The geology of Elba Island: an historical introduction

THE GEOLOGY OF THE ELBA ISLAND: AN HISTORICAL INTRODUCTION

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ABSTRACT

The studies on the geology of the Elba Island began toward the middle of the 19th century. The first detailed survey was performed by Lotti for the first edition of the Geological Map of Italy. All the formations were considered autochthonous and pertaining to a single stratigraphic succession. Termier in 1910 introduced the nappe concept in the geology of the Island. At the end of the second world war, the geology of the Island was renewed by the studies of the researchers of the Pisa University. The geological scheme of Trevisan (1950,1951), modified in the sixties as the result of the new geological survey for the second edition of the Geological Map of Italy, constituted a basic synthesis of the sedimentary and tectonic evolution of the Island, which was considered a stack of five tectonic complexes. Only partial modifications have been carried out to this model till the end of the nineties, when a detailed geological survey of the central and eastern Elba was performed by the authors and colleagues of the Florence University. Their stratigraphic and structural interpretation is based on the presence of nine main tectonic units which belong to the Piedmontese, Ligurian and Tuscan domains. Their present very complex tectonic piling up is due to both syn-orogenic thrusting, and low angle extensional detachments partly triggered by the Neogene plutons uplift.

INTRODUCTION

The geology of the Elba Island is very peculiar due: i- to the complex relationships between the various units that compose its tectonic pile; ii- to the mechanisms and timing of their emplacement; iii- to the Neogenic intense magmatic activity and related mineralisations. Intriguing is also its geographic position: Elba is located halfway between Corsica and Tuscany; it can be considered to be the westernmost extension of Northern Apennines, and the link with the "Alpine" Corsica.

Traces of tectonic (-metamorphic) events of probable Hercynian age are recorded in the Palaeozoic rocks of the Tuscan basement. The Tuscan Succession deposited on this eroded basement, starting from Middle Triassic. The Alpine orogenic evolution, which onset is likely of Late Cretaceous/Eocene age, caused the early deformations of the Ligurid and "Schistes Lustrés"-type tectonic units, remnants of the Tethyan Ocean, which paleogeographic location was between Elba and Corsica Islands. Tectonic activity persisted until the Late Miocene-Pliocene (i.e. the age of the last horizontal displacements), and eventually involved also the Tuscan Units. Tectonics caused the complete consumption of the Western Tethys ocean, the consequent collision and deformation of the Europe (Corsica) and Adria margins (Tosco-Umbria Domain) and, finally, the collapse of the orogenic chain and the opening of the Tyrrhenian Basin (Boccaletti et al., 1980; Abbate et al., 1980; 1994; Principi and Treves, 1984; Carmignani et al., 1995; Bartole, 1995 cum bibl.).

As long and complex has been the geologic evolution, so long, complex and contradictory has been the evolution of the ideas. The researchers that tried to explain the geology of the Elba Island, were constrained to the knowledge and the belief of their times. Therefore, the tectonic units of Elba have been interpreted alternatively in autochthonous and allochthonous key, until more recent times, with the advent of the Plate Tectonics theory.

STRATIGRAPHY and TECTONICS

Savi (1833), **Studer** (1841, which published the first sketch map we found), **Krautz** (1840, in **Lotti** 1886), **Collegno** (1848), **Cocchi** (1870) and **vom Rath** (1870) inaugurated the geological study of the Elba Island. **Lotti** (1884) carried out the first organic geological mapping of the entire island at the scale 1:25.000 (see the post card in the pocket) and prepared the related monograph (Lotti, 1886 with bibl.). He interpreted all the rock formations of Elba as parts of an unique autochthonous succession that extends from the pre-Silurian schists to the Eocene limestones and sandstones.

Termier (1909; 1910, Fig. 1), recognised the presence of allochthonous units. In particular, he distinguished three "series" separated by thrust surfaces ("surfaces de charriage"). From western to eastern Elba they are: **a**- the lower "Série I", formed by autochthonous formations (the Mt. Capanne granite and its metamorphic aureole, the Eocene flysch formations injected by "microgranite" dikes and the Lotti's "pre-Silurian marbles, micaschists and gneiss"); **b**- the intermediate "Série II", made up of "Schistes Lustrés", identical to the ones typically found in Corsica, and that includes a serpentinite lens at their top; **c**- the upper "Série III", that comprises a non metamorphic succession ranging in age from Silurian to Lias and which is "encircled" by an ophiolitic complex (Eocene?). Termier suggests that the lower and upper successions can be traced eastwards, to the Apennines. He also proposed that the intermediate "Schistes Lustrés" Unit, that can be also traced in the Gorgona and Giglio Islands and in the Argentario Promontory, continued eastwards, in Southern Tuscany, where it can not be distinguished from the "Série III", due to the "crystallinity loss".

Some tens years after, **De Wijkerslooth** (1934) (Fig. 2), proposed a re-elaboration of the Termier tectonic scheme, in which the "Série II" is considered as a portion of the metamorphosed Tuscan succession and not an equivalent of the "Schistes Lustrés". He recognised a total of six tectonic units, three of which belong to Complex I (or "Unterer Schuppenteil") and three to the Complex II (or "Oberer Schuppenteil"). From the bottom to top, they include:

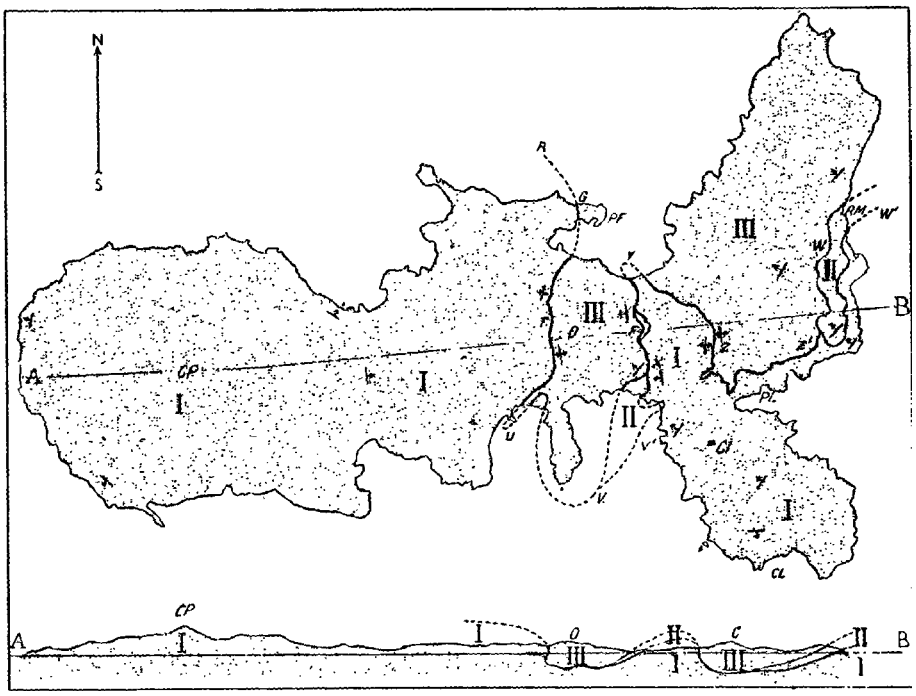

Fig. 1 - Tectonic map of the Elba Island. Pf- Portoferraio; PL- Porto Azzurro; RM-. Rio Marina; CP- Mt. Capanne; Ci- Capoliveri; O- Mt. Orello; G- Ghiaie; AB- Section profile; RTUVV'XYZZ'WW'- The two thrust surfaces; I, II, III- The three rock series. (after Termier, 1910).

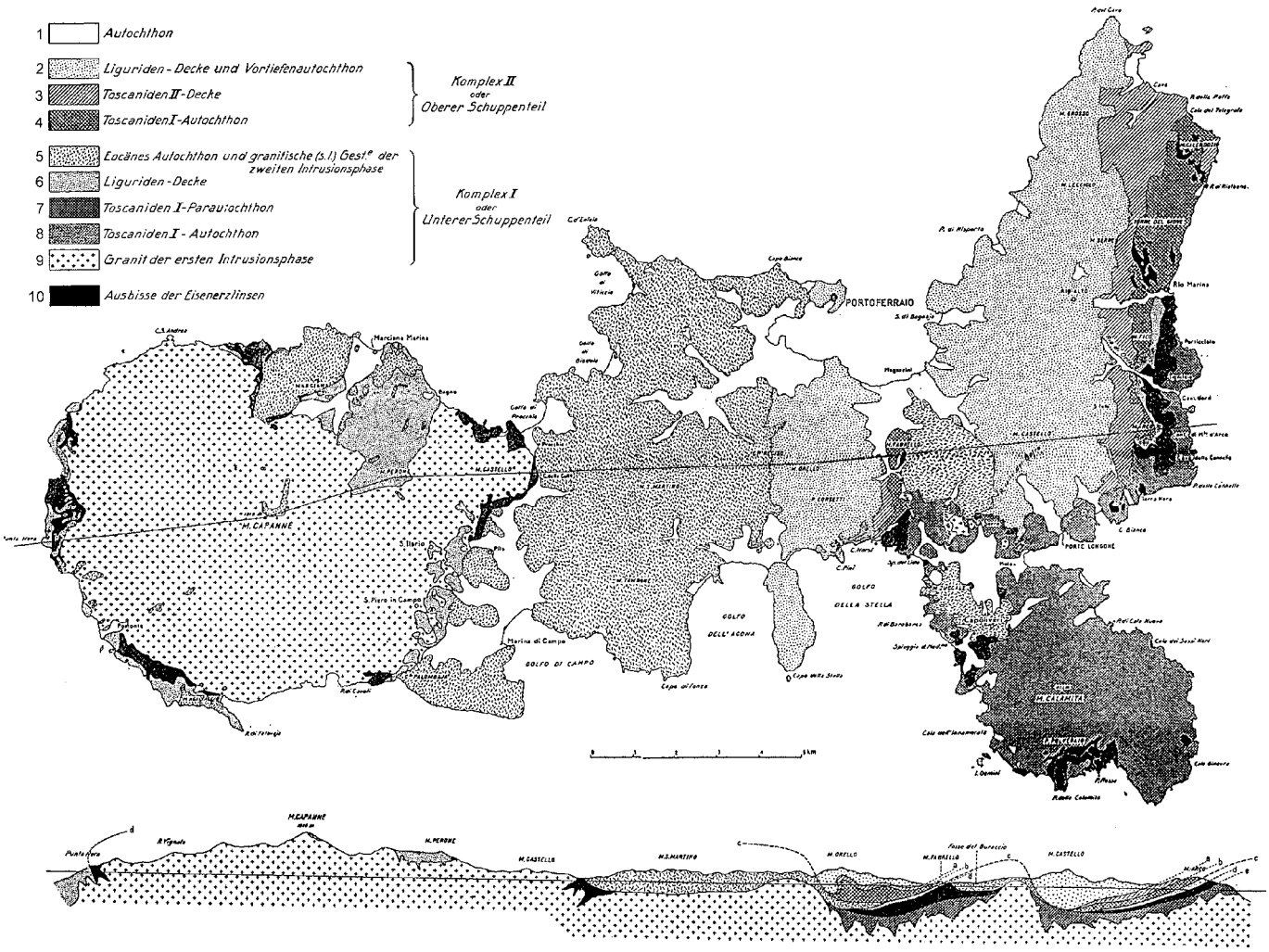

Fig. 2 - Tectonic map and profile of the Elba Island. 1- Autochthon (Neogene). Complex II: 2- Ligurian Nappe and buried Autochthon; 3-"Toscaniden II" Nappe; 4- "Toskaniden I" - Autochthon. Complex I: 5- Eocene Autochthon and granitic (l.s.) rocks of the second intrusion phase; 6- Ligurian Nappe; 7- "Toskaniden I - Parautochthon"; 8- "Toskaniden I - Autochthon; 9- Granite of the first intrusion phase. 10- Lenses of Fe-ores. Thrust contacts: a- between 2 and 3; b- between 3 and 4; c- between Complex II and I; d- between 6 and 7/8; e- between 7 and 8 (after De Wijkerslooth, 1934).

