B - EASTERN ELBA

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THE METAMORPHIC TECTONIC UNITS AND THE FE-ORES BETWEEN PORTO AZZURRO AND RIO MARINA (EASTERN ELBA)

M. Benvenuti and E. Pandeli

In the eastern Elba Island the tectonic pile is well exposed (Barberi et al., 1967; 1969). In this part of the field trip (Fig. 1) we will visit the best outcrops of the lowermost tectonic units (from the bottom: Porto Azzurro, Ortano, Acquadolce and Monticiano-Roccastrada Units), to recognise their tectonic relationships (Fig. 2) and the setting of the hosted Fe-ore bodies.

From Portoferraio to Porto Azzurro. A few kilometres beyond Porto Azzurro, along the road to Rio Marina, we turn right to the Spiaggia di Reale.

Stop 1 - *The tectonic units of the Spiagge Nere area (Fig. 3).*

In this area the contact (Zuccale Fault) of the Porto Azzurro Unit with the overlying embricate units (Acquadolce Unit and Monticiano-Roccastrada Unit) crops out.

a- Mt. Calamita Formation (Calamita Gneiss Auctt. *pro parte)*, is made up of grey to grey-greenish polydeformed micaschists whose protolith is probably Paleozoic in age (Puxeddu et al., 1984; Pandeli et al., 1994). The Alpine main schistosity has an attitude of N120/45 or N310/25 and is strongly overprinted by static thermometamorphic minerals (e.g. static biotite) due to the La Serra-Porto Azzurro monzogranitic intrusion (5.4-6 Ma radiometric age: Borsi and Ferrara, 1971; Saupé et al., 1982; Ferrara and Tonarini, 1985; 1993), which crops out west of this area (Barbarossa Beach). The micaschists do not show Fe-mineralisations and are cross-cut by centimetric/decimetric white tourmaline-bearing aplites, which belong to the dike network of the Messinian granitoid. These dikes are locally dissected by N250-trending shear bands. The top contact with the overlying mineralised cataclastic horizon is sharp and the dikes end abruptly against this surface. The contact is gently dipping to the W/WNW. Looking to the North, we can see a fine view of the Terranera Lake and of the mining area. We go 5-6 m up the cliff to the beginning of a canyon which is cut in the cataclastic rocks.

b- Zuccale cataclasite (Zuccale Fault). It is an about 10 m-thick horizon consisting of an ochre-yellowish, often foliated polymictic breccia. Its clasts (millimetric up to 10-15 cm) derive mostly from the underlying Mt. Calamita Fm. (micaschists cut by aplitic dikes more or less kaolitised) and from the overlying Monticiano-Roccastrada Unit (e.g.: the black graphite phyllites of the Rio Marina Fm.). The angular/subangular clasts are generally aligned along the foliation and the whole rock is affected by pervasive Fe-oxides /hydroxides mineralisations and by decimetric/metric asymmetric to overturned W-facing folds. Moreover, clasts and metric, more or less minera1ised, tectonic slices of the Acquadolce Unit (green quartzitic phyllites) are included in the breccia; one of these slices, tectonically capped by the graphitic Rio Marina Fm., crops out along the road to the cottage.

Fig. 1 - Itinerary and stops

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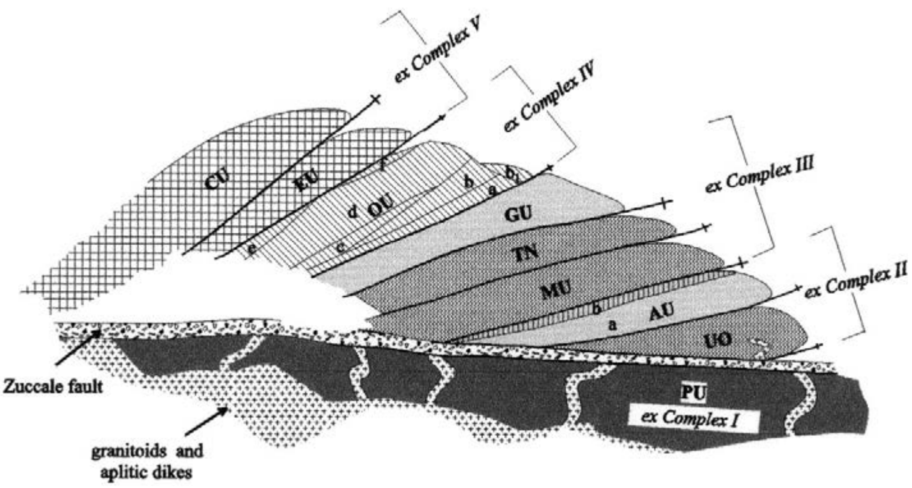

Fig.-2 - The central and eastern Elba I. tectonic pile according to Bortolotti et al. (2001). PU- Porto Azzurro Unit; UO- Ortano Unit; AU- Acquadolce Unit (a. Porticciolo Subunit, b- St. Flomena S.); MU- Monticiano-Roccastrada Unit; TN- Tuscan Nappe; GU- Gràssera Unit; OU- Ophiolitic Unit (a- Acquaviva Subunit; b- Mt. Serra S.; b_1- Capo Vita S.; c- Sassi Turchini S.; d- Volterraio S.; e- Magazzini S.; f- Bagnaia S.); EU- Paleogene Flysch Unit; CU- Cretaceous Flysch Unit.

The Carboniferous-Permian Rio Marina Fm. (Monticiano-Roccastrada Unit) tectonically rests on the cataclastic horizon. This formation includes black graphitic phyllites with grey quartzitic metasiltstones and metasandstones locally imprinted by thermometamorphic biotite or andalusite spots.

We continue down to Spiagge Nere where the tectonic breccia is well exposed.

c- Zuccale cataclasite. Here the foliated breccia (plunging to the N or W) includes also many carbonatic and rare foliated, more or less chloritised serpentinite clasts in a dominant phyllitic-carbonate matrix. Metric tectonic slices of whitish to yellowish bedded marbles and grey-whitish calcschists are locally present within the cataclastic horizon. These carbonate rocks probably belong to the Acquadolce Unit (Ortano Marbles, Calcschists) or correspond to the Mesozoic cover of the Porto Azzurro Unit. The marbles show pervasive cataclastic textures, while the calcschist and phyllite levels are also boudinaged even at a sub-centimetric scale. Microscopic observations reveal the absence of blastesis along the pervasive foliation of the cataclastic horizon, indicating that the thermometamorphism predates the cataclastic event. These data point to a "cold" nature of this cataclastic horizon, which was formed after the intrusion of the La Serra-Porto Azzurro monzogranite. Therefore, the foliation of the breccia seems to be due to mechanical iso-orientation of its clastic elements, possibly in a fluid-rich environment. Several kinematic indicators (asymmetry of folds, intrafolial "mantled" or faulted clasts, etc.) reveal a "top to NE" or a "top to SW" sense of shear. The opposite sense of shear could suggest a repeated utilisation of this cataclastic horizon during the last emplacements of the eastern Elba Units. Finally, in this outcrop the foliation appears gently folded, possibly by a later deformation event.

The promontory, which closes to the north Spiagge Nere, is made up of the Mt. Calamita Fm. (see before, a-). The contact with the overlying cataclasite horizon has an antiformal shape. The cataclastic horizon disappears northwards, below the quartzites and the green to whitish-pearly phyllites of the Triassic "Verrucano". This latter represents the core of a NW-SE trending syncline of the Monticiano-Roccastrada Unit.

We reach the eastern part of the beach in front of the Terranera Lake.

Stop 2 - *Fe-ores of the Terranera area* (Fig. 3).

Here the graphitic phyllites and quartzites of the Rio Marina Fm. crop out, cross-cut by N320-360 trending fractures and faults filled by hematite±quartz±adularia mineralisations. Eastwards, beyond a main mineralised fault, the uppermost levels of the Acquadolce Unit (serpentinite altered in talcschist tectonically covering chloritic phyllites and metasandstones) underlie the Rio Marina Fm.

The Fe-ores of the Terranera mine. Mining works at Terranera started in the 18th century and ended about 30 years ago. They were partially carried out by open pit excavations, now occupied by the Terranera Lake, fed by both fresh and marine

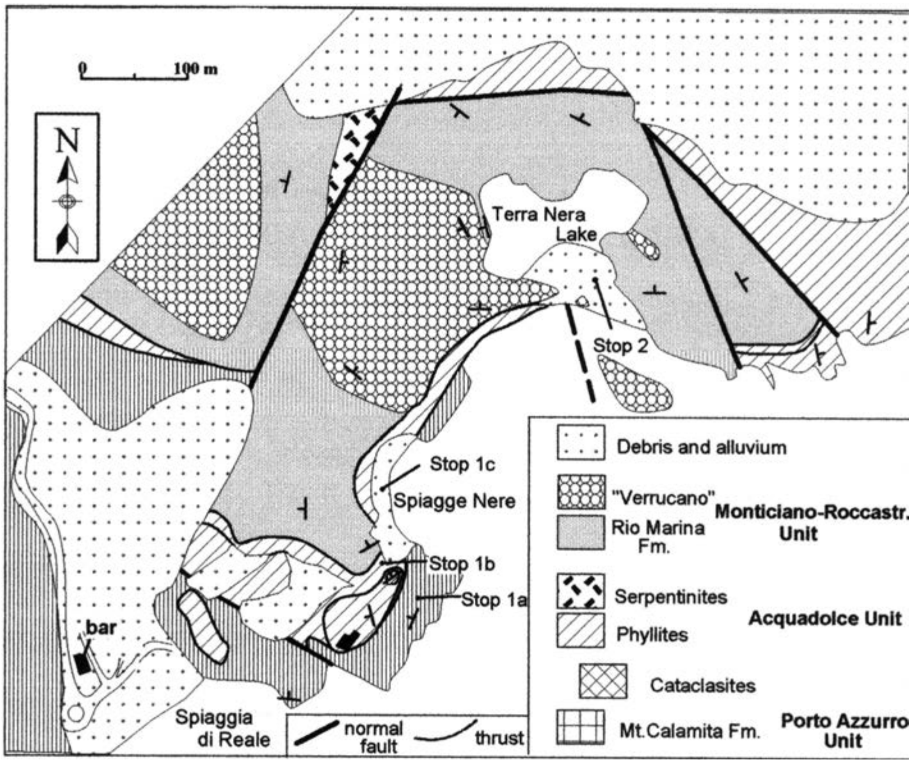

Fig. 3 - Geological map of the Spiaggia di Reale-Spiagge Nere-Terranera mining area.

waters. The exploited ores consisted of lenses of Fe oxides (hematite with minor magnetite) and pyrite at the tectonic contact between the Paleozoic basement (Rio Marina Fm., Trevisan's Complex III) and the overlying "Verrucano" succession. The upper portion of the deposit was predominantly constituted by limonitic masses, derived from the exogenous alteration of pyrite. According to Lotti (1886), the iron orebody extended even below the low-angle normal fault (Zuccale Fault) which separates the Rio Marina Fm. from the underlying Calamita Fm. (Trevisan's Complex I). The genetic processes leading to the development of this deposit still await to be better defined. Ongoing research should try to solve several problems, among which the predominance of hematite over magnetite (which is otherwise the dominant Fe oxide south of Rio Marina) and the relationships with the skarn bodies (extensively cropping out at the nearby Punta delle Cannelle).

