order to gather information on the occurrence of anisotropic distributions, unimodality or multimodality of the circular frequency distributions, degree of concentration of measures around the mean direction and, finally, confidence angles of the mean direction (Capaccioni et al., 1997).
Fabric data of some pyroclastic flow deposits from the Vulsini and Cimini Volcanic Districts have been obtained by using the described image analysis method, and their relative transport and depositional mechanisms have been interpreted. Samples were collected vertically at metric intervals of up two sections through each deposit. Where it was possible the analysed sections were selected along the same paleovalleys, at different distances from the source area.
The "Orvieto-Bagnoregio Ignimbrite" (from VVD) and "C Ignimbrite" (from VV) are not-welded but lithified due to secondary mineralization. They have similar depositional sequences and the geometries of their deposits are also similar. They show both vertical fluctuations in the mean particle orientation values of about ±60°, and large variations in the strength of particle iso-orientation with height. The circular frequency distributions of particle orientations are almost always anisotropic and unimodal, in line with a theoretical Von Mises distribution (the circular equivalent of a unimodal, log-normal distribution) (Capaccioni et al., 2001; Valentini, 2002, 2003).
In contrast, the welded "Cimina Ignimbrite" (from CVD) shows vertical homogeneities in mean orientation values with height, and generally lower degrees of anisotropy. The circular frequency distributions of particle orientations are almost always anisotropic and unimodal, with cases of isotropic or polimodal distributions as well. A parallel-to-flow iso-orientation is present in the unimodal samples, whereas the polimodal distributions show two main modes. One is placed parallel-to-flow, the other transverse-to-flow. Detailed analysis of these samples has shown the link between sizes and shapes of the clasts, and the direction of the iso-orientation obtained (Capaccioni et al., 2001; Valentini, 2002), in accordance with some models proposed in the literature (Lindsay, 1968; Best, 1992).
Such differences have been interpreted as being the results of different depositional mechanisms: (a) incremental deposition at the base of a density-stratified, partially turbulent flow for the "Orvieto-Bagnoregio Ignimbrite" and the Vico "C Ignimbrite", and (b) "en masse" deposition of a viscous-dominated laminar mass flow for the "Cimina Ignimbrite". In the former case, during transport, particles under solidus temperature are subjected to a frictional regime, as well as gliding and dispersive pressures, which eventually produce size-inverse grading and variable degrees of iso-orientation.
The iso-orientation varies according to the residence time of particles in the basal shear conditions. In the case of the Cimina Ignimbrite (VVD), elongated particles, supported in a laminar flowing viscous matrix, undergo periodic motions which tend to develop parallel-to-flow iso-orientation. Fabric data in the deposit suggest a general vertical homogeneity of the rheological properties of the flow and only rare plug horizons.
In addition, analyses in progress on the Latera D Ignimbrite, combined with its textural and structural features, allow us to interpret the mechanism for incremental deposition at the base of a density-stratified and partially-turbulent flow, as the possible depositional mechanism of much of this deposit. On the contrary, textural data obtained through image analysis on the "Nenfro Ignimbrite" (VVD) better agree with an "en masse" deposition from a laminar mass flow.

2.5 Use of the ignimbrites

Up to the Prehistoric Age the ignimbrites of Latium were used as living caves. The Etruscans and Romans then used them to make tombs, monuments, temples and amphitheatres. Today, they are used for walls or insulation and sound-proofing. Their mechanical and physical characteristics seem to be related both to their structure and to the lithification process that the deposit underwent. Apparent density, bulk density and porosity, as well as compressive and tensile strength, on naturally dry and saturated samples were measured on Nenfro, Orvieto-Bagnoregio Ignimbrite, Latera C and D Ignimbrites. Uni-axial compression tests have been carried out on cylindrical samples with H = 2D. Tensile strength was measured by using the indirect Brasilian test. A summary of these results is shown in Table 2.

2.5.1 The Etruscan tombs of Sovana

The area surrounding Sovana was one of the most important Etruscan centres, whose earliest settlements date back to the 8th century B.C. It remained an important centre during the whole Etruscan period, up to the Roman civilization (Bianchi Bandinelli, 1929; De Feo, 1993, 2001).

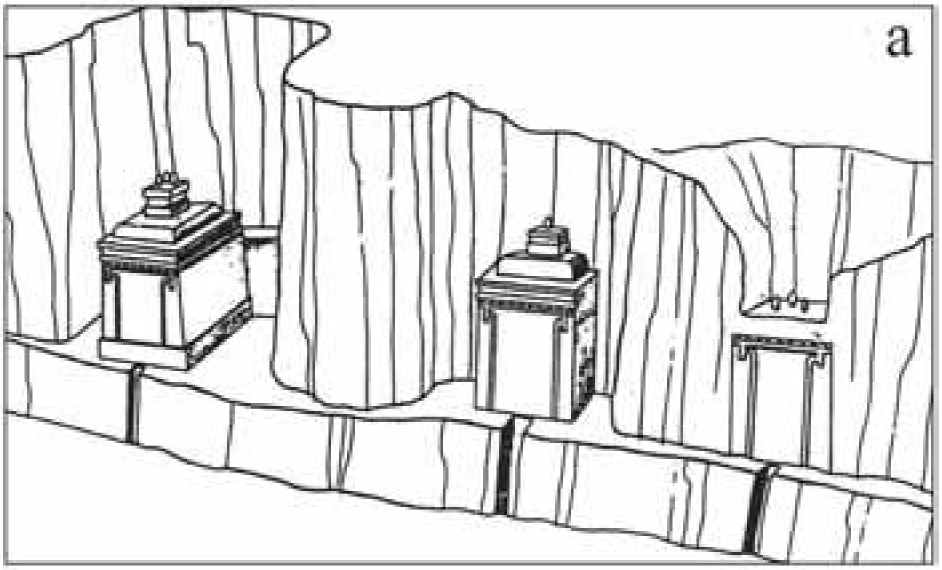
The pyroclastic successions of Sovana were thoroughly worked during this entire period. Tombs, necropolises, sacred pathways, wells, drainage channels, huge chiselled rocks and sculptures are so common as to make this area unique in terms of the quality and quantity of its great excavated works. Indeed, Sovana is also called "The City and Civilization of Tufa".