Complex I. **a**- "Toscaniden I Autochthon" made up of Calamita gneiss and the metamorphic Paleozoic succession of the eastern coast, that the author correlates with the Apuan autochthon; **b**- "Toscaniden I-Parautochthon", made up of what Termier called "Schistes Lustrés"; **c**- "Liguriden-Decke and Bedeckendes Autochthon-Semiautochthon" (= Ligurian Nappe and buried Autochthon-Semiautochthon) that comprises the Ortano serpentinite and the main portion of the metamorphic Ligurian outcrops that rim the Mt. Capanne intrusion, transgressively covered by the "Eocene" flysch succession.

Complex II **d**- "Toscaniden I-Autochthon", made up of members of the Tuscan succession which ages range from Carboniferous (Lotti's "Silurian") to Triassic; **e**- "Toscaniden II-Decke", which includes the Jurassic Tuscan succession, transgressively covered by the "Eocene" flysch; and finally, **f**- the "Liguriden-Decke," made up of ophiolites and their Jurassic pelagic cover. According to the author, the nappe emplacement was caused by the gliding downward of the previous units from a "Ligurische Geoantiklinale" located in the Tyrrhenian area.

In the following year, **Collet** (1935, in Collet, 1938, Fig. 3), in agreement with the interpretation of **Cadish** (1929), confirms the Termier's tectonic units **a**- ("Série I") and **b**- ("Série II"). He also suggests a subdivision for the upper nappe ("Série III") into two units. The lower of these units (**c**-) is an unmetamorphosed succession which recalls the La Spezia nappe, and the upper one (**d**-) is an ophiolitic Ligurid nappe. Furthermore he agrees with Termier by interpreting the De Wijkerslooth's unit **b**- as "Schistes Lustrés" ("Termier a été, sans aucun doute, le plus grand connaisseur des schistes lustrés…."). Finally, the author accepts the tectonic emplacement of the nappes from east to west, as previously proposed by **Staub** (1933).

According to all these previously mentioned authors, the allochthony of the tectonic units was interpreted on the basis of the nappe model.

Beneo and **Trevisan** (1943) and **Beneo** (1948, "in perfetto accordo di vedute" with Trevisan) (Fig. 4), recognised four tectonic units. From bottom to top they are: **I**- the autochthonous pre-Silurian Calamita gneiss and its metamorphic cover (Valdana area), which include, at its top both a serpentinite level and a non-metamorphic transgressive succession; **II**- ("Falda I") the (Tuscan) "Lido series", made up of a basal phyllitic-marble succession (pre-Carboniferous?) with serpentinite, a Carboniferous-Triassic phyllitic-arenaceous succession, and at its top the Rhaetian-Dogger carbonate-clayey non-metamorphic succession; **III**- ("Falda II") the ophiolitic succession; **IV**- ("Falda III" and "Falda III_1") the unmetamorphosed "Flysch series", lying on the above said Complexes and also on the autochthonous Mt. Capanne granite. In both units **II**- and **III**- were interested by internal shear zones (tectonic slices) are present.

Afterwards, **Trevisan** (1950), studying in detail eastern Elba, modified the model, hypothesising the existence of five tectonic "Complexes" (Fig. 5), derived from an unique stratigraphic succession. From bottom to top they are:

Complex I (= Calamita Gneiss Auctt). It includes an autochthonous succession made up of gneissic schists transgressively covered by (Carboniferous?) crystalline dolomitic limestones, marbles, micaschists and quartzitic schists. The gneiss are extensively intruded by aplitic and tormaliniferous dikes. All the other complexes lie on top of Complex I.

Complex II. It comprises a metamorphic Permian-Upper

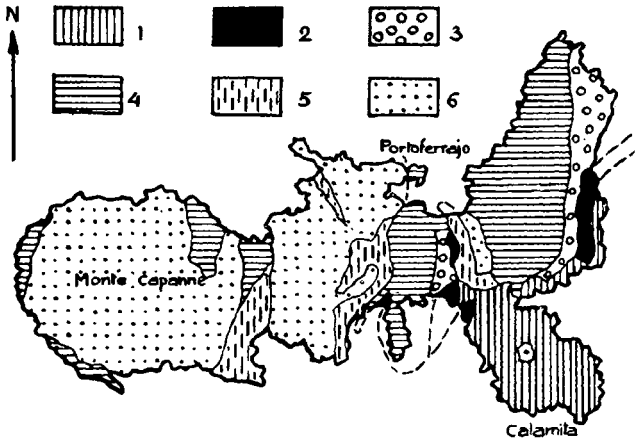

Fig. 3 - Tectonic map of the Elba Island. 1- Calamita gneiss; 2- "Schistes lustrés"; 3- La Spezia Nappe; 4- Radiolarites and ophiolites nappe; 5- Tertiary; 6- Tertiary granite (after Collet, 1935; 1938).

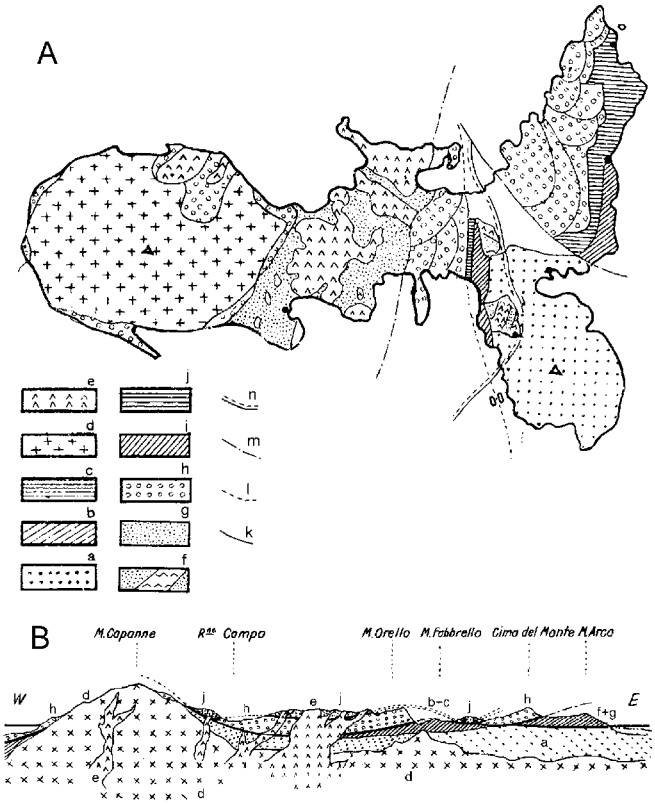

Fig. 4 - A. Geotectonic sketch. Autochthon: a- Calamita Gneiss, b- Metamorphic sedimentary series (West of n), c- Non-metamorphic sedimentary series (West of n), d- Mt. Capanne granite, e- Quartzitic porphyries. Allochthon: " Falda I" (Nappe I): f- Metamorphic sedimentary series, g- Non-metamorphic sedimentary series (East of m); "Falda II" (Nappe II): h- Ophiolitic series; "Falda III" (Nappe III): i- Flysch; "Falda III_1" (Nappe III_1): j- Flysch. k- Western limit of Nappe I; l- Eastern limit of Nappe II; m- Eastern limit of Nappe III; n- Eastern limit of Nappe III_1. B. W-E cross section of the Island. (redrawn after Beneo, 1948).

Jurassic succession which from bottom to top includes: **a**- Ortano and Valdana gneiss which include "porphyroids"; **b**- marbles, calcschists and phyllites ("Serie dei cipollini e degli scisti lucenti") that Trevisan compared to the "Schistes Lustrés" of Corsica and of Western Alps. A serpentinite lens, identical to those commonly found in Complex IV, lies at the top of the Complex. The previous succession is intruded by rare aplitic/pegmatitic dikes and shows a variable

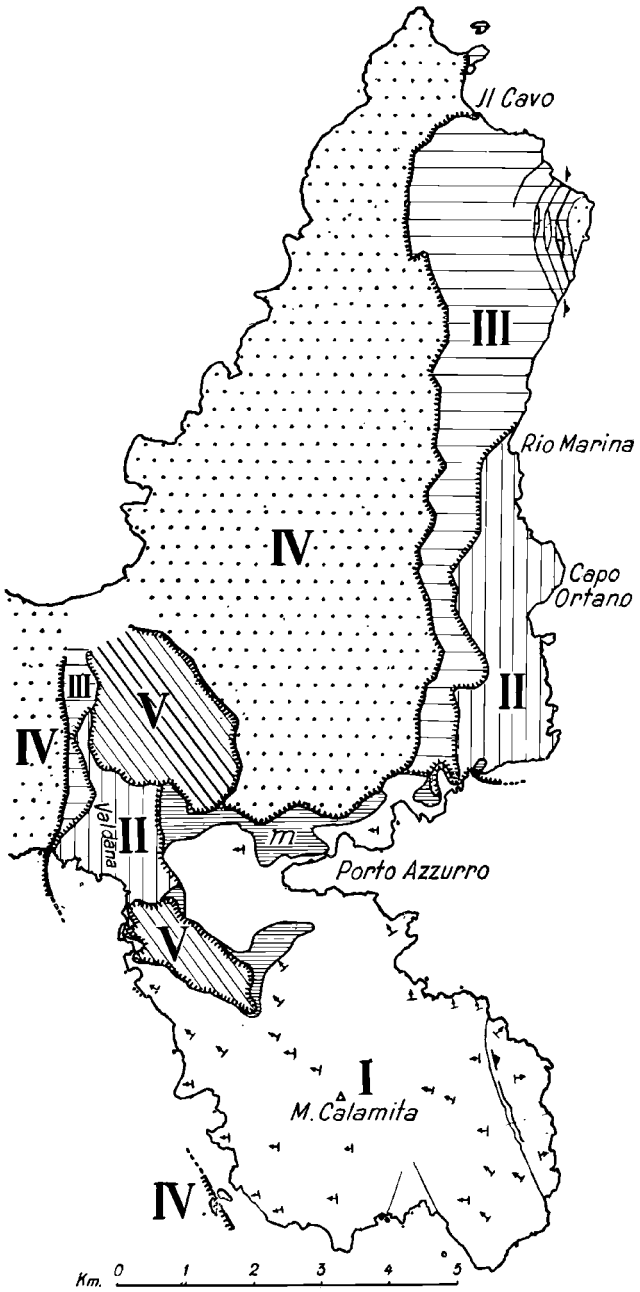

Fig. 5- Schematic map of eastern Elba. I- Complex I; m- mylonite levels; II- Complex II; III- Complex III; IV- Complex IV: V- Complex V (after Trevisan, 1950).

thermometamorphic imprint.

Complex III. It is a non metamorphic succession which, from bottom to top, is composed of: **a**- Carboniferous graphitic and locally thermometamorphosed shales covered by Permian quartzitic sandstones and anagenites; **c**- transgressive, vacuolar, and more or less dolomitic limestones, passing upward to black limestones (identical to the Rhaetian facies of Tuscany); **d**- massive limestones (Hettangian); **e**- cherty limestones, nodular limestones and finally, **f**- thin bedded limestones with marly interbeds of Late Liassic or Dogger age.

Complex IV (= "Argille scagliose ofiolitifere") which consists of: **a**- sericitised varicoloured shales ("Argille variegate"), **b**- "Argille scagliose" with "palombini" limestones (Tithonian-Valanginian), **c**- ophiolites (i- Lherzolitic-harzburgitic serpentinites; ii- Gabbros; iii- Basalts); **d**- cherts, **e**. Calpionella Limestones (Cretaceous); **f**- "Scaglia"-type marlstones (?Eocene).

The author notes that the complexes III and IV could be a continuous succession because in north-eastern Elba, the varicoloured shales (IV-**a**) seem to be the stratigraphic top of the thin bedded limestones (III-**f**). According to the previous hypothesis , the Elba Island could represent the only locality in which the base of the "Argille scagliose" is exposed. However, he also observed that Complex III and IV occur often separated by tectonic contacts: in fact, south of the Cavo area, the "Argille variegate" tectonically lay on on top of the Rhaetian or more ancient rocks.

Complex V includes a calcareous-marly-arenaceous flysch formation, in part similar to the Macigno of continental areas of Tuscany, which age is Eocene, possibly Oligocene/Early Miocene.

The main differences between the Trevisan's work and that of Beneo (1948) (Figs. 4 and 5), concern the subdivision of the Complex II ("Falda I") of Beneo in two "Complexes": according to Trevisan, its upper part, the non metamorphic succession, is separated from the metamorphic lower section (Trevisan's Complex II), and constitutes a different unit (Trevisan's Complex III). Moreover, Trevisan assigns to Complexes II and III. a portion of the successions of the Valdana area, which were previously considered as the cover of the Autochthon.

