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CHAPTER 8
Lamproitic rocks from the Tuscan Magmatic Province

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8.1 HYSTORICAL PERSPECTIVE

Torre Alfina – This characteristic village is developed around the castle from which it has had origin. In the 809 with the descent of Carlo Magno in Italy, four relatives settled down themselves in central Italy. One of them, stopped in Orvieto and gave origin to the family of the Monaldeschi; they had the control of many castles of the zone, Torre Alfina included. After a struggle against Filippeschi family in 1316, Monaldeschi family became undisputed master of the area. After several vicissitudes and with extinction of the family the castle passed to marquises Bourbon del Monte and Trevinano. They held it until 1881 when it was acquired and saved from the ruin by marquis Edoardo Cahen. Today is private people. The village had been developed around the castle from the 1451 and was independently organized. In 1555 the first statutes of Torre Alfina was proclaimed. During the second half of the 1700 the village was aggregated to Orvieto, while in 1818 it becomes a fraction of Acquapendente.

Orciatico – The area was known since Etruscan times. However historical events of Orciatico can be followed from 1186 when it was under the rule of Ildebrando of the Pannocchieschi, bishop of Volterra. Occupied by Peter Gaetani, Pisa nobleman, also Orciatico came under the rule of Florence. In 1434 Orciatico was rebelled to the Florentine dominion, trusting in the aid of Niccolò Piccinino but in that same year the Florentines reconquered the rebellious castles, and Orciatico came dismantled for reprisal. The Pieve of Orciatico has remote origins, having surely memoirs from 1204. Reconstruction started at beginning of XVI century and it was consecrated in 1509 from Contugi archbishop. In the vicinities of Orciatico, in called locality «Borboi» there is the presence of one «Mofeta». The «mofete» are natural carbon dioxide emissions of geothermal origin that naturally create conditions similar to those would be had on the entire land surface in case increasing of the greenhouse effect. Their importance is due to the fact that the phenomenon is active from centuries, and therefore biological adaptations have already had place. Similar conditions are difficult to study in other way. It is notewhorty that in some of these localities exist new species animals and vegetables acclimatized to the new conditions.

Montecatini Val di Cecina - Villages around Montecatini Val di Cecina were known since the times of the Etruscans, and the old copper mine in the outskirts of Montecatini seems was

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exploited from that time. Now a powerful tower, the ancient residence of the Belforti family, dominates over Montecatini Val di Cecina and the surrounding territory. The village shows all the typical characteristics of the medieval settlement grown up around the buildings representing the political and religious power: the Palazzo Pretorio with a crossvault porch and the 14th century Church of S. Biagio.

Sisco – Corsica (France) - Hystory of Sisco village is connected with that of Corsica and it is turbulent, thunderous and ripped open by streaks of lightning from constant invasion. Corsica was both a victim of its geographical position and the radiance of its natural beauty.

Already in the pre-neolithic there are traces of humans living in caves. Successively, in the Bronze Age Society organizes itself into a hierarchy and villages were fortified and castles grow in number probably designed with both defensive and cultural features. Situated at the crossroads of the major trade routes of the Old World, it is immediately coveted by the Etruscans who are allied to the Carthaginians of Africa. The contribution of these successive civilizations is remarkable. Democratic processes, artistic and technical achievements with the notable development of the Eastern plain through the cultivation of vine and olive trees. Mineral extraction and fishing industries are all developed at this time.

After a long and devastating conquest (259 - 111 b.c.) Rome finally seized the island that followed Roman history. Up to the fall of the Roman Empire when Corsica received contributions from each of its successive invaders: Vandals and Ostrogoths, Byzantines and Saracens. The Saracens (Moors) - who would be at the origin of the symbol of Corsica: the Head of Moor- have set up strategic bases on the isle which would be a threat for the shipping trade up until the 10th century.

From the end of the 11th century to the end of the 13th, the island takes advantage of the wisdom and the benefits of its colonisation by Pisa. From 1284 to 1768 there were five centuries of Genoese Time, even if Genoa fully established itself there only by the middle of the 14th century, during which time the island was threatened by plague.