We come back to Spiaggia di Reale and continue the road to Rio Marina. Along the road we cross many outcrops of ophiolites and of their cover (Ophiolitic Unit; see Stop.13). After the San Felo Pass, the serpentinite sheet at the top of the Acquadolce Unit is visible on the right, at the Mt. Fico quarry (see Stop. 3-i). At the round-about of Rio Elba, we turn to the right and reach the Ortano Residence.

Stop 3. *The tectonic stack of the Ortano Valley (Ortano, Acquadolce, Monticiano-Roccastrada, Tuscan Nappe, Gràssera Units).*

We walk along the southern part of the Residence as far as the wharf ruins; then we continue southwards along the quartzitic cliff (path) until a landslide.

Near the sea, phyllitic-quartzitic rocks crop out which represent the geometrical base of the non-fossiliferous, W-plunging **Ortano Unit** (Figs. 4 and 5). The Ortano succession recalls the Ordovician lower-middle part of the well-known Tuscan Paleozoic basement of the Apuan Alps (Pandeli et al., 1994) (Fig. 4), and of the central Sardinia (Nappe Zone Auctt., Pandeli and Puxeddu, 1990; Duranti et al., 1992). In particular (Fig. 5), this unit corresponds to the "Acidic metavolcanites and metasediments" (Porphyroids and porphyritic schists) and "Transgressive metasiliciclastic cover" (Silver-grey phyllites and quartzites, Capo d'Arco Schists). The lithological-petrographical similarities of the Capo d'Arco Schists and the Silver-grey phyllites and quartzites (below and above the Porphyroids, respectively) could suggest that they represent the same stratigraphical unit at the top of the Porphyroids. Therefore, the Ortano Unit as a whole may represent an east-vergent megafold with the Porphyroids at the core.

a- Capo d'Arco Schists. (Ortano Schists Auctt.) (Ordovician?). They consist of grey-greenish to brown phyllites, quartzitic phyllites, micaschists and minor quartzites which include typical syn- and post-tectonic quartz veins and local thermometamorphic "spots". Locally, graphitic phyllite levels are present. In the surrounding areas, the Capo d'Arco Schists include lenticular, metric to decametric horizons of coarse pale-grey/whitish quartzites and quartzitic metarudites. Looking to the SE, the morphological discontinuity in the Isolotto d'Ortano corresponds to the contact between a quartzitic body and the metapelites of the Capo d'Arco Schists.

Coming back along the path up to the wharf, we can see well exposed outcrops of the overlying Porphyroids.

b- Porphyroids (Midd1e Ordovician?). They are massive to poorly stratified, grey to brownish acidic metavolcanites which are characterised by a millimetric (3-4 mm) augen texture due to quartz and feldspar porphyroclasts. In the middle and upper parts of this unit, the levels of augen quartzites and quartzitic phyllites ("Porphyritic Schists") probably correspond to volcanic-rich metasediments. Post-tectonic veins of chlorite+quartz+epidote±tremolite/actinolite locally occur.

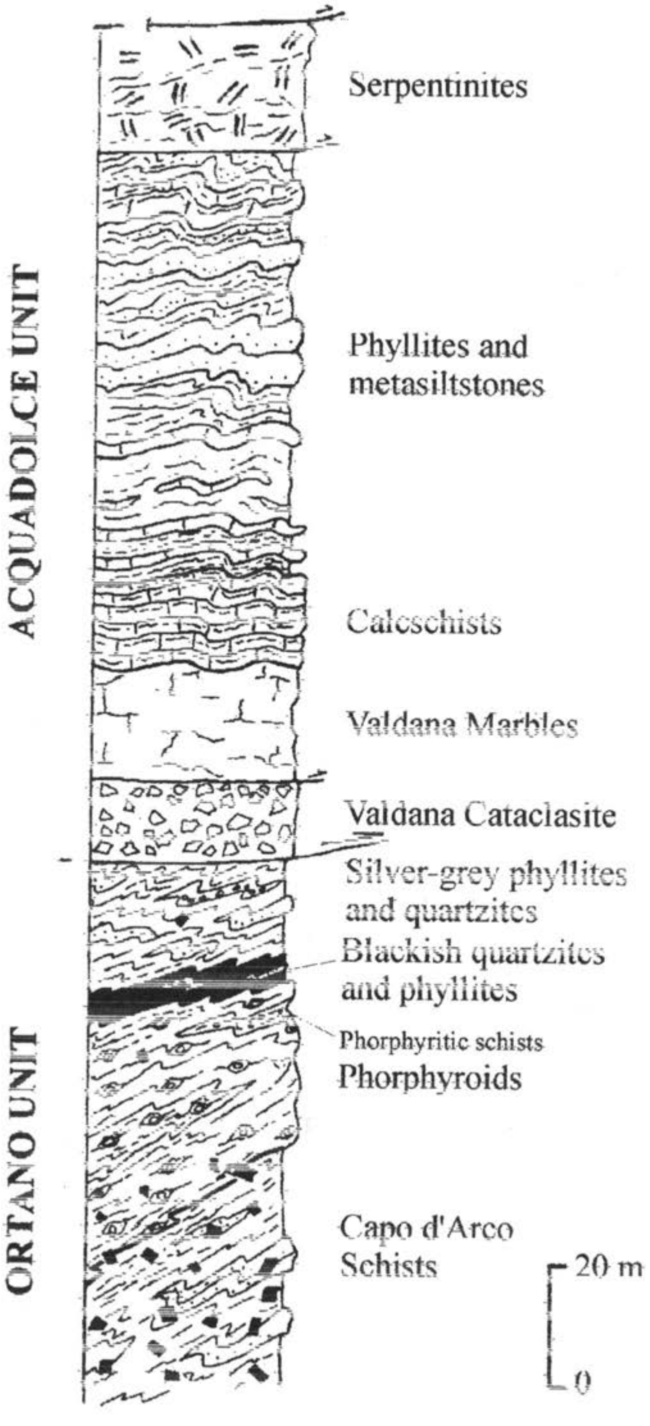

Fig. 4 - Tectonic-stratigraphic sketch of the Ortano and Acquadolce Units (thicknesses of the formations, approximate).

We continue along the white road until a little square in front of the theatre of the Residence. At the top of the Porphyroids, black rocks are exposed.

c- Blackish quartzites and phyllites (Middle Ordovician?). This is a metric horizon of alternating dark-grey/black quartzitic phyllites and 10-20 cm-thick fine-grained quartzitic levels. These rocks pass upwards to:

d- Silver-grey phyllites and metasandstones (Late Ordovician?). They are shining silver-grey phyllites with pale grey/whitish, decimetric to metric, locally coarse-grained quartzitic metasandstones and metaconglomerates. These lithotypes are locally crosscut by quartz±chlorite veins.

Walking along the road of the Residence, we reach the southern quarry, where we can observe the lower formations of the metamorphic **Acquadolce Unit,** plunging westwards. The Acquadolce Unit (Fig. 4) was traditionally interpreted as a Mesozoic-Cainozoic Tuscan-type metamorphic sequence (Trevisan, 1951; Barberi et al., 1969; Perrin, 1975; Boccaletti et al., 1977; Keller and Pialli, 1990) which represented the “cover” of the underlying Paleozoic rocks (Ortano Unit). On the contrary, Duranti et al. (1992) and Pertusati et al. (1993) considered it as a part of the Ophiolitic Unit (Trevisan’s Complex IV*)* which was deformed and metamorphosed by the intrusions of the Messinian-Pliocene granitoids. On the other hand, Corti et al. (1996) correlate this succession to the “Schistes Lustrés” of the Gorgona Island; the analogies of this sequence with the “Schistes Lustrés” were also pointed out by Termier (1910).

e- Valdana cataclasite. (“Calcare Cavernoso“ or “Vacuolar dolomitic limestone” Auctt.). It is a 10-15 m thick, pale grey to yellowish carbonate rock, roughly stratified and affected by variable recrystallisation which often obliterates the previous textures. Locally it is a vacuolar, well-cemented calcareous breccia with marble and subordinate phyllite clasts (more frequent in the lower part). Dolomitic horizons are locally present. In spite of the recrystallisation, cataclastic textures are frequent at the microscopic scale as scattered Fe-oxides and pyrite, especially in the carbonate-micaceous-quartzitic matrix. This unit is considered a tectonic breccia formed during the emplacement of the Acquadolce onto the Ortano Unit.

Locally, a thermometamorphic imprint is present (clinopyroxene±garnet±amphibole). Thick skarn (hedenbergite±ilvaite) horizons are associated to the cataclasite north of the Ortano Valley (Ortano pyrite±pyrrhotite mine). Therefore, this horizon represented an important pathway for the metasomatic fluids and Fe-ores (e.g. the Tignatoio and Porticciolo skarns and ores, north of the Ortano area, along the same structural alignment).

f- Valdana Marble (“Ortano Marble” Auctt., Cretaceous?). This unit is about 15 m thick and includes massive grey-whitish, medium to coarse grained, saccharoidal marbles with local yellowish bands and horizons of dolomitic marble. Rare and discontinuous millimetric phyllitic levels also occur.

The transition with the overlying calcschists is marked by an about 1 m thick alternating marble-calcschist horizon. Along this contact decimetric folds are locally present.

We cross the valley and reach the same contact behind the souvenir shop.

g- Calcschists. This more than 50 m thick unit is made up of 10-40 cm thick, grey and grey-greenish calcschists beds with millimetric grey green to black phyllite layers. Siliceous white quartzitic bands and nodules (metacherts) are present, particularly in the middle-upper part of the succession along the road (about 100 m after the souvenir shop). Veins of caIcite±pyrite±quartz and adularia are ubiquitous. The contact with the overlying phyllites with calcschists intercalations is gradual.

We continue along the road for about 200 m.

h- Grey and greenish phyllites and metasiltstones, with calcschist intercalations (Early Cretaceous). They are represented by a more than 250 m-thick succession of grey, grey-greenish and black quartzitic phyllites and metasiltstones with local decimetric/metric levels of calcschists and rare grey-greenish metagraywackes. Post tectonic veins of adu1aria±tremolite/actinolite±albite are locally present. North of Ortano (Porticciolo area), Duranti et al. (1992) found radiolarians, calpionellids and globigerinids of Early Cretaceous in the carbonate intercalations.