According to **Trevisan** (1951, report on the 55th summer meeting of the Italian Geological Society, Fig. 6), the Elba units, considered as parts of a single succession, have been dismembered and partly metamorphosed (Complexes I and II) by the granitoid intrusions. Therefore, in this work (see also Trevisan, 1950) the ophiolite unit results stratigraphycally intercalated within the Tuscan-type succession (Figs. 7 and 8), and the metamorphic succession of the Valdana area is assigned again to the Complex I. Trevisan also correlates the successions of the Elba (metamorphic and non-metamorphic) with the "Tuscan Succession" of the continental areas (Fig.7): the crystalline carbonate rocks of Complex I and the "Cipollini e scisti lucenti" of the Complex II, are considered Rhaetian-Jurassic in age, with a Tuscan affinity. Finally, the author interpreted the piling up of the Complexes as the result of two phases of gravity tectonics due to the successive uplift of the Capanne and the Porto Azzurro ridges. Fig. 8 (Trevisan, 1950) schematises this type of eastward-directed gravity movements, Fig. 9 the tectonic evolution of the Elba Island from the Oligocene (Trevisan, 1951).

During the same period **Bonatti** and **Marinelli** (1953) performed detailed petrographic studies on the igneous and metamorphic rocks of the Elba Complexes.

Bellincioni (1958), recognised the tectonic, anomalous superimposition of the ophiolitic successions ("argille scagliose ofiolitifere") on the Flysch units, west of Colle Reciso, along an east-dipping, west-vergent surface, that he explained as the effect of local gravitational movement

According to **Bodechtel**'s studies of eastern Elba (1960, in Bodechtel 1964a; 1964b; 1965), "the imbricated zones of the Isle of Elba display a continuous succession from Palaeozoic to Tertiary in several repetitions. Five large thrust-zones override an autochthonous Eastern unit" (Fig. 10). From bottom to top they are: **a**- Autochthonous Calamita gneiss the author recognises: **b**- the parautochthonous Palaeozoic-Mesozoic succession of the eastern coast (Complexes II and III of Trevisan), in which the debated "Schistes lustrés" of Termier are again interpreted of Paleozoic age; **c**- a "Schuppenzone" that comprises three sec-

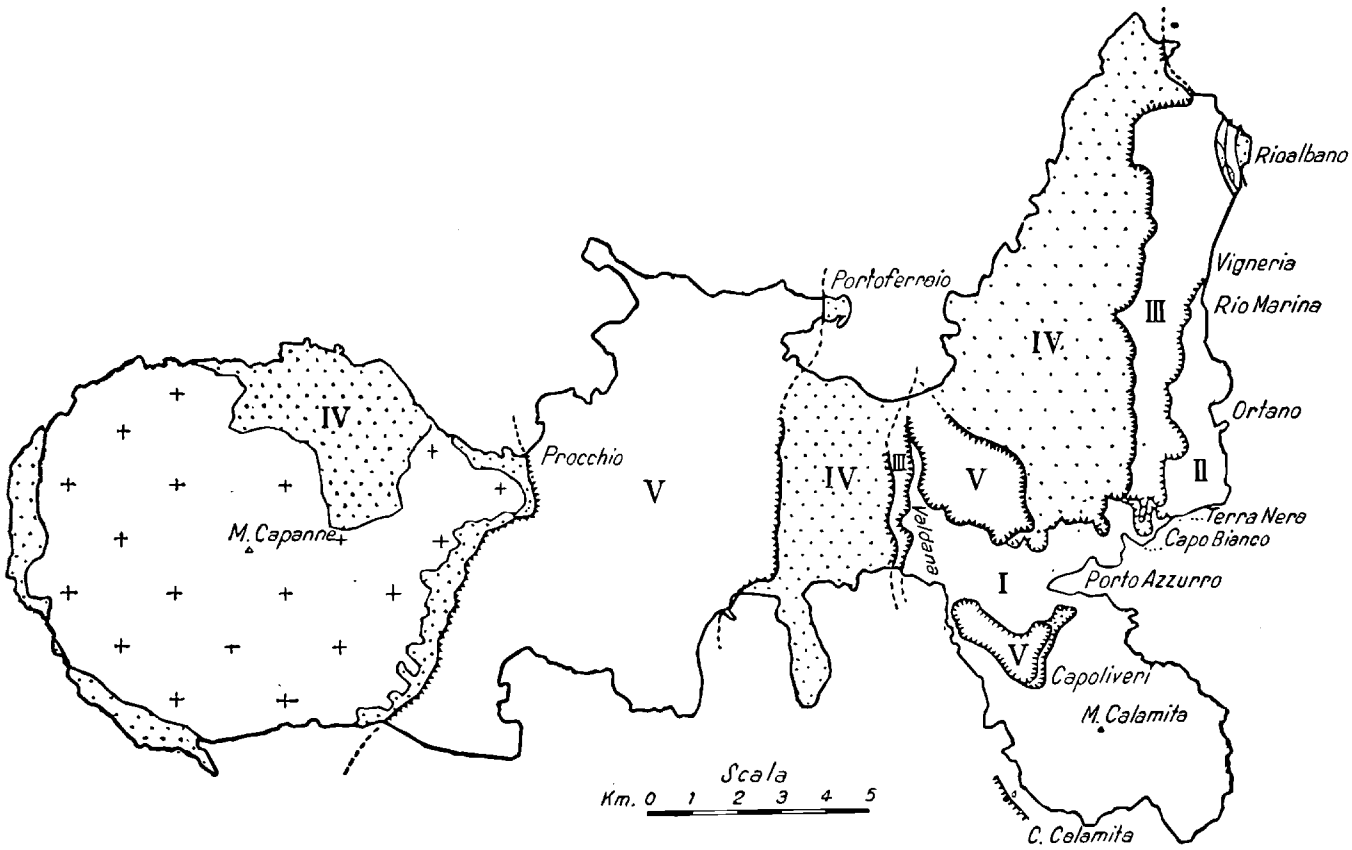

Fig. 6 - Distribution of the Complexes in the Elba Island. Crosses- Mt. Capanne granite. Other symbols as in Fig. 5 (after Trevisan, 1951).

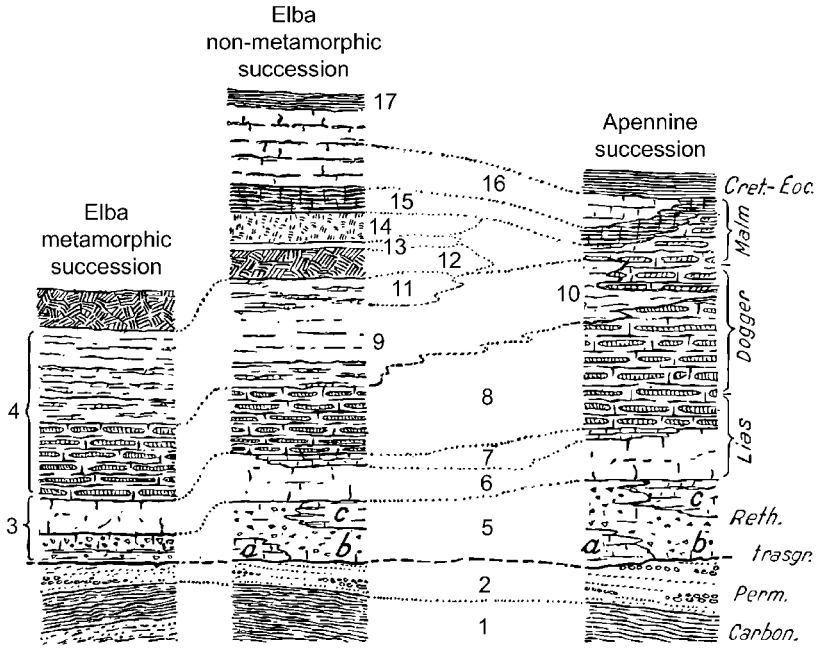

Fig. 7 - Stratigraphic scheme showing the relationships between the Elba successions (metamorphic and non-metamorphic) and the Tuscan Succession of the Tuscan Apennine. 1- Slates; 2- Quartzitic conglomerates ("Anageniti") and quartzites; 3- Marbles; 4- "Cipollini" and "scisti lucenti" (= Schistes lustrés); 5- a. dolostones, b- vacuolar limestones, c- *Avicula contorta* limestones; 6- Hettangian massive limestones ("Calcare Massiccio"); 7- Sinemurian limestones; 8- Cherty limestones; 9- Shales; 10- *Posidonomya* marlstones; 11- Shales and limestones ("Argille e calcari"); 12- Serpentinites; 13- Gabbros; 14- Basalts; 15- Cherts; 16- *Calpionella* Limestones; 17- "Scaglia"; trasgr.- transgression (after Trevisan, 1951).

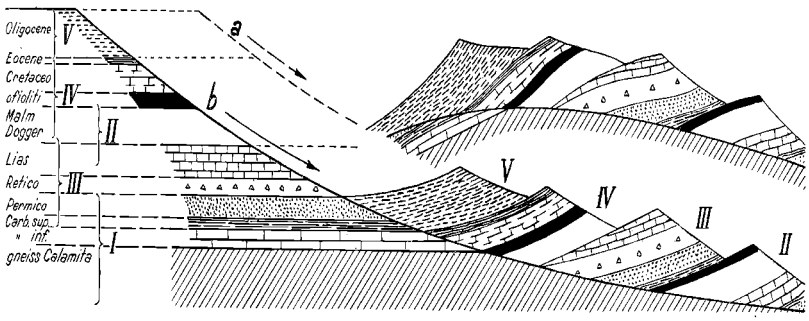

Fig. 8 - Scheme of the supposed gravitational sliding of the complexes, starting from a single succession. a- first gliding surface; b- second gliding surface. Other symbols as in Fig. 5 (after Trevisan, 1950).

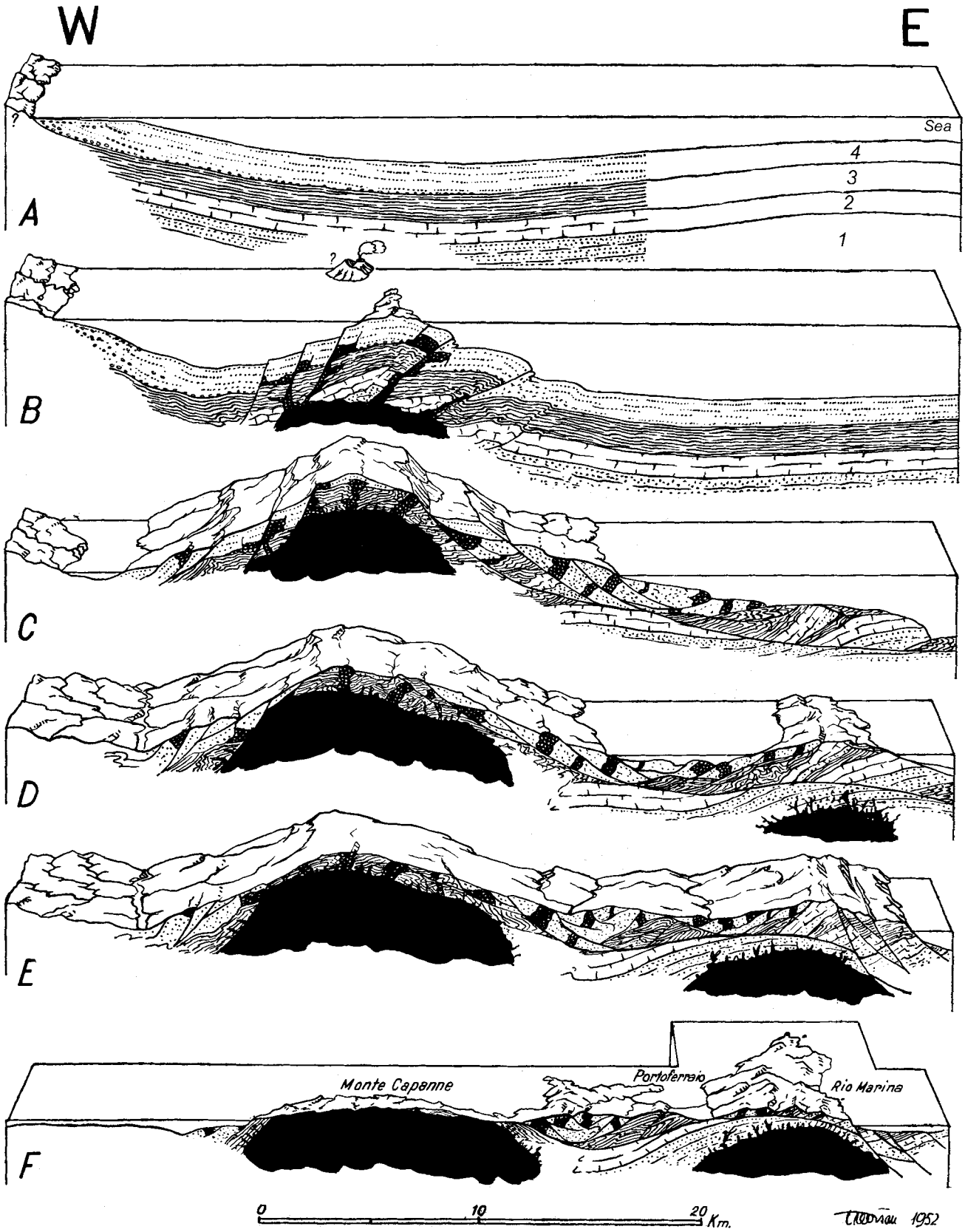

Fig. 9 - Scheme of the tectonic evolution of the Elba Island. A- End of the Oligocene, before the tectonic deformation; B- Beginning of the tectonic deformation; C- Continuation of the tectonic deformation. The uplift of the Mt. Capanne triggers gravitational slidings towards the east; D- Birth of a new uplift due to the La Serra-Porto Azzurro pluton, which deforms the previous sliding surfaces; E- Further uplift of the pluton; reactivation of the eastward sliding; development of a normal faults system on the eastern side of the uplift, with formation of the skarns and Fe-ores; F- The present situation, due to further collapse phases (after Trevisan, 1951).

