APPENDICE
APPENDIX

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Geological heritage along the tyrrhenian margin of central Italy (Guide to the excursion 1)
Patrimonio geologico lungo il margine tirrenico dell'Italia centrale (Guida all'escursione 1)

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1. – INTRODUCTION

Along the course of this excursion it is possible to observe someone of the most important geological sites in the Latium region. They are key-sites for the comprehension of the Plio-Quaternary geology of this region or represent peculiar landscape forms.

At the same time it is possible to realize about the state of these sites; in fact someone are actually protected by laws and managed, someone are only protected but not managed, while the others (the greater number) neither are protected nor managed.

2. – STRUCTURAL EVOLUTION OF THE CENTRAL ITALY TYRRHENIAN MARGIN

The Tyrrhenian margin of Central Italy is basically characterised by two different tectonic structures that strongly controlled the Plio-Quaternary evolution of this area: the Apennines thrust belt on the North-East and the Tyrrhenian basin on the South-West.

The Neogene architecture of the Central Apennines thrust belt is due to the superposition of three tectonic deformation styles (PAROTTO & PRATURLON, 1975). The orogenic "wedge" was built up during the Upper Miocene-Pliocene by the stacking of the Meso-Cenozoic sedimentary sequences along NW-SE and N-S oriented thrust planes. In the middle of this orogenic "wedge" a main tectonic line ("Olevano-Antrodoco" line; PAROTTO & PRATURLON, 1975; CASTELLARIN *et alii*, 1978; SALVINI & VITTORI, 1982) is present. Along this tectonic feature, the northerns Sabina units overthrusted onto the southerns Latium-Abruzzi platform units.

After the emplacement of the main thrust sheet, strike-slip tectonics and large scale block rotation processes occurred (MATTEI *et alii*, 1991). Strike-slip tectonics developed mainly with N-S trending right-lateral (for example the Sabina fault, north of Rome, ALFONSI *et alii*, 1991) and NW-SE trending left-lateral shear zones linked with the clockwise rotation of the Sabina area and counterclockwise rotation of the Latium-Abruzzi platform (MATTEI *et alii*, 1991).

Finally, extensional tectonics, linked with the Tyrrhenian Basin opening, determined the collapse of the Apennine wedge, cutting through and locally reworking both thrust and strike-slip structures via a system of NW-SE normal faults and extensional basins. It has been affected by extended volcanism since the Miocene, which represents the final expression of continental extension and crustal thinning processes of the Tyrrhenian Basin.

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Along the Tuscan-Latium area (BARTOLINI *et alii*, 1982), at the northeastern margin of the Tyrrhenian basin, extensional structures are represented by NW-SE to NNW-SSE striking basins that are filled with thick sequences of marine and continental clastic units. This area is characterized by a less than 25 km thick crust (WIGGER, 1984) and anomalous heat flow (MONGELLI & ZITO, 1991). The extensional structures are regularly linked by NE-SW transfer faults. Considering the oldest post-orogenic ("neo-autochthonous") sedimentary deposits as syn-rift deposits, we can assume that the growth of these Latium margin basins occurred between the Upper Messinian and the Lower Pleistocene. Moreover the age of each basin indicates a general north-eastward migration of the depocenter towards the Apennine chain. Southeast, along the Latium Tyrrhenian margin, extensional tectonics started during the Messinian and seem to mark the end of the block rotation processes (MATTEI *et alii*, 1994; SAGNOTTI *et alii*, 1994).

The volcanic districts of Latium began their activity at the border of one of these basins, 2.5 Ma after the deposition of the first syn-rift deposits (*G. puncticulata* Zone, BRANDI *et alii*, 1970).

Finally, both the NW-SE and NE-SW systems along the Latium Tyrrhenian margin are locally cut by a system of N-S faults. This tectonic system, which represents the main extensional trend of the Northern Tyrrhenian Sea, is particularly evident along the western border of the Latium-Apennine chain from the Sabina area to the Tyrrhenian coast, through the middle Tiber valley. While the NE-SW and NW-SE systems are rather well known from a structural and geological point of view, the N-S system represents an original and relatively recent tectonic feature of the Latium area; in particular, its interaction with the Alban Hills Volcanic District seems to play an important role in the regional volcanism.

Volcanism developed in four main phases, from 14 Ma B.P. to the Pleistocene-Holocene boundary, with a time-space migration from west to east (CIVETTA *et alii,* 1978; SERRI *et alii,* 1991). Along the Latium margin two main volcanic groups occur: the felsic Cimini-Tolfa-Ceriti group, which developed from the Upper Pliocene (DE RITA *et alii,* 1994) to the Lower Pleistocene, and the alkali-potassic group which was active during the Upper Pleistocene. The latter group is characterized by five alkali-potassic, mainly explosive, volcanic districts, elongated on the NW-SE trending Tyrrhenian margin (FUNICIELLO *et alii*, 1976; LOCARDI *et alii*, 1977).

Despite the widely accepted connection between extensional processes and magmatism, the local structural relationships between the main volcanic centers and various crustal structures is still a matter of discussion (FUNICIELLO *et alii,* 1976; LOCARDI *et alii,* 1977). In fact the Alban Hills volcano evolved in a peculiar area, where first order tectonic structures of the Central Apennines intersec its geology and structural evolution seem strongly controlled by these pre-existing structures.

3. – PLIO-QUATERNARY LATIUM GEOLOGY

The feature of Plio-Quaternary geology is very complex for the presence of active tectonics which developed during these times, as described in the chapter of the structural evolution. It is possible to summarize these events as a continuos sequence of blocks uplift and collapses of some blocks along fault systems trending N-S; NW-SE and NE-SW. The final result was the closing or the formation of marine or continental sedimentary basins (MALATESTA & ZARLENGA, 1986), in many cases half-graben type (FACCENNA *et alii,* 1994; DE RITA *et alii,* 1994a; DE RITA *et alii,* 1994b; DE RITA *et alii,* in press), starting from Messinian to Middle Pleistocene.

Starting from the Middle Pleistocene, when the volcanic activity begun, the sedimentary basins were little, of prevailing continental type, and connected to local subsidence. Alluvial fill of the valleys as consequence of raising sea level during the interglacials periods were developed along the fluvial network.