200 m ahead along the road, to the

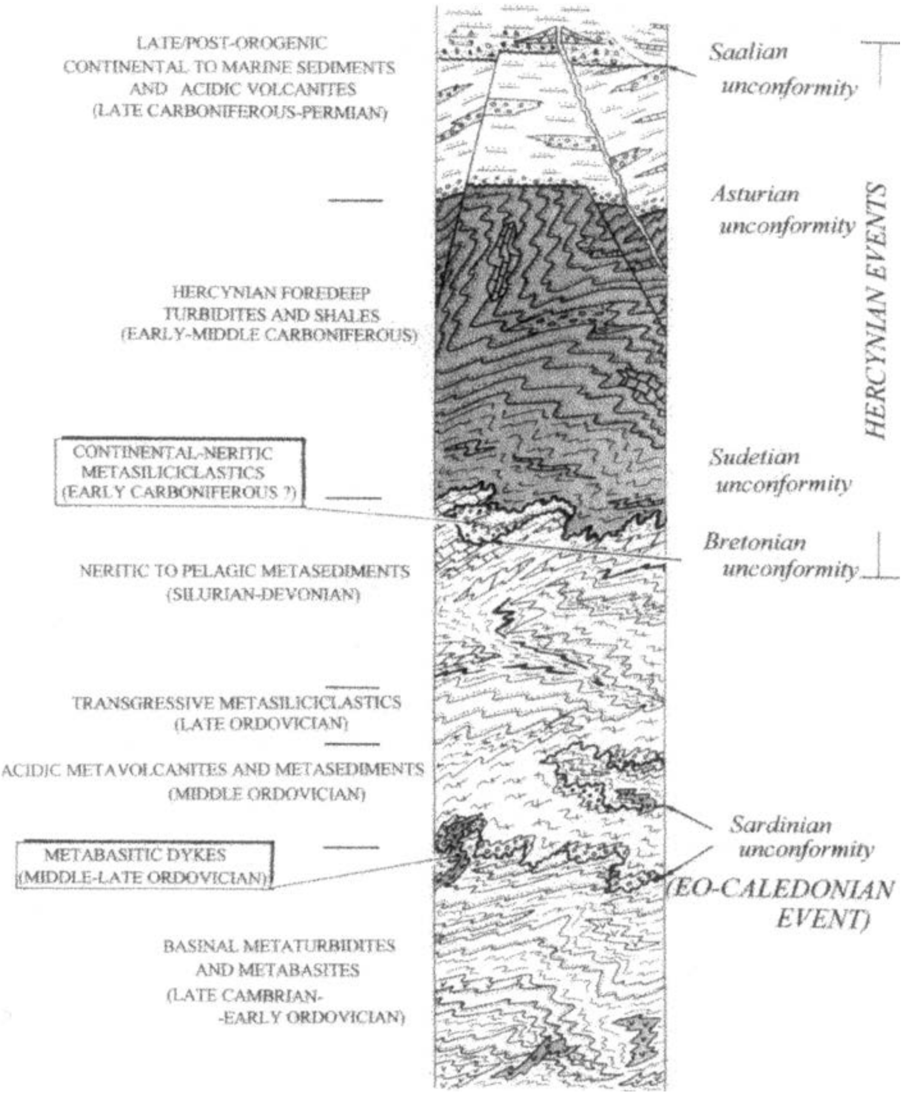

Fig. 5 - Restored “type”-succession of the Northern Apennines Paleozoic basement (after Elter and Pandeli, 1996).

right (near a house) the serpentinite sheet at the top of the Acquadolce Unit crops out.

i- Serpentinite. It is massive dark green serpentinite (lherzolite) about 100 m thick. Local shear bands and foliation are present.

We reach the curve of the road close to a small house (to the left), where the Monticiano Roccastrada Unit is thrust onto the serpentinite of the Acquadolce Unit.

The **Monticiano Roccastrada Unit** (Fig. 8) includes here only the Rio Marina Fm.

l- Rio Marina Formation (Late Carboniferous-Early Permian). In this section the maximum thickness of this formation is about 50 m. Its lithologies are black graphitic phyllites and metasiltstones with grey quartzitic metasandstone intercalations. Post tectonic veins of quartz±pyrite are locally observed.

After the curve of the road, a high-angle, west-plunging normal fault (Terranera Fault) puts in contact the Rio Marina Fm. with the basal carbonate breccia (“Calcare Cavernoso”) of the **Tuscan Nappe**.

m- “Calcare Cavernoso”. Its thickness is about 150 m. A massive grey, cataclastic, calcareous-dolomitic breccia, locally characterised by vacuolar structures, is the dominant lithotype. At times, grey-pearly and greenish phyllitic clasts and quartz grains are present. Calcite±Fe-oxides/hydroxides also occur. Horizons or metric boulders of poorly stratified Triassic dolostones and dolomitic limestones are sometimes recognisable as well as karst alterations and sedimentary fillings (yellowish carbonate sand).

About 300 m ahead, we find the tectonic contact (by a system of high angle normal faults) (St. Caterina Fault) between the “Calcare Cavernoso” and the **Gràssera Unit** (Cavo Fm., see Stops 8 and 10).

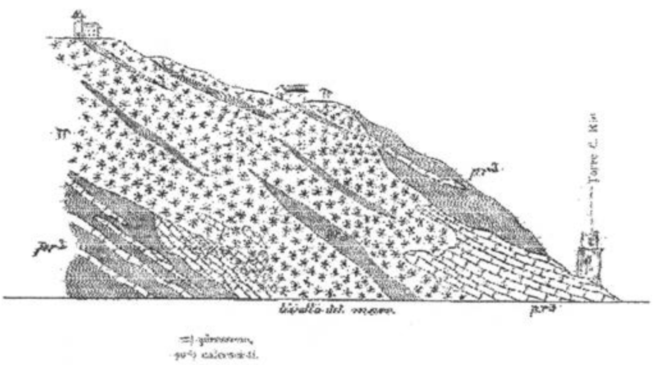

Fig. 6 - View from the sea of the skarn bodies at Torre di Rio (after Lotti, 1886).

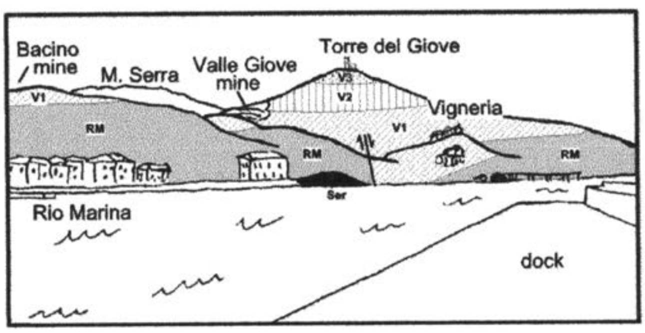

Fig. 7 - Panoramic view of the Rio Marina mines. Ser- serpentinites; RM- Rio Marina Fm. V- “Verrucano” Group (V1- Verruca Fm.; V- Mt. Serra Quartzites (V2- Green Quartzites Member; V3- White-pink Quartzites Member).

n- Cavo Formation. It consists of grey-greenish and vine-reddish slates and siltstones with syn-/post-tectonic quartz veins. Local blackish manganiferous levels and rare siliceous limestone beds are present.

The Gràssera Unit tectonically underlies the Palombini Shales of the Ophiolitic Unit.

The trip continues coming to the round-about of Rio Elba and reaches the central square of Rio Marina (in front of the panoramic dock). We walk along the dock as far as the old tower with the clock and then we took the road on the right, along the cliff.

Stop 4. *The calcschist bodies and the skarn of Torre di Rio.*

The calcschist bodies. Here the upper portion of lower subunit (Porticciolo Subunit) of the Acquadolce Unit crops out. It is represented by a NW-plunging succession of centimetric to decametric marbles and calcschists (a metric grey/whitish calcschist is well exposed along the road) with minor grey/greenish quartzitic phyllites. Going on the road, all the rocks show more and more evidence of hydrothermalism (yellow-green epidote) which obliterates the tectono-metamorphic texture. The appearance of fan-shaped hedenbergite crystals marks the contact with the Torre di Rio skarn.

The skarn of Torre di Rio. This skarn is exceptionally well developed (Fig. 6). It preferentially replaces the calcareous interbeds in the phyllites of the Acquadolce Unit, forming large, almost monomineralic masses of epidote, hedenbergitic pyroxene and ilvaite, with associated quartz, chlorite and minor amounts of iron minerals (magnetite, pyrite and pyrrhotite), which justified a limited exploitation activity in the past. Mesoscale textures clearly indicate that the calcschist are replaced by skarn minerals occurring preferentially along the schistosity planes of the rock, as already pointed out by Lotti (1886, p. 205-206).

Here, in 1802 were described for the first time some black, prismatic crystals, vertically striated and with submetallic luster, subsequently attributed to a new mineral species, called “ilvaite” after the Latin name (“Ilva”) of Elba Island.

We come back to the clock tower and continue along the dock to the small tower.

Stop 5. *The Rio Marina mining area*

This tower is built on a decametric horizon of grey-whitish to grey-greenish calcareous interbeds within the phyllites of the Acquadolce Unit. Synmetamorphic tight to isoclinal folds with a pervasive axial plane schistosity are well exposed. Deino et al. (1992) obtained a $^{40}Ar/^{39}Ar$ radiometric age of 19-20 Ma for this schistosity.

Looking to NW (Fig. 7), the landscape is dominated by the Rio Marina mines (from the left: Bacino, Zuccoletto, Valle Giove and Vigneria mines) and by the Mt. Torre del Giove, with the ruins of a castle of the 16^{th} century. The Rio Marina ores are hosted in the Permo-Carboniferous (Rio Marina Fm.) and in the Triassic “Verrucano” Group metasiliciclastics of the Monticiano-Roccastrada Unit (Fig. 8). To the north of the last house of Rio Marina (Fig. 7), the tectonised serpentinite lying at the top of the Acquadolce Unit crops out and is tectonically covered by the Permo-Carboniferous metasediments of the Rio Marina Fm. (graphitic phyllites and metasiltstones with quartzitic

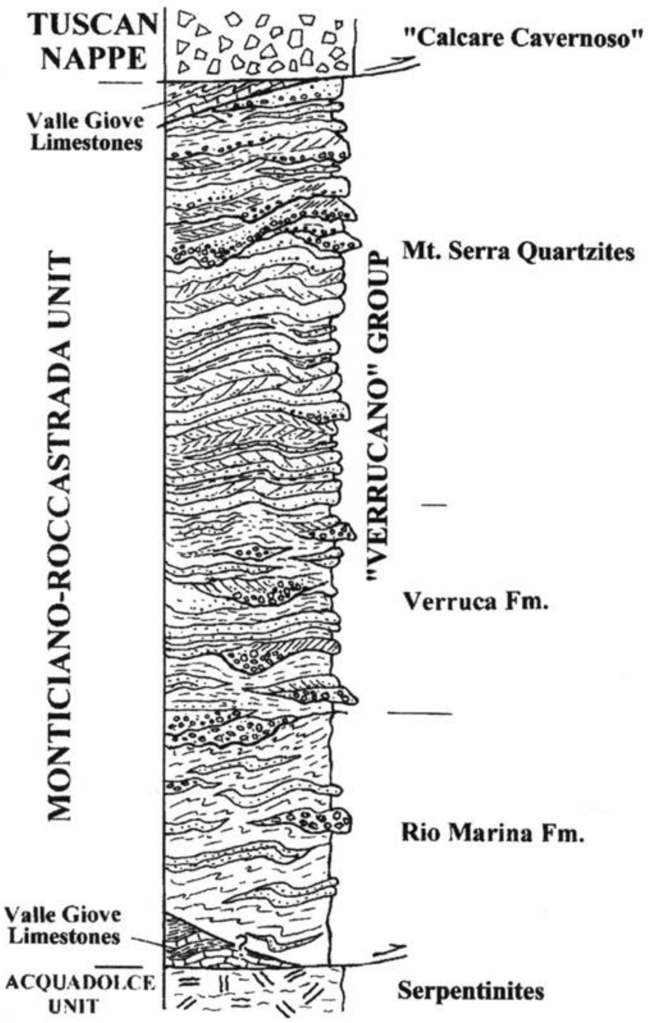

Fig. 8 - Tectonic and stratigraphic sketch of the Monticiano-Roccastrada Unit (the thicknesses of the formations are approximate).

metasandstones and minor metaconglomerates. Paleoenvironment: deltaic-coastal). Behind Rio Marina and Vigneria (Torre del Giove) (Fig. 7), the whole "Verrucano" Group succession crops out at the top of the Rio Marina Fm.