The Genoese period ended with the War of Independence and in 1789 with the Treaty of Versailles Corsica was integrated with France and from there followed France history, even if many Independence movements are still operating.

In Sisco village only remnants starting from X century are present, such as Church of St Michel in roman style. Interesting are the fortified hamlet of Teghie going back to the XIV century and the manor of St Catherine with a church restored during the XV century. Of the same period is the church of St Martin enlargement of a older building.

8.2 GEOLOGICAL SETTING

Sisco – The body crops out at SW of the Sisco village (Corsica; see Part II, Chap. 1, Fig. 1). It occurs as a sill of variable dimension (1.5 – 4.0 m), interlayered with schists belonging to the «Blue Schists» unit (Velde, 1967). On the East the contact is sharp, whereas to the west the contact is much more crenulated. Rocks yield an emplacement age of 14-15 Ma (Civetta *et al.*, 1978), very older with respect to all the other outcrops of the Tuscan Magmatic Province.

Torre Alfina – Torre Alfina Volcano is located a few kilometres north of the Vulsini district. It consists of few tiny lava flows erupted from a small volcanic centre, and a small neck cropping out north of Torre Alfina village (Conticelli, 1998; Fig. 1). Torre Alfina volcano was active for a short span of time around 0.82 Ma (Nicoletti *et al.*, 1981), coeval with the nearby Radicofani volcano (Barberi *et al.*, 1994) and the Monte Cimino volcano (Nicoletti, 1969), and predating the oldest Roman-type volcanic products of the Vulsini district by about 300 ka (Barberi *et al.*, 1994). The Torre Alfina volcanic rocks rest directly on the sedimentary basement, which consists of cretaceous, carbonaceous and argillaceous rocks belonging to the Ligurid units. The Torre

