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2 - ELBA ISLAND
A - INTRODUCTION

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GENERALS

The geology of the Elba Island is very interesting for its structural complexity, for the relationships between Mio-Pliocene magmatism and tectonics and for its location between Corsica and Northern Apennines. In fact, it is the southwesternmost outcrop of the Northern Apennines chain.

The first tectono-sedimentary events come back to the Palaeozoic. In fact, in the Palaeozoic basement are clearly recorded the Hercynian and, probably, also the Caledonian events. The Alpine sedimentary succession began during the Triassic and its tectonic evolution begins in Late Cretaceous - Early Tertiary and goes on until Late Miocene - Pliocene. The compressive movements started with the consumption of the Mesozoic Western Tethys (Liguria-Piedmont Basin), went up to the collision of European (Corsica) and Adriatic (Tuscany Domain) margins (Abbate et al., 1980, Boccaletti et al., 1980; Bortolotti et al., 2001a), and terminated with the successive polyphase deformations, which originated the Apennine orogenic chain.

Trevisan (1950), proposed a geological frame of the Elba I. which, successively slightly modified by Barberi et al. (1967; 1969), which has been the geological starting-point for all successive studies. This model divides the nappe pile of the Island into five Complexes.

New stratigraphical and structural data modify this frame. The new scheme we propose (Bortolotti et al., 2001a), comprises nine tectonic units, built up of Tuscan (Adria continental margin), Ligurian and Liguria-Piedmont (Jurassic-Eocene oceanic domains) successions, piled up with a very complex frame.

This frame is complicated by post-orogenic extensional events, that produced the thinning of the Tuscan crust that underlies the Elba Units, the uplift of the Moho and the birth and evolution of the Tyrrhenian Basin (Boccaletti et al., 1985; Bartole et al., 1991; Bartole, 1995 cum bibl.; Carmignani et al., 1995). To this phase is linked the emplacement of the monzogranitic bodies and the formation of ore deposits and skarns. These latter constitute one of the best known geological features of the Island (Marinelli, 1975; Serri et al., 1991; Tanelli, 1977; 1983 cum bibl.).

THE TECTONIC UNITS

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Trevisan's model

Termier (1910) was the first one to discover allochthonous units in the Elba I. Afterwards, Trevisan (1950; 1951) and Barberi et al. (1967, the geologic map inserted in the pocket at the end of this volume; 1969) proposed a model comprising five thrust complexes. For a more complete description of the evolution of the geological interpretations see Bortolotti et al. (2001b).

According to Trevisan's model, the Tuscan Units (Complexes I, II and III) are overlain by Ligurian Units (Complexes IV and V) (Fig. 1).

Complex I (= Calamita Gneiss Auctt). This Complex mainly consists of muscovite-biotite schists with andalusite and plagioclase, which locally include quartzitic and amphibolitic levels. These lithotypes are attributed to the Paleozoic (Permo-Carboniferous?). The upper part is made of quartzites ("Verrucano") and crystalline dolomitic limestones of Triassic-Liassic age. They are extensively thermometamorphosed by the La Serra-Porto Azzurro monzogranite and its aplitic dikes.

Complex II. This Complex comprises a Metamorphic Tuscan Succession similar to the Apuan Alps one. From the base we can recognise: **a**. "Scisti macchiettati" (thermometamorphic schists with biotite and andalusite spots), often graphitic, probably of Permo-Carboniferous age; **b**. thermometamorphic vacuolar dolomitic and calcareous-dolomitic rocks of Norian-Rhaetian age; **c**. Marbles, passing upwards to calcschists and "cipollini" (Liassic calcschists); **d**. Calcareous phyllites with calcschist intercalations (Dogger). At the top of this complex, a disrupted serpentinite slab is present.

Complex III. This is a Tuscan succession which includes from the base: **a**. Quartzarenites, arenaceous schists, quartzitic conglomerates and graphitic schists (Late Carboniferous) A thermometamorphic imprint is recognisable south of the Rio Marina area; **b**. Transgressive quartzitic sandstones, conglomerates and schists, which can be correlated with the Ladinian-Carnian "Verrucano" of the Monte Pisano; **c**. Vacuolar more or less dolomitic limestones, eteropic with *Rhaetavicula*-bearing black limestones with marly intercalations (Norian-Rhaetian); **d.** Massive Lime-