Geology of the Rio Marina mines.

The "Verrucano" Group metasediments represent the basal transgression of the Alpine sedimentary cycle. The "Verrucano" succession of Elba Island (Deschamps, 1980; Deschamps et al. 1983; Pandeli, in progress), probably late Ladinian-Carnian in age and more than 350 m thick, is made up of three lithological units correlatable with the "Verrucano" Group succession of the Pisani Mts. (Rau and Tongiorgi, 1974). From the base to the top they are:

Verruca Formation. It widely crops out in the mining areas behind and to the north of Rio Marina (e.g. Bacino, Valle Giove and Vigneria). This formation is made up of violet and minor greenish phyllites and metasiltstones, laminated quartzites and lenticular (up to 4-5 m thick) quartzitic metaconglomerates. Paleoenvironment: continental with medium to high sinuosity rivers.

Monte Serra Quartzites. They are exposed in the upper part of the Valle Giove mine and on the eastern flank of the Mt. Torre del Giove. Two members were distinguished; from the base they are: 1- *Green quartzites Member (= "Quarziti verdi")* Parallel- to cross-stratified (e.g. herring-bone cross-bedding), pale grey-greenish quartzites with phyllitic interbeds and rare metaconglomerates. Paleoenvironment: littoral. 2- *White-pink quartzites Member (= "Quarziti bianco-rosa")*. Prevailing quartzitic pale grey/pink metaconglomerates and quartzites with minor phyllitic levels. Paleoenvironment: deltaic?

In the westernmost part of the Valle Giove mine, slices of non-fossiliferous, varicoloured marbles, calcschist and calcareous phyllites (Valle Giove Limestones) are tectonically intercalated in "Verrucano" succession or underlie the "Calcare Cavemoso"(see Fig. 8). Similar lithotypes are also present in the Vigneria sub-surface (Vigneria Limestones, Fig. 8) tectonically interposed between the serpentinite and the Rio Marina Fm. These varicoloured lithotypes probably represent tectonic slices of an epimetamorphic Tuscan succession of Mesozoic-Cainozoic age (e.g. the Capo Castello succession of the Stop 7).

The Fe-ores of the Rio Marina mines. The iron deposits occurring at Rio Marina and northwards of it, almost up to Cavo (Valle Giove, Rialbano, etc.) are constituted by stratiform, massive or vein bodies, hosted by Trevisan's (1950) Complex III rocks, preferentially at the contact between Permo-Carboniferous phyllites (Rio Marina Fm.) or quartzitic/phyllitic rocks ("Verrucano", Middle Triassic) and the overlying calcareous levels ("Calcare Cavemoso"). According to some authors (cf. Gillieron, 1959) in the northern sector (Cala Seregola, Rialbano) the setting of orebodies is markedly controlled by tectonic lineaments, produced during the Apenninic event. Nevertheless, at least at Rio Marina (Valle Giove area), Deschamps et al. (1983) recognised the occurrence of stratiform pyrite mineralisation within a particular horizon of the "Verrucano", which could represent the relic of a syngenetic iron protore. All these deposits include hematite as the main ore mineral (variety "oligisto"), which may show either a typical lamellar-micaceous habitus or flattened, rhombohedral crystals, often covered by iridescent films of iron hydroxides. Pyrite is also common, predominantly as pyritohedra, although octahedra or cubes have been observed as well. Exogenous limonites, massive or concretionary (sometimes stalactitic) may locally constitute the main ore minerals, especially at Rialbano and other northern mineral showings. To be noticed that in the 50's-60's underground mine workings partly exploited a hematite pyrite orebody associated with skarn silicates, known in the literature as "Rio Marina profondo". The scarcity of geologic documentation and the unaccessibility to underground workings do not allow to study in more detail the otherwise peculiar setting and mineralogic features of the deposit.

The trip continues along the road to Cavo.

After the Vigneria mine the graphitic Rio Marina Fm. crops out as far as to the Ripabianca area where the contact with the basal phyllites and quartzites of the "Verrucano" Group succession is exposed (beyond a wire-net protection).

We cross the Rialbano Creek (view on the Mt. Sassera cliff, made up of Mt. Serra Quartzites) and go up (outcrops of Triassic violet phyllites and pink quartzites of the Verruca Fm.) of the Rialbano mining area (hematite+limonite±pyrite). Here the mineralised high-angle contact between the basal "Verrucano" and the slates of the Gràssera Unit is due to an east-plunging normal fault (Punta del Fiammingo Fault). At the top of the Mt. Calendozio, Triassic dolomite limestones tectonically rest onto the Mt. Serra Quartzites ("Verrucano" Group).

About 1 km ahead, along the road, the Gràssera Unit is in tectonic contact (Punta del Fiammingo Fault) with the Rio Marina Fm.

We continue as far as Fornacelle Creek (close to the Cala del Telegrafo).

THE TUSCAN NAPPE SOUTH OF CAVO

M. Fazzuoli

In the Eastern Elba Island, south of Cavo, a sedimentary succession, pertaining to the Tuscan Nappe, crops out. This link has been recognised by many Authors for a long time (e.g. Cocchi,1871; Lotti,1886; Trevisan, 1950; Barberi et al., 1969; Perrin, 1975; Boccaletti et al., 1977).

From the bottom upwards, the sedimentary succession consists of the following formations (Fig. 9):

"Calcare Cavernoso", Pania di Corfino Fm., Mt. Cetona Fm., "Calcare Massiccio", Grotta Giusti Cherty Limestones, "Rosso Ammonitico", Limano Cherty Limestones, Posidonia Marlstones (see Bortolotti et al., 2001).

From le Fornacelle Creek northwards, along the Road Rio Marina - Cavo, most of these formations crop out.

Stop 6. ***The Tuscan Nappe succession***

Owing the severe block faulting of the area, it is not possible to observe a continuous stratigraphic succession, but four partial, stratigraphic intervals, all along the main road.

Interval 1 (see Fig. 10)

Mt. Cetona Formation. From Fornacelle Creek up to the fault in correspondence of the road bend overlooking Cala del Telegrafo.

The main lithotypes, are dark grey calcilutites, up to 1 m thick, abundant marlstones cm- to dm- thick, and dolomitised calcilutites or coarsely crystalline dolomites, 1 to 2.5 m thick. In the upper portion of the formation, dark grey, 20-50 cm thick, bioclastic and oolitic grainstones and packstones beds crop out. Dm-thick coquina beds, corresponding to storm-layers, also occur.

Interval 2 (see Fig. 10)

Grotta Giusti Cherty Limestones **(**upper portion). The formation consists of grey calcilutites and subordinately fine calcarenites, 5-100 cm thick (mainly 10-20 cm) with abundant horizontal laminations and rare chert nodules and silicified areas. Cm-thick shaly beds are frequent, as well as dm-thick beds of more or less shaly marlstones. The beds plunge 30-50° northwards. The transition with the overlying formation is stratigraphic.

Rosso Ammonitico. The section consists mainly of pink or pale grey calcilutite beds, up to 70 cm thick (prevailing thickness is 20 cm), with cm-thick, grey or pink shaly beds. Grey chert nodules are present. Calcilutite beds, sometimes nodular, are intersected by abundant stylolites parallel to bedding or wavy. In the upper half of the section, 45 cm thick calcirudite bed occurs. Beds plunge 30-40° to the north.

Limano Cherty Limestones. Grey or pale brown or pinkish calcilutite beds with rare grey chert nodules constitute the main lithotype. In the lower portion of the section the beds, up to 140 cm thick, are intersected by abundant stylolites, parallel to the bedding. In the upper portion, 5-30 cm thick beds prevail. The bedding joints consist of stylolites and of mm-thick shaly and marly beds. Grey calcarenite beds up to 180 cm thick are present, as well as two 50 cm thick calcirudite beds with cm- to dm-sized calcareous and cherty clasts, and slump and debris flow structures. Most beds plunge 30-40° northeastwards.

Posidonia Marlstones. The lower half of the section mostly consists of grey or pinkish, slightly marly, calcilutite beds, up to 360 cm-thick, characterised by abundant stylolites parallel to the bedding and inclined cleavage joints. Grey calcarenites and calcirudites, up to 25 cm-thick are also present. The calcarenites show horizontal laminations; calcirudites show slump structures, graded bedding and laminations, indicating turbiditic and mass-flow processes.

The upper half of the section mostly consists of pale grey, more or less marly and silty calcilutite beds, up to 160 cm-thick, sometimes with parallel laminations. Grey shales and marlstones, cm- to dm-thick, often with slaty cleavage, are abundant. Dm-thick beds of dark grey calcarenites with filaments are present and, in the uppermost portion of the section, also five beds of calcirudites, 50 to 160 cm thick, with cm- to dm-sized calcareous and subordinate cherty clasts.

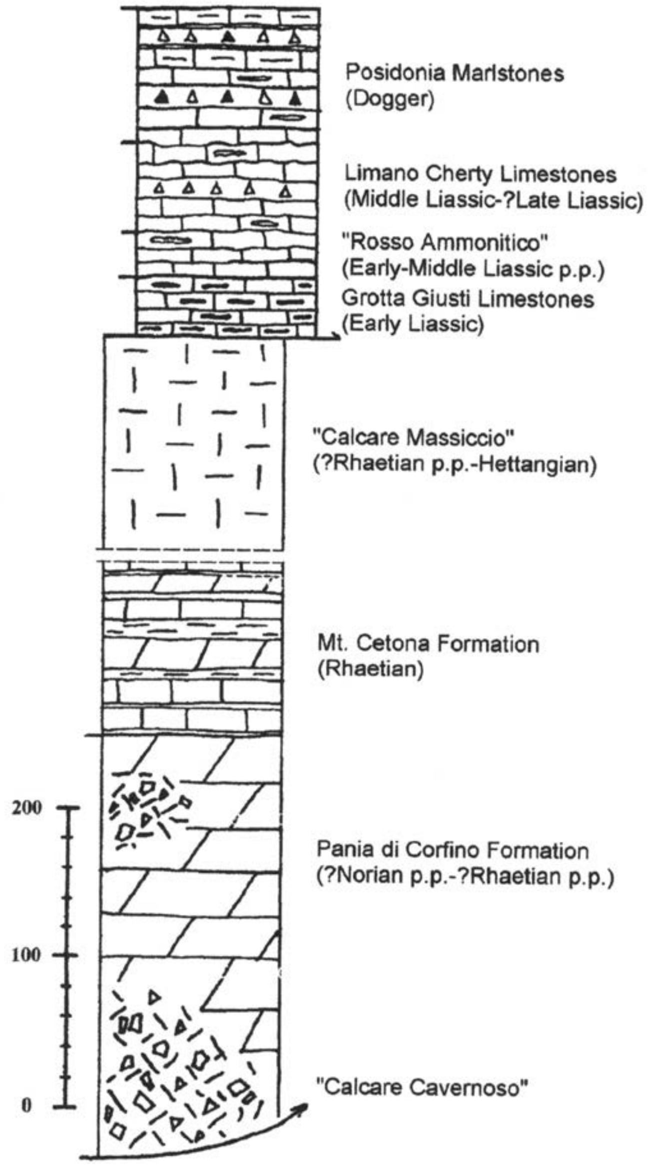

Fig. 9 - Schematic columnar section of the Tuscan Nappe succession.