From Middle Pleistocene to Holocene three important uplift phases of the continental margin produced raising coastal beaches or alluvial fills terraced:

30 m between 0.6-0.48 Ma (DE RITA *et alii*, 1994)

10-15 m around 0.15 Ma (DE RITA *et alii*, 1994)

30 m between 0.12-0.08 Ma (DE RITA *et alii*, 1994)

15 m between 0.08-0.04 Ma (ARNOLDUS-HUYZENDVELD *et alii,* 1993).

The available data on the geological setting of "Bassa Campagna Romana" Basin, comprised between Rome and the Tyrrhenian Sea (CONATO *et alii*, 1980; MALATESTA & ZARLENGA, 1986; 1986a; 1988; MARRA & ROSA, 1995), indicate the presence of Plio-Pleistocene sediments outcropping in some localities, coinciding with high structural zones.

The Lower Pliocene clayey sediments, belonging to the *Globorotalia margaritae* and *Globorotalia puncticulata* zones (here a new subdivision of the Pliocene will not be discussed; cfr. CARBONI *et alii*, 1991) outcrop in the area of Rome at Monte Mario (Marne Vaticane Auct.) at Pomezia and in the area of Anzio-Lavinio. They represent facies from bathial to littoral environment. During the Middle Pliocene the northern sector of the Roman Basin was uplifted and the sedimentation was localized in a narrow area, trending N-S, where was deposited the "Macco" Formation, a calcareous sandstone. Upper Pliocene clayey and sandy sediments, belonging to the *Globorotalia aemiliana and Globorotalia inflata* zones, outcrop in Rome and in the Pomezia area with littoral facies.
Lower Pleistocene clayey and sandy sediments constitute the Monte Mario Formation (or Unit, for MARRA & ROSA, 1995), subdivided in to the older M. Mario Serie and the younger M. delle Piche Serie. Faunistic assemblage, micro (*Hyalinea baltica*) and macro fauna (*Arctica islandica*), indicates an age corresponding to the Santernian-Emilian interval. The sediments, outcropping in the Rome area (Monte Mario) and along the coast at Ponte Galeria, Pomezia and Anzio-Lavinio, are rich of "Northern guests": *Arctica islandica, Pseudamussium septemradiatum, Spisula elliptica, Chlamys islandica*, etc.

This Lower Pleistocene sequence is closed by an uplift of the basin and on the erosion surface lies the Ponte Galeria Formation, that represents the first Middle Pleistocene (lower part 0,6-0,48 my) sedimentary cycle. It is a complex cycle, also recently mentioned as "depositional third order sequence" by MILLI (1992) (really MILLI considers that the Ponte Galeria sequence is extended between the Lower-Middle Pleistocene limit to the Present), constituted, from the bottom to the up, by fluvial gravel, lacustrine clay, marine sands and gravel, lagoonal and palustrian clay which present on the top the first product of Alban volcanic district (I pyroclastic flow). This sequence is correlated to the Middle Pleistocene for the presence of characteristic Mammalian faunas, in the continental layers, while the marine cold faunas are yet typical of lower Pleistocene.

The deposits, coinciding with the Middle Pleistocene (middle and upper part; 0,48 and 0,15 my), represent several orders or cycles of alluvial fills of the Tiber river valley and the complex palaeonetwork of its tributaries (CALOI et alii, 1994). These sedimentary cycles are unconformable on those of Middle Pleistocene (lower part) (= "Ponte Galeria Formation") and older; they were also recently mentioned as "depositional fourth order sequences" by MILLI (1992). They are linked with the high standing phases of the sea level during the interglacial periods and distinguished as Formations: from older to younger, San Cosimato, Aurelia and Vitinia Formation, respectively corresponding the isotopic stages 11, 9 and 7 (CAVINATO *et alii*, 1993; CONATO *et alii*, 1980; DE RITA *et alii*, 1991; MALATESTA & ZARLENGA, 1986; 1986a; 1988).

The lack of uplift phases between the depositional cycles produced the missing of the alluvial terraces and on the contrary the presence of several alluvial fills overlapping, sensu LEOPOLD *et alii* (1964). The top of these deposits reaches an elevation of 50 and 80 m above present sea level, according to their larger or shorter distance from the sea. The depositional cycles show interbedded layers of brackish and marine environment in the outcrops near the coast and in the highest part of the sequences. The cycles are separated by three deep erosional surfaces, mostly palaeovalleys or erosional channels, they were formed during the low phases of the sea level and have been correlated to isotopic stages 12, 10 and 8. DE RITA *et alii* (1991; 1993) have evidenced how during these phases of low standing the most important volcanic episodes of Albano volcano have been also produced.

The Upper Pleistocene deposits (= Tyrrhenian = stage 5e= 0,125 m.y.) are present along the coast at an altitude lesser than 35 m a.s.l., only in the Pomezia area they reach an altitude of 45 m, related to a stronger uplift of that area (MILLI & ZARLENGA, 1991). Younger sediments, from marine to continental, are located in Maccarese area (0,08-0,04 my.) at an altitude of 15 m; finally the sediment of Versilian age, connected to the rise of sea level after the last glacial period, get embanked against all previous (ARNOLDUS-HUYZENDVELD *et alii*, 1993).

4. – CENTRAL LATIUM VOLCANISM: THE SABATINI VOLCANIC DISTRICT AND THE ALBAN HILLS VOLCANIC DISTRICT

The Sabatini Volcanic District and the Alban Hills Volcanic District are located about 25 km northwest and 20 km southeast of Rome respectively. They are part of the Central Italy alkali-potassic volcanic area, also known through the world as Roman Comagmatic Province (WASHINGTON, 1906; APPLETON, 1972; ROGERS *et alii,*, 1985).

This area, characterized by a very high K_2O enrichment relative to silica in the volcanics, includes several volcanic districts developed starting from 0.6 Ma (BARBERI *et alii,* 1994). From north to the south: Vulsini Volcanic District, Vico Volcano, Sabatini Volcanic District, Alban Hills Volcanic District and Mean Latina Valley District are present, located inside a structurally depressed area, NW-SE striking, parallel to the Tyrrhenian Coast.

Volcanism is generally referred to the crustal extensional regime affecting the western margin of the Italian peninsula during the geodynamic evolution of the Tyrrhenian basin. Moreover the volcanic rocks have elevated concentrations of incompatible elements and typical lithospheric Sr, Pb and Nd isotopic compositions, indicating an origin and evolution of the corresponding magmas dominated by the interaction between crust and mantle components.