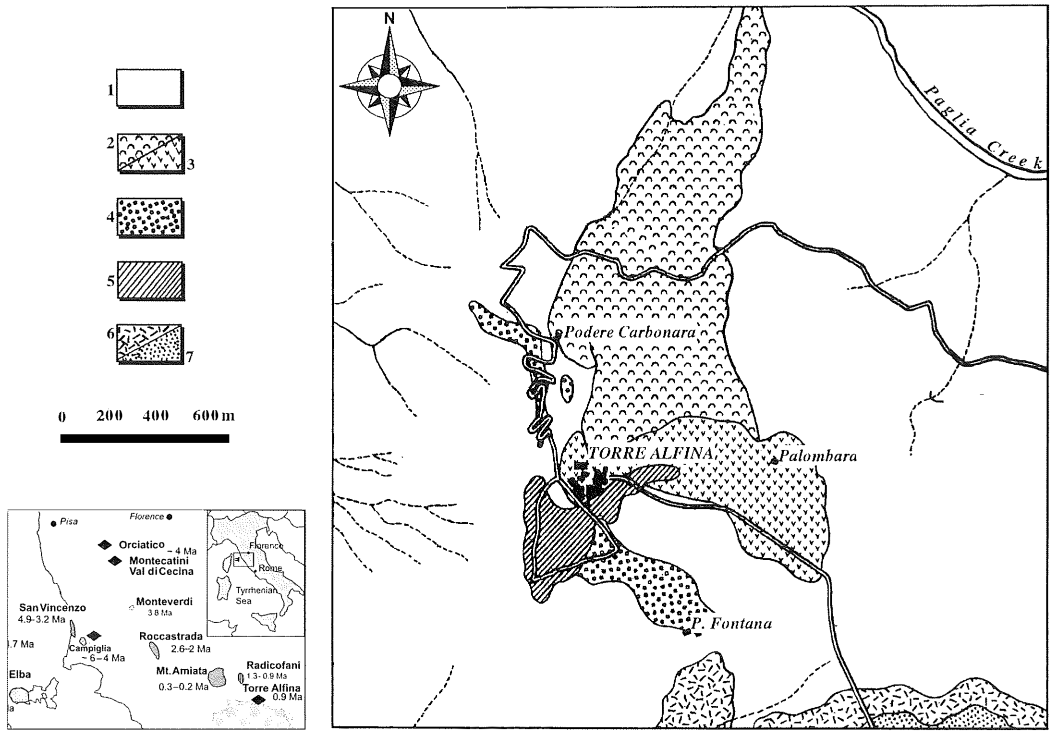

Fig. 1 – Schematic geologic map of Torre Alfina area. Modified after Conticelli (1998); 1) cretaceous sedimentary rocks (Ligurid units); 2) blocky olivine–latite lava flows; 3) low viscosity olivine–latite lava flows; 4) low-viscosity olivine–latite lava flows; 5) lapilli and scoriae surrounding the vent; 6) leucite-bearing lava flows (Vulsini district, Roman Province); 7) leucite-bearing pyroclastic rocks (Vulsini district, Roman Province).

Alfina lava flows were erupted at the top of the hill and flowed partly into the canyon formed by the Paglia river (Fig. 1). Two slightly different types of lava can be recognized. They were emplaced contemporaneously, and have different colours, vesicularities, and porphyritic indices. First lava type is dark grey in colour, almost aphyric, and bears abundant ultramafic xenoliths (2.0–4.0 cm), as well as a few crustal xenoliths of variable size 5.0–10.0 cm and nature. The second lava type is the most widely represented at Torre Alfina volcano. It is dark grey to light grey in colour, with a variable porphyritic index and vesicularity, and some flattened vesicles of a few centimeters in length. This type bears abundant crustal xenoliths of variable size 2.0–30.0 cm , some large 3.0–20.0 cm magmatic mica-rich inclusions, and rare ultramafic xenoliths.

Orciatico and Montecatini Val di Cecina – The Orciatico (ORC) and Montecatini Val di Cecina (MVC) bodies crop out near their two type localities, a few km NW of the town of Volterra. Their emplacement was probably controlled by the NNW-SSE trending faults related to the post-tectonic extensional regime. They yield an emplacement age of 4.1 Ma (Borsi *et al.*, 1967), an age which overlaps with the most young rocks from Tuscan Magmatc Province, but which precedes the Roman magmatism by 3.0 Ma.

ORC magma was intruded into shallow level Pliocene sediments in the form of a sill-laccolith body fed by a narrow NW-SE