Beds plunge 30°- 50° northwards (that is seawards). The outcrop of *Posidonia* Marlstones continues along the E-W oriented stretch of the road.

Going on towards Cavo, two normal fault, oriented SE-NW and N-S, individuate a minor horst of "Calcare Massiccio", with the *Posidonia* Marlstones to the East and Grotta Giusti Cherty Limestones (lower portion) to the West.

Interval 3 (see Fig. 10)

Grotta Giusti Cherty Limestones (lower portion). The outcrop consists of 5-15 cm-thick beds of dark grey fine calcarenites and calcilutites, horizontally laminated, with abundant beds and nodules of grey cherts. The beds plunge 30° to 50° northwards: here an east-west trending fold system deforms the earlier north-south system.

Interval 4 (see Fig. 10)

"Calcare Massiccio". The "Calcare Massiccio" crops out

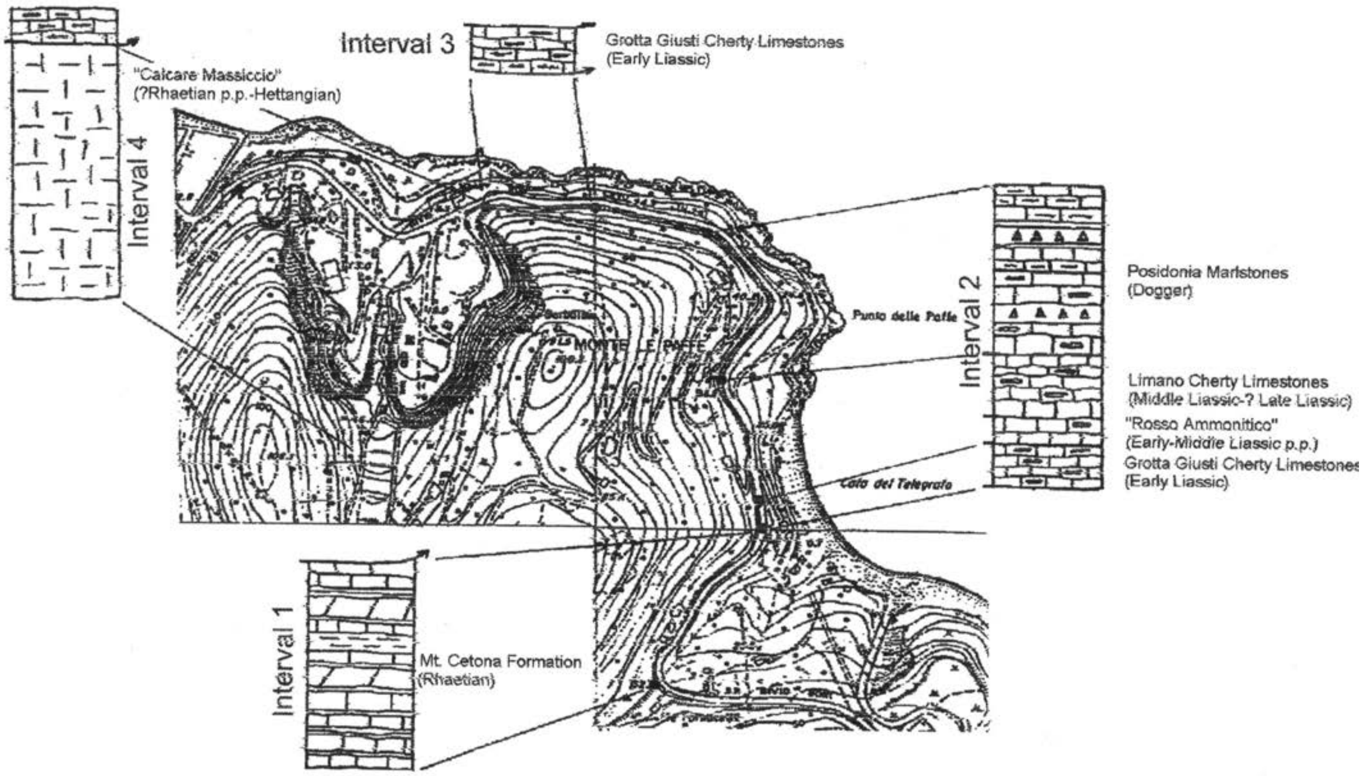

Fig 10 - Schematic columnar sections of the Tuscan Nappe succession at the Stop 6.

in a big quarry on the left side of the road (western slope of Mt. le Paffe). The formation consists of massive, pale grey or whitish calcarenites and calcilutites, sometimes intensely recrystallised and dolomitised. The quarry is intersected by pervasive fracture systems, the main of which trends east-west and plunges 70° northwards. On both sides of the quarry, the "Calcare Massiccio" is tectonically overlain by the Grotta Giusti Limestone.

THE TUSCAN EPIMETAMORPHIC SUCCESSION OF CAPO CASTELLO

E. Pandeli

We cross Cavo and continue northward as far as reaching the parking area of the Capo Castello (Fig. 11).

Stop 7. *The Tuscan epimetamorphic succession, Cala dell'Alga.*

In the parking area and along the beach to the north, the Palombini Shales of the Ophiolitic Unit crop out, which overlie a thick ophiolitic breccia (on the beach). Eastwards, a high-angle normal Cala dell'Alga Fault separates the Ligurid formations from the Capo Castello epimetamorphic rocks.

The Capo Castello fossiliferous metamorphic succession (cropping out also at the Capo Scandelli and the Isola dei Topi, to the north and to the south of the Capo Castello, respectively, see Fig. 11A) belongs to the Tuscan low-grade metamorphic succession of the Monticiano-Roccastrada Unit (Pandeli et al., 1995) and includes (from the bottom): **a**- Varicoloured cherty calcschists and crystalline limestones (Capo Castello Calcschists, Late Dogger?-Malm?); **b**- "Maiolica"-type, grey cherty limestones (?Early Cretaceous); **c**- Varicoloured phyllites and calcschists with metal-imestones and metacalcarenites (Varicoloured Sericitic Schists, Late Cretaceous/Eocene) and, **d**- metagraywackes ("Pseudomacigno", Oligocene). From the structural point of view, at least three ductile deformation events (D_1, D_2 and D_3), the first two syn-metamorphic in the greenschist facies, are distinguished.

From the parking area, we take the road to Capo Castello. After about 100 m, we turn to the right and go down a little road with stairs till the Cala dell'Alga. We turn left and reach the first two little rocky promontories along the northern side of the gulf. Here the **Varicoloured Sericitic Schists** are well exposed and clearly show their tectono-metamorphic imprint.

The "Varicoloured sericitic schists" are made up of varicoloured phyllites and calcschists with levels and metric bodies of recrystallised, at times cherty, grey limestones. These rocks show a main continuous penetrative schistosity (S_1 = calcite+sericite±quartz±hematite±chlorite), which is parallel to the lithological subdivisions (S_0) and is associated to the D_1 hectometric isoclinal, recumbent fold defined along the Cala dell'Alga-Capo Castello-Isola dei Topi alignment (see Fig. 11A and B).

The D_1 structures were deformed by the D_2 event into centimetric to decametric close to isoclinal synforms and antiforms (e.g. the synformal anticline of the eastern part of Capo Castello) with sub-vertical, NNW/SSE-trending axial planes and spaced, zonal to discrete crenulations (C_2/S_2 = hematite±sericite) (Fig. 12). Gentle to open folding, generally with sub-horizontal axial plane crenulations/kinking (C_3, Fig. 12) and fracture cleavage, represent the coaxial D_3 event and a possible anti-Apenninic-trending D_4 event.

The low-grade metamorphic succession of Capo Castello probably represents part of the pristine cover formations of the Triassic "Verrucano" metasediments belonging to the Monticiano-Roccastrada Unit and reconstructs in the Elba Island the stratigraphical typical succession of the Tuscan

Metamorphic Ridge (from the Apuan Alps-Mt. Pisano to the Monticiano-Roccastrada area).

Coming back to the parking area, the trip continues along the la Parata (from Cavo to Rio Elba) panoramic road.

THE GRÀSSERA AND OPHIOLITIC UNITS

V. Bortolotti, G. Principi and E. Pandeli

The la Parata road exposes the two lowest subunits of the Ophiolitic Unit (Mt. Serra and Acquaviva Subunits) and the underlying Gràssera Unit. From Cavo to Case Braschi we cross only the Gràssera Unit.

Stop 8. *The Gràssera Unit.*

We stop at a big curve of the road to the left, some hundred metres from Cavo. Here the upper portion of the Gràssera Unit (Cavo Formation, see Bortolotti et al, 2001) crops out. It consists of greenish and wine-red slates and siltstones with rare manganiferous siliceous limestones and cherts. These rocks show a pervasive slaty cleavage, deformed by open to close folds with a spaced fracture cleavage. Syn-tectonic quartz veins are also present.

Near Case Braschi we enter the **Ophiolitic Unit** (see Bortolotti et al., 2001; Fig 13), but the contact is covered by a slide. The first outcrops pertain to the Acquaviva Subunit. Here ophicalcites and Palombini Shales are tectonically repeated as lenses. At the watershed before the Gorgoli Creek we cross the thrust contact between the Acquaviva and the overlying Mt. Serra Subunit, represented here by Calpionella Limestones. This formation crops out for some hundred metres and no evident structures are visible along the road.