4.1. – THE SABATINI VOLCANIC DISTRICT

The Sabatini District cover an area of about 1200 km^2, limited to the North by the Vico Volcano, to the East and Southeast by the Monte Soratte sedimentary structure and the Tiber River Valley, and to the southwest by the Tyrrhenian Sea.

Volcanic activity, which had a very explosive character, started, as in the other Districts, about 0.6 Ma, in correspondence with a climax of the extensional tectonic activity of the Tyrrhenian Margin.

The sites of volcanic activity in the Sabatini Volcanic District, the styles of eruptions, and the relationships and distribution of volcanic units are strongly controlled by the pre-volcanic lithology and structural setting of the sedimentary basement (DE RITA & SPOSATO, 1986; DE RITA *et alii,*, 1996).

The most important structural feature of this District is the Bracciano Basin, a volcano-tectonic depression occupied by the Bracciano Lake.

The first K-rich volcanic activity begins, with ignimbrites and strombolian and hydromagmatic products, in the eastern margin of the District on the est border of a NW-SE oriented main graben that cross the District, close to Monte Soratte at about 0.6 Ma (CIONI *et alii,* 1993), in a continental murshy environment (Morlupo-Castelnuovo di Porto centers).

Between 0.55 and 0.50 Ma a huge ignimbrite was emplaced in the eastern margin of the District: the "Tufo giallo della via Tiberina" ignimbrite.

This deposit includes almost three flow units separated by erosional surfaces and by fall and/or surges levels. These units shows homogeneous characteristics with a lithified yellow matrix rich in orange yellow, altered, small-sized pumices due to zeolitizzation processes. The deposition of this huge ignimbrite caused the diversion of the ancient Tiber river course from west of the Monte Soratte to the east (ALVAREZ, 1973).

The following activity, at 0.5-0.4 Ma (CIONI *et alii,* 1993), moved westward to the area of Sacrofano, at the boundary between the previous named graben and the Baccano-Cesano carbonatic "horst" (DE RITA *et alii,* 1983). This activity, mainly strombolian, produced a thick sequence (more than 50 meters) of ashy-pyroclastic fall deposits.

At about 0.43 Ma (CIONI *et alii,* 1993), in coincidence with the pick of regional extension (CAVINATO *et alii,* 1993), volcanism expanded westward to the NE-trending faults that cut the northern part of Baccano-Cesano "horst". This episode deposited a large-volume (about 10 Km^3) trachy-phonolitic ignimbrite, the "tufo rosso a scorie nere" sabatino, that was emplaced all the way to the periphery of the District and was influenced by the pre-existing topography, being absent on the Baccano-Cesano "horst" (CAVARRETTA *et alii,* 1990).

After this eruption, from 0.40 Ma to 0.28 Ma (FORNASERI, 1985), the continuing regional extension was accompanied by strombolian and effusive activity, and by the subsidence of the Baccano-Cesano "horst". Interbedding of scoria cones with lava flows, geometry of these flows, and pre-effusive morphology indicate that the vents were located south and west of the Bracciano Lake area, perhaps at the intersection of NE-trending faults with the faults bounding the BC "horst".

After the lavas, three ignimbrite were deposited out of fault systems just north of those that erupted the lavas , the last one, the "Bracciano Tuff" was dated to 0.17 Ma (BONADONNA & BIGAZZI, 1970). Co-ignimbrite breccias indicate that the vents were located the first close to the village of Anguillara, on the southeastern margin of the Lake, the second at its southern margin, and the third at its northwestern margin (CIONI & SBRANA, 1991), north of Bracciano Town.

Minor effusions of lava out of the same fracture system followed the ignimbrites. Lavas were emplaced also north of the Lake, where they are interbedded with scoria cones. Most of these cones aligned NE and NW. At this time the Bracciano depression had partially formed, as shown by the lava that flowed towards its center. The last volcanic activity, from 0.17 Ma to less than 0.08 Ma (FORNASERI, 1985), erupted hydromagmatites from craters located at the eastern margin of the Bracciano Lake.

4.2. – THE ALBAN HILLS VOLCANIC DISTRICT

The Alban Hills Volcanic District is characterized by the presence of a main central structure, called Tuscolano-Artemisio, whose caldera rim is still recognizable and by a younger edifice, called Le Faete, developed inside the collapsed area. Volcanic activity started almost 0.6 Ma B.P. and ended about 0.02 Ma B.P. (MERCIER, 1993), when intense hydromagmatic explosions from several craters occurred in the western and northwestern sectors of the District.

The Alban Hills volcano developed on a sedimentary substratum, mainly consisting of marine to continental clays, sands and sandy clays (DE RITA *et alii,* 1992) of Plio-Pleistocene age.

The volcanic history of the Alban Hills can be subdivided into three main phases of activity:

- The Tuscolano Artemisio phase (from 0.6 to 0.3 Ma), during which volcanism was characterized by a very high explosive activity producing ignimbrites and lavas. This phase ended with the Tuscolano-Artemisio (TA) central area volcano-tectonic collapse.
- The Faete phase (from 0.3 to 0.2 Ma), during which activity was from the Faete edifice, located inside the collapsed TA area.
- The hydromagmatic phase (from 0.20 to 0.02 Ma), when violent phreatomagmatic explosions occurred from several craters in the western and northern sectors of the Alban Hills volcano.

All the volcanic products are characteristic of a high-potassium series (HKS) with less than 50% SiO_2 content (FORNASERI *et alii,* 1963; BERNARDI *et alii,*1982; TRIGILA *et alii,* 1995).

4.2.1. – *The Tuscolano-Artemisio phase (0.6-0.3 Ma)*

This phase was the most important one in the life of the volcano. In this period more than 90% (by volume) of the products were erupted (283 km^3) and it is characterized by the emplacement of several ignimbrites, and subordinate lavas. Each ignimbrite is covered by fall products that reduce in thickness from east to west, separated from the subsequent eruption unit by a paleosol. Four main cycles of activity have been distinguished, each characterized by the emplacement of ignimbrites at the base and fall and lava flows at the top. The emplacement of the TA ignimbrites determined important changes in the pre-existing drainage network of the volcanic area, contributing to the shifting of important river courses (Paleotiber westward, Paleoaniene northward) and in some cases to the complete inversion of the drainage direction (Paleosacco, in the Valle Latina area) (DE RITA *et alii,* 1990).