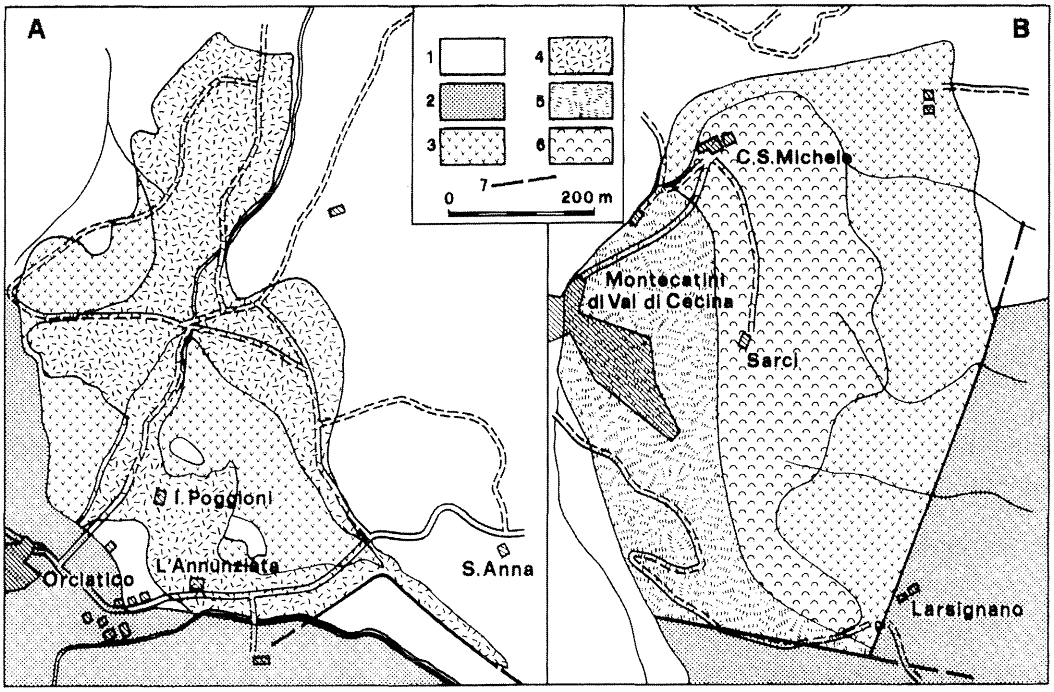

Fig. 2 – Schematic geologic map of Orciatico and Montecatini Val di Cecina areas; modified after Conticelli *et al.* (1992); see inset in figure 1 for outcrop location; 1) Quaternary; 2) Miocene sediments; 3) thermally metamorphosed rocks; 4) Orciatico lamproites; 5) Montecatini Val di Cecina jointed facies; 6) Montecatini Val di Cecina massive facies; 7) faults.

trending dyke (Conticelli *et al.*, 1992; Fig. 2). The external portion of the body has the typical characteristics of a chilled margin, with texture varying from glassy to slightly porphyritic. The inner part of the body shows a massive holocrystalline texture. At their contact with the igneous body, the country rocks underwent thermal metamorphism in the pyroxene-hornfels facies.

The MVC body was intruded in the form of a shallow level plug, and it is bordered by recent normal faults that dissect its original shape (Fig. 2). On the basis of field relations and microscopic observations Conticelli *et al.* (1992) divided the MVC igneous body in three distinct facies. A marginal facies, represented by a few metres of a massive reddish-brown glassy chilled margin. This border facies grades into a massive crystalline facies, represented by a brownish rock which is cut by scarce leucocratic veins. The veins sometimes reach a thickness of 15 cm, and, in some places, widen out into globular masses (ocelli). The latter range in size from few mm up to 25-30 cm. On the west side of the body, a third facies is present, and is in tectonic contact with not metamorphosed country rocks. This facies is columnar jointed, red-brown in colour, and is cut at right angles by a dense grid of rectilinear leucocratic veins with a maximum size of 2.0 cm.

Veins, have a parallel rectilinear pattern and intersect the linear fluidality at right angle (70-90). This probably indicates that the leucocratic veins could have been formed by the opening of cracks during the upward movement of the magma in the form of a crystal mush. Furthermore, on the basis of the field relationships, it appears possible that the massive crystalline facies represents the original top, whereas the columnar jointed facies correspond to the deepest part, of the Montecatini val di Cecina plug. Successive tectonic movements dissected, tilted and lifted up the two portions of the MVC body giving them their present day arrangement.

8.3 Petrography

Sisco – The body has a quite homogeneous mineralogical assemblage constituted mainly by phlogopite, amphibole and K-feldspar; olivine is commonly altered in clay minerals. The external parts of the body is less crystalline and phlogopite is oriented parallel to the contact, groundmass is microcrystalline and contain mainly sanidine and phlogopite. The central part of the body is coarser grained. Amphibole is dispersed in the microcrystalline groundmass. Accessory minerals are apatite, titanite, rare quartz and diopside.

Torre Alfina – The first type of lavas have variable textures, from almost aphyric to slightly seriate porphyritic. Olivine is the only phenocryst and occurs in several different morphologies testifying to the complex cooling history of the magmas. The groundmass has an intersertal microcrystalline texture formed by microphenocrysts of olivine, phlogopite, and colorless clinopyroxene, surrounded by smaller sanidine, olivine, ilmenite and magnetite. Euhedral chromite inclusions are abundant in some olivines. The second type of lavas show porphyritic seriate textures. Olivine is still the only phenocryst present, with polyhedral and kink-banded rounded textures predominating over hopper types. Embayed and rounded xenocrysts of plagioclase, biotite, cordierite, orthopyroxene, and quartz are also present. The groundmass has a microcrystalline texture with microphenocrysts of olivine and colorless clinopyroxene surrounded by totally resorbed mica, sanidine, olivine and oxides. Petrography of different type of xenoliths can be found in Conticelli and Peccerillo (1990) and Orlando *et al.* (1994).