Stop 9. *The Gorgoli anticline.*

We stop at the bridge along the Gorgoli Creek ad go upstream some tens metres crossing the whitish and thick beds of the Calpionella Limestones; beyond a fault cutting the creek, we can observe the core of a big anticline trending NNW-SSE, with a NE vergence. On the right side a succession dipping to the NE crops out, here made up of: i- a few metres of pillow lavas, ii- a cliff some metres high of thin-bedded red cherts and siliceous shales (Mt. Alpe Cherts) and, iii- the Nisportino Fm., here formed, just from the base, by the pale grey marly calcilutites of the Rivercina Member. On the left side of the

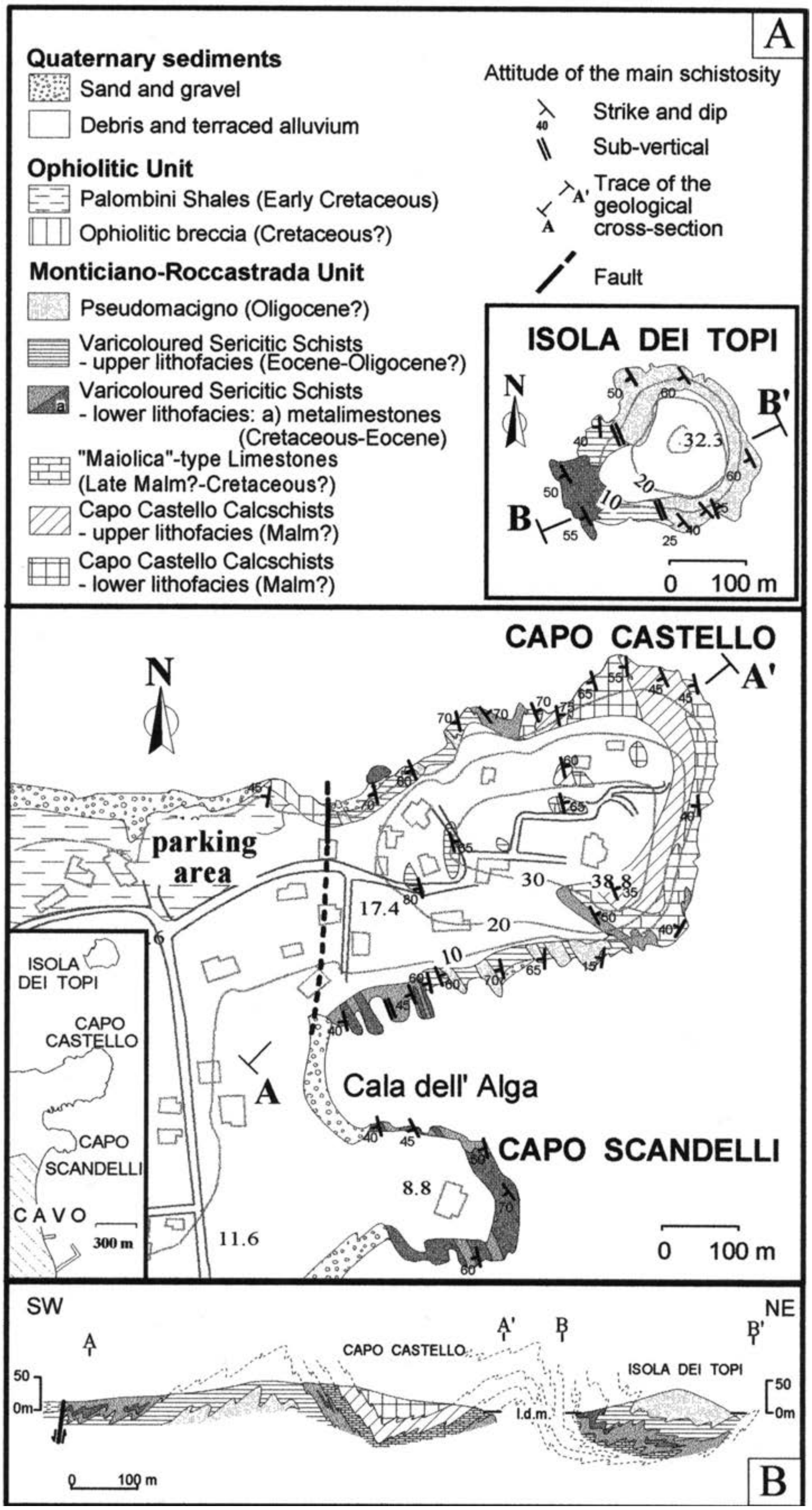

Fig. 11 - Geological sketch map (A) and cross-sections (B) of the Capo Castello area.

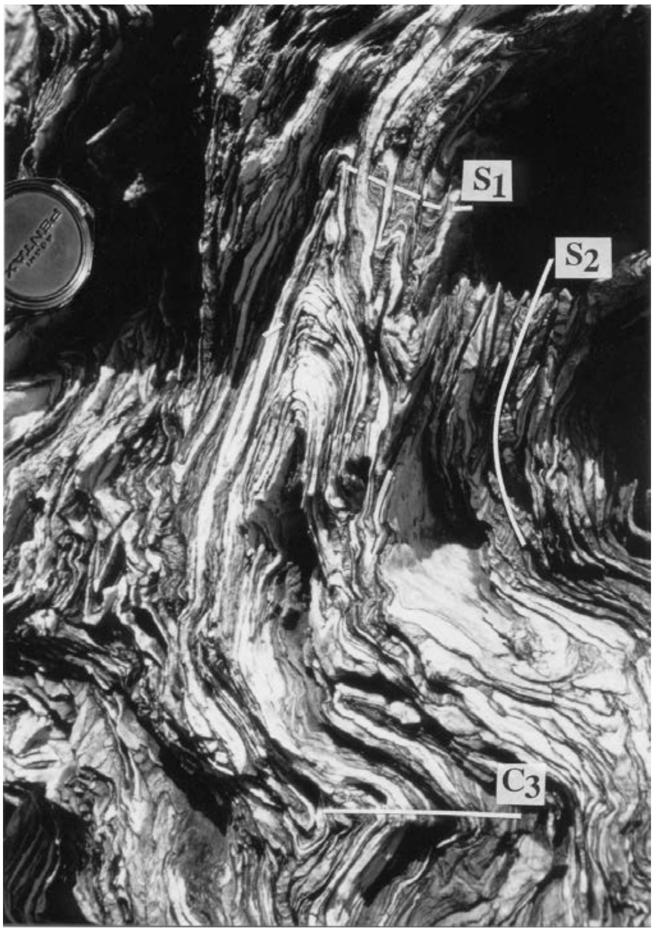

Fig. 12 - The Varicoloured Sericitic Schists in the Cala dell'Alga area. For details see text, Stop 7.

structure the same succession dips to the NW.

Coming back to the road, we cross twice the same anticline, faulted on its eastern side. After 1 km of very folded Calpionella Limestones we cross again the Acquaviva Subunit. The contact along the road is faulted. In this area we can reconstruct the disrupted and condensed succession of this subunit: at the top of the ophicalcites of the little quarry on the right, some chert beds (Mt. Alpe Cherts) crop out in the Mediterranean scrub; along the road the cherts grade upwards to Palombini Shales.

From here, to near the La Parata Pass, for about 2 km, the road cuts the Acquaviva Subunit terrains with minor internal thrusts: on the road two contacts between Palombini Shales and the overlying ophicalcites are well exposed.

250 m before the La Parata Pass we cut the hidden thrust contact between the Ophiolitic and the underlying Gràssera Unit.

In the La Parata zone four units of the eastern Elba tectonic pile crop out very closely spaced. The road runs on the Gràssera Unit. Immediately above the road lies the thrust contact with the overlying Ophiolitic Unit. On the other side of the road, the Mediterranean scrub covers the faulted contact with the Tuscan Nappe and, a little to the east, the faulted contact between this latter and the Monticiano-Roccastrada Unit.

Stop 10. *The thrust contact Tuscan Nappe-Gràssera Unit.*

Along the road, 200 m south of the Pass, a little outcrop of Triassic limestones ("Calcare Cavernoso") of the Tuscan Nappe shows the thrust contact with the overlying Gràssera Unit (Fig. 14). The latter is here represented by its basal portion: brown-grey polydeformed calcschists (Calcschist Member of the Cavo Fm.). In the calcschists the last folding event is very pervasive on a previous tectono-metamorphic layering (see the intrafolial schistosity relics).

Nearby, until the 16^{th} century flourished the charming Gràssera village, destroyed by the terrible pirate Khair Eddin (Red Beard).The only remains are the ruins of the San Martino church, immediately on the left of the road, the underground aqueduct and the name of the creek. We gave this name to the Unit in its memory.

From here we can enjoy a spectacular panorama on the Fe-mines of Rio Marina (foreground, the Valle Giove Mine) and on the Mt. Torre del Giove where the upper two members of the Triassic "Verrucano" of the Monticiano-Roccastrada Unit (see Stop 5) crop out. Westwards (the western side of Mt. del Giove), the "Verrucano" is in contact, through a high-angle normal fault (Terranera Fault), with the "Calcare Cavernoso" of the Tuscan Nappe.

We continue southwards 200-300 m along the Parata road up to the crossroad with the little road (to the left) for the cemetery of Rio Marina. Here the road intersects the St. Caterina Normal Fault high angle normal fault, just observed in the Ortano Valley (Stop 3 m, n). This structure is part of the system of westward-high-angle normal faults which dissects the tectonic pile of eastern Elba. To the North, it lowers the Mt. Serra Subunit, with respect to Acquaviva Subunit and the underlying Gràssera Unit; to the South, the same structure lowers the Gràssera Unit with respect to the Tuscan Nappe.

Afterwards, the road turns south-west and crosses some tens of metres of ophicalcites.

Stop 11. *The ophicalcites.*

These ophicalcites probably constitute the base of the Mt. Serra Subunit, although in many cases their upper contact with the basalts is more or less tectonised. We prefer to call these rocks ophicalcitised serpentinites because they do not show all the structures of the typical ophicalcites of eastern Liguria. They are pervasively fractured serpentinites with scattered calcite veins without any preferential trend. The veins become more and more frequent near the upper contact.

A little more than 100 metres passed the ophicalcites we enter a strongly folded zone, made up of the sedimentary cover of the Mt. Serra Subunit (from Mt. Alpe Cherts to Calpionella Limestones).

Stop 12. *The base of the Nisportino Formation.* (Fig. 15).

Near the first creek we can observe the contact between Mt. Alpe Cherts and Nisportino Fm.