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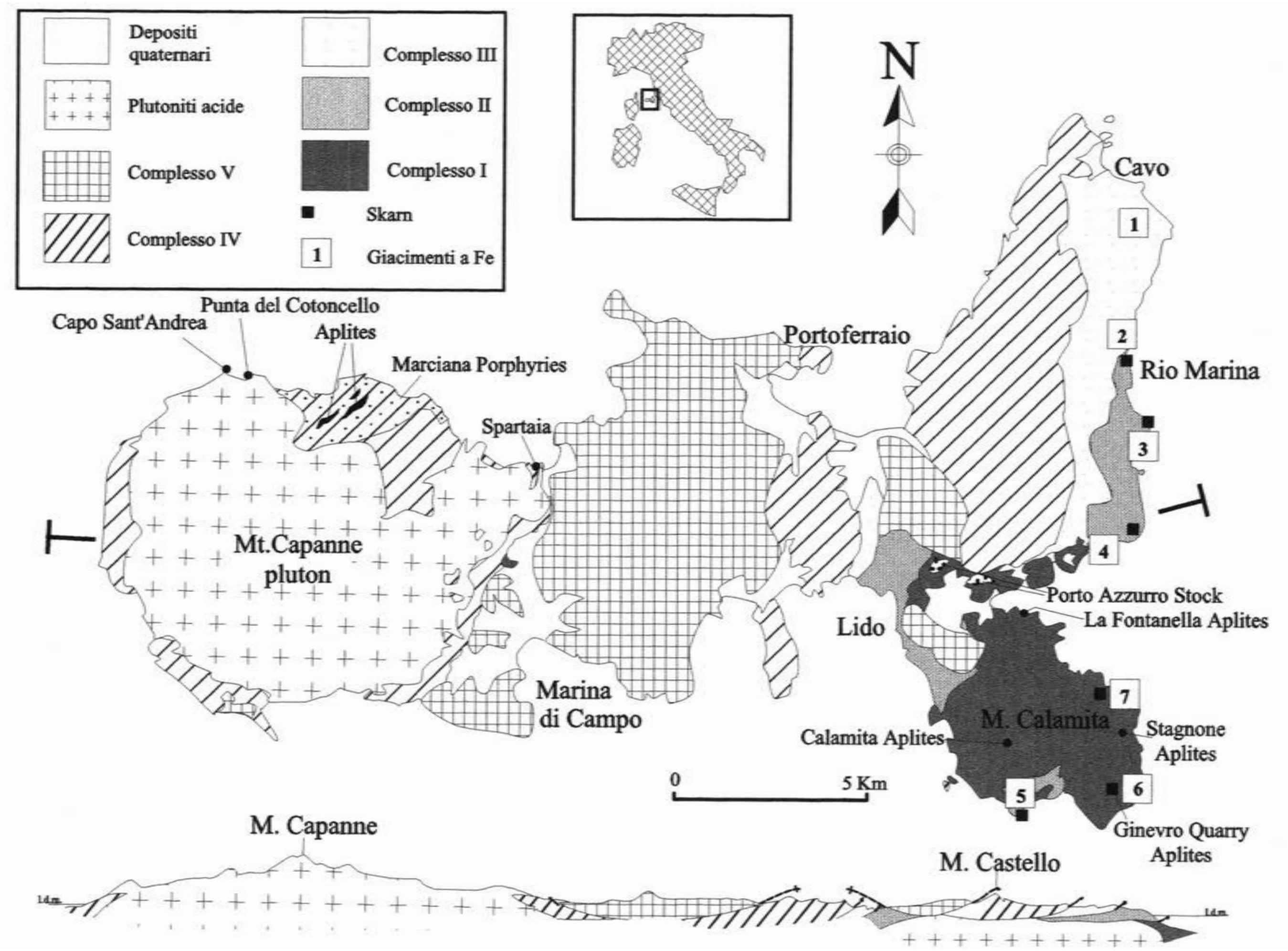

Fig. 1 - Geological sketch-map of the Elba Island according to Barberi et al. (1969), with the location of the Neogene magmatic bodies (after Saupé et al., 1982) and of the main iron deposits: 1- Rialbano; 2- Rio Marina; 3- Ortano; 4- Terranera; 5- Calamita; 6- Ginevro; 7- Sassi Neri.

stones (Hettangian); **e.** Cherty Limestones (Liassic); **f**. Varicoloured marly shales and rare cherty calcareous levels (Dogger).

Complex IV. This is the lower Ligurian Complex and consists of: **a**. Lherzolitic-harzburgitic serpentinites; **b**. Gabbros; **c**. Basalts; **d**. Radiolarites (Malm); **e**. Calpionella Limestones (late Tithonian?-Early Cretaceous); **f**. Shales with siliceous limestones ("Argille a Palombini", Early-mid Cretaceous)

Complex V. It includes two flysch formations, tectonically superimposed. From the base: **a**. Paleocene-Eocene shales with intercalations of marly limestones and subordinately sandstones and ophiolitic breccias; **b**. Late Cretaceous quartz-feldspatic sandstones and conglomerates, grading upwards to a marly-calcareous succession.

In eastern Elba the imbricated stack of the four upper complexes lies directly on the substantially autochthonous Complex I.

The Authors consider this setting as due to polyphase east-verging tectonics which first overthrust, in a compressive regime, the Ligurian Units onto the Tuscan ones; afterwards, gravity tectonics emplaced and reorganised this tectonic stack on Complex I. The late extensional events were related to the uplift linked to the intrusion of the Mio-Pliocenic stocks of Mt. Capanne and Serra-Porto Azzurro.

The new model

During the last twenty years the tectonostratigraphical frame of the Elba I. has been improved by local studies (Perrin, 1969; 1975; Deschamps et al., 1983; Puxeddu et al., 1984; Pandeli and Puxeddu, 1990; Keller and Pialli, 1990; Deino et al., 1992; Duranti et al., 1992; Pertusati et al., 1993; Bortolotti et al., 1994; Pandeli et al., 1995), as reported in Bortolotti et al., 2000b. On the basis of both new data and of our mapping of central and eastern Elba, we elaborated a more complex tectonostratigraphical model. The five "Complexes" of Trevisan, have been re-interpreted and renamed (Fig. 2). We recognised, from the base upwards, the following nine tectonic units:

1. Porto Azzurro Unit ("PU")	Complex I
2. Ortano Unit ("UO")	Complex II p.p.
3. Acquadolce Unit ("AU")	Complex II p.p.
4. Monticiano-Roccastrada Unit ("MU")	Complex III p.p.
5. Tuscan Nappe ("TN")	Complex III p.p.
6. Gràssera Unit ("GU")	Complex III p.p.
7. Ophiolitic Unit ("OU")	Complex IV
8. Paleogene Flysch Unit ("UP")	Complex V p.p.
9. Cretaceous Flysch Unit ("CU")	Complex V p.p.

1. Porto Azzurro Unit "AU" (Complex I). This unit shows a complex tectonometamorphic history, which ends with the cornubianitisation process linked to the Serra-Porto