First TA cycle

The early products erupted from the Alban Hills volcano are not well known because the thick cover of the younger volcanics; they are only present as lava lithics inside the subsequent ignimbrites or as reworked volcanics interbedded with coastal and fluvial sediments.

The oldest outcropping primary deposits are two ignimbrites visible around the extreme periphery of the entire volcano. From bottom to top: "Tor di Cenci Unit" and "Palatino Unit". These deposits predominantly consist of an ashy matrix with minor pumice, frequently with laminated and cross laminated structures, that contain lava and sedimentary lithics. Levels enriched with centimetre-sized accretionary lapilli are frequent, from which the ancient name of these products is derived. These characteristics have been interpreted as due to magma\water interactions during the eruption and indicate that tectonic events, more than magmatic overpressure, were responsible for triggering the explosive activity. The presence of a paleosol interbedded indicates a quiescence period between these two events.

Fall products are present at the top of these ignimbrites, particularly in the eastern sector of the volcano, whereas lavas outcrop at the distal western margin (Acquacetosa lava flows). These lava flows represented a significant extrusive event in the history of the volcano and are connected to fracture systems that developed during a climax of the regional extensional tectonism. In this episode more than 2 Km^3 of phono-tephritic magmas were erupted. These extrusive lavas closed the first TA cycle activity.

Second TA cycle

One of the most important ignimbrites, in volume and extent, belongs to the second cycle of the Tuscolano-Artemisio phase: the "pozzolane rosse" unit (FORNASERI *et alii,*1963). The "pozzolane rosse" Eruption Unit consists of a basal scoria-lapilli fall level directly overlaying a paleosol and dispersed toward the southwestern sector of the volcano (ROSA, 1995). The above mentioned ignimbrite is loose and massive, with a reddish sandy matrix containing reddish scoria and enriched in thermo-metamorphosed sedimentary and holocrystalline (leucite + pyroxene) lithics. Many pipe structures developed in the upper part of the deposit where its thickness reachs a maximum. This unit is more than 30 m thick and covered an area of about 1000 Km^2 with an almost circular distribution around the central sector. The "pozzolane rosse" ignimbrite has a volume in dense rock equivalent (DRE) of about 12 Km^3. Its eruption probably caused a caldera collapse, presently masked by the subsequent activity. Stratigraphic correlations between this unit and the coastal depositional sequences, compared with the oxygen isotopic scale of SHACKLETON *et alii,* (1990), make it possible to attribute to it an age of between 0.5 and 0.4 Ma (MARRA *et alii,* 1995).

At the top of the ignimbrite, fall products prevail in the southern and eastern sectors, whereas lavas mainly outcrop in the western sector. Outcrops and drilling data also indicate that at the end of this cycle large lava flows occurred (Vallerano lava flows; DE RITA & ROSA, 1990). Emplacement of these lavas occurred during a period of strong erosion (lowstanding sea level correlated with isotopic stage 12, MARRA *et alii*, 1995a;) and so they filled a progressively shifted paleovalley excavated inside the "second TA pyroclastic flow unit", reaching a thickness of about 20 m. BERNARDI *et alii* (1982) indicate an age of 0.46 ± 0.006 Ma for these lava flows, in agreement with stratigraphic data. A volume of more than 0.5 Km^3 of erupted magma has been calculated for this extrusive episode.

Third TA cycle

The second and the third TA cycles are separated by the presence of a paleosol. Above this paleosol is present another ignimbrite: the "pozzolane nere" unit.

The pozzolane nere Eruption Unit to which the "pozzolane nere" ignimbrite belongs has a basal scoria-lapilli fall level, dispersed mainly towards the east in the Valle Latina area and showing a variable thickness up to a maximum of 75 cm. Above this deposit, a 2-15 cm-thick level is present that consists of lava lithics and crystals which is impoverished in fines; it has been interpreted as a ground layer; it is overlaid by an ashy deposit having an average thickness of 30 cm (layer 2a of SPARKS *et alii,* 1973). This last basal ash layer, sometimes lithified, is always present at the base of the "pozzolane nere" ignimbrite around the entire volcano, representing an important marker horizon for stratigraphic correlations. The ignimbrite above is loose and massive, with a black sandy matrix containing black scoria and thermo-metamorphosed sedimentary and lava lithics. The unitís thickness is highly variable from 1 m in the distal western area (south of Rome) to more than 20 m in the eastern sector. A volume in DRE of about 8.7 Km^3 has been calculated (ROSA, 1995). In the upper part of the deposit pipe structures are locally present where the ignimbrite reachs its maximum thickness. At the Fontana Ranuccio locality (Sacco River valley), the radiometric K/Ar dating of two leucite-rich levels (one below and the other above the "pozzolane nere" ignimbrite; BIDDITTU *et alii,* 1978) ascribe to this unit an age of between 0.528 ± 0.006 and 0.487 ± 0.0075 Ma. These ages, however, are not in agreement with the stratigraphic evidence which allows the correlation of the "pozzolane nere" ignimbrite with coastal sediments deposited between the isotope stages 10 and 11 (MARRA *et alii,* 1995a). This correlation ascribes an age younger than 0.40 Ma to the "pozzolane nere" ignimbrite.

The "pozzolane nere" ignimbrite, as the previous ones, is covered by fall products whose maximum thickness is visible in the eastern sector. The preferential dispersal of the fall products in the eastern sector is probably due to the prevailing wind direction. Like the previous two cycles, the third TA cycle ends with lava extrusions, mainly encountered by drillings in the western and eastern sectors.