The most important tombs of Sovana are located along the "Folonia", "Calesine" and "Picciolana" valleys, inlaid from the homonymous streams. Two main types can be distinguished: (1) the dado (cubic), semi-dado and false dado tombs, and (2) the niche and the temple tombs.

The first type, which is the most common, can be considered a more highly evolved version of the ancient, simple dado type, already known in southern Etruscan towns (Figure 13). A substantial enrichment with decorative architectural elements, and the relocation of the funeral room to the lower level of the tomb, are the main changes. A false carved door, which symbolizes the entrance to the world beyond the grave, was placed in front of the dado. The funeral room containing the mortal remains, located under the dado, was accessible through a long, deep open passage (dromos). The sepulchral monument appears to be composed of two parts: a cubic block jutting out from the rock wall with a false door and moulded crowning; a small rectangular over-structure, called an "altar-bring cippus", also decorated with a moulding. The variegated, monumental tombs of the second

Sample	*Bulk density (ℑ g/cmc*	*Apparent density (ℑ) g/cmc*	*Porosity (P) %*	** Compressive strength (⇑) Mpa*	** Tensile strength (⇑) Mpa*	*§ Compressive strength (⇑) Mpa*	*§ Tensile strength (⇑) Mpa*
1	*1.19*	*2.52*	*53*	*44*	*7.2*	*40*	*6.5*
2	*1.34*	*2.45*	*45*	*68*	*9.0*	*46*	*5.6*
3	*1.07*	*2.52*	*57*	*28*	*4.5*	*22*	*4.5*
4	*1.07*	*2.38*	*55*	*25*	*4.1*	*22*	*-*
5	*1.36*	*2.25*	*39*	*105*	*11.8*	*78*	*9.5*
6	*1.32*	*2.48*	*47*	*52*	*7.8*	*42*	*-*
7	*2.11*	*2.63*	*20*	*214*	*21.6*	*-*	*-*

Table 2 - Mean values of mechanical and physical parameters of pyroclastic flow deposits from the Vulsini (1-6) and Cimini (7) Volcanic Districts: 1) Nenfro Ignimbrite; 2) the Orvieto-Bagnoregio Ignimbrite distal quarry; 3) Orvieto-Bagnoregio Ignimbrite at Orvieto town (Manfredini et al., 1980); 4) Latera C Ignimbrite; 5) the Latera D Ignimbrite distal quarry; 6) the Latera D Ignimbrite proximal quarry; 7) Cimina Ignimbrite. Symbols: * dry samples; § saturated samples.



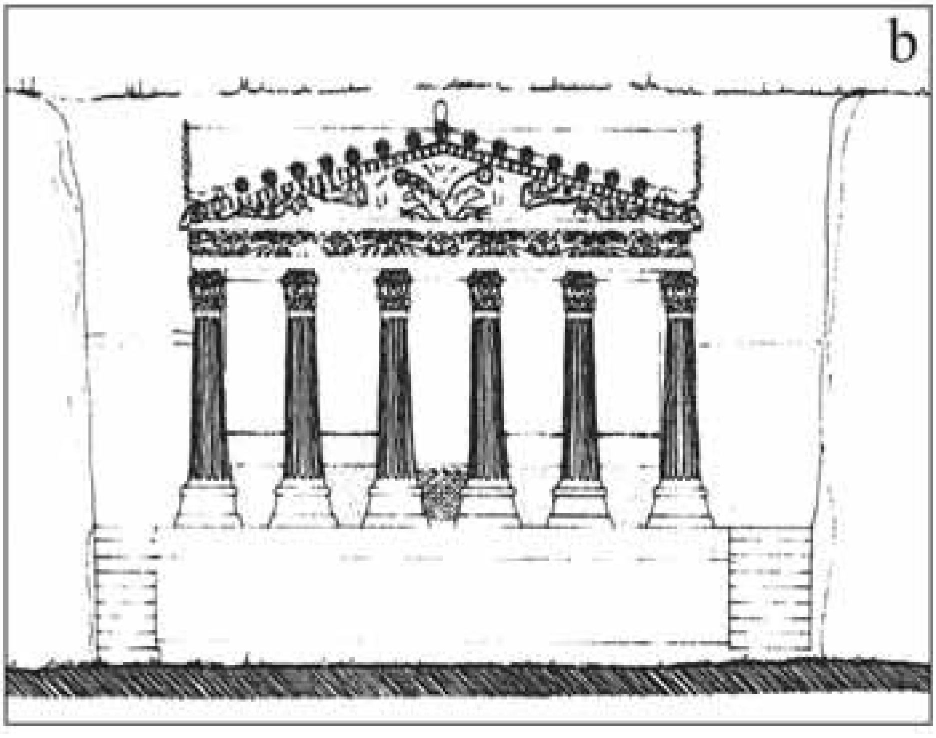


Figure 13 - Sepulchral monument types: a) dado (cubic), semi-dado and false dado tombs; b) temple-style tomb.