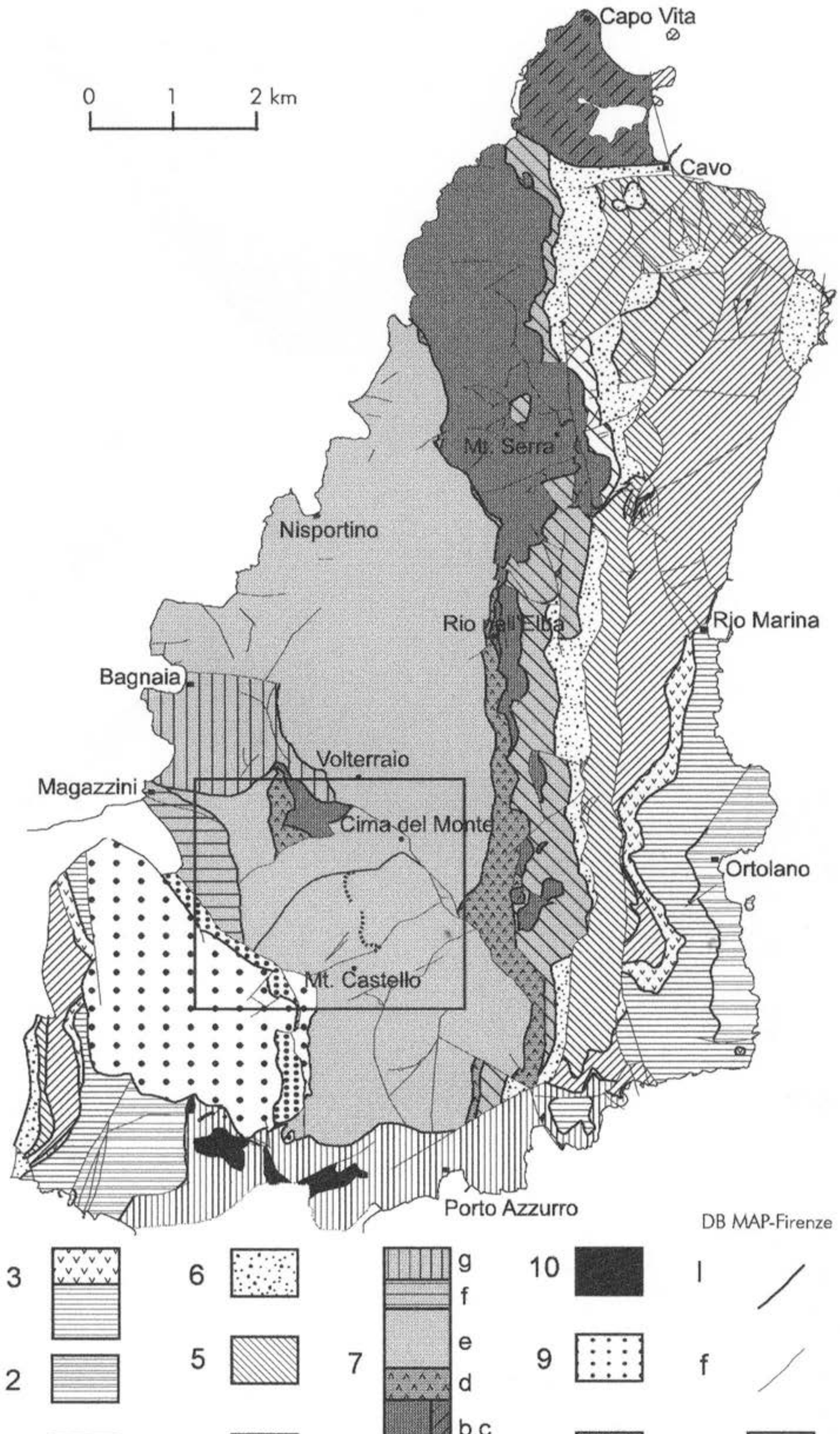

Fig. 2 - Structural map of eastern Elba. 1- Porto Azzurro Unit; 2- Ortano Unit; 3- Acquadolce Unit (a- Porticciolo Subunit; b- Santa Filomena Subunit); 4- Monticiano-Roccastrada Unit; 5- Tuscan Nappe; 6- Gràssera Unit; 7- Ophiolitic Unit (a- Acquaviva Subunit; b- Monte Serra Subunit; c- Capo Vita Subunit; d- Sassi Turchini Subunit; e- Volterraio Subunit; f- Magazzini Subunit g- Bagnaia Subunit); 8- Paleogene Flysch Unit; 9 Cretaceous Flysch Unit; 10- La Serra - Porto Azzurro Monzogranite; l- low-angle tectonic contacts (thrusts and detachments); f- high-angle normal and transfer faults.

Azzurro monzogranitic intrusion (Tortonian), which obliterated the primary textures. Its quartzitic phyllitic succession represents the Tuscan basement, and probably includes Cambro-Ordovician and Carboniferous formations (Puxeddu et al., 1984). Some amphibolite intercalations are intraplate metabasites similar to those found in the buried Paleozoic sequence of Southern Tuscany. The affinity to the Tuscan Metamorphic Sequence is further on strengthened by the presence of a transitional stratigraphical unit between the "Verrucano" and the overlying Mesozoic carbonate succession, very similar to the Tocchi Fm. (Carnian), with the same stratigraphical position in the Southern Tuscany successions (Costantini et al., 1987/1988, with ref.).

A gently westward dipping cataclastic horizon, up to 10 m thick (locally with Fe mineralisation) follows the contact (Zuccale Fault) with all the overlying tectonic units (Keller and Pialli, 1990; Pertusati et al., 1993). East of Porto Azzurro, the Neogene aplitic dikes (cutting the Porto Azzurro Unit) do not cross this low angle tectonic surface and, consequently, the fault must post-date the intrusions.

2. Ortano Unit "UO" (Complex II *pro parte*). It corresponds to the successions of Complex II below the "Calcare a cellette" (= vacuolar limestone = "Calcare Cavernoso") of Trevisan (1951).

It comprises at the base more or less cornubianitised phyllites, quartzites (Capo d'Arco Schists) locally crosscut by rare and thin aplitic dikes. At their top porphyroids and porphyritic schists grade upwards to phyllites and quartzitic metasandstones and metaconglomerates. This succession can be correlated with the Hercynian Lower Paleozoic basement of the Apuan Alps and central Sardinia (Pandeli and Puxeddu, 1990; Pandeli et al., 1994*)*. Probably, this unit is structured as a kilometric isoclinal fold with Ordovician metavolcanites at the core.

3. Acquadolce Unit "AU" (Complex II *pro parte*). It corresponds to the Complex II successions from the top of the "Calcare a cellette" upwards. The complete succession begins with massive marbles, partly dolomitic; they grade upwards to (sometimes cherty) calcschists topped by a metapelitic siliciclastic succession with local calcschist intercalations. Recently, Duranti et al. (1992) found therein a Lower Cretaceous microfauna; thus, they consider all the succession as a metamorphosed Ligurid Unit, which was deformed and recrystallised by the Mio-Pliocenic intrusions. On the other hand, Deino et al. (1992) obtained a 19-20 Ma age for the main schistosity, which rules out its link with the granitoid intrusion. As suggested by Termier (1910) and Corti et al. (1996), these terrains probably correspond to a Liguria-Piedmont oceanic succession, as the "Schistes Lustrés" of Corsica (e.g. Inzecca Units, Durand Delga, 1984) and the calcschists of the Gorgona I. (Capponi et al., 1990). Also the presence of a serpentinite sheet at its top agrees with this interpretation.