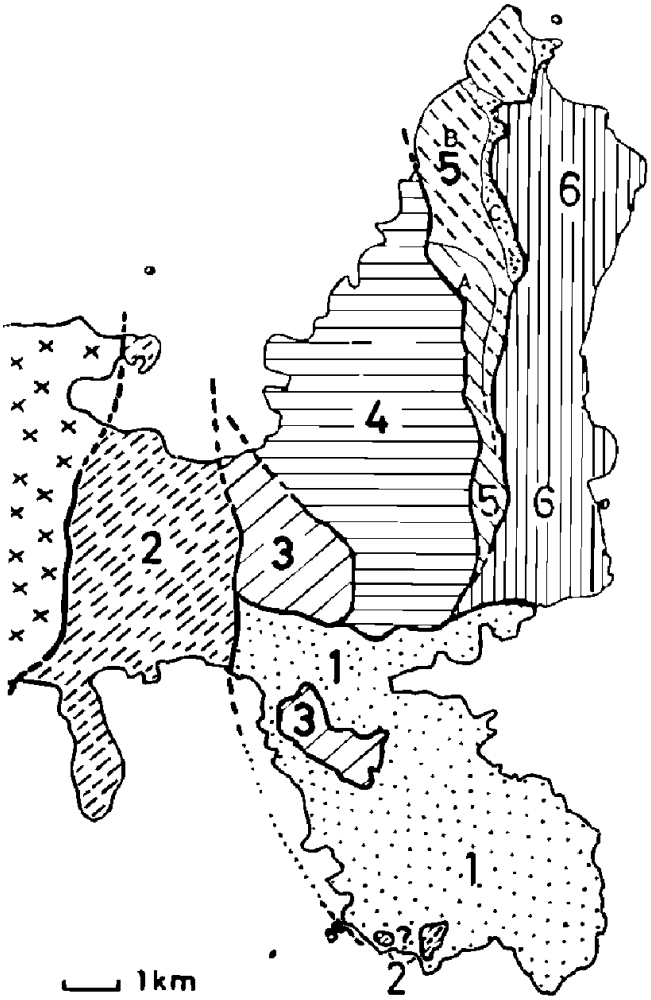

Fig. 10 - Scheme of the tectonic units of the eastern Elba. 1- Autochthon; 2- Mesozoic and Paleozoic succession of central Elba between Colle Reciso and Valdana; 3- Flysch slices of Valdana and Capoliveri; 4- Ophiolitic complex; 5- "Shuppenzone", subdivided in three minor slices (A,B,C from bottom to top); 6- Paleozoic-Mesozoic "Parautochthonous" successions along the eastern coast of the Island; ×- Flysch of central Elba (after Bodechtel, 1964a).

ondary slices (the basal portion of Trevisan Complex IV); **d**- a calcareous-cherty-ophiolitic complex (the upper portionof the Complex IV); **e**- Valdana and Capoliveri Cretaceous flysch unit (Trevisan Complex V); and finally, **f**- the Palaeozoic-Mesozoic successions of central Elba (according Trevisan a repetition of the Complex IV).

According to **Richter** (1962) the Tuscan and Ligurian formations of Elba were deposited in a common depositional basin; therefore the author denies the existence of large horizontal movements. Alternatively, he proposes that the tectonic pile of Elba is made up of large tectonic sheets ("Schuppenbau") and that the Elba flysch is transgressive on the Mt. Capanne granite.

Wunderlich (1962; 1963; Fig 11) interpreted the areas of central and eastern Elba as a succession of large scale, recumbent folds, and concluded that "a sudden change from miogeosynclinal to eugeosynclinal conditions culminating in a thick flysch succession, took place at the Late Jurassic-Early Cretaceous boundary" (1963, p. 161). Citing Richter (1962), the author hypothesises a relative autochthony of all the successions, which were only interested by east-vergent thrust sheets.

All the previous authors consider that the ophiolitic succession formed on the same basement that the other successions (e.g. Figs. 7 and 8), and that the ophiolites are remnants of Jurassic magmatism occurred in the western portion of the "Tuscan Succession" basin.

The Working Group of Pise (**Bellincioni**, 1958; **Barberi** and **Innocenti**, 1965; **Raggi et al**., 1965; 1966; **Barberi et al**., 1967a; 1967b; 1969a; 1969b), at the conclusion of the new geologic survey of the Island for the second edition of the Geological Map of Italy, (published also in two sheets at the scale 1:25,000 -Barberi et al., 1997a-, and inserted in the pocket at the end of this volume), proposed some minor modifications to the general frame of Trevisan (1950; 1951), also because of the increased understanding of the geology of the Northern Apennines. The new model had represented until now the starting point for any geological study of the Elba Island.

Within the Elba tectonic pile, the previous authors assigned the Complexes I, II, III to the Tuscan Domain and the Complexes IV and V to the Ligurian Domain.

Complex I (Permo-Carboniferous? - Triassic). Except for

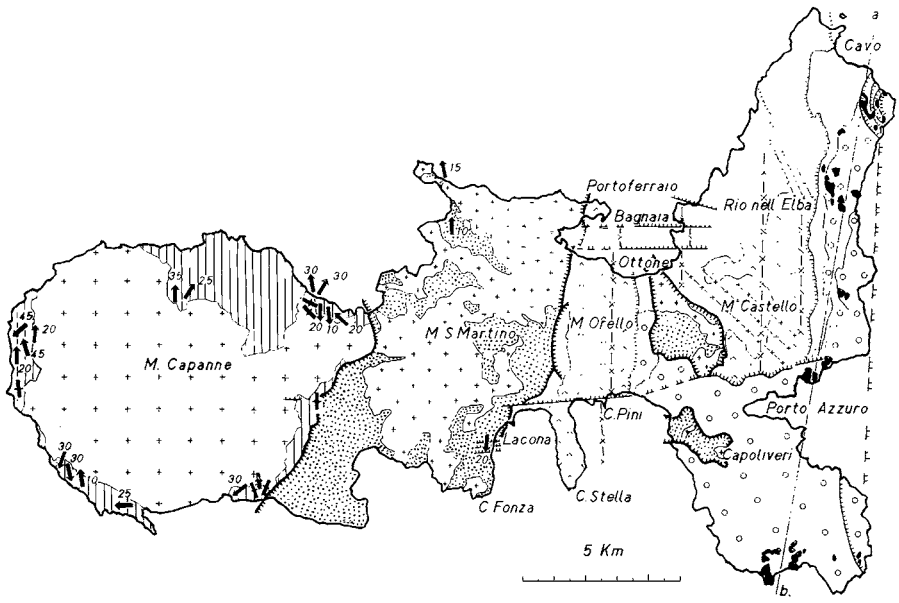

Fig. 11 - Tectonic scheme of Elba. From west to east: +- Mt. Capanne granite with, |||- its metamorphic aureola, ➜- fold axes; close dots- Flysch with, +- porphyrites; ∧- Ophiolitic complex of Mt. Orello and Mt. Castello; white- Mesozoic cover; O- pre-Mesozoic of Valdana, Capoliveri and eastern coast; black- fe-ores (after Wunderlich, 1963).

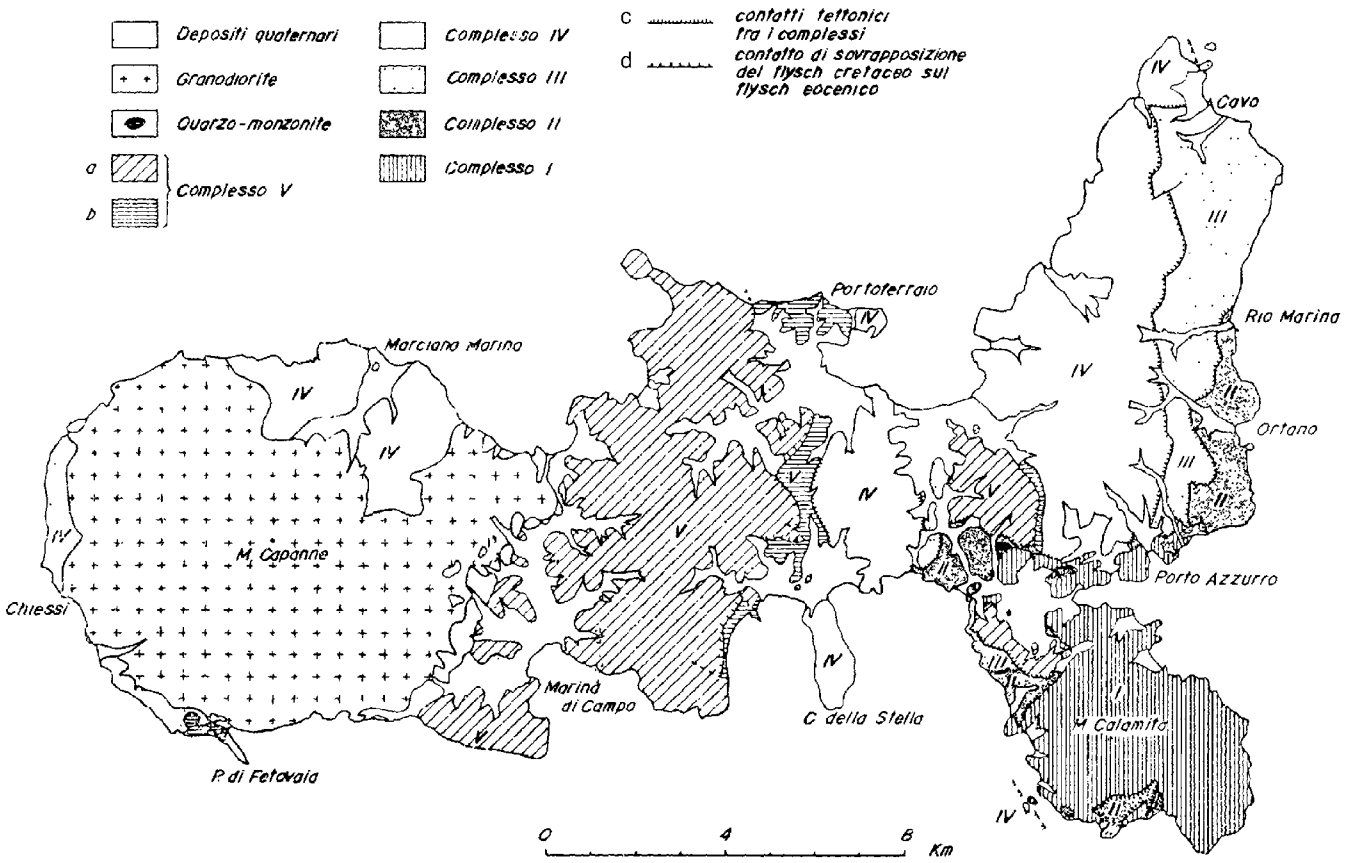

Fig. 12 - Tectonic scheme of the Elba Island. *I*- Complex I; *II*- Complex II; *III* Complex III; *IV*- Complex IV; *V*- Complex V (a- Upper Cretaceous flysch on top of b- Middle Eocene flusch); c- Tectonic contacts between the Complexes; d- Tectonic superposition of Cretaceous flysch on the Eocene flysch (after Raggi et al, 1965).