Fourth TA cycle

The "tufo lionato" and the "tufo di Villa Senni" ignimbrites represent the lower and upper flow units respectively, belonging to the same eruption unit named the "Villa Senni eruption unit" (VSEU) (ROSA *et alii,* 1993; GAETA *et alii,* 1994). At the base of the eruption unit an ashy layer with laminar structures exists that is interpreted as a ground surge deposit; it ranges from 0 to 10 cm in thickness. Above this level, a scoria-lapilli fall deposit is locally present, with an average thickness of 50-60 cm and a NE-oriented dispersal axis. A discontinuous lithics and crystals-rich ground layer deposit is present between the basal deposits and the above mentioned ignimbrite. The "tufo lionato" ignimbrite is lithified and is characterized by a yellowy-reddish ashy matrix containing yellow pumice, black scoria and lava lithics; leucite and pyroxene phenocrysts are dispersed in the matrix and holocrystalline (leucite + pyroxene) lithics (italite of WASHINGTON, 1920; 1927) are present in the basal part of the ignimbrite. The unit always shows intense zeolitization of the vitric matrix. Pipe structures are present sometimes in the upper part of the deposit. In distal areas the unit is confined to deeply eroded paleovalleys , suggesting emplacement during a lowstanding of the sea level. Correlation with coastal sediments indicates a correspondence with isotopic stage 10. At the base of the upper flow unit ("tufo di Villa Senni") a co-ignimbrite breccia layer is present in the proximal part of the western sector. Large lava lithics of this breccia are often observed "sunk" inside the upper part of the lower flow unit ("tufo lionato"), suggesting a short time interval between the emplacement of the two flow units and the still plastic behaviour of the "tufo lionato". The "Villa Senni" ignimbrite is usually loose, massive and leucite rich. The presence of abundant euhedral leucite crystals (about 1 cm in size) is considered a diagnostic characteristic. Holocrystalline lithics with leucite and pyroxene (italite of WASHINGTON, 1920, 1927) are also abundant. The "Villa Senni" ignimbrite age was determined in an extremely accurate methodology study performed by RADICATI DI BROZOLO *et alii* (1981), who used different radiometric methods ($^{40}Ar\backslash^{39}Ar$ and Rb\Sr) to define the following ages: an average $^{40}Ar\backslash^{39}Ar$ age of 0.338 ± 0.008 Ma and Rb\Sr ages ranging from 0.380 ± 0.020 Ma to 0.330 ± 0.020 Ma. According to this data, stratigraphic correlations with coastal sediments indicate that its deposition occurred during isotopic stage 10. The eruption responsible for the emplacement of these ignimbrites caused a caldera collapse, which concluded the Tuscolano-Artemisio phase. The caldera collapse was accompanied and followed by strombolian activity, with lava extrusions from the collapse fissures and local scoria cones. A work regarding the complex relationships between the "Tuscolano-Artemisio" caldera and the strombolian activity is in progress. In fact, this activity appears to be too great (more than 500 m in thickness) to be related to a single collapse event. This new research hypothesizes that tectonic events contributed to greatly enlarge the original collapsed area.

4.2.2. – *Faete phase (0.30-0.20 Ma)*

After the collapse of the Tuscolano-Artemisio caldera, and after the syn- and post-calderic strombolian activity, a new edifice formed inside the collapsed area: the Faete edifice. This new, smaller edifice erupted a much smaller volume of products (about 6 Km^3) and had mainly strombolian activity, with large extrusions prevailing during the last period of its activity. Interbedded with the scoria and lapilli levels is a massive pyroclastic flow deposit ("Campi di Annibale pyroclastic flow deposit") that only outcrops inside the northern wall of the Nemi crater. The huge leucititic Capo di Bove lava flow, on which the ancient Roman Appia road was built, was emplaced during this phase (0.292 ± 0.006 Ma K/Ar age; BERNARDI *et alii,* 1982).

The activity of the Faete edifice ended with a summit caldera collapse that formed the Campi di Annibale caldera, on whose rim the last Colle Iano and Monte Cavo scoria cones built up.

4.2.3. – *Final hydromagmatic phase (0.20-0.020 Ma)*

Hydromagmatic explosions from several craters, mainly located in the western and subordinately northern sectors, represent the last activity of the Alban Hills Volcanic District. The centers in the northern sector (Pantano Secco, Prata Porci, Valle Marciana and Castiglione) have smaller craters (about 1 Km in diameter) and are mainly monogenetic. The products of these craters are interbedded or covered by lava flows.

The case of the Castiglione crater is peculiar, as it seems to have developed in correspondence to an important collapsed sector (ROSA, 1995). The sediments filling the Castiglione crater have been drilled by an 88 m deep continuous borehole for multidisciplinary studies (concerning geochronology, geochemistry, fauna and pollen), and the age of the entire sequence has been estimated at slightly more than 250,000 years (NARCISI *et alii,* 1992). In order of age the following western sector craters were active: Ariccia, Nemi, Giuturna and Albano. Giuturna was active between the last but one and the last Albano explosions. These centers show polygenetic activity with bigger coalescent craters that are aligned along regional N-S and NW-SE fractures. All craters are tuff ring type and erupted wet and dry surges and lahars. Ariccia, which is the oldest one, is the least known because its products are covered by the subsequent Albano and Nemi products. Nemi had complex activity, with eruptions from two different craters coalescent along N-S fractures. The Nemi activity (De Rita & Narcisi, 1983) included the emplacement of a massive pyroclastic flow unit. Albano consists of almost five craters coalescent along NW-SE regional fractures. De Rita *et alii,* (1988a) recognized four, almost complete cycles characterized by the emplacement of wet and dry surges separated by paleosols. The last activity from Albano has been dated by Mercier (1993) with the thermoluminescence method at about 0.019 Ma.

5. – ITINERARY DESCRIPTION

First day 23/5/96

STOP 1: Tuscolo

It is one of the more spectacular and panoramic point of view to observe the morphology of the central area of the Latian Volcano. It has been also one of the most loved site from the Romans, who built up here their holiday houses and a small theatre that is still well preserved. The association of these historical beauties with that of naturalistic and geological interests and the possibility to observe from there the maestosity of an ancient volcanic edifice make this site particularly impressive. The road, ascending the Tuscolo Mount, cuts the welded scoria erupted from annular fracture systems active during the collapse of the central part of the Alban Hills volcano, almost 338.000 years ago (Radicati di Brozolo *et alii*, 1981). At the top, below the cross of the Tuscolo, it is possible to see the outcrops of the welded scoria known as "sperone". This is one of the stones used for the construction of the Coliseum in Rome. From here it is possible to have an almost complete view through the Tuscolano-Artemisio caldera rim which appears opened toward West with an horse-shoe shape. The rim encircles the wide area of the Atrio (the collapsed area) from which many small scoria cones raise up. The highest of these scoria cones is Monte Cavo which is a scoria cone built up on the caldera rim of the Le Faete edifice, during the last phases of its activity. Behind the top of Monte Cavo it is possible to see the wide area of the Le Faete caldera which is limited by the Colle Iano scoria cone. If the weather is clear it is possible to see the northern rim of Albano crater.