4. Monticiano-Roccastrada Unit "MU" (Complex III *pro parte*). The base of this Unit is made of fossiliferous graphitic metasediments of Carboniferous-Permian age (Rio Marina Fm.), on which the detrital Triassic "Verrucano" successions were deposited (Deschamps et al., 1983; Pandeli, unpublished data). To this Unit we ascribe also the epimetamorphic succession of Capo Castello, which includes formations from Late Jurassic (siliceous metalimestones) to Oligocene ("Pseudomacigno"; Pandeli et al., 1995); they could represent part of the "Verrucano" cover.

5. Tuscan Nappe "TN" (Complex III *pro parte*). In the Porto Azzurro-Rio Marina, and Norsi-Valdana areas, it consists only of calcareous-dolomitic breccias ("Calcare Cavernoso" Auctt.). Northwards, also the overlying carbonatic (Pania di Corfino Fm., Mt. Cetona Fm. and "Calcare Massiccio", Late Triassic-Hettangian), carbonatic-cherty ("Rosso Ammonitico", Grotta Giusti Limestones and Limano Cherty Limestones, Middle-Late Liassic) and marly-calcareous formations (*Posidonia* Marlstones, Dogger) crop out.

6. Gràssera Unit "GU" (Complex III *pro parte*). This unit has an uncertain paleogeographic position. Its formations were attributed to the *Posidonia* Marlstones, at the top of the Tuscan Nappe (Barberi et al., 1969). The Unit comprises a basal level of calcschists, sometimes with cherts, but most of the unit is made up of varicoloured slates and siltstones with rare manganiferous, siliceous and calcareous beds. Its lithofacies are different from all those of both the Tuscan and Ligurian Domains. Moreover, they show a slight metamorphism (anchizone up to epizone boundary), which is lacking in the Tuscan Nappe and in the Ligurian formations lying the base and top of the unit, respectively. It lies in tectonic unconformity on different terrains of the Tuscan Nappe. These facts let us propose a provenance from a paleogeographic domain west of the Tuscan one, possibly the Liguria-Piedmont Domain, as the underlying AU.

7. Ophiolitic Unit "OU" (Complex IV). Its succession corresponds to the Vara Supergroup (Abbate and Sagri, 1970). It is built up of several thrust sheets (Subunits, Fig. 2), with ophiolites, belonging to Western Tethyan ocean basin. Serpentinites and gabbros crop out only in the lower Subunits; at their top, and in the upper subunits, is generally present a more or less complete basaltic and sedimentary (Mt. Alpe Cherts, Nisportino Fm, Calpionella Limestones and Palombini Shales) cover of Late Jurassic-Early Cretaceous age. This unit can be interpreted as relic of a trapped oceanic crust originally located near the Corsica European margin.

An idealised complete succession of this unit is shown in Fig. 3.

The subunits we identified (Fig. 2) are, from the bottom: a-Acquaviva, b- Mt. Serra, (and b_1- Capo Vita) c- Sassi Turchini, d- Volterraio, e- Magazzini, f- Bagnaia (see Bortolotti et al., 2000).

a) *The Acquaviva Subunit* (ASU) mainly consists of serpentinites (or/and ophicalcites), and Palombini Shales with rare, thin, Mt. Alpe Cherts levels at their base.

b) *The Mt. Serra Subunit* (SSU) has a succession beginning with an ophicalcitised serpentinite level followed by basalts, Mt. Alpe Cherts (from few to some tens m), Nisportino Fm. (some tens m) and the Calpionella Limestones.

b_1) *The Capo Vita Subunit* (CSU) is made up only of the uppermost terranes of the succession (Calpionella Limestones and Palombini Shales). It can be interpreted as an upper portion of b- shifted northeastwards.

c) *The Sassi Turchini Subunit* (TSU) includes exclusively by serpentinised lherzolites and harzburgites with gabbro dikes and masses.

d) *The Volterraio Subunit* (VSU) is the most complete and thickest succession. From the bottom it comprises gabbros, basalts (3-400 m), Mt. Alpe Cherts (100-150 m), Nisportino Fm. (100-120 m) and Calpionella Limestones (at least

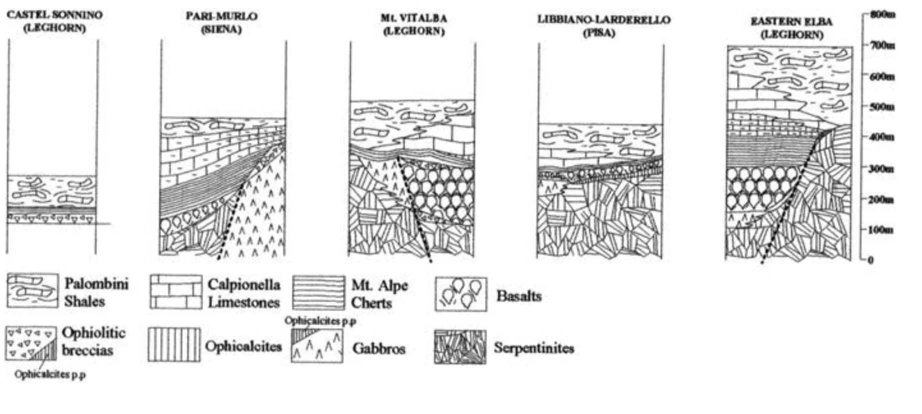

Fig. 3 - Stratigraphical columns of the Vara Supergroup in Southern Tuscany and Elba Island.

100 m) which; only to the west of Mt. Orello, are topped, with a tectonised contact, by a few tens metres of Palombini Shales.

e) *The Magazzini Subunit* (MSU) has a succession made up only of basalts, Mt. Alpe Cherts and Nisportino Fm.

f) *The Bagnaia Subunit (BSU)* comprises the same formations of the VSU, except the Palombini Shales.