Barberi et al. (1967a and 1967b) in which, the areal extension of the Complex is the same proposed by Trevisan, the other works (e.g. Raggi et al, 1965, Fig. 12 and Barberi et al., 1969a) suggest that the calcareous succession on top of the Complex should not longer be considered the cover of the Calamita gneiss, but it should be attributed to Complex II (even if in the geological map -Geological Map of Italy, Sheet 126- no thrust contacts are placed in between the two units). Within the Calamita gneiss, the authors distinguished Paleozoic muscovite-biotite schists with andalusite and plagioclase, including quartzitic and amphibolitic levels, locally capped (e.g. Barabarca area) by quartzites and microanagenites which can be correlated to the Triassic "Verrucano" Fm. The authors also point out that the high recrystallisation characteristic of these rocks is due to the overprint of the thermometamorphism of the Porto Azzurro granitoid onto a regional-type metamorphic framework. Moreover, mylonitic horizons were defined at the top and inside the Complex I.

Complex II (pre-Carboniferous-Dogger). It is exactly the same of the previous works but a horizon of thermometamorphic, at times vacuolar, dolomitic limestones was also distinguished between the porphyroids/porphyritic schists and the overlying marbles. The correlation, that the authors propose, of this horizon with the Upper Triassic evaporites strengthened the analogies of the Complex II with the Tuscan Succession ("recalls the Apuan autochthonous").

Complex III. It is a Carboniferous - Dogger stratigraphic succession which "recalls the La Spezia series". The "Argille variegate" at the base of the Complex IV of Trevisan (1950) is included in the Dogger sediments of the Complex III.

Complex IV (Malm - Early-middle Cretaceous) It is characterised by an ophiolite unit at the base and by a sedimentary cover, with the Palombini Shales at the top.

Complex V is divided in two flysch subunits separated by a thrust contact: the lower one is a Palaeocene-Eocene shaly-calcareous succession with minor sandstone and ophiolitic breccias; the upper one is an Upper Cretaceous succession with basal sandstones and conglomeratic levels passing upward into a calcareous-marly-flysch with minor occurrence of sandstones.

The Complexes II-IV are thrust onto the Complex I in a single tectonic phase. Because of their imbricate structure, in eastern Elba all these complexes lie directly on the "virtually autochthonous" Complex I (Fig. 13A, Raggi et al., 1966; Fig 13B, Barberi et al, 1969b). In contrast, the Complex V overrode only later onto the other units, and was not involved in the tectonic imbrication. The previous two eastward-facing movements took place along sub-horizontal thrust surfaces. A third, younger tectonic phase is characterised by extensional movements, along the N-S normal faults of eastern Elba.

To sum up, the timing of the tectonic events, proposed by the authors, is: a- thrusting of the Cretaceous on the Eocene Flysch units; b- intrusion of the acidic dikes in the previous units; c- gravitational emplacement of Complexes II-III and IV on Complex I, right after it was injected by the acidic dikes; d- gravitational gliding of Complex V on the previous ones; e- block tectonics accompanied by ore mineralisations (hematite, pyrite, etc.).

None of the previous works deals with the problem of

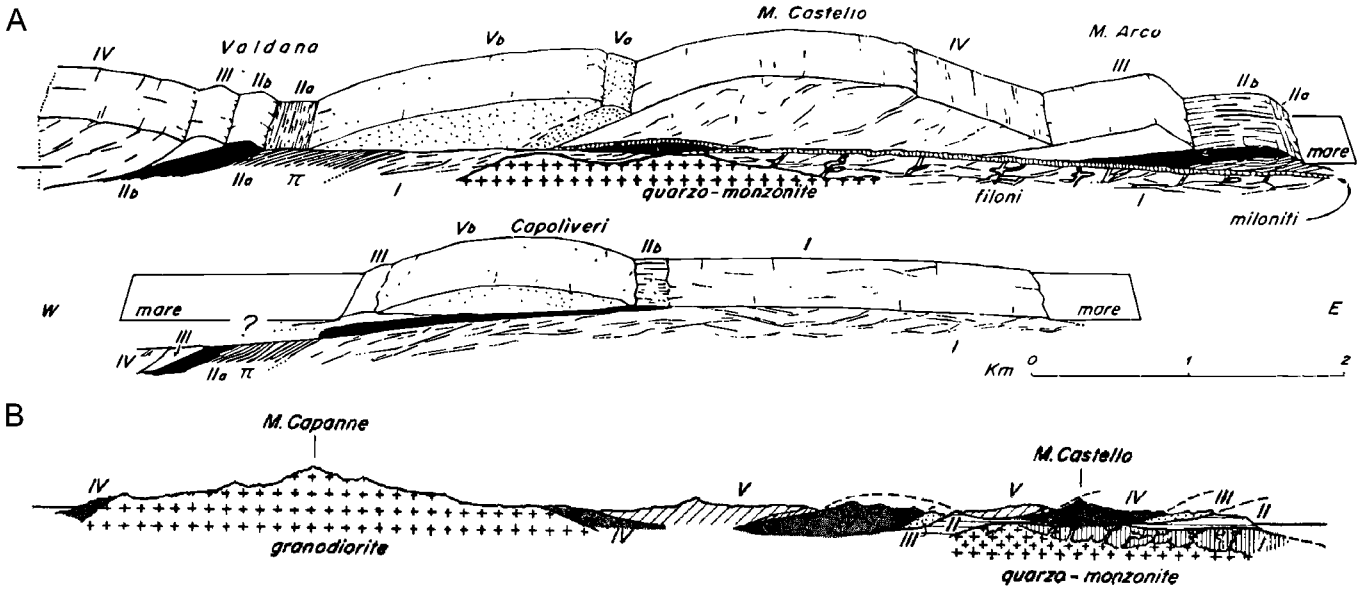

Fig. 13 - The relationships between the five complexes in the Elba Island. A. West-East section of eastern Elba. *I*- Mt. Calamita Schists, Complex I; *IIa*- Lower formation of the Complex II, *π*- porphyroids and porphyritic schists; *IIb*- Upper formations of the Complex II (Calcschists, "cipollini", marbles and dolostones); *III*- Complex III (along this section only the lowermost formations: Carnian quartzitic conglomerates and Carboniferous phyllitic schists); *IV*- Ophiolitic series; *Va*- Eocene Flysch; *Vb*- Cretaceous Flysch (after Raggi et al., 1966). B.East-West section of the Island. Symbols as in Fig. 5 (after Barberi et al., 1969b).

what was the basement on which the ophiolite succession formed. In effect, only between the end of the fifties and the beginning of the sixties some authors (e.g. **Glangeaud**, 1957) surmise that before the Alpine-Apenninic orogenesis, the European and African cratons drifted apart, producing, by crustal stretching, a basin resting on the lower crust and upper mantle, in which the ophiolitic sequences formed, independently from the cratonic (e.g. Tuscan) successions.

Actually, these were the times of the birth of the plate tectonics theory and of the first approvals on the oceanic nature of the ophiolites. Regards to the Apennine, safe for the forerunners ideas of Glangeaud, **Decandia** and **Elter** (1969), **Abbate et al**. (1970), and **Boccaletti et al**. (1971), were the first authors that proposed models of oceanisation and formation of a basin with oceanic crust (Ligurian-Piedmont Basin) as the place of sedimentation of the Ligurian successions

The first sedimentological and petrographic data on the flysch successions of the central Elba have been presented by **Parea** (1964). **Aiello et al.** (1977) interpreted the Elba flysch as a deep sea fan, deposited near the Corso-Sardinian continental margin.

Perrin (1969), studying the ophiolitic succession; of eastern Elba, recognised four "sous ensembles tectoniques" and the presence of a transitional level ("calcaires CB") between the radiolarian cherts and the typical facies of the Calpionella Limestones

Afterwards, **Perrin** (1975) distinguished within the Elba Island two main tectonic buildings (Figs. 14 and 15):

a) a *central-eastern building,* pertaining to the Apennine chain, that is made up of the first four Trevisan's Complexes. He proposed a more complex tectonic and stratigraphic framework for the Tuscan Complexes (I-III). In particular, in Complex II he separates the "Unité d'Ortano" from an overlying "Unité des schistes et cipolins" and the topmost Ligurian "Serpentine intercalaire". In Complex III he distinguished three units (from bottom to top): **a**- "Rio Marina-Calendozio" Unit, including the Carboniferous-Permian and Verrucano metasediments and the Jurassic-Cretaceous (see **Perrin** and **Neumann**, 1970) Capo Pero and Capo Castello succession; **b**- "Unité calcaire SA", formed by the non metamorphic Jurassic Tuscan Succession ranging from Calcare Cavernoso to Posidonomia Marls; **c**- "Unité calcaire SB ", constituting a tectonic doubling of SA, south of Cavo. Moreover he suggested a Miocene age (post-Aquitanian) for the polymictic non-metamorphic breccias ("Madonna delle Grazie breccia", that according to the author is of sedimentary origin) unconformably overlying the Calamita gneiss of the Complex I, already injected by aplitic dykes of the La Serra-Porto Azzurro monzogranite.

b) a *western tectonic building*, with Alpine affinity, represented by Trevisan's Complex V and the thermometamorphic Ophiolitic Unit (Trevisan Complex IV) of the Mt. Capanne aureola. The latter unit was separated from the Complex IV because it shows a tectono-metamorphic imprinting which predates the contact metamorphism induced by the Mt. Capanne granitoid.

According to this view, Perrin located the limit between the Alpine and the North Apenninic chains in the central part of the Elba Island.

Trevisan's geological scheme was confirmed in a report of CNR (**Boccaletti et al**., 1977) where more careful correlations between the tectonic units of Elba and those of Tuscany and Liguria are proposed.

In 1981 **Soffel** published the first and only paleomagnetic survey of the eastern Elba ophiolite successions. The author describes two components of remanent magnetisation. The first, roughly parallel to the present geomagnetic field, was interpreted as a thermoviscous remagnetisation, the second one, which gives only reversed polarities, could be interpreted as a magnetic overprint acquired during the Early Cretaceous.

During the eighties, three works on the Mt. Capanne metamorphic aureola were published: **Spohn** (1981) and **Reutter** and **Spohn** (1982) confirm the pre-Miocene