STOP 2: Albano Lake

Albano crater developed in the western sector of the Alban Hills volcano where the convergence of favourable structural, hydrogeological and volcanological conditions allowed the final hydromagmatic activity (from almost 200.000 years ago to less than 20.000 years ago). The Albano crater developed along an important regional fracture system NW trending. Its activity consists in 5 explosive cycles coming out at least from 5 craters morphologically identified. The explosions probably started in the northern sector and ended in the southern one. The craters developed on the slope of the old central edifice of Le Faete and the southern ones are directly dug into its lava flows and pyroclastic deposits. The lithology of these deposits affected the morphology of the craters and controlled the emplacement of the products. The presence, in the explosive sequence, of rich soil levels and vegetation provides an useful indication to subdivide the Alban hydromagmatic activity in 5 main explosive cycles. The cycles have at the base an important explosive breccia followed by a sequence of parallel, cross-bedding and massive intervals. Each cycle consists of several levels rich in sedimentary and lava ejecta interpreted as small breccia levels caused by migration or deepening of the explosive axes along the NW-SE fracture.

STOP 3: Solforata

This place showed in the last centuries B.C. a marshy landscape, with a small lake rich in sulphurous gas emissions.

Here, the "Grotta del Fauno" site, unfortunately not open to the public, was considered by ancient local people as the Faunus Oracle home.

In the last century this site was interested by intensive mining in order to exploit the local high content in sulphur of the pyroclastic deposits outcropping, mainly ignimbrites, for intense hydrothermalization processes.

At present the quarry is closed and neglected.

STOP 4: Pomezia (Tacconi Quarry)

Pliocene and Quaternary sandy-clayey sediments, underlying tuffs of the Alban Hills Volcanic District, outcrop at Tacconi Quarry. Here the stratigraphic succession is constituted by (from bottom to the top):

- Upper Pliocene clays,
- Lower Pleistocene (Emiliano) sands with *Hyalinea baltica* and *Arctica islandica*,
- Lower Pleistocene grey clays with *Pecten jacobeus*,
- Lower Pleistocene blue clays with *Venus multilamella,*
- Upper Pleistocene (Tyrrhenian = 0,125 m.y. = stage 5e) gravel and red sands.

The area represents a structural high (Pomezia high), bordered southward by the Ardea half-graben (FACCENNA *et alii*, 1994) active until Middle Pleistocene. The very complex and poliphased tectonics started beginning from the Middle Pliocene and controlled the sedimentation by two prevailing fault systems, trending NW-SE and NE-SW. The last tectonic phase, started after 0,125 Ma, produced the uplift of the Tyrrhenian sediments to 45 m a.s.l.

From the sands with *H. baltica* and *A. islandica* a rich molluscan fauna was collected (GLIOZZI *et alii,* 1986; MALATESTA & ZARLENGA, 1985; 1994); the fossil assemblage, amounting to 169 species (1 Brachiopods, 4 Scaphopods, 88 Gastropods and 77 Bivalves), correspond to a biocenosis from infralittoral to circalittoral stages. From the chronological point of view the presence of some survivors of the Pliocene fauna, such as *Nucula placentina, Chama placentina, Trachicardium multicostatum, Haustator vermicularis, Niso terebellum, Aporrais uttingeriana* and *Dentalium rectum*, which represent more than the 20% of the assemblage, with 5 Northern Guests (*Arctica islandica, Chlamys islandica, Pseudamussium septemradiatum, Spisula elliptica* e *Achantocardia echinata*) and the contemporary presence of *H. baltica* allowed to correlate the deposits to the Emilian substage of the Lower Pleistocene.

The Upper Pleistocene sediments are constituted by three stratigraphical-depositional units, separated by erosive surfaces connected with a relative lowering of the sea level. The lowest of these units reveals a progradational beach facies association, while the upper units are the fluvio-lacustrine (braided fluvial environment) and marshy facies filling little incised valleys (MILLI & ZARLENGA, 1991).

STOP 5: Tor Caldara (WWF Oasis)

Southward of the "Pomezia high" is present the Ardea half-graben, which is bordered southward by another structural high: the "Anzio high", in which northern border is localized the Tor Caldara WWF Oasis. Here a natural reserve of 40 hectares exists; it is managed by Administration of Anzio Municipality and by WWF of Italy.

In this area the sequent sedimentary succession is possible to recognize (from bottom to the top):

- Lower Pliocene grey clay with gypsum /Lower Pleistocene sandy-clayey with *Arctica islandica*
- Middle Pleistocene gravels and sands
- red sands.

The Lower Pleistocene sandy-clayey contain a molluscan fauna with *Arctica islandica* on which the intense hydrothermalism phaenomena produced the substitution of the shells with sulphur.

The Middle Pleistocene gravel and sands represent beach facies organized with particular sedimentary structures (plano-parallel laminae, erosion surfaces, bioturbation, etc.).

This site is very important from a policy and management point of view, in fact it is protect under law but the most important fact is related to its management by WWF.

In this area the mining activity for the exploitation of the sulphur begun in Roman Age and lasted till recent times.