Orciatico – External part has texture varying from glassy to slightly porphiritic (Conticelli *et al.*, 1992). Skeletal olivine and clinopyroxenes are the most abundant mineral phases, with minor phlogopite, oxides and K-feldspar microlites. Massive holocrystalline texture of the inner part has abundant euhedral and rounded olivine phenocrysts, red-brown unzoned phlogopite plates, minor colourless clinopyroxene and rare amphibole. Oxides and K-feldspars are the most abundant phases in the groundrmass.

Montecatini Val di Cecina – Microscopically, the marginal facies is characterizided by large and abundants red-brown phlogopite laths with minor totally replaced skeletal olivine, colourless clinopyroxene, K-feldspar and apatite. Quartz is present only in the most weathered samples as an alteration product (Conticelli *et al.*, 1992). The massive crystalline and the columnar jointed facies have a porphyritic hypidiomorphic texture with abundant zoned mica, feathery K-feldspar, minor colourless clinopyroxene, apatite, as well as rare oxide, zircon, thorite, quartz and perrierite. In the columnar jointed facies glomeroporphyritic mica aggregates and upper crustal xenoliths are sometimes present. The micas have a fabric that resembles a primary linear fluidality, due to crystallization and orientation of this phase parallel to the flow direction. These structural characteristics strongly controlled the formation of the joints during cooling of the magma. Veins and ocelli are characterized by a fine-grained, slightly porphyritic texture. K-feldspar is the most abundant phase.

8.4 Petrogenesis

Tuscany lamproites are ultrapotassic, silica oversaturated, high-silica rocks with high Mg# (Mg/Mg+Fe atomic ratio = 75-80), Ni (up to 350 ppm) and Cr (up to 800 ppm), and low Al, Ca, Na (Peccerillo *et al.*, 1988; Conticelli *et al.*, 1992; Conticelli, 1998). Contents of Large Ion Lithophile Element (LILE: Rb, Th, K, Light

REE, etc.) and ratios of LILE/HFSE (High Field Strength Elements: Ta, Nb, Zr, etc.) are high and the mantle normalized incompatible element patterns (Fig. 3) closely resemble those of some upper crustal rocks (e.g. shale, gneiss, granitoids). Sr, Nd and Pb isotopic compositions also fall in the range of the upper crust (Vollmer, 1976; Hawkesworth and Vollmer, 1979; Peccerillo *et al.*, 1988; Conticelli, 1998; Conticelli *et al.*, 2001a) (Part II, Chap. 1, Fig. 7). The Sisco lamproite has higher contents of HFSE (e.g Hf 33 vs 15) and lower Sr isotope ratios (0.712 vs. 0.716) in respect to the other Tuscany lamproites.

Tuscany lamproites have similar patterns of incompatible elements as the Oligocene lamproites from Western Alps (Venturelli *et al.*, 1984).

Lamproitic rocks have mafic composition and their Mg#, Ni and Cr contents often are well within the range of mantle equilibrated melts (Peccerillo *et al.*, 1988). LMP rocks display high K_2O and MgO, and low Al, Na and Ca (see also Foley *et al.*, 1987). The low Ca, Na and Al of LMP rocks, indicates a genesis in an upper mantle that was depleted in these elements. This suggests partial melting of a peridotite mainly formed by orthopyroxene and olivine, and devoid of clinopyroxene (harzburgite), being clinopyroxene lost during previous melting events. Moreover, the silica saturated to oversaturated nature of LMP magmas points to melting at low pressure (Wendlandt and Eggler, 1980). Therefore, the LMP magma can be envisaged as formed by melting at low pressure of a residual harzburgitic (lithospheric) mantle that has suffered an early extraction of basaltic magma before being affected by metasomatic introduction of potassium to form phlogopite. Patterns of LILE of LMP resemble typical upper crustal rocks (Fig. 3); this feature clearly requires the involvement of mantle and crustal end-members in their genesis. Although assimilation of wall rocks was a process that certainly occurred during magma ascending,