type are more elaborate than those in the southern Etruscan, rupestrian necropolises. Sovana, in fact, is considered one of the most thriving centers for the elaboration of architectonic shapes in funerary art. The shrine tombs, with their underlying funeral room, can consist of a simple empty tympanum, without decorations (for example, the group of tombs located at the top of “Poggio Stanziale”), or, as in the

Figure 14 - a) Boundary wall of the town of Pitigliano, which is built on top of the complete series of the Vulsinian ignimbrites. b) Necropolis of Sovana, the Tomba Pola Temple. c) Sutri, Roman amphitheatre. d) Necropolis of Sovana, the Tomba Ildebranda funeral room

case of the "Tomba del Tifone", they can be painted with symbolic decorations. In some cases the front of the tomb looks as if it was composed of columns, assuming the architectural character of a temple (e.g., "Tomba Ildebranda", "Tomba Pola"; Figure 13b); a circular plan with a columned front can be found at "Tomba del Sileno".

Other monuments have a more complex structure, with an image of the deceased lying on a funerary bed, located on the floor of the rectangular room or vaulted niche, under the tympanum between the two doorjams of the shrine (e.g.,"Tomba Siena", "Tomba della Sirena"). A vaulted niche also appears in some smaller tombs at "Poggio Stanziale" and "Poggio Grezzano", where the image of the deceased is replaced by a false door.

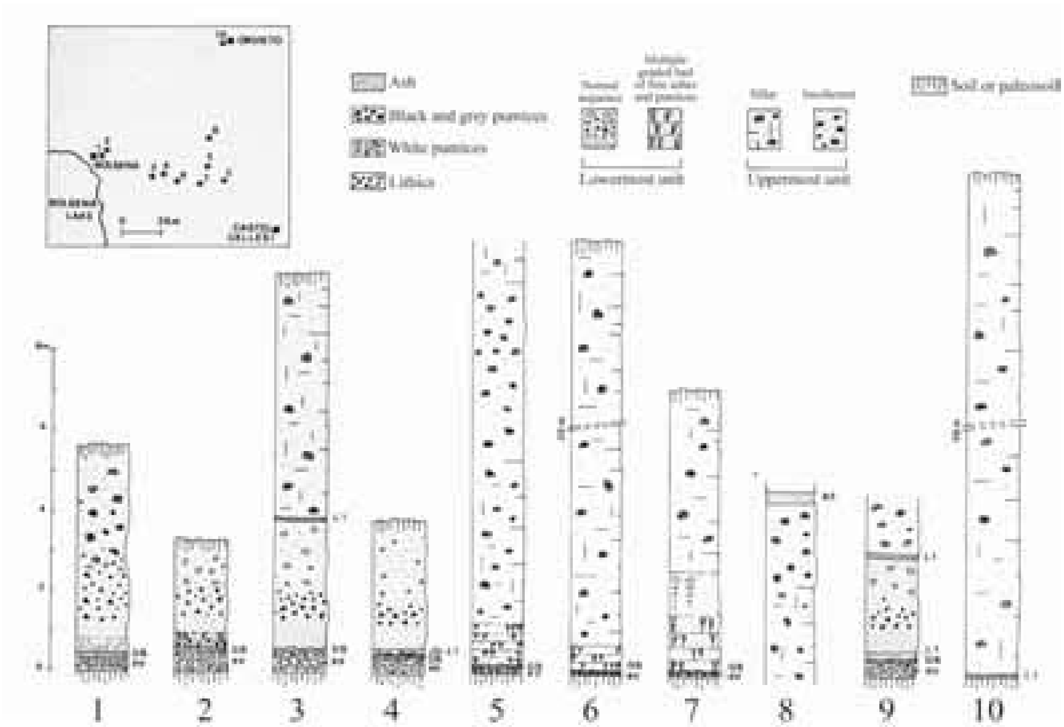


Figure 15 - Representative stratigraphic sections of the OBI pyroclastic sequence (modified from Nappi et al., 1994b). PF = pumice fall; GS = ground surge deposit; L1 ="layer 1" deposit; JD = jetted deposit; AF= co-ignimbrite ash fall.

Field trip itinerary

DAY 1
(from Florence to Bolsena)

Stop 1.1:
Orvieto

Starting from the railway station parking lot, we will walk up to the cable car station. We will then cross the sillar facies of the Orvieto-Bagnoregio Ignimbrite (OBI) in a cable car, arriving at the panoramic terrace where the "Pozzo di San Patrizio" is located (Santini, 1995).

The OBI is at its maximum thickness of 60 m (Figure 15, log 10) at Orvieto. The main body of the ignimbrite is a reddish sillar-type deposit, generally strongly zeolitized, containing analcimized leucite-bearing black pumices, from which the Italian name of "Tufo rosso a scorie nere" derives. In this area only the uppermost unit is present; the most abundant facies is represented by a lithified massive deposit, whereas a loose facies occurs only at the "Bardano" outcrop. The juvenile fragments are made up by black glassy pumices, containing large analcimized leucite crystals, with devitrified structures. The pale to grey pumices are rare and show a porphiritic structure with sanidine crystals in a generally fine-grained matrix (Nappi et al., 1994b).

Most of the town of Orvieto (Santini, 1995) spreads out across a small ignimbritic plateau. The pyroclastic flow deposit, easily quarried and shaped according to the requirements of the area's inhabitants, is the material from which the town's houses and buildings have been built. A network of caves has been tunnelled into the ignimbrite. Wells, cisterns and large caves for pressing olives and grapes were excavated during the Middle Age.