8. Paleogene Flysch Unit "UP" (Complex V *pro parte*). It consists of a shaly-marly succession with turbiditic calcilutites, sandstones and rare ophiolitic breccias, of Eocenic age.

9. Cretaceous Flysch Unit "CU" (Complex V *pro parte*). This second turbiditic unit, on top of the Palombini Shales, includes a lower section, represented by siliciclastic sandstones and conglomerates (Ghiaieto Sandstones) and an upper one with sandstones and marly limestones (Marina di Campo Fm). According to our interpretation, the minor ophiolitic slabs, with Calpionella Limestones and Palombini Shales cropping out north-east of Porto Azzurro could represent the tectonised basal terms of this unit.

These Flysch units are cut by aplitic and porphyritic dikes, probably linked to the Mt. Capanne monzogranite. The latter has an average age of 6.8 Ma (Ferrara and Tonarini 1993, Rb/Sr; Juteau et al., 1984, U/Pb), whereas the dikes give an age of 8.5-7.2 Ma. All the dikes are cut by the tectonic contact with the underlying units.

In western Elba, the Mt. Capanne monzogranite and its thermometamorphic aureole are exposed. The latter consists of cornubianitised ophiolitic sequences (ophiolites and sedimentary cover), which Marinelli (1959), Barberi and Innocenti (1965; 1966), and Bouillin (1983) related to the Ophiolite Unit of Trevisan's Complex IV. On the contrary, Perrin (1975), Spohn (1981), Reutter and Spohn (1982) referred them to Ligurian tectono-metamorphic rocks (similar to the "Schistes Lustrés") which were later cornubianitised and deformed by the Mt. Capanne monzogranite. In the Fetovaia area, a weakly recrystallised Flysch Unit (similar to those of Trevisan's Complex V; Barberi et al., 1969), tectonically lies on the cornubianitised oceanic rocks. This Flysch Unit includes a basal ophiolitic-calcareous breccia which is overlain by a marly-calcareous sequence with an olistostrome at the top (Reutter and Spohn, 1982). In the ruditic level, Paleocene-Eocene fossils were found (Bouillin, 1983; Spohn, 1981 cum bibl.).

THE MIO-PLIOCENE MAGMATISM IN TUSCANY

S. Conticelli

The magmatism of Elba Island belonging to the intense magmatic activity, related to the post-collisional phase of the Apennine orogeny, took place along the Tyrrhenian border of the Italian Peninsula during Late Miocene-Pleistocene (Peccerillo, 1985; 1990; 1993). This caused the emplacement of a wide variety of rocks at different crustal levels (i.e., from volcanic to intrusive), with marked differences in petrologic affinities, from strongly alkaline (ultrapotassic) to calc-alkaline (Peccerillo et al., 1987; Poli et al., 1989; Innocenti et al., 1992).

Crust- and mantle-derived magmas cropping out in the Tuscan Archipelago and Southern Tuscany (Fig. 4) were once grouped in a single magmatic province (Tuscan Magmatic Province) owing to the consanguinity attributed to them (Marinelli, 1961). Recently a number of authors have shown that only granites and rhyolites were originated in the crust, whilst calc-alkaline, potassic and ultrapotassic magmas were originated in a metasomatised lithospheric mantle source (Peccerillo et al., 1987; Conticelli and Peccerillo, 1992, Peccerillo, 1993).

Crust-derived magmas form (i) the plutons and subvolcanic bodies of Elba, Montecristo, and Giglio islands, (ii) the granite intrusion of the Vercelli Seamount, (Northern Tyrrhenian Sea), (iii) the intrusive bodies of Gavorrano, Campiglia and Monteverdi, in Southern Tuscany, and (iv) the lava flows of San Vincenzo and Roccastrada-Roccatederighi, in Southern Tuscany (Fig. 4; Peccerillo et al., 1987; Pinarelli et al., 1989; Poli et al., 1989; Poli, 1992; Innocenti et al., 1992). These crust-derived magmas were emplaced between 8 and 2 Ma (e.g., Borsi et al., 1965, 1967; Borsi, 1967; Borsi and Ferrara, 1971; Juteau, 1984; Juteau et al., 1984; Ferrara and Tonarini, 1985; Villa et al., 1987; Barberi et al., 1994), and have a general westward ageing (Barberi et al., 1971; Civetta et al., 1978). Mantle-derived magmas overlap, in time and space, with crust-derived magmas (e.g., Peccerillo et al., 1987; Innocenti et al., 1992), although they were emplaced in a wider span of time, from ~14 Ma (Sisco, Corsica) to 0.08 Ma (Vico and Bolsena areas) (e.g. Fer-