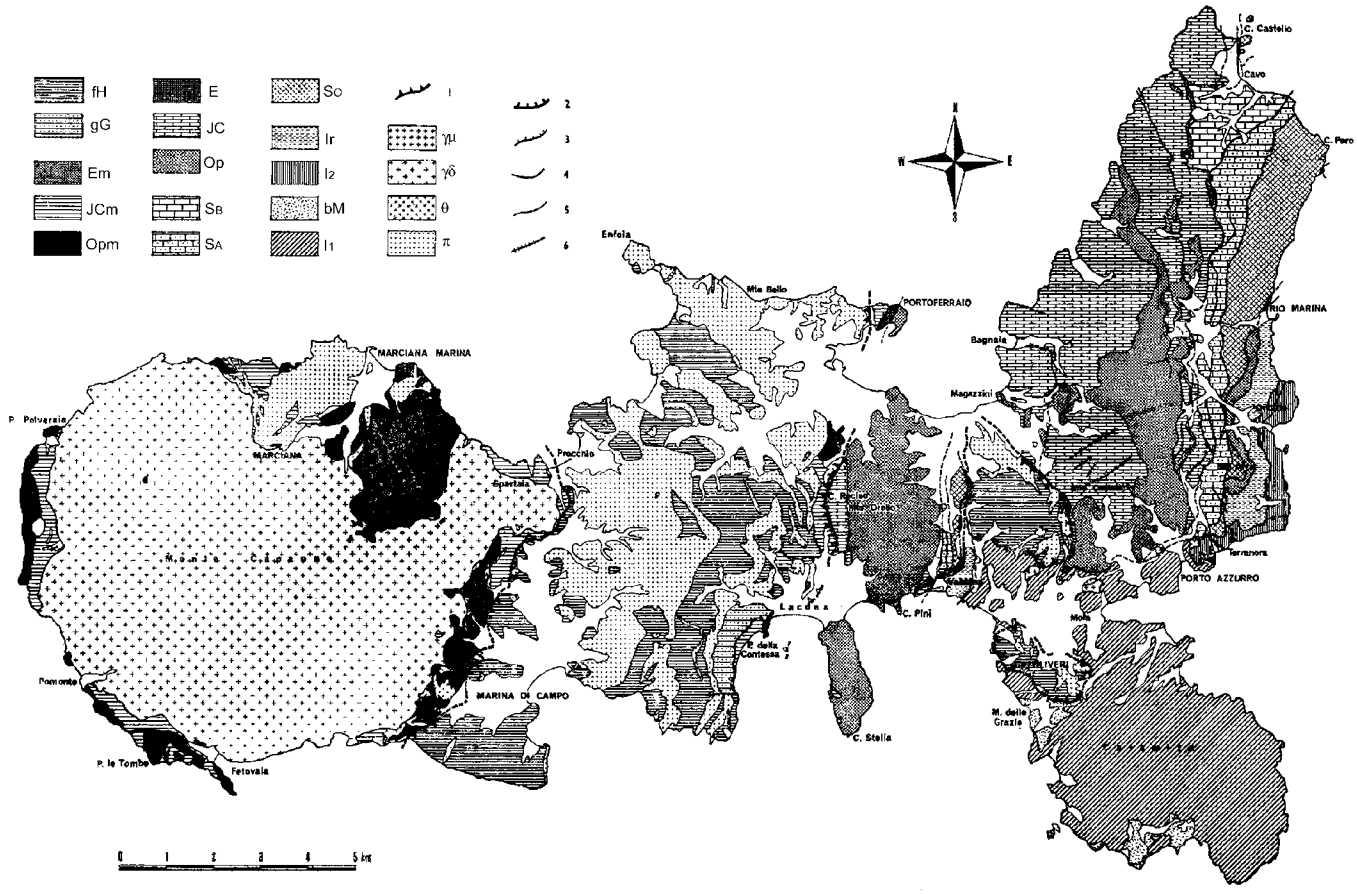

Fig. 14 - Areal distribution of the main units in the Elba Island. Western Building: fH- Helmintoid Flysch; gG- Ghiaieto Sandstones; Em- Eocene breccias; JCm- Cover of the western Elba ophiolites of; Opm- Western Elba ophiolites. Central-eastern Building: E- Eocene breccias; JC- Cover of the central and eastern Elba ophiolites; Op- Central and eastern Elba ophiolites. Upper Tuscan Units: SB- Upper calcareous Unit (thrust onto SA); SA- Upper calcareous Unit (thrust onto SO); SO- Rio Marina-Calendozio Unit. Lower Tuscan Units: Ir- Schists and "Cipollini" Unit; I_2- Ortano Unit; bM- Miocene Madonna delle Grazie breccias; I_1- Calamita Unit. Acidic intrusions: γμ- Serra quartzmonzonite; γδ- Mt Capanne granodiorite; θ- tourmaline-bearing dikes (south-west of Mt. Capanne); π- Porphyritic and aplitic dikes cutting the Western Building. 1- Thrust contact of the upper part of the western building onto the Central and eastern Building; 2- Contact between the Mt. Capanne massif and the upper part of the Western Building slided eastwards; 3- "Anomalous" contacts between the units of the same building; 4- Other "anomalous" contacts; 5- "Décollement" contacts; 6- Faults (after Perrin, 1975).

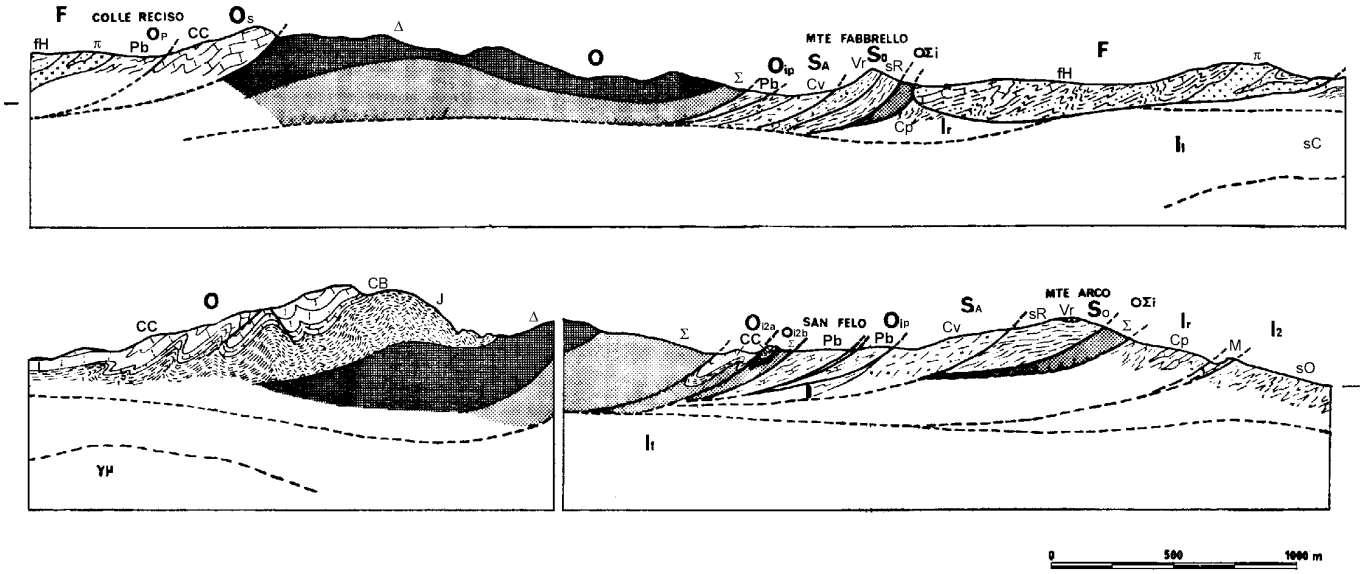

Fig. 15 - West-East section in the central-eastern sector of Elba. Formations: fH- Helminthoid flysh; π- "porphyries"; Pb- Palombini shales; CC, CB- *Calpionella* Limestones (CB- basal level); J- Cherts; Δ- Diabases; Σ- Serpentinites; Vr- Verrucano; sR- Rio Marina schists; Cp- Schists and "cipollini"; M- Ortano marbles; sO- Ortano schists; sC- Calamita schists. Units: F- Helminthoid flysch unit with OP- Palombini shales slice; OS- Ophiolitic nappe, upper slices; O- Ophiolitic nappe, main body; Oi2a, Oi2b- Ophiolitic nappe, Casa Leonardi slices; Oip- Ophiolitic nappe, Palombini shales slices; SB- Calcareous unit SB; SO- Calcareous unit SA; SO- Rio Marina.Calendozio unit; OΣi- Serpentinite slice, intercalated between Ir and SO; Ir- Schists and "cipollini" unit; I2- Ortano unit; It- Calamita unit (after Perrin, 1975).

tectono-metamorphic framework of the ophiolitic units in the aureola west of the intrusion and relate it to the deformations of the Apennine chain. In contrast, **Bouillin** (1983) interprets the same schistosities and folds as due to the dynamic blastesis and deformation connected to the Mt. Capanne intrusion, in agreement with Marinelli's model (see later, and Pertusati et al., 1993).

Voisenet et al. (1983), recognise a succession Palombini Shales - "varicoloured formation" at the base of the Ghiaieto Sandstones, as previously pointed out by **Sagri** (1969). This formation (Campanian in age), and the Marina di Campo Fm. at its top, are interpreted as a submarine fan, deposited near the Corso-Sardo Domain

Baumgartner (1984), performed in the Mt. Alpe Cherts successions of Elba the first biostratigraphical study, through the radiolarian associations, in the Northern Apennines, and attributed to the formation a late Oxfordian - probably early Kimmeridgian age. This age was successively slightly modified by **Conti** and **Marcucci** (1986), **Marcucci** and **Marri** (1990), **Chiari et al**., 1994, **Marcucci** and **Conti** 1995, and finally, by **Chiari et al**. (2000), which attributed the lower portion of the formation to middle-late Oxfordian - late Oxfordian-late Kimmeridgian

Keller and Pialli, in 1990 (Fig. 16) distinguished, within Complex III, the Massa Unit (that is, the epimetamorphic Rio Marina Fm-"Verrucano" succession) from the overlying Tuscan Nappe (non-metamorphic "Calcare Cavernoso" to *Posidonia* Marlstones succession). They also propose an up-to-date evolutionary model for the Elba tectonic pile which, according to the authors would have been formed in three main stages: a) a Cretaceous-Eocene accretionary stage due to underplating; b) an Oligo-Miocene collision of the accretionary prism with the Adriatic continental margin and thrusting of the Ligurid nappes onto the latter. The Adriatic margin suffered wedging and local metamorphism. Out of sequence events also occurred (e.g. the serpentinite slice interposed between the Tuscan Complexes II and III). c) an extensional tectonics that started in Late Miocene, due to the re-equilibration of the overthickened tectonic pile; it produced high angle normal faults, detachments and the intrusion of the Neogene granitoids. The previous authors defined the tectonic surface on the top of the Complex I as a low-angle detachment fault (Zuccale Fault, Fig. 16) which represent the main extensional structure of eastern Elba (Zuccale and Terranera areas).

Pandeli and **Puxeddu** (1990) carried out petrographic-lithologic studies on Complex II. They attributed the lower phyllitic-quartzitic-metavolcanic portion of the Complex II to the Ordovician successions of Tuscany (Apuan Alps) and Sardinia. Moreover, the authors ruled out the affinity of the upper part of the Complex II (marble-calcschists-phyllite) with the Apuan Mesozoic successions, and suggested for it a possible Ordovician-Silurian age. Finally, they considered the vacuolar limestones (Triassic evaporites, Barberi et al 1969b) an Upper Tertiary tectonic breccia produced by the detachment of the Marble from the underlying metasiliciclastics (e.g. Porphyritic schists).

Duranti et al. (1992) found Lower Cretaceous fossils in the calcschists-phyllite succession (named Punta dell'Acquadolce Carbonate-Schist "Unit" of the Complex II) which they correlate to a Ligurian formation (Palombini Shales). The authors also suggest that the main metamorphic imprint was acquired because of the ballooning of the Mt. Capanne intrusion (see also Pertusati et al., 1993). The underlying Marble was again considered as a Tuscan Liassic rock.

The previous hypothesis has been ruled out by **Deino et al** (1992) who obtained an age of 19.68±0.5 Ma for the main schistosity of the Punta dell'Acquadolce "Unit" using $^{40}Ar/^{39}Ar$ laser technique.

A primary role of the extensional detachments in relation to the emplacement of the Neogene granitoids has been recently proposed by **Pertusati et al.** (1993, Fig. 17) and **Daniel** and **Jolivet** (1995). According to these authors, the Zuccale Fault became active just after the intrusion of the Porto Azzurro monzogranite and has been dissected and deformed by both the final doming of the magmatic body and the successive high angle normal faulting.

In the last ten years the classic Trevisan's model has been refined and partly modified by a series of new studies.

As regards to Complex IV, **Bortolotti et al.** (1991) recognised four tectonic sub-units (from bottom to top): the Acquaviva, the Sassi Turchini , the Mt. Serra and the Volterraio sub-units. Within the last two sub-units, **Bortolotti et al.** (1994b) defined a transitional formation between the Mt. Alpe Cherts and the Calpionella Limestones, named Nisportino Formation. In the same paper a slaty unit of uncertain origin, found between the Tuscan units and the Ligurids: the "Gràssera Unit" was defined for the first time. During the same year, **Bortolotti et al.** (1994a) and **Tartarotti** and **Vaggelli** (1994), characterised the eastern Elba serpentinites and noted that the only difference that occurs between the serpentinite sheet at the top of the Complex II and the serpentinites of Complex IV is that the first one had suffered an intense tectono-metamorphic evolution.