The most important well in the town is the "Pozzo di San Patrizio", one of Orvieto's main attractions. The well was ordered by Pope Clemente VII to ensure a water supply in the event of the town being besieged. The architect "Antonio from San Gallo the Younger" was commissioned to do the work, which began in 1528. The well has attracted many curious visitors, ever since it was re-opened in 1956. It is about 62 m deep and 13.40 m wide. It is circular, with a series of two diametrically-opposed doors, which lead into two concentric spiral staircases independent from each other and non-communicating. Each stairway has 248 steps, which are easy to descend for pack-animals. The excavation extends through the OBI to the Tertiary clay.

Stop 1.2:
Civita di Bagnoregio

We will leave the town via the steep walls which encircle Orvieto's entire eastern sector, where the works of rock-consolidation can be observed. We will then move southwards, climbing the old lava flows which border the Bolsena caldera. Then, moving across the OBI plateau, we will arrive at Bagnoregio. We will pass through the entire village moving eastwards and, finally, descending to the bridge of Civita di Bagnoregio.

Here the OBI is mainly represented by the upper unit with sillar-type facies (Figure 15, log 6). The lower part is constituted by decimetric ash levels with reversely-graded pumices. A fine-grained ash bed with travertine deposits is present at the base. The town of "Civita di Bagnoregio" was developed on (and partially inside) the sillar-type facies of the OBI. Ignimbrite overlies all the pyroclastic deposits of the Paleobolsena and Bolsena Volcanic Zones from the older plinian fall deposit (Basal Pumices, 576 ka; Nappi et al., 1994a) to the basal plinian deposit of the OBI (333 ka; Nappi et al., 1994b).

Stop 1.3:
"Pidocchio" Spring

Leaving Bagnoregio we will take the road for Lubriano, traveling north-east for about 1.5 km, until we get to "Pidocchio" spring. Both the zeolitized and the loose facies of the upper unit of the OBI are present in this outcrop (Figure 15, log 5). The lower unit of the pyroclastic deposit appears to be composed of multiple, inversely-graded pumice layers.

Stop 1.4:
Bolsena town, the "Giglio" Convent

This is one of the most proximal outcrops of the OBI (Figure 15, log 1). At the bottom of the sequence we can observe a plinian fall deposit that is pedogenized and shows its maximum thickness. It is overlain by a basal, fine-grained, slightly-laminated, crystal-rich ash layer. We then find multiple ash levels with inversely-graded white pumices, which become a coherent ash –deposit, rich in lithic fragments and white pumices in the upper part. A final unit, composed of black pumices and rare lithic fragments, is present at the top of the sequence.

DAY 2
(from Bolsena to Sovana)

Stop 2.1:
Montefiascone

We are located along the Montefiascone caldera rim on a spatter-cone that arose after the formation of the caldera. A scoria quarry, related to the final circumcalderic strombolian and hydromagmatic activities, can be observed. The Martana and Bisentina Islands, which are visible in front of us, represent the final sub-lacustrine activity of the Bolsena District. The Martana Island is a surtseyan tuff-cone; the Bisentina Island is also of surtseyan origin, but followed by final effusive activity.

Stop 2.2:
Pitigliano

The succession observable in this outcrop (Figure 16) includes most of the Latera ignimbrites in their typical facies. The lower and the upper Latera ignimbrites (A and F; Sparks, 1975) are not present here; the A Ignimbrite, however, can be observed during the visit to the Ildebranda Tomb (stop 2.3).

Following the succession from the top to the bottom, the first sillar-type deposit is represented by the E Ignimbrite (Sparks, 1975). It is a 15-m-thick deposit, probably constituted by more than one flow unit, which are not clearly visible here. The intense zeolitization which affects the ash-sized matrix, in fact, obliterates the flow units. The matrix contains tabular-shaped, pale and black pumices, with subordinate, heterogeneous lithic fragments. Consolidated and laminated light-yellow ashes with tree holes are present at the base, underlain by a lithified ash bed (basal surge). The underlying e Ignimbrite (Sparks, 1975) appears to be constituted by reverse-graded multiple layers of light-grey fine ashes with accretionary lapilli. At the bottom, four decimetric ash layers with tree holes are present. Because of the presence of tree holes at their base, the E and e Ignimbrites have often been confused with one another. The lower deposit is represented by Sparks' (1975) D Ignimbrite or Vezzoli et al.'s (1987) "Sorano Formation" of. It is one of the most widely used building materials, as evidenced by the many quarries in this ignimbrite in the northern Vulsini District. In this outcrop the D Ignimbrite appears to be un-consolidated and it

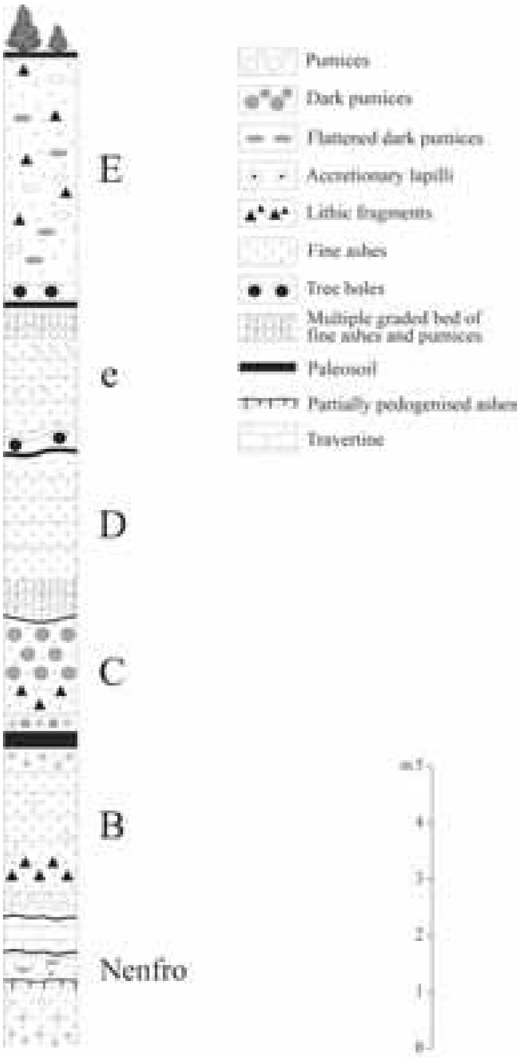


Figure 16 - Stratigraphic succession of the Vulsinian ignimbrites near the town of Pitigliano.