STOP 6: Castel Porziano (Holocenic Dune)

In the area of Castel Porziano is largely diffused a trasversal Holocenic Dune. It is extended for about 100 km from Castel Porziano to S. Felice Circeo in the area of coastal plain, except on the high structural area of Anzio, or in those areas where man has built constructions near the sea. Its formation is very recent (Holocene) and it is connected to the raising sea level consequently the last deglaciation. It is constituted by sands of marine environment at the bottom after evolved in dune, reaching a maximum elevation a.s.l. of 9 meters, for that it is well evident in the landscapes. It has an important environmental function for the presence of a luxuriantly pioneer (toward the sea) and mediterranean vegetation (toward the land), unfortunately the action of the man (buildings, roads, etc.) has introduced strong modifications as erosions or in the worse cases its complete destruction. (ARNOLDUS-HUYZENDVELD *et alii,* 1995)

Second day 24/5/96

STOP 1: Bracciano Lake

The Bracciano lake developed inside a volcano-tectonic depression which, in its turn, developed inside a NE-trending half-graben formed during the Pliocene as a result of regional extensional tectonism affecting the Tyrrhenian margin of the Italian peninsula. An intense explosive volcanism issued from reactivated faults which had controlled the half-graben collapse. During a phase of intense extensional tectonic activity, magma rose to shallow depth (4-7 Km) along the main NE trending faults, forming a magmatic laccolithic body as magma chamber. Extensional faults intersected the magmatic body approximately 0.4-0.3 Ma, triggering the explosive eruption of an important ignimbrite (the sabatinian "tufo rosso a scorie nere"). Further magma then erupted to form a thick sequence of lava flows which issued from NE-striking swarms of feeder dykes in the southern area of the depression. After 0.17 Ma the Bracciano depression suffered its maximum subsidence during which lava effusions and scoria cone eruptions occurred in the northern area. The lake morphology has since been modified by the superposition of N-S strike-slip tectonism which affected pre-existing structures in the Central Italy from around 0.17 Ma to late Pleistocene time.

STOP 2: Caldara di Manziana

This is a crater-shaped little basin, with sulphureus springs and CO_2 gas emissions from a small lake. But, notwithstanding the mistaken park-poster point out to the visitors, it is not an eruptive vent, because of the absence of eruptive products. In fact only lacustrine deposits and the "Bracciano tuff" primarily brecciated deposits, an older ignimbrite (0.17 Ma; BONADONNA & BIGAZZI, 1970) which vent is located northwest of the Bracciano Lake, outcrops at the margins of the small lake.

On the contrary of Tor Caldara site, this place is not well valorised with a satisfactory naturalistic and geologic guide, and with a staff of watchmen for help the visitors and to keep the site clean.

STOP 3: Sasso

Mt. Ceriti constitute the most southern part of the Tolfa-Cerite-Manziate area, located at most south-western edge of the Sabatinian Volcanic District, North of Rome (DE RITA *et alii*, 1994).

Volcanism of the Tolfa-Ceriti-Manziate area represents one of the earliest volcanic events (Upper Pliocene) with an acid character affecting the Central Italy in relation to the evolution of the Tyrrhenian margin.

The geological and petrochemical characteristics of this volcanic district represent a very important point to understand the meaning and the evolution of the Latium volcanism.

Gravimetrical data indicate that the Ceriti volcanic area developed in structural low area with a NE-SW orientation and filled up by a thick cover of Pliocene sediments. The structural analysis demonstrates that the NE-SW alignments is preferential and the domes developed along NE-SW oriented fractures with a space time evolution from West to the East. The volcanism developed in successive effusive episodes interbedded with an explosive event. The morphological shape of the domes changes from upheaved plug domes in the western sector to low lava domes (or coulee) in the easternmost part and the chemical composition of the lava domes correspondently changes from ryolites (to the West) to trachydacites (to the East). The ryolite domes are the most ancient while the trachydacite domes are youngest. It is then possible to suppose that the emplacement of the less differentiated domes can be related to the effects of the maximum extensive stresses acting in the area.

STOP 4: Monte Razzano

Mt. Razzano is a volcanic edifice which had mainly hydromagmatic activity. Its morphology is that typical of tuff cones. It developed after the Sacrofano caldera collapse almost 0.33 Ma., on the western margin of the Sacrofano caldera rim. Its western margin is faulted by a NW-trending extensional fault system, probably active during the explosive activity of the Baccano volcano to the west. Wet surges deposits are visible along the road climbing up the cone. At the top the last debris flows are well exposed. All the products are lithified by zeolitization processes. From the top of the cone it is possible to have a complete view of the Sabatini area. To the North, during clean days, it is visible the Vico edifice, with the Monte Venere central scoria cone; to the east the almost continuous rim of the Sacrofano caldera, with the parassitic scoria cones. To the east, the beautiful view of the composite caldera of Baccano, limited by the Monte San Angelo tuff-cone. Further on, the Martignano lake.

STOP 5: Tor Marancia

The Tor Marancia area is located in the southeastern part of the city, between the Via Ardeatina, the Via di Grottaperfetta and the Via Sartorio. This small area, of few Km^2, has geological and morphological rarities.

The morphology of this small area is typical of the Campagna Romana before the strong urbanization; it is possible to recognize the plateaus of the subsequent ignimbrites that expanded as far as from the central area of the volcano, filling the paleovalleys developed during the glacial periods of the Quaternary age. Observing the dipping of the flow deposits we can reconstruct the drainage network evolution of the Campagna Romana from 0.6 Ma. until now. This appears particularly interesting because the Tor Marancia area could represent a laboratory area to study the relationship between the urbanizzazion processes and their effects on a naturalistic area not yet involved in these processes. The area, if it will be urbanized, can be also subject to strong global geological risk. Our observations are still qualitative, but indicate that the area has a strong hydrogeological risk determined by its paleomorphology and by the fact that most of the rivers are used as drain pipes. Our study suggests that when all the rivers will have had the same destination and when the area will be interested by the foundations of the buildings, probably it will subject to flooding. This is particularly dangerous because the Tor Marancia area is localised near the ancient Appia natural park, which is a very ancient and historical area of Rome rich in archaeological structures and catacombs.

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Mozione finale del secondo symposium internazionale sulla conservazione del patrimonio geologico – ProGEO '96

Declarations of the second international symposium on the conservation of the geological heritage – ProGEO '96

PREMESSA

ProGEO è una libera associazione il cui scopo primario è la promozione della conservazione del patrimonio geologico. GEOSITES è un progetto, promosso congiuntamente da JUGS ed UNESCO, per produrre un inventario mondiale dei siti geologici, geomorfologici e paesaggistici di rilevante interesse.

L'Italia occupa un ruolo importante nella geologia dell'Europa. Questa conferenza ha mostrato che esistono già un notevole numero di contributi e di attività per la geoconservazione (= conservazione dei geotopi) in Europa. I seguenti sei punti riguardano il contesto europeo; seguiranno quattro punti sulla strategia italiana per la geo conservazione.