Further improvements on the stratigraphy of the Elban successions have been presented in the two following papers In the Capo Scandelli-Capo Castello-Isola dei Topi area (NE of Cavo), **Pandeli et al.** (1995) recognised a Tuscan-type epimetamorphic succession including Mesozoic cherty calcschists and Maiolica-like crystalline limestones, Cretaceous-Eocene "Varicoloured sericitic schists" and Oligocene "Pseudomacigno". This succession has been correlated to the sedimentary cover of the epimetamorphic "Verrucano" succession of Complex III. Preliminary data of the new geological mapping (scale 1:10.000) of the central and eastern Elba were presented by **Corti et al.** (1996) during the 78th Summer Meeting of the Geological Society of Italy. The authors included the Marbles of the Trevisan's Complex II in a tectono-metamorphic unit (Acquadolce Unit) correlated (with the serpentinite slice at the top), with the Piedmontese Units of the Gorgona Island (cfr. also Termier, 1910). According to these authors, the Gràssera Unit (including calcschists, recrystallised siliceous limestones and manganesiferous cherts) recalls some facies of Corsica "Schistes lustrés".

Keller and **Coward** (1996), racognised that the thrust set of eastern Elba had a NE transport direction, while the following extensional low angle detachment faults: the "Capanne fault" (CEF of **Dini**, 1997a; 1997b) and the Zuccale detachment fault had a direction of transport towards east-southeast.

Muhlstrasser and **Frisch** (1998), studied the fault systems of northeastern Elba, and separated three tectonic phases; compressional the first one, extensional "as a gravitational response to nappe stacking" the second one, and finally a Pliocene third event, triggered by eastern Elba pluton.

Finally, in the new tectono-stratigraphic model that we propose (**Benvenuti et al**., 2001; **Bortolotti et al**., 2001), the five Complexes of Trevisan (1950), have been re-interpreted and re-named, and integrated in a new and more

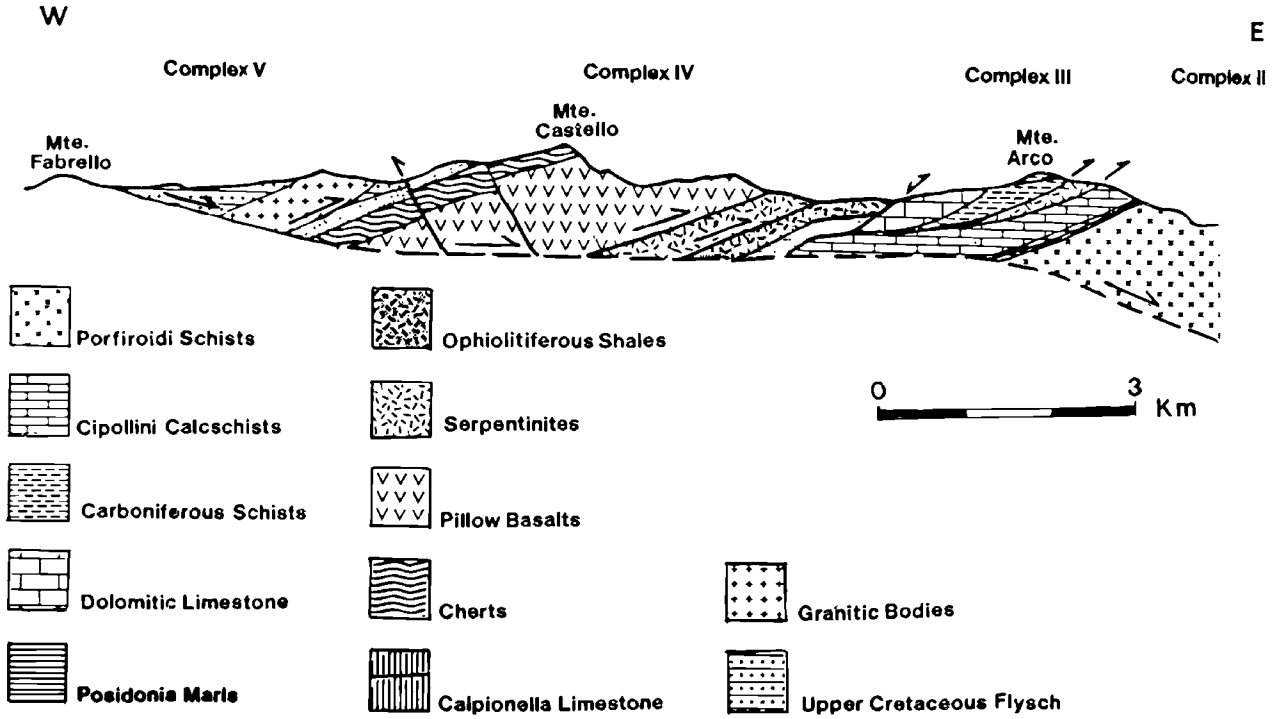

Fig. 16 - Cross-section of eastern Elba from Mt. Fabbrello to Mt. Arco (after Keller and Pialli, 1990).

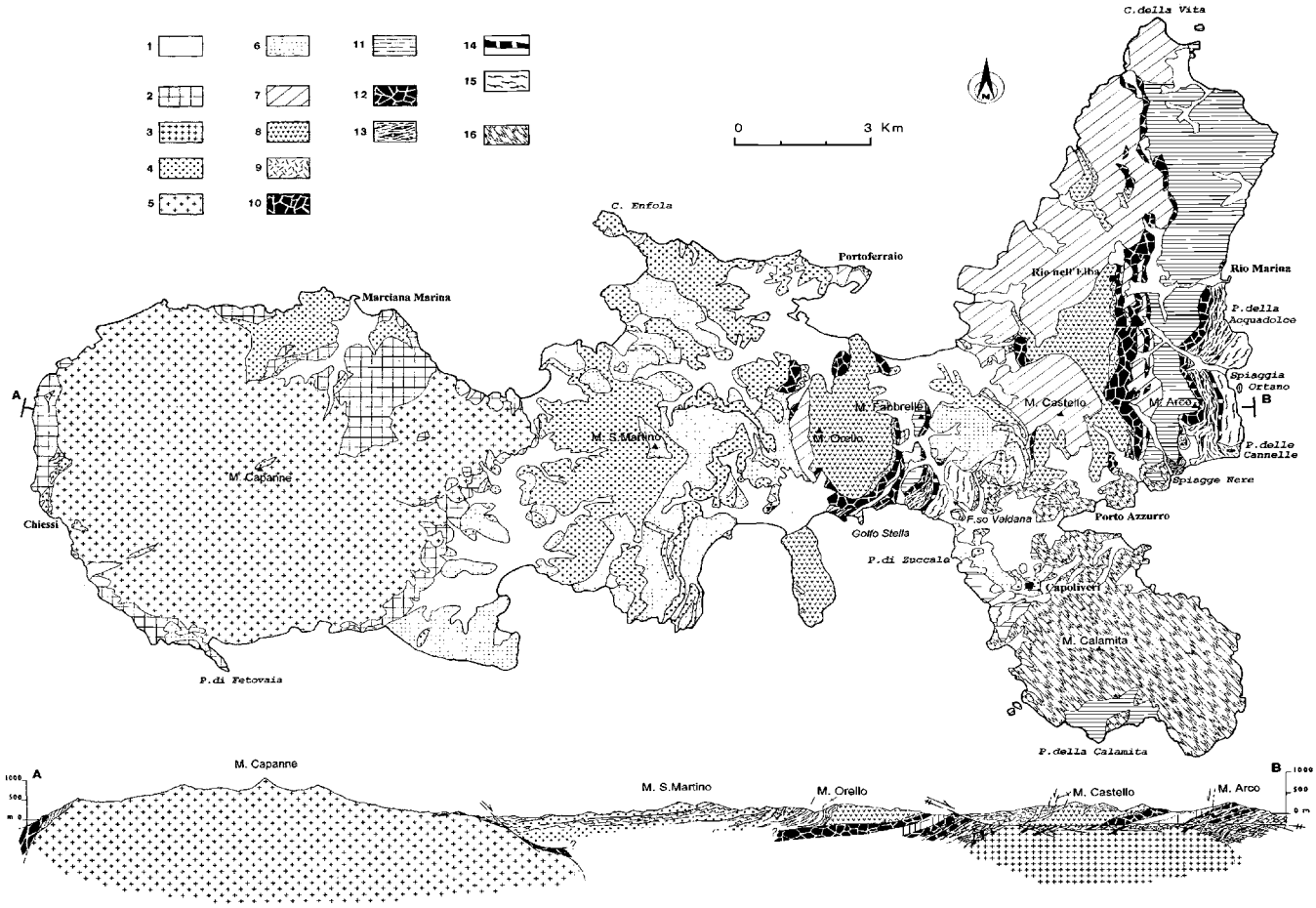

Fig. 17 - Schematic geologic map of Elba Island. 1- Quaternary deposits; 2- Rocks of the metamorphic aureola of Mt. Capanne; 3- Porto Azzurro monzogranite; 4- Granitic and granodioritic porphyries and aplites; 5- Mt. Capanne granodiorite. Complex V: 6- Cretaceous and Paleocene-Eocene flysches. Complex IV: 7- Sedimentary cover of the ophiolites (Malm-Early/"mid" Cretaceous; 8- Diabases; 9- Gabbros; 10- Serpentinites. Complex III: 11- Tuscan succession (Triassic-Oligocene). Complex IVa: 12- Serpentinites; 13- Metamorphic Palombini shales (upper part of Early Cretaceous). Complex II: 14- Metalimestones (Hettangian?); 15- Micaschists, porphyroids and associated terrigenous metasediments (Cambrian-Ordovician?). Complex I: 16- Mt. Calamita andalusite and cordierite micaschists (Early Paleozoic?) (after Pertusati et al., 1993)..

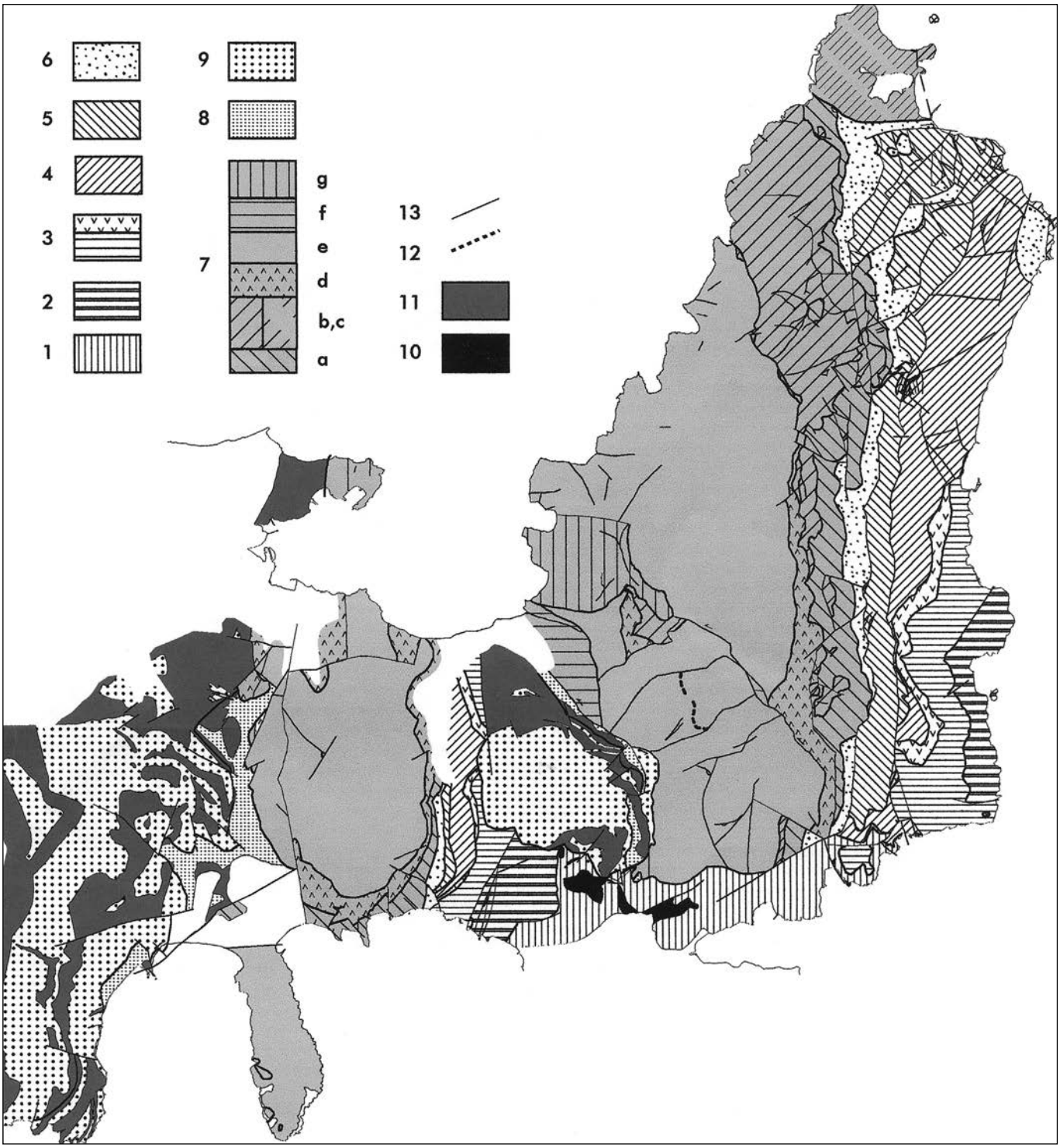

Fig. 18. Tectonic scheme of central and eastern Elba. 1- Porto Azzurro Unit; 2- Ortano Unit; 3- Acquadolce Unit (a- Porticciolo Subunit; b- Santa Filomena Subunit); 4- Monticiano Roccastrada Unit; 5- Tuscan Nappe; 6- Gràssera Unit; 7- Ophiolitic Unit (a- Acquaviva Subunit; b- Mt. Serra Subunit; c- Capo Vita Subunit; d- Sassi Turchini Subunit; e- Volterraio Subunit; f- Magazzini Subunit; g- Bagnaia Subunit); 8- Eocene Flysch Unit; 9- Cretaceous Flysch Unit; 10- La Serra-Porto Azzurro monzogranite; 11- Neogene aplites and porphyries; 12- Mt. Catello shoshonitic dike; 13- Faults (after Bortolotti et al., 2001).