is composed by multiple, fine-grained ash layers with centimetric rounded pumices. The underlying C Ignimbrite (Sparks, 1975), often represented by a coherent sillar-type facies, was the most widely used deposit in Etruscan times, and into which tombs were bored. In this outcrop, the pyroclastic deposit is mostly composed of black pumices containing analcimized leucite crystals in a loose brown matrix, with a base enriched in lithic fragments. At the base this ignimbrite always shows a pale-yellow ash bed (which in this outcrop is 40 cm thick) enclosing grey pumice clasts and accretionary lapilli. Palladino and Simei (2002) have related this level to direct fallout from the gas-pyroclastic suspension, with or without a late clast-by-clast tractional stage. The lowest deposit of the Latera succession corresponds to Sparks' (1975) B Ignimbrite, which is formed by multiple, fine-grained ash levels with accretionary lapilli and large lithic fragments. At the base there is a 40 cm thick pumice fall level. The e, D and B Ignimbrites, being constituted by a repetition of beds, often inversely-graded and showing traction features, may be correlated to Palladino and Simei's (2002) type 2 deposits. On the contrary, the E and C Ignimbrites, with their massive, poorly-sorted main bodies, correlate to the type 3 deposits. Below this, a travertine ash-layer, underlain by a meter thick pyroclastic flow deposit, can be observed. This pyroclastic deposit may be referred to the oldest Vulsini ignimbrite (the Nenfro Ignimbrite) related to the Paleobolsena activity. An ash deposit with accretionary lapilli can be observed at the base of the sequence.

Stop 2.3:
Sovana

The first sporadic settlements in Sovana date back to the Neolithic and Bronze Ages. Indeed, archeological excavations have confirmed that in this early period an inhabited center already existed. At the beginning of the Iron Age these centers were suddenly abandoned, to be later re-occupied by the Etruscans, starting from the 9th – 8th centuries B.C. (Figure 17).

The Etruscan "Suana" or "Suama" was an important center, from both a commercial and cultural standpoint. Sovana reached its maximum size around the 4th – 3rd centuries B.C., as evidenced by the monumental necropolis attributed to this period, and it remained an important center even during the Roman colonization. The number of Etruscan inscriptions from the Roman period, in fact, reveal that the national language and culture still existed.

By the 4th century A.D., Sovana was the seat of the local Bishopry and in 935 A.D. the town was chosen by the "Aldobrandeschi" counts as the capital of their country. This area was also chosen as a refuge by hermits and ascetics (there are some examples of these hermit caves in Sovana), thus contributing to the spread of Christianity. Moreover, Sovana was the birthplace of Pope Gregorio VII, born in the 11th century.

His name, "Ildebrando di Sovana", suggests there might be a relationship with the Aldobrandeschi family. In 1312 the city became a property of the

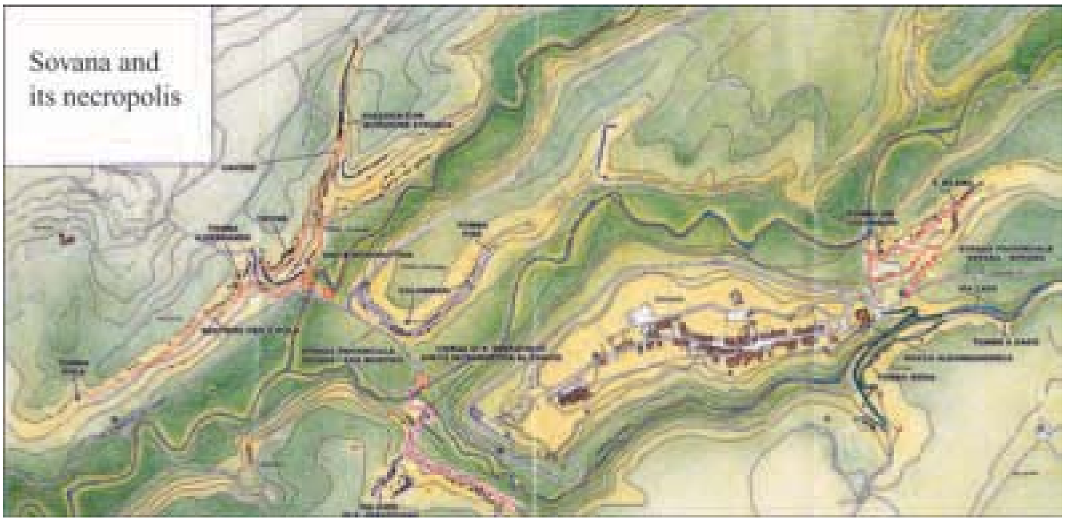


Figure 17 - Ancient Etruscan footpaths around Sovana.

Orsini family, which maintained control until 1410, when it was occupied by the army of the Sienese Republic. From this moment onwards, Sovana began its slow decline, sinking into a state of total abandon and ruin. Only its recent rediscovery breathed new life into the town after centuries of neglect (Bianchi Bandinelli, 1929; De Feo, 1993, 2001).