Nisportino Formation. This formation is composed of three distinct members, from the bottom: **a**. A basal level (15-30 m thick), made up of siliceous calcilutites, red siliceous siltstones and, locally, marlstones and/or shales; **b**. A level, formally distinguished as Rivercina Member (11-30 m), consisting of marly calcilutites; **c** An upper section (50-70 m characterised by red siltstones and/or shales with rare

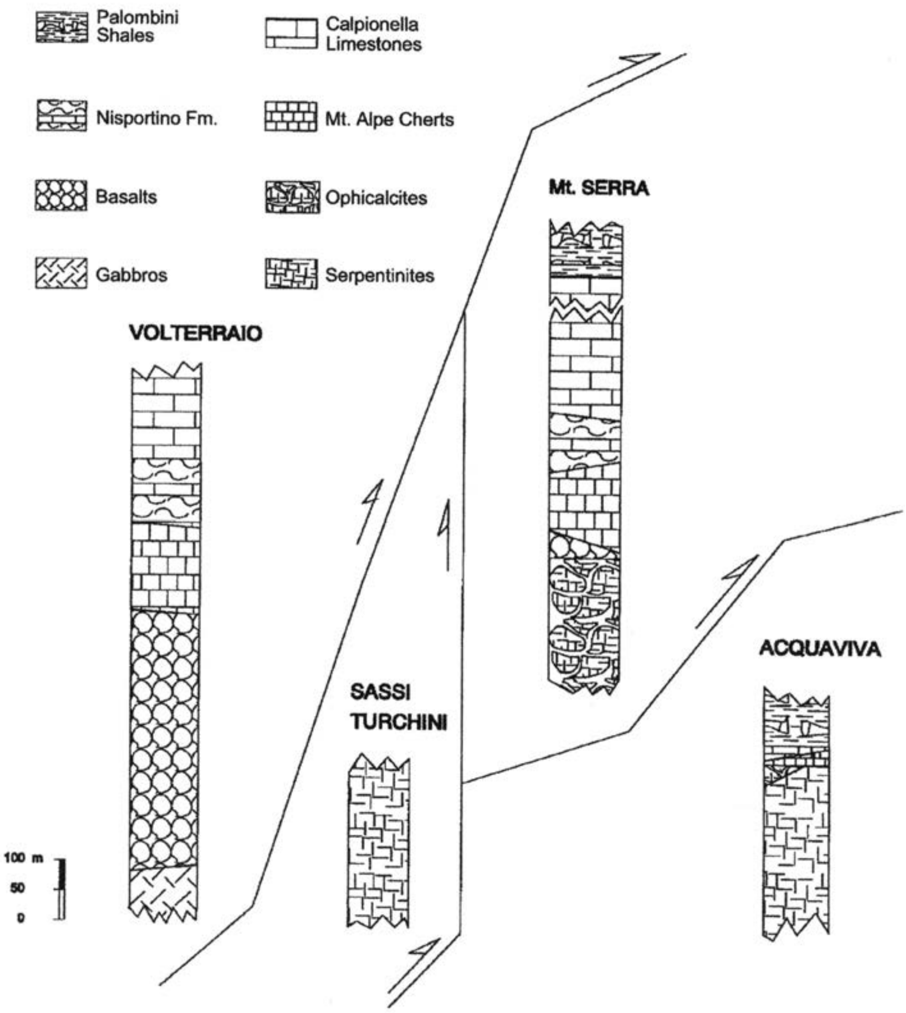

Fig. 13 - Schematic columnar sections of the main subunits of the Ophiolitic Unit (after Bortolotti et al., 1994).

beds of siliceous calcilutites, followed upwards by calcilutites prevailing on the siltstones. The upper section ends with a few meters of siltstones and marly shales. According to calcareous nannofossils the age is Berriasian.

Along the road the upper levels of the Mt. Alpe Cherts crop out. Here red siliceous claystone and siltstone beds prevail on radiolarites and laminated clay-rich cherts. All the sequence is thin-bedded. Five metres above the road, on the right side of the creek, we find a very little quarry. On the right, to its base and at the top, we can observe two cherty calcilutite beds, and in between a thin-bedded sequence of siliceous siltstones and claystones with rare cherts. The contact between Mt. Alpe Cherts and Nisportino Fm. has been placed at the base of the first calcareous bed. Going upwards we find five more metres of the same type of succession and then 15-20 metres of light grey marly calcilutites, a key level of the formation that we called Rivercina Member. It ends upwards with a thick bed of siliceous calcilutite. The upper levels of the formation will be seen in the next stop.

We come back to the road, to San Pietro and turn right towards Nisporto. Along this road we see cherts and serpentinites in tectonic contact. At a curve to the left with a big oak we cut again the contact between Mt. Alpe Cherts and Nisportino Fm. Here the limestones are completely decalcified. At the first bend of the road we cross the core of a reverse anticline trending N-S and with clear NE vergence, exposing the top of the Mt. Alpe Cherts and the basal portion of the Nisportino Fm.

Stop 13. *The Nisportino Formation.* (Fig. 15).

We stop at the last bend of the road. The Rivercina marly calcilutites are tectonically cut away, but we can see the siliceous limestone beds at their top. The upper portion of the formation consists of alternating marly and siliceous siltstones, cherty and siliceous calcilutites and rare clay-rich cherts. Upwards, the calcilutites, scarce at the base, become more and more abundant. The top of the formation is marked by a thick level of light grey marly siltstones. Above, the

Fig. 14 - The thrust contact between the Tuscan Nappe (Triassic "Calcare Cavernoso" - T.N.) and the overlying Gràssera Unit (G.U.) (La Parata Thrust Fault, Bortolotti et al., 2000), 200 m south of Parata Pass, Stop 8.

well-bedded, whitish calcilutites, without any silty or shaly intercalations, constitute the Calpionella Limestones Fm. The transition can be observed in the quarry near the pass, on the right of the road, where it is dissected by some minor faults.

The road exposes some fragments of the serpentinite slices which run along the thrust contact between the Mt. Serra and the overlying Volterraio Subunit (Fig.2), which constitutes the hills to the South.

In front of us, looking westwards (Fig. 16), we can observe the succession of the Mt. Serra Subunit, overthrust by the Volterraio Subunit, to the left (Pietre Rosse Hill). The well exposed succession of the latter subunit includes basalts at the base, overlain by Mt. Alpe Cherts and, then by the Nisportino Fm (type-section).

We go back to San Pietro, then to Rio nell'Elba, where we cross a complicate, thin "Schuppenzone", in which the Mt. Serra, Sassi Turchini and Volterraio Subunits are implicated. An outcrop of serpentinite of the Sassi Turchini Subunit is immediately below the village.

We continue up to the Volterraio Pass, crossing a thick basalt succession. From the pass we enjoy a wonderful view to the east, toward the zone visited in the morning, and to the west, toward the Portoferraio Bay and, on the horizon, to the Mt. Capanne Massif, which we will tour the next day. We proceed, and stop some hundred metres further on, where the road skirts long high walls.

Stop 14. *Pillow lavas.*

Here, along the walls, the basalts are represented by large sized pillow-lavas, characterised by a strong oceanic alteration and by the crystallisation of chlorite, albite, actinolite and pumpellyite. In some of these pillows we can see some pillow-shelves.

We come back to Rio nell'Elba and go toward Porto Azzurro. The road, beyond la Ginestra, runs near and crosses, before, the thrust contact between the Sassi Turchini serpentinite and the Mt. Serra basalts and, further on, the thrust contact between the Sassi Turchini serpentinite and the Volterraio gabbro. Shortly after the Fosso delle Maceratoie we enter the Acquaviva Subunit

Stop 15. *San Felo ophiolitic succession*

Shortly passed San Felo, we can observe an ophiolitic Klippe, pertaining to the Mt. Serra Subunit, which shows a very reduced succession, well exposed in a little quarry on the right of the road. This Klippe constitutes an east-vergent, reverse, almost isoclinal syncline (Fig. 17). The succession comprehends, from the bottom: **a**. Ophicalcites, cropping out on the road, which show two different facies. Far from the quarry they are fragmented serpentinites with calcite veins very close one another ("Breccia di Levanto" type, see Cortesogno et al., 1987). Close to the quarry, and on its left side, they show a detrital facies, with small fragments of serpentinite dispersed in a calcitic cement ("Framura Breccia" type see Cortesogno et al., 1987); **b**. A few meters of a basalt breccia on the

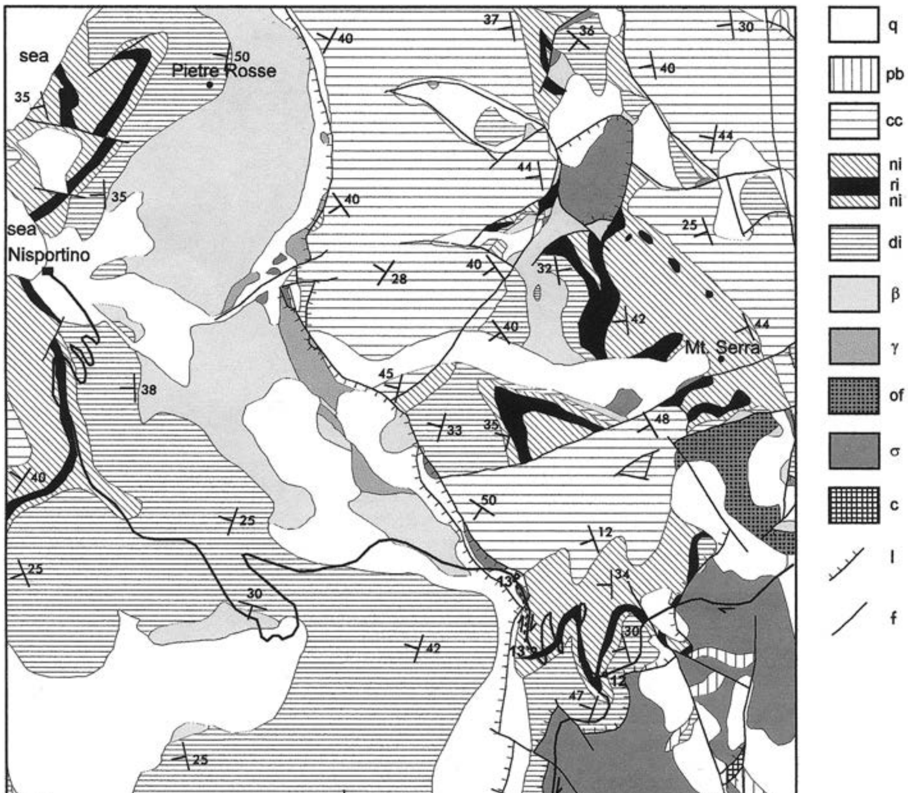

Fig. 15 - Geological map of the area south-east of Nisportino, with the location of Stops 12 and 13. q- Quaternary deposits. Ophiolitic Unit: pb- Palombini Shales; cc- Calpionella Limestones; ni- Nisportino Fm, with ri- Rivercina Member; di- Mt. Alpe Cherts; β- Basalts; γ- Gabbros; of- Ophicalcites; σ- Serpentinites. Gràssera Unit: c- Cavo Fm. l- low angle tectonic surfaces: thrusts and detachments; f- normal faults.

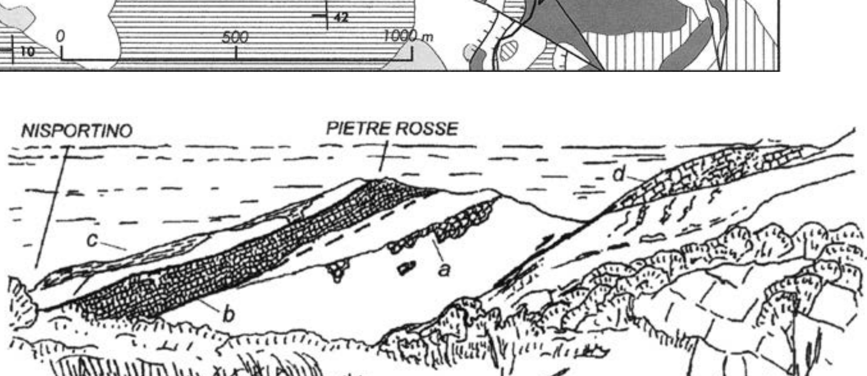

Fig. 16 - Panorama from Mt Strega-Mt. Serra pass towards Nisportino-Pietre Rosse. The succession of the Mt. Serra Subunit (to the right) is overlain by the Volterraio Subunit (central-left part of the figure). The Nisportino-Pietre Rosse zone is the type locality of Nisportino Fm. a- Basalts; b- Mt. Alpe Cherts; c- Nisportino Fm.; d- Calpionella Limestones; → Thrust surface between Mt. Serra and Volterraio Subunits.