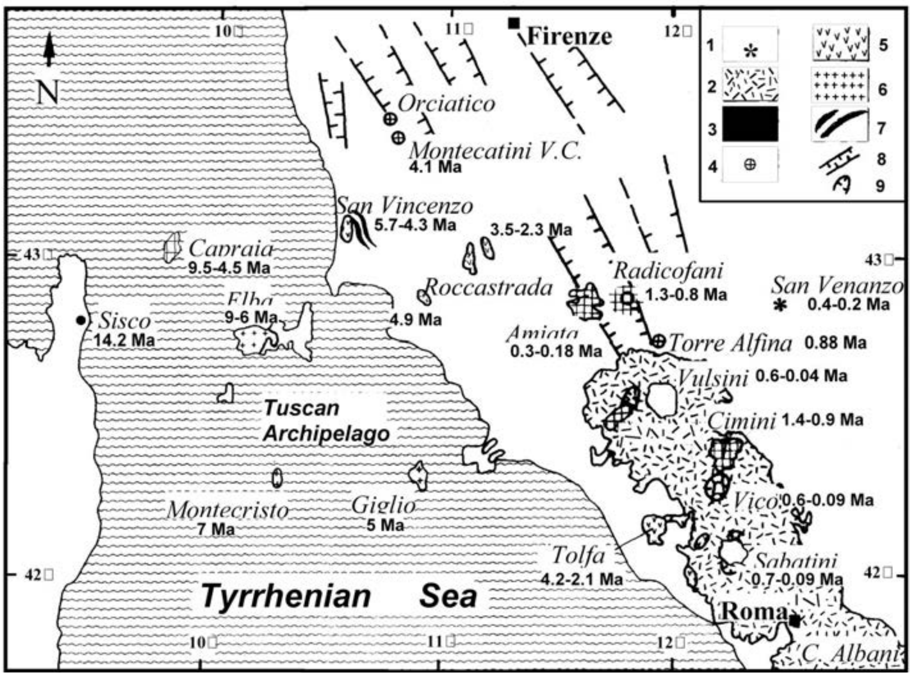

Fig. 4 - Sketch map of the Plio-Pleistocene magmatism distribution in the Northern Italian Peninsula with ages of the magmatic rocks (for data sources see text). 1- mantle-derived ultrapotassic rocks with kamafugitic affinity; 2- mantle-derived ultrapotassic and potassic rocks of the Roman Comagmatic Province; 3- mantle-derived ultrapotassic, potassic to calc-alkaline rocks formerly included in the Tuscan Magmatic Province; 4- mantle-derived ultrapotassic rocks with lamproitic affinity; 5- crustal-derived rhyolitic lava flows; 6- crustal-derived granitic to granodioritic intrusive rocks; 7- swarm dykes; 8- limits of main hinterland basins; 9- main caldera structures (redrawn from Conticelli and Peccerillo, 1992).

rara and Tonarini, 1985; Fornaseri, 1985; Turbeville, 1992; Cioni et al., 1993; Barberi et al., 1994).

Elba Island granitoids

Two plutonic masses crop out in the eastern (La Serra-Porto Azzurro) and western (Mt. Capanne) sectors of the Elba Island, respectively (Fig.1), along with microgranite, aplite and pegmatite dikes. Subvolcanic masses of rhyolitic porphyries also occur in the central and eastern sectors of the Island (Marinelli, 1959; Boccaletti and Papini, 1989; Poli, 1992). Recently in the eastern part of the Elba I., the occurrence of a mantle-derived shoshonitic dike has been reported (Conticelli et al., 1997; 2001). K/Ar and Rb/Sr ages of the plutonic and subvolcanic rocks establish a range of cooling ages from about. 8 to 5 Ma (e.g., Juteau, 1984; Juteau et al., 1984; Ferrara and Tonarini, 1985; Conticelli et al., 1997; Dini and Tonarini, 1997), generally decreasing eastwards. Subvolcanic porphyries and aplitic dikes are associated to the main monzogranitic bodies. Regarding those associated to the Mt. Capanne pluton, minor porphyritic dikes are present at its western margin, but the widest masses of rhyolitic porphyry crop out on the northern edge, between Spartaia and Sant'Andrea (Marciana porphyries, Fig. 1). Aplitic dikes crop out along the axis of the main porphyry body.

Petrogenesis

Mineralogical, geochemical and petrological data on the Mt. Capanne and Porto Azzurro rocks point to an origin by partial melting (anatexis) of a crustal source, similar to the garnet-bearing micaschists cropping out in the Palaeozoic Tuscan basement (Giraud et al., 1986; Poli et al., 1989).

The relatively high temperature (800-850°C), required to accommodate the degree of melting experienced by this crustal source (35-45 wt.% on the basis of trace element modelling, Poli et al., 1989), is difficult to reconcile only with the isostatic re-adjustment following the collisional event of the Apennine orogeny.

Underplating of mantle-derived magmas could have acted as complimentary supply to the heat budget required to achieve high degrees of melting under the general fluid-absent conditions prevailing at middle- to lower-crust levels (Clemens and Vielzeuf, 1987).

In the Elba I. the rock composition closest to that of parental magma has been recognised in the rocks where enclaves are absent (leucocratic facies, hereafter LF; Poli et al., 1989; Poli, 1992). On the other hand, the chemical composition of the main facies (MF) has been modified by the physico-chemical interaction with mantle-derived magmas and the LF parental magma (contamination and fractional crystallisation process, CFC; Poli and Tommasini, 1991). The occurrence of such a process is testified by the ubiquitous microgranular enclaves (ME) found in the MF of the Mt. Capanne pluton. The extent of such modification, however, is difficult to quantify because it is directly dependent upon the relative amount of basic and acid magma: the more the basic magma the higher the equilibrium temperature and the more the "residual" basic magma available for mixing with the surrounding acid magma (stage 3, Poli and Tommasini, 1991). To complicate things further, disruption and mingling of the basic magma, as testified by the ME, during attainment of the thermal equilibrium with the acid magma (stage 2, Poli and Tommasini, 1991) is liable to have modified the composition of the surrounding granite magma owing to the incorporation of fragments from the basic magma (schlieren-like texture exhibited by some ME, Figs. in Stops 3-4).

ORE DEPOSITS OF SOUTHERN TUSCANY AND ELBA ISLAND

M. Benvenuti

Tuscany has been representing for about three millennia one of the most important mining regions of Italy and the whole Mediterranean region. Apart from economic aspects, the Tuscan metallogenic province remains of primary scientific relevance due to the occurrence of diverse hydrothermal deposits associated with volcano-sedimentary, magmatic, metamorphic and geothermal environments (Lattanzi et al., 1994). They include, among the others, the Fe oxides deposits of Elba Island (Tanelli et al., 1991). Fig. 5 provides a sketch map of the distribution of major ore deposits and mineral belts of Southern Tuscany and of Elba Island.

A description and discussion of the metallogenic aspects of Tuscany can be found in Tanelli (1983) and Lattanzi et al. (1994), according to which three main metallogenic epochs seem to be relatively well established in Tuscany (Fig. 6): i- a Middle-Late Palaeozoic, ii- a Palaeozoic-Triassic(?), iii- an Apenninic stage. To the second one would pertain the Fe (and Ba) metallogeny of Elba I.

For the Fe oxide and/or pyrite deposits of Elba I. two basic genetic models have been so far proposed (Tanelli and Lattanzi, 1986): a) "plutonistic epigenetic" (cf. Marinelli, 1983; Dechomets, 1985); b) "syngenetic/hydrothermal-metamorphic" (cf. Deschamps et al., 1983; Lattanzi and Tanelli, 1985). The first line of thought makes reference to the intrusion of the late-Apenninic granitic stocks as the key event for the ore genesis, whereas the authors favouring the second hypothesis acknowledge the importance of the Apenninic tectonomagmatic event in metamorphosing and partly remobilising the pyrite ± Fe oxide ± barite ores, which, at least as pre-concentrations, would have formed in a sedimentary and/or hydrothermal sedimentary environments of Triassic and/or Palaeozoic age (stage *ii* of Lattanzi et al., 1994)).