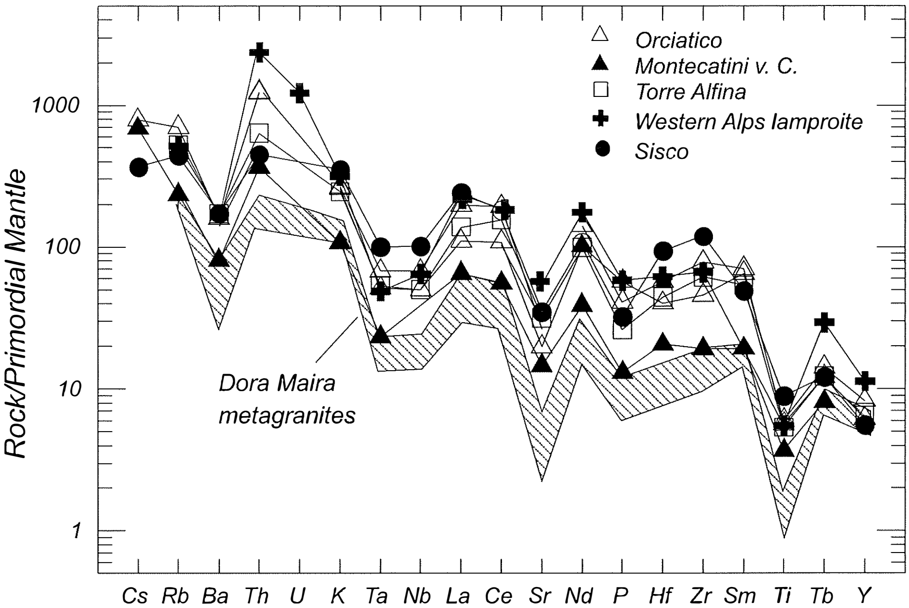

Fig. 3 – Incompatible element patterns for lamproitic rocks from Tuscan Magmatic Province and Western Alps. Dora Maira metagranites are reported for comparison. Data from Cadoppi (1990), Peccerillo *et al.* (1988), Conticelli (1998).

such a process is unable to explain the crustal signatures of Tuscany LMP rocks. In fact, the very primitive geochemical nature of some of these rocks, places strong limits to the amount of crustal assimilation. Moreover, assimilation has a dilution effect on most LILE abundances and does not modify significantly LILE ratios and Sr-Nd isotopes (Conticelli, 1998). Therefore, the only alternative is that upper crustal rocks were introduced into the upper mantle and contaminated the source of Tuscany magmas. The close similarity of incompatible element patterns of LMP rocks and of metagranitoids from the Dora Maira massif (Fig. 3) strongly supports this hypothesis and suggests bulk addition of upper crust to the mantle, without significant element fractionation. The age of such a process is uncertain. A clue may be furnished by the occurrence of ultrapotassic lamproitic activity in the internal zones of Western Alps. These rocks have an age of 30 Ma and have almost identical geochemical composition as the LMP rocks from TMP (Fig. 3). Moreover, LMP rocks in the Western Alps are associated with CA and SHO volcanics, as also observed in Tuscany. Therefore, geological and geochemical evidence suggests that the mafic rocks from Western Alps, Corsica and Tuscany derived from a common source which had the same evolutionary history. If this hypothesis is accepted, the obvious conclusion is that an age of at least 30 Ma must be assumed for metasomatism beneath Tuscany. Tilton *et al.* (1989) suggested that the isotopic signatures of western Mediterranean lamproites may be related to mantle contamination by upper crustal material with a composition as that of the deeply subducted Dora Maira rocks. The Western Alps, Corsica and Tuscany lamproites resemble strikingly the metagranites from the Dora Maira massif (Fig. 3). Therefore, LMP rocks strongly support the hypothesis of Tilton *et al.* (1989). Subduction of Dora Maira rocks may have occurred during east-directed Alpine subduction process of European plate beneath African continental margin (e.g. Doglioni *et al.*, 1999).