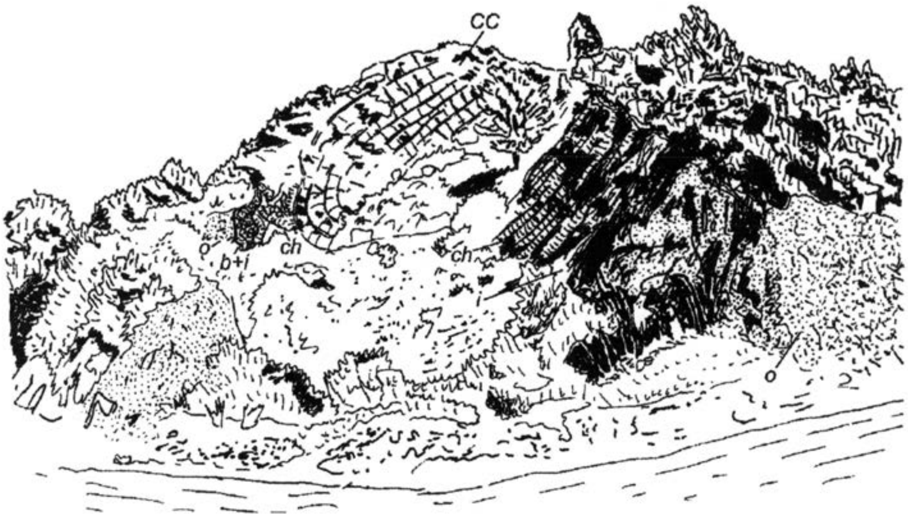

Fig. 17 - The little quarry near San Felo. oph- Ophicalcites; Ba- Basalts; Ya- Pillow breccia; Ch- Mt. Alpe Cherts; cc- Calpionella Limestones.

right side of the quarry while, on its left side few pillow lavas; **c**. The Mt. Alpe Cherts, in their typical facies. At the base some dm of red shales including a big pillow; upwards about ten metres of thin bedded radiolarites alternating with siliceous siltstones and shales, more and more abundant going upwards; **d**. Calpionella Limestones, with the typical well-bedded, whitish calcilutites. The contact is sharp and probably tectonised: no traces of the Nisportino Fm.

Some hundred metres further on, we reach the Acquaviva Creek.

Stop 16. *Fosso Acquaviva, serpentinites.*

Just crossed the bridge, we turn right along the river and stop at the end of the small road. We go up a big boulder, made up of serpentinised tectonites. They have a composition ranging from spinel-bearing lherzolites to spinel-bearing harzburgites. The rock of the boulder contains interstitial clinopyroxene and plagioclase. The plagioclase occurrence is usually concurrent with stable spinel. We can see also some dikelets crosscutting the peridotite with different trends. They are made up of altered plagioclase and clinopyroxene. At some distance from the dikelets (2 cm) clinopyroxene forms mm-sized poichiloblasts enclosing serpentinised olivine grains These data can suggest that the Sassi Turchini peridotites have been extensively impregnated by mafic melts producing plagioclase and clinopyroxene patches and veins. The presence of impregnated mantle peridotites is reminiscent of the upper-mantle-lower oceanic crust transition zone (Bortolotti et al., 1994; Tartarotti and Vaggelli, 1994a; 1994b).

We come back to the road and, turning right, we go through Porto Azzurro and, just before the cross-road to Spiaggia del Lido, we turn right towards il Buraccio. We cross the Ghiaieto Sandstones, the Campanian-Maastrichtian siliciclastic flysch of the Cretaceous Flysch Unit, the higher unit of the Ligurian Domain in the Elba Island. Near the divide we cross repeatedly the contact with a very large dike. It is a porphyry, belonging to the Upper Miocene dike swarm linked to the Mt. Capanne monzogranite. Just before the pass, we turn left, on a very very bad and narrow road (only for little cars). Here we cross a thin outcrop (10-20 m) of Paleogene Flysch Unit and we enter immediately the Ophiolitic Unit (all these tectonic contact are not observable). Going up, we can observe on the left a very complicated folded structure in the Calpionella Limestones and the underlying Nisportino Fm.

Stop 17. *Mt. Castello-Cima del Monte Pass. The folded structure of the Volterraio Subunit and the shoshonitic dike* (Fig. 18)**.**

We stop on the Pass and go down by foot some tens metres. We stop on a small rock spike. We just crossed an important normal fault, dipping NW, which uplifts the Mt. Alpe Cherts, on which we are, respect to the Nisportino Fm. We can note the difference of the tectonic style on the two sides: the cherts are strongly deformed, with tight, vertical isoclinal folds, the Nisportino Fm shows a large anticline, with some minor folds at the core (Fig. 19), which is on our right (E) in the Mt. Alpe Cherts. We have to note that in spite of the very complicated folds present in the cherts, the contact line with the underlying basalts is very softly folded. We can see this contact immediately beyond the little church (Madonna di Monserrato), where the rugged landscape of the cherts is substituted by smooth and woody hills.

In the hills close the sea the underlying units crop out, included the metamorphic Paleozoic basement (Ortano Unit) that constitutes the coastal relieves of Porto Azzurro.

We go down some metres westward end we can observe, along the fault plane a cataclastic breccia, some metres thick, made up only of cherts; the marly limestones on the other side are undisturbed. Along the fault plane we can observe a mafic dike, some dm thick (Conticelli et al., 1997; 2001). This dike more west turns right (N-S) and crosscuts the Mt. Alpe Cherts, the Nisportino Fm. and the Calpionella Limestones, finally it enters a successive E-W fault (Fig. 16). It has a porphyritic texture with phenocrysts of olivine, plagioclase and clinopyroxene, with seldom large K-feldspar xenocrysts. The original mineralogy is strongly altered and replaced by secondary minerals. Clinopyroxene and plagioclase in some cases are still preserved, whereas olivine is entirely replaced by smectite aggregates. Euhedral Mg-chromite inclusions also occur in the olivine ghosts. In the most fresh samples the groundmass is made by clinopyroxene, k-feldspar, plagioclase, magnetite and apatite. $^{39}Ar/^{40}Ar$ dating performed on the k-feldspar-rich groundmass give a cooling age of 5.83±0.14 Ma. The whole rock chemistry indicates that the parental magma has a

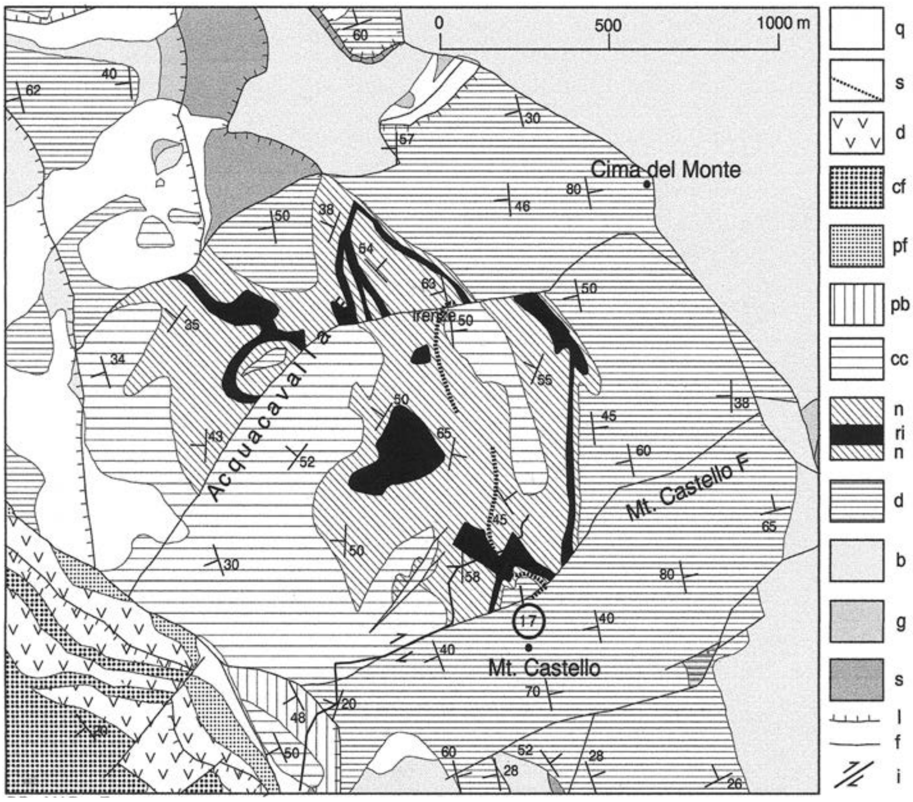

Fig.18 - Geological map of the area north of Mt. Castello. l- low angle tectonic surfaces (thrusts and detachments); f- normal faults; i- itinerary with the location of Stop 17. Q- Quaternary deposits; s- Shoshonitic Mt. Castello dike; d- Neogene acidic dikes; cf- Marina di Campo Fm.; pf- Colle Reciso Fm.; pb- Palombini Shales; cc- Calpionella Limestones; ni- Nisportino Fm, with ri- Rivercina Member; di- Mt. Alpe Cherts; β- Basalts; γ- Gabbros; σ- Serpentinites.

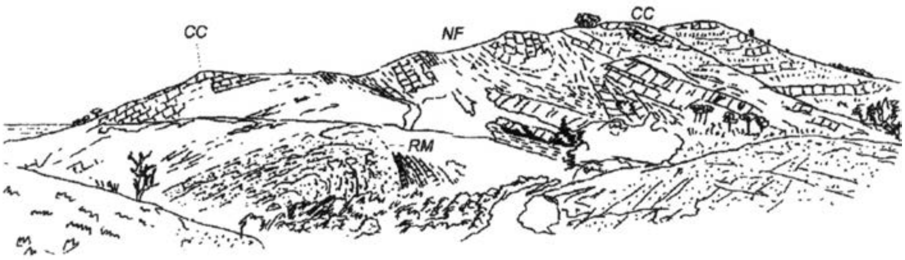

Fig. 19 - Panorama on the complex anticline north of Mt. Castello. The core is made of Rivercina Fm. (RM) overlain by the upper portion of the Nisportino Fm. (NF) and, finally, in the external limbs, by the Calpionella Limestones (CC).

shoshonitic composition, with a clear alkaline-potassic affinity. These data together with trace element data and mineral chemistry suggest that the magma belongs to the Italian Plio-Pleistocene potassic suite, and closely resemble the rocks cropping out at the Capraia Island and in the Southern Tuscany. The presence of olivine ghosts with euhedral Mg-chromite inclusions suggest that the magma has a strong primitive composition. The presence of xenocrysts from a monzogranite, and the lack of reaction paragenesis clearly indicates that the mafic magma intruded the monzogranite successively to its cooling.

This dike is very important for dating the brittle tectonics of the eastern Elba. In fact the SW-NE fault system is older that 5.8 Ma, and is cut by the NW-SE system, which is younger (Fig. 18). This latter moves the thrust of the Volterraio Subunit on the Acquaviva (transfer faults?) and does not interrupt the N-S fault system to the east.

We come back to the main road, and then to Portoferraio.

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