The Elba Island Fe deposits

The iron deposits hosted in the eastern part of Elba Island fed a long-standing mining and metallurgical activity, dating back to the "first Mediterranean Iron" (beginning of the 1st millennium B. C.) and continued almost uninterruptedly since the Etruscans up to fifteen years ago. In order to preserve and turn to better account such a long mining tradition and invaluable mineralogical heritage, a "Mining and Mineralogical Park" has been recently established in eastern Elba (cf. Tanelli and Benvenuti, 1996).

The location of the main iron deposits of eastern Elba is reported in Fig. 1. In the northern portion of this district (Rio Marina, Valle Giove, Rialbano mines) the iron deposits occur either as stratiform or irregular bodies, preferentially at the contact between the Rio Marina Fm. ("Verrucano") and the overlying carbonatic levels ("Calcare Cavernoso"). The main ore mineral is hematite, frequently associated with pyrite and/or its weathering products ("limonites"). Moving southwards from Rio Marina up to Mt. Calamita, magnetite is generally the most abundant ore mineral, and the iron ores are preferentially hosted within Trevisan's (1950) Complex II terrains (AU in the new interpretation, see above), often in close association with pyroxene-epidote-ilvaite skarn bodies. There is still much debate on the genesis of Elba iron ore deposits, i.e., the source(s) of iron, the mechanisms and time(s) of deposition. In the past, but also recently, a number of authors have put forward "pyrometasomatic-epigenetic" theories, according to which the intrusion of the late-Apenninic (8-6 Ma) monzogranitic stocks would represent the key event for ore genesis. Unlike the previous theories (cf. De Launay, 1907; Lotti, 1929), the epigenetic models proposed in the last fifteen years (e.g. Marinelli, 1983; Dechomets, 1985) considered the intrusions only as the heat sources, which favoured the circulation of hydrothermal fluids, seeking elsewhere the source(s) of the fluids themselves and of the dissolved elements. On the other hand other authors (e. g. Bodechtel, 1965; Deschamps et al., 1983) suggest that the deposits, at least as protores, predated the tectonomagmatic event and were formed in sedimentary

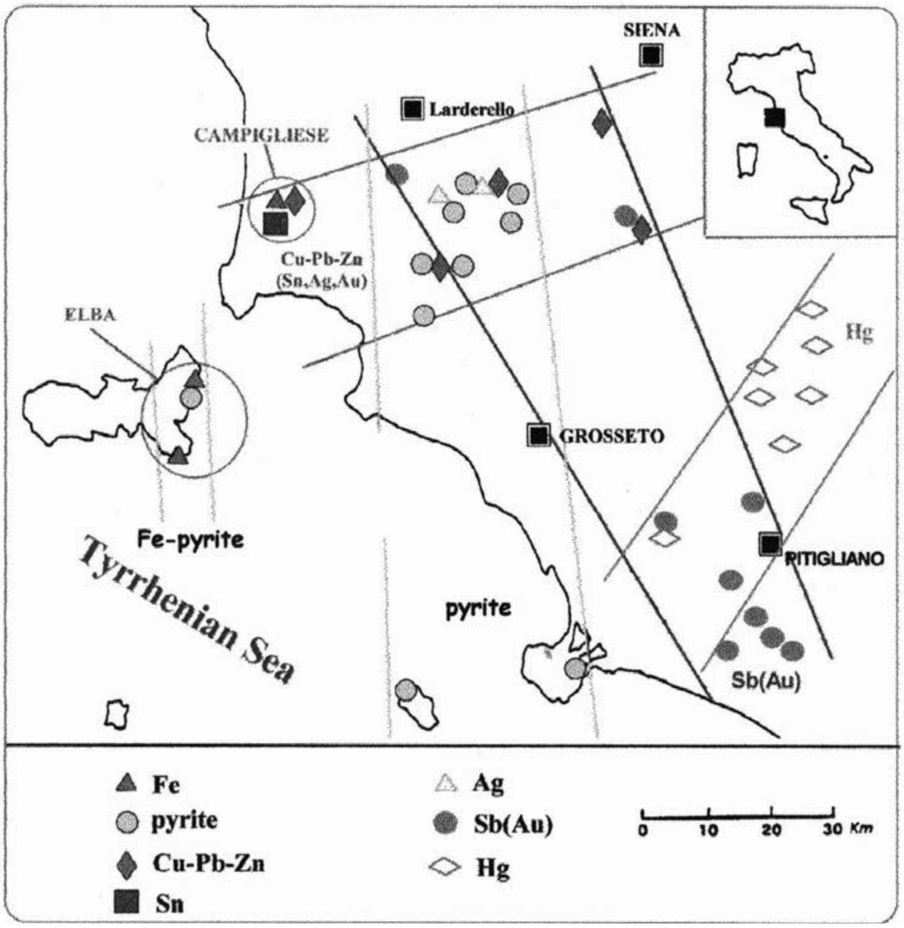

Fig. 5 - Location of the most important ore deposits of Southern Tuscany and of Elba Island (after Tanelli and Lattanzi, 1983, modified).