Sovana's most spectacular monument is its beautiful cathedral. Dedicated to the Apostle Saint Peter, it is a rare example of a church in Romanesque and Gothic styles. The cathedral was probably built on the first, original site of the Etruscan acropolis; it would seem to be the oldest area, dating back to the earliest settlements, because of its position on the highest and best-defended point in Sovana.

The walls, arches and cupolas of the cathedral were built using blocks quarried from the local ignimbritic outcrops. The building's walls were constructed using the Latera C Ignimbrite (an orange sillar-type deposit with black pumices); the supporting arches were built using the Latera D and E Ignimbrites, while most of the sculptures were carved in the Latera D Ignimbrite.

This cathedral is unique for the excellence of its sculptured decorations and the harmonious architecture of its interior. The original structure of the building probably dates back to the 9th century, through it owes its current appearance to work carried out between the 12th and the 14th century.

The marble doorway, with its decorations executed in Gothic style, is perhaps the most remarkable element of the cathedral. The portal consists of an external arch, with a sculpture of the human spirit on the upper part and two lion heads in the middle section. Sculptures with various symbolic motifs (a mermaid, a human figure, two peacocks, a rose, a warrior and some geometric motifs) are found in the lower part. A second internal arch is formed by two columns decorated with a spiral design. The innermost part of the portal is decorated with symbolic motifs, such as flowers (symbols of the unfolding of life) and spirals (a symbol of life and all-pervading energy). All these symbols, found all over the external walls of the church as well, predate Christianity.

The internal part of the cathedral is divided into three principal naves. The bones of Saint Massimiliano, the Patron of Sovana, are contained above the altar on the left aisle. The sculptures on the upper section of the columns' capitals, representing biblical scenes and attributed to the 11th century Lombard school, are considered very important. Other important works include the baptismal font of engraved travertine from 1434, and the 17th century canvas, by Domenico Manenti, representing the Martyrdom of Saint Peter (De Feo, 2001).

Stop 2.4:

The necropolis of Folonia valley

This necropolis is located along the way to "San Martino sul Fiora", heading towards Saturnia. It was discovered in the 1850s, but excavations started in 1920. The entire necropolis is set within the Latera C Ignimbrite and the underlying pomiceous deposits. The monuments of the tombs are engraved in the C Ignimbrite, while the funerary rooms containing the mortal remains were excavated within the mainly pomiceous, reworked, pyroclastic deposits, below the basal ash level of the C Ignimbrite.

At the beginning of the necropolis we find the openings of two great paths. One of them is closed, but the other (the spectacular ***"Via Cava of San Sebastiano"***) can be walked on. This Etruscan road is about five hundred meters in length, with twenty-five-meter high walls. There are several incisions, often unreadable, high up on the walls. Halfway along the road, there is a deviation to the top of the path, where there are several small chamber tombs. Two of these chambers were used in the Middle Ages as shelters for hermits during the early Christian period: several incisions of Christian crosses are visible on the walls. Ancient tombs, which date back to the 7th century B.C., are also located at the beginning of the necropolis. Numerous other tombs, dating from the 7th to the 2nd century B.C., can be found along the valley. Along the necropolis we find a series of well-preserved façade tombs, also dating back to the 3rd century B.C.. The top of the tombs, used for sacrifices and offerings, can be reached by lateral steps; on the front of the tombs, carvings representing the entrance to the afterlife are visible. The names of the dead are also engraved on these tombs.

Further into the necropolis we find the famous ***"Tomba della Sirena"***, which dates back to the 3rd century B.C. and is one of the major examples of Etruscan work in the Hellenic style. This large niche-type monument is an arch hewn from a single rock mass. A double tailed mermaid, which symbolizes the Sea Goddess and the afterlife, is carved on the front. In addition, a figure lying on the funeral bed, with the inscription of a woman's name over it, is carved on the inside of the arc. On both sides of the monument are sculpted figures representing protective spirits of the tomb. The small room with funerary beds, below the facade, can be reached through a narrow passage (Fiocchi and Nicolai, 1988; De Feo, 1993, 2001).

The ***Ildebranda tomb*** represents one of the most important examples of Etruscan stone architecture, and the only exstant, well-preserved Etruscan temple tomb. It was discovered in the 1920s and dates back to the 3rd century B.C. The front of the tomb rests on twelve columns (perhaps corresponding to the twelve capital towns of Etruria). Many floral decorations and sacred animals were carved on the tympanum of the temple. Along the cornice of the tympanum, several complex figures, some of which are probably related to the zodiac, can be seen. Two funerary corridors lie below the temple. The main one leads down to the center of the temple to a cruciform funeral chamber. The lateral corridor leads to a chamber thought to be even older (4th century B.C.). Its ceiling is carved with concentric squares, reproducing the ceiling of an Etruscan house, and several funerary beds are set along the walls.

There are also two recently-discovered, niche tombs between broad stairways. One of the tombs depicts the front of the temple while two sculpted lions guard the entrance to the other tomb. Excavation here is still in progress and these tombs cannot be visited (De Feo, 2001).

Not far from the Ildebranda Tomb, near a group of recently-discovered tombs, lies the ***Pola Tomb***. It is a huge rock whose face was carved into the shape of a temple (eight columns supporting a decorative tympanum). The tomb dates back to the 3rd century B.C. Below the temple, a deep, long corridor leads to a cruciform burial chamber.