1) La geoconservazione deve essere considerata da tutti una parte essenziale della protezione del nostro patrimonio naturale e culturale. I progressi nella geoconservazione, come ogni iniziativa tesa a sensibilizzare i cittadini sull'importanza del patrimonio geologico, si basano sui dati recenti di Scienze della Terra e su descrizioni precise delle caratteristiche geologiche. Conseguentemente la conoscenza scientifica per ogni attività di una certa importanza circa i siti geologici le politiche di ProGEO si sviluppano su tali fondamenta.

2) ProGEO è un'associazione Europea di geologi che operano per la geoconservazione. Noi speriamo che la sua struttura venga adottata altrove in ogni regione del mondo e stiamo lavorando anche per creare legami con altre associazioni per la geoconservazione.

3) Noi sosteniamo che ProGEO debba muoversi in direzione di una regionalizzazione, essendo questo lo schema ideale di funzionamento.

4) ProGEO sostiene sia i criteri che gli schemi regionali e nazionali già adottati per GEOSITES.

Questo Symposium approva integralmente e raccomanda l'approccio sistematico adottato per GEOSITES (compresi i suoli ed il paesaggio), lavorando sulla base di evidenti schemi regionali, sia strutturali che stratigrafici, evitando le metodologie "ad hoc" del passato.

Noi riteniamo importante ed urgente l'inclusione dei siti geologici nella Lista del Patrimonio Mondiale dell'UNESCO; tuttavia ciò deve essere realizzato con attenzione e con misura, e tale inserimento deve essere basato sulle metodologie già sperimentate per GEOSITES.

5) GEOSITES offre notevoli ed impensati vantaggi in termini di incremento di contatti e di lavoro. Si propone infatti di formare una Task Force per esaminare le possibilità di allargare e migliorare il concetto di Geosites, anche per quanto riguarda i progetti Litosfera/Geosfera.

6) Noi intendiamo avere un quadro geologico-tettonico ed una rete di siti geologici definiti per l'Europa nel 1988, connessi con le reti nazionali e regionali e sviluppati gradualmente sulla base della documentazione descrittiva.

UNA STRATEGIA PER LA GEOCONSERVAZIONE IN ITALIA

7) Noi intendiamo esercitare una costante pressione sulle Autorità competenti e sulla pubblica opinione affinché la legislazione vigente sia applicata. In tal modo la conservazione del nostro patrimonio geologico sarà garantita, oltre ad offrire più ampie possibilità di lavoro alle nuove generazioni di geologi e di altri specialisti.

8) Il passo più importante è la promozione di un inventano nazionale di quei geotopi che abbiano una valenza nazionale ed internazionale. Contemporaneamente sarà necessario promuovere inventari su scala regionale, invitando le Autorità ad operare nel rispetto dei presupposti tecnico-scientifici adottati a scala nazionale ed in accordo con i criteri proposti da JUGS e dal progetto GEOSITES.

9) Noi intendiamo promuovere l'opinione che la selezione, la conservazione e la gestione dei geotopi presso Stato e Regioni debba essere eseguita nel più ampio contesto della pianificazione culturale, ambientale e territoriale.

10) Siamo infine certi che il più importante dei fattori di protezione del patrimonio culturale sia rappresentato dalla conoscenza perciò riteniamo di fondamentale importanza la divulgazione delle Scienze della Terra a vari livelli educativi a partire dalle scuole elementari fino all'Università.

PREAMBLE

ProGEO is an open association whose primary aim is the promotion of geoconservation. GEOSITES is a project, under the auspices of IUGS and with the support of UNESCO, to devise a globai inventory of geologicai, geomorphological and landscape sites.

Italy has an important piace in the geology of Europe. Through this conference it has been shown that a wide range of activities are already making an important contribution to European geoconservation. The following declaration sets the European context. It is followed by an integrated Italian strategy.

1) Geoconservation is regarded by society as an essentiai part of the protection of our naturai and culturai heritage. Achievements in geoconservation (= geotope conservation), as well as any successes making the publie aware of geologicai heritage, are based on modem Earth-science data and up-to-date descriptions of geological features. Thus scientific lmowledge underpins all worthwhile activity on GEOSITES: upon this cornerstone ProGEO policies are founded.

2) ProGEO is the European geoconservation network - we hope that its structure is adopted elsewhere in other regions of the world. We agree to work towards links with other regionai networks.

3) We uphold ProGEO's move towards regionalisation as the ideal fiinctional framework.

4) ProGEO supports the regional and nationai eontextual criteria and frameworks already adopted for GEOSITES.

This Symposium approves fully and recommends the systematic approach adopted for GEOSITES (includings soils and landscapes), working in clear regional, strueturai and strati graphic frameworks, avoiding the ad hoc methods of the past.

We look for the incorporation of geologicai sites and terrains in World Heritage sites as soon as possible: however, this should be done with care and balance, and inclusions under World Heritage should be based on the sound GEOSITES method.

5) GEOSITES offers great, previously unanticipated, gains in terms of improved communications and working. It is proposed to form a Task Force to examine the possibilities for enlarging and building upon the geosite concept, and the possibilities for Lithosphere/Geosphere reserves

6) We intend to have a geological/tectonic framework and the network of GEOSITES established for Europe in 1988, meshed with nationai and regionai networks, developing descriptive documentation gradually.

A STRATEGY FOR ITALIAN GEOSCONSERVATION

7) we intend to exert continuous pressure on the competent authorities and public opinion, so that that existing laws are applied. Jn that way the Conservation of the Geologicai Heritage may be guaranteed, as well as offering wider employment possibilities for new generations of geologists and other competent specialists.

8) A maj or step forseen is the promotion of a nationai inventory of geoconservation sites/geotopes which have intemationai andior nationai value. Concurrently we will promote regionai inventories, inviting the Authorities to operate autonomously, both within the technical-scientific context agreed at A nationai level, and in accordance with the IUGS GEOSITES criteria.

9) We intend to promote the opinion that fulì weight should be given by States and Regions to geotope selection, conservation and management, placing this in the wider context of environmental, territoriai and culturai planning.

10) We are aware that an important factor in the protection of the culturai heritage is lmowledge. Therefore we consider of paramount importance the propagation of Earth Sciences at various educationai levels, ranging from elementary school to University.

Postscript

This conference looks forward to meeting again next year to advance the cause of European geosconservation, to consider the evolving Geosite list, and in two years in Sofia for ProGEO '98, to discuss a drafi European list which ProGEO will submit to IUGS and UNESCO.