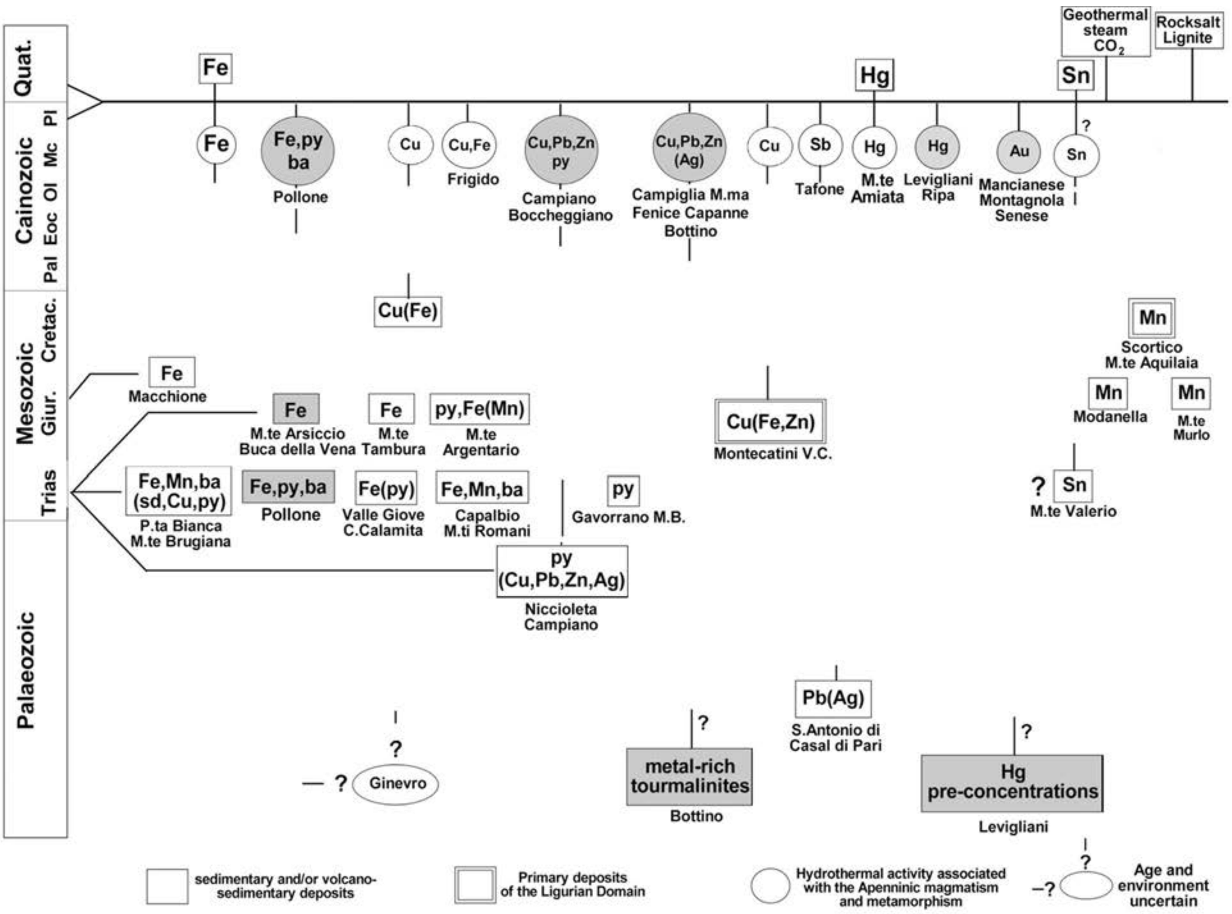

Fig. 6 - Metallogenic evolution of Tuscany (after Lattanzi et al., 1994).

and/or hydrothermal-sedimentary environments of Paleozoic-Triassic age. For more details on both descriptive and genetic features of Elba iron ores, as well as their general metallogenic framework (Fig. 1), the reader is referred to Tanelli et al., (2000).

THE TECTONIC EVOLUTION

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The complex structure of the Island, which includes units of the Tuscan, Ligurian and Piedmontese Domains, makes it difficult to reconstruct its tectonic evolution (see Bortolotti et al., 2000a). In any case three stages can be recognised:

Accretionary stage

This stage includes all the events that piled up the Ligurian and Liguria-Piedmontese on the Tuscan Units, culminated with the deformation of the Adriatic paleomargin. Deformation and horizontal displacement began in the oceanic domain in the Eocene (or Late Paleocene) and went on during the Late Eocene, Oligocene and Early Miocene, during collision and ensialic thrusting (Boccaletti et al., 1980; Principi and Treves, 1984; Carmignani and Kligfield, 1990). During these last events the Porto Azzurro, Ortano, Monticiano-Roccastrada, Tuscan Nappe Units, but also the Acquadolce Unit (which has a Piedmontese affinity and is correlatable with the Corsica and Gorgona Islands “Schistes Lustrés”) acquired their main deformational imprint. Its metamorphic imprints, in fact, has an age of 19-20 Ma (Deino et al., 1992). In Southern Tuscany (Roselle, Mt. Argentario areas), east of Elba I., Early Miocene was also the time in which the successions with “Schistes Lustrés” affinity were thrust on Tuscan Units.

Pre-intrusion extensional stage

The extensional processes are linked to the uplift of the Apenninic orogen, caused by both the isostatic re-equilibration at the end of the nappes stacking, and the uplift of the asthenosphere in the area where the Tyrrhenian Sea will open (Boccaletti e Guazzone, 1972; Boccaletti et al., 1985; 1990; Malinverno and Ryan, 1986; Channel and Mareshal, 1989; Jolivet et al., 1991; Kastens and Mascle, 1990; Serri et al., 1991; Carmignani et al., 1995). The beginning of these processes in the Tyrrhenian area corresponds to the opening of the Corsica Basin during the late Burdigalian-Langhian (Bartole et al., 1991). Likely, at this time also the Elba tectonic building began to be completed, through low angle faults, which dismembered and juxtaposed units coming from different structural levels (e.g. the tectonic intercalation of the Acquadolce Unit between two Tuscan Units) somewhere linked to high angle transfer faults. This tectonic regime produced also the first normal fault systems.

Syn- and post intrusion stage

The emplacement of the Mio-Pliocenic intrusive bodies (Mt. Capanne and La Serra-Porto Azzurro monzogranites) caused the thermometamorphism and the horizontal movements of the Elba Units (see Trevisan, 1950, and more recently Pertusati et al., 1993; Boullin et al., 1994; Daniel and Jolivet, 1995). The main low angle surface which separates the Porto Azzurro Unit from the overlying tectonic pile (Zuccale Fault) had probably two movement phases, the first one, with the main displacement, linked to the Mt. Capanne pluton uplift, the second minor phase linked to the La Serra-Porto Azzurro pluton uplift: in fact, all the dikes of the last pluton end upwards at the fault surface. Only in more recent times originated the main part of high angle normal faults, to which the hematite-rich minerogenetic and hydrothermal processes are connected.

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