Below the high cliff of "Poggio Stanziale", in front of the Ildebranda tomb, stands a group of façade tombs. One of these is the ***Tifone Tomb***, a fine Hellenistic monument of the 2nd century B.C.. The name of this niche tomb derives from the sculpture on the tympanum of the façade, representing the mythological "Tifone" (typhoon), the sea monster symbolizing the Ocean and the afterlife, from whose mouth blew the terrifying winds of the tempest. Lateral steps lead up to the top of the tomb, where funeral rites were celebrated. Some corridors, one of which leading to the funerary chamber, lie under the monument.

The ***Cavone*** is a huge Etruscan passage located beneath the Ildebranda Tomb. Moving beyond the entrance, high up along the top of the passage, we find several burial chambers, some of which were lived in by hermits during the Middle Ages. Remains of a fresco of the Madonna and Child in a carved niche can be seen. Several incisions, visible on the walls of the Cavone, are ascribable to different periods, including Roman and Christian eras, as evidenced by several crosses. For this reason the Cavone was named "Devil's Road" and is still considered a cursed place. About halfway down the passageway, an Etruscan inscription (*VERTNE*) dated to the 4th - 3rd centuries B.C., is visible. It was probably dedicated to the Etruscan god, *Vertumno* or *Veltha,* while the swastika near the inscription was a symbol of the Sun and the Cardinal Points (Fiocchi and Nicolai, 1988; De Feo, 2001).

DAY 3

(from Bolsena to Rome)

Stop 3.1:

Vitorchiano quarry

Starting from the Orte-Viterbo freeway, 300 m on the left heading towards Orte, we find the large Vitorchiano quarry, within the Cimina Ignimbrite (hereafter CI).

The CI (1.35-1.19 Ma; Lardini and Nappi, 1987) extends radially around Mt. Cimino (Figure 9), and it crops out across an area of about 40 km^2, because it is partially buried by the younger deposits from the Vico Volcano. The magma-volume of the CI can be estimated as being around 15 km^3. The distribution of the ignimbrite appears to be strongly influenced by the paleo-topography, and it shows its maximum thickness near the feeding vent, where drilling recorded 150-200 m of depth (Micheluccini et al., 1971). The deposit appears quite homogeneous in its textural parameters, and massive along its entire thickness. It is probably a multiple-ignimbrite even if the number of the flow units is difficult to evaluate. One flow unit, two meters thick, can be observed at the top of this outcrop. The CI is a grey, highly-welded deposit, which grades into a pink, non-welded, pumiceous facies in the distal sectors. The ash-sized matrix contains biotite, feldspar and pyroxene crystals. In the welded zone, flattened quartz-latitic pumice clasts and glassy shards define a eutaxitic texture. The black “fiamme” are from a few centimetres up to one meter in length, and from a few millimetres to 3-4 cm thick. The sparse lithic clasts, represented by sedimentary and lava-dome fragments, do not provide any evidence of lateral size-grading. The basal unit appears to be very rich in the lava-dome fragments. Looking upwards some lithic-rich zones are also visible, probably marking the base of different flow units.

Stop 3.2:

Soriano nel Cimino lava dome

Many lava domes of different shapes and dimensions formed in the central part of the Cimini Volcanic District (Figure 9). This outcrop represents the culmination, at different levels, of a single dome-mass that has intruded into the Pliocene clay-substratum. The surface of the dome is generally covered by large, angular, and irregularly-shaped blocks. The occurrence of large sanidine crystals is the constant characteristic of the lava dome. Phenocrysts of plagioclase, biotite and orthopyroxene are also present. The average phenocryst content is about 42%.

Stop 3.3:

Capranica

Following the Cassia road, past the village of Capranica, we will park on the left near the “Todis” supermarket. We pass through a tunnel leading to the “Forte delle rocce”; 300 m further along the road we will find the series of the Vico ignimbrites (Figure 18). As regards the A Ignimbrite, only the upper part of the deposit can be observed; it appears as a purple, ash-sized matrix with analcimized leucite and biotite crystals, with a lower part which is rich in lithic fragments (marl, limestone and thermo-metamorphic rocks), while the upper part is constituted by deeply-pedogenized fine ashes. The pedogenized horizon is covered by a loose, coarse, ash level, black in color, showing cross and planar lamination. Several deposits relate to the B Ignimbrite. First off, a light grey pumice zone can be observed at the base. As we move upwards this becomes a welded deposit containing flattened black scoriae and rare lithics and pumice clasts, which are sometimes concentrated in lenses. Flattened black scoriae and large lithics contained in a welded matrix are present at the top. The next deposit (C Ignimbrite) begins with a basal plinian fall deposit made up of subaphiric pumices, with rare sanidine and clinopyroxene, and lithic fragments (sienite and thermometamorphic rocks). The series continues with multiple pumice flow units composed of a stratified deposit of rounded pumices in fine ash matrix, about 2.5 m thick. On the upper part a breccia deposit, made up by brown pumices, black scoriae with sanidine and leucite, and large lithics (lava, clay and skarn fragments), can be observed. The breccia horizon is covered by a coarse-grained deposit of welded and flattened black scoriae. This deposit grades vertically to a sillar facies with large black scoriae in a zeolitized, ash-sized matrix. The matrix shows rounded microvesiculated grey pumices at the top of the outcrop.

Stop 3.4:

Sutri

The town of Sutri stands on a tufa spur, surrounded by deep valleys with small streams, at the foot of the Cimini (to the N-E) and Sabatini Mountains (to the S-W). It is located along the ancient natural passage between the southern Etruscan inland and the coastal strip, as well as along the transit line between

Rome and the northern part of Latium. Thanks to its strategic position, Sutri was an important center until the late Middle Ages. Fragments of manufactured objects found in this area have even been attributed to the last phase of the Bronze Age (10th century B.C.), bearing witness to the habitual visiting of this area as early as the proto-historic age. Materials of impasto used for habitations (attributed to the late final Bronze Age) and remains of "pit tombs" and "small well tombs" containing ceramic products (dating back to the second half of the 8th century to the first decades of the 7th century B.C.), were found at the La Ferriera site, along the Cassia road about 3.5 km south-east of Sutri. Remains of habitations from the Iron Age were previously reported on Rocca Romana and the Calvi Mountains, about 7 km south of Sutri; these settlements died out during the 7th century B.C. (Giuntella, 1980; Morselli, 1991).

The most famous monument in Sutri, the amphitheatre, was unknown until the beginning of the last century. The whole amphitheatre was excavated in the tufa promontory which lies opposite the town. The inner arena is elliptically-shaped, with a 49.6 m-long major axis oriented NE-SW and a 40.8 m-long minor axis. There are two wide underground passages with barrel vaults at the end of the major axis. The entrance facing the Cassia road is badly damaged, the entry gallery with the upper tiers having almost entirely collapsed. The arena is surrounded by a high podium, which extends from the main entrances and separates the arena from the "*cavea*". Along the podium there are ten doors located at regular intervals, five on each side; they access a ringed walkway, which ends at the main entrances.

The *cavea* is subdivided into three orders of stands, and as many narrow corridors. The lower *cavea* can be reached by a series of small steps, located along the underground walkway, at the sides of the doors which lead directly into the first enclosure. The middle *cavea* could be accessed through four *vomitoria* (only one, on the north side of the west gallery has been preserved) excavated at the end of the two principal entrances. On the walls of the *vomitorium* there are the remains of a rainwater canalisation system, going from the *cavea* to the outer side of the amphitheatre. Eight small semicircular cavities, distributed at regular intervals, are located in the middle *cavea*. A wide rectangular niche, whose original configuration and function are still unknown, is found in the central part of the west side. The upper *cavea* is badly damaged. At the top on the north-western side, there is a trumpet

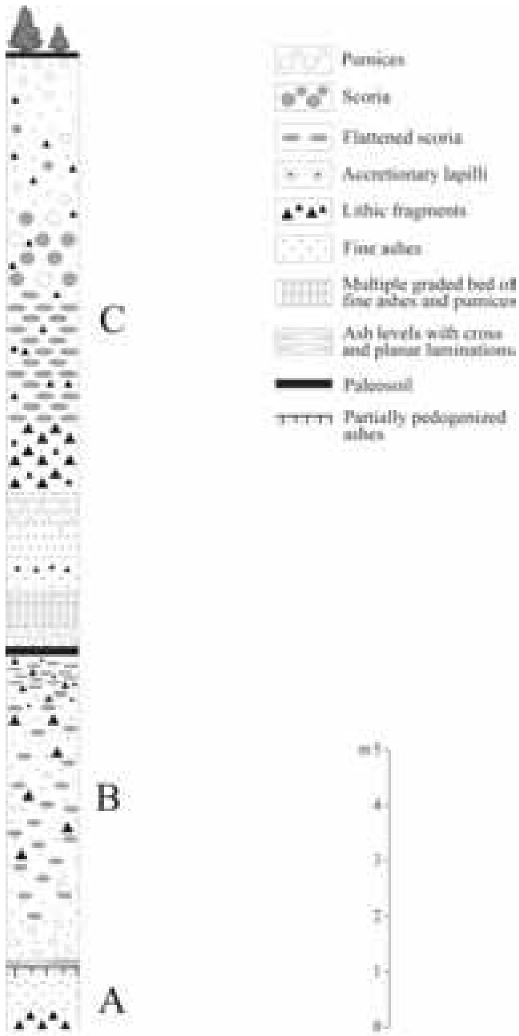


Figure 18 - Stratigraphic succession of the Vico Volcano ignimbrites near the town of Capranica.

vertically cut into the tufa bed. It is decorated with semi-colons in relief and ends with a cornice. On the opposite side this element is not present, because the tufa bed is lower. Here the steps end in a wide corridor that leads to the end of the outer perimeter. The morphological features of the monument suggest that it dates back to the period between the end of the 1st century B.C. and the 1st century A.C. (Morselli, 1991). The necropolis constitutes one of the most important examples of Roman tombs in tufa. A number of the 64 tombs are actually visible in the tufa walls, distributed on several levels. Already plundered in the early Middle Ages, the tombs continued to deteriorate. The necropolis extends for about 150 meters along the rupestrian front bordering the Cassia road.

Several tomb types can be recognized: one-room tombs, double-room tombs, with or without an arch opening, rectangular niches with or without a cinerary urn cavity, arched niches. Both the cremation and burial funeral rites were practiced in the necropolis. Only one tomb was exclusively used for cremated corpses, while the most frequent types are the mixed rite tombs; three are only burial tombs.

The most important tombs are marked by carved pediments on their outer sides, often with a rectangular cavity where the inscription was made.

Two twin vaults lined with burial niches show more elaborate decorations, with an arch set in the pediment and simple sculptures at the outer corners. Remains of painted stucco can be observed everywhere, especially in the interiors; nevertheless, they are not well-preserved, due to the numerous touchings-up which have occurred again and again since the Middle Ages.

This necropolis is architecturally similar to other monuments in the southern Etruscan area, in particular in the countryside around Bomarzo ("Selva di Malano"). The architectonic features, the prevalence of cremation, the epigraphs carved in marble slabs, suggest that the necropolis may date back to the same period as the singular stone amphitheatre (Morselli, 1991), situated on the nearby hill.

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