complex frame (Fig. 18). We recognise a total of nine tectonic units, that from bottom to top are: **a**- Porto Azzurro Unit (Trevisan's Complex I); **b**- Ortano Unit (Complex II p.p.); **c**-Acquadolce Unit (Complex II p.p.); **d**- Monticiano-Roccastrada Unit (Complex III p.p.); **e**- Tuscan Nappe (Complex III p.p.); **f**- Gràssera Unit (Complex III p.p.); g- Ophiolitic Unit (Complex IV), with seven subunits; **h**- Palaeogene Flysch Unit (Complex V p.p.); **i**- Cretaceous Flysch Unit (Complex V p.p.).

*Porto Azzurro Unit***.** It is composed of the thermometamorphosed phyllites and metasandstones of the Paleozoic Tuscan basement, including amphibolite levels. In some locality, a Triassic-?Hettangian cover is present, in which is noteworthy the presence of a transitional unit very similar to the Tocchi Fm. of Southern Tuscany (Carnian), that occurs between the "Verrucano" and the overlying carbonate succession. A cataclastic, locally mineralised (Fe oxides/hydroxides) horizon about ten metres thick, located along a

low angle fault (Zuccale Fault) constitutes the contact with the overlying imbricate tectonic units (Keller e Pialli, 1990; Pertusati et al., 1993). East of Porto Azzurro the unit is cut by the aplitic dikes of the Serra-Porto Azzurro monzogranite intrusion (6.0 Ma, Maineri et al., in prep.). These dikes do not cross the Zuccale Fault, which, therefore, postdates their intrusion.

Ortano Unit. It includes Porphyroids and Porphyritic schists grading upward to Phyllites and quartzitic metasandstones and metaconglomerates. Moreover, more or less cornubianitised micaschists, phyllites, quartzites with rare and thin aplitic dikes (Capo d'Arco Schists) geometrically underlie the Porphyroids. This Unit 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, it represents a kilometric overturned isoclinal fold with the Ordovician metavolcanites (Porphyroids) at the core. A vacuolar carbonate cataclasite is present at the contact with the overlying Acquadolce Unit.

Acquadolce Unit. It is composed of massive marbles, partly dolomitic, which grade upwards to calcschists (sometimes cherty). They are capped by a thick siliciclastic succession, which includes some levels of calcschists showing a Lower Cretaceous microfauna (Duranti et al., 1992). The previous authors consider the succession, except for the marbles, as a metamorphosed Ligurid Unit, which was deformed and recrystallised during the Mio-Pliocenic intrusion. In our opinion, these rock formations probably correspond to a Piedmontese oceanic succession, like the "Schistes Lustrés" of Corsica (e.g. Inzecca Units, Durand Delga, 1984), and the calcschists of the Gorgona I. (Capponi et al., 1990). The occurrence of a serpentinite sheet at its top of this unit strengthens our interpretation.

*Monticiano-Roccastrada Unit***.** The base of this Unit is made of fossiliferous graphitic metasediments of Carboniferous-Permian age (Rio Marina Fm.), on which the detrital "Verrucano" successions were deposited (Middle?-Late? Triassic; Deschamps et al., 1983; Benvenuti and Pandeli, in Benvenuti et al., 2000). The epimetamorphic succession of Capo Castello can be also ascribed to this unit: it includes formations from Upper Jurassic siliceous metalimestones to the Oligocene Pseudomacigno (Pandeli et al., 1995), and can represent the sedimentary cover of the "Verrucano".

Tuscan Nappe. In the areas located between Porto Azzurro and Rio Marina, and Norsi and La Valdana, this unit includes only calcareous-dolomitic breccias ("Calcare Cavernoso" Auctt.). Northwards, in the Cavo area, it includes also carbonatic (Pania di Corfino Fm., Cetona Fm. and "Calcare Massiccio", Late Triassic-Hettangian), carbonatic-cherty (Limano and Grotta Giusti Cherty Limestones, and "Rosso Ammonitico", Middle-Late Liassic), and marly-carbonatic formations (*Posidonia* Marlstones, Dogger).

Gràssera Unit. It is a unit of uncertain paleogeographic position. The base is composed of calcschists, sometimes associated with cherts, but most of the unit is composed of slates and siltstones. These rocks have been previously included in the *Posidonia* Marlstones, which stratigraphic position is on top of the Tuscan Succession (Barberi et al., 1969a; 1969b). However, the lithologies of this Unit differ significantly from those of all the formations of both Tuscan and Ligurian Domains. Moreover, these rocks show a slight metamorphism (anchizone/epizone) and lie on different formations of the Tuscan Nappe with a tectonic unconformity. The previous observations can suggest that the origin of this unit is a paleogeographic domain west of the Tuscan one, possibly in the Piedmont oceanic domain.

Ophiolitic Unit. Its succession belongs to the Vara Supergroup (Abbate and Sagri, 1970). This Unit is built up of four main thrust sheets (Subunits), from bottom to top they are: *Acquaviva Subunit* (serpentinites/ophicalcites, Mt. Alpe Cherts and Palombini Shales), *Mt. Serra Subunit* (ophicalcites, Mt. Alpe Cherts, Nisportino Fm., Calpionella Limestones), *Sassi Turchini* Subunit (serpentinites), and *Volterraio Subunit* (gabbros, basalts, Mt. Alpe Cherts, Nisportino Fm., Calpionella Limestones, Palombini shales). The age of the sedimentary cover ranges from Late Jurassic to Early Cretaceous. This unit can be interpreted as a relic segment of trapped oceanic crust of the Ligurian oceanic basin, which original position was close to the Corsica European margin.

Paleogene Flysch Unit. It includes a shaly-marly succession with turbiditic limestones, sandstones and ophiolitic breccias, of Palaeocene-Eocene age.

*Cretaceous Flysch Unit***.** In this uppermost flysch unit, the Palombini Shales and the Varicoloured Shales grade upwards into turbiditic siliciclastic sandstones and conglomerates (Ghiaieto Sandstones), and finally to alternating marlstones and marly limestones (Marina di Campo Fm). A thin "schuppenzone" with ophiolites, Mt. Alpe Cherts, Calpionella Limestones and Palombini Shales lenses probably belong to this unit.

These Flysch-bearing units, and in particular the uppermost one, are cut by aplitic and porphyritic (e.g. "eurite" Auctt) dikes probably related to the Mt. Capanne monzogranite.

NEOGENE MAGMATIC BODIES (Fig. 13B)

The acidic stocks of Elba (the Mt. Capanne and the La Serra-Porto Azzurro monzogranites) have been considered Tertiary intrusions since the first geological studies of the Island (e.g. **Savi**, 1833; **Lotti**, 1886; **De Wijkerslooth**, 1934). **Aloisi** (1910; 1912; 1919, with older geological-petrographical references), presented petrographical studies on the "granites" and related dikes of Elba, and considered the Mt. Capanne a pre-Eocene (possibly Cretaceous) intrusion. Other lithological-petrographical data are presented in **Manasse** (1912) and **Bonatti** and **Marinelli** (1953). **Marinelli** (1955; 1959) published two monumental syntheses on the Elba Tertiary magmatic complexes and related hornfelses, and during the same years (**Marinelli**, 1961) recognised the anatectic origin of the acidic plutonic rocks (confirmed recently by Serri et al., 1991), and proposed a model for the emplacement of the magmatic bodies and for the deformation of the host rocks. Cornubianitic rocks bounding the plutons were studied by **Barberi** and **Innocenti** (1965; 1966), **Barberi et al.** (1967b), **Bouillin** (1983). **Boccaletti** and **Papini** (1989) pointed out the complex frame of the structural features of the Mt. Capanne stock -e.g. the existence of two main magmatic domes- and evidenced its relationships with the dike swarm which pre-dates the stock intrusion.

Serri et al., (1991), confirmed the anatectic origin of the acidic rocks, pointed out the mixing with sub-crustal magmas, and proposed a model for the emplacement of the magmatic body and for the deformation of the host rocks. Further detailed studies on the Mt. Capanne stock were published by **Poli et al**. (1989) and **Poli** (1992).

Orlandi et al. (1990), **Pezzotta** (1993; 1994) and later **Orlandi and Pezzotta** (1997) studied the aplites and pegmatites of the Mt. Capanne dike complex which are famous

all over the world for the abundance of varicoloured tourmaline crystals (e.g. the peculiar Elbaite).

Bouillin et al. (1993), using magnetic susceptibility (MS and AMS) data, detailed the mode of emplacement of the Mt. Capanne which would be related to a pull-apart void linked to an about E-W trending sinistral transform fault.

Daniel and **Jolivet** (1995) detailed the structural frame of the thermometamorphic aureola of the Mt. Capanne and suggested an evolutionary model for the syn-intrusion tectonics of the Elba Island through low angle detachments triggered by the pluton uplift.

Dini (1997a; 1997b) performed geological, geochronological, mineralogical and geochemical studies on the aplitic to microgranitic, porphyritic dykes of the central and western Elba and defined five main types of porphyries.

Radiometric ages

In the last thirty years, many works on radiometric datings (K/Ar, Rb/Sr, U/Pb and $^{40}Ar/^{39}Ar$) on the Elba stocks and dykes were published. They suggested out an age of about 6.8 Ma for the Mt. Capanne intrusion (**Ferrara et al.**, 1961: 6-7 Ma; **Eberarhardt** and **Ferrara**, 1962: 7.6-9.8 Ma; **Borsi** and **Ferrara**, 1971: 7 Ma; **Juteau et al.**, 1984: 5.8-8.1 Ma; **Ferrara** and **Tonarini**, 1985; 1993: 6.4-7.2 Ma; **Boccaletti et al.,** 1987: 7.9-8.1 Ma), while the age of the La Serra - Porto Azzurro intrusion was inferred to be about 5 Ma (4.9→5.9 Ma) such as that of its aplitic dikes and the thermometamorphism of the host Mt. Calamita Fm (= Calamita Gneiss Auctt.) (**Saupé et al.**, 1982: 5.1-6.2 Ma; **Ferrara** and **Tonarini**, 1985; 1993: 4.9-6.2 Ma).

On the other side, the porphyries and the aplitic dikes, cutting the Mt. Capanne stock and the Flysch Units, show an age slightly older to slightly younger with respect to the age the Mt. Capanne intrusion (**Ferrara et al.,** 1961: 5.7-7.5 Ma; **Eberarhardt** and **Ferrara**, 1962: 6.4 Ma; **Borsi** and **Ferrara,** 1971: 8.5-9 Ma; **Juteau et al.**, 1984: 8.2-9.5; **Ferrara** and **Tonarini**, 1985; 1993: 5.1-7.3 Ma; **Boccaletti et al.**, 1987: <8 and <9 Ma; **Dini et al.**, 1996: <7.2-8.4 Ma; **Dini** and **Laurenzi,** 1999: 6.8-7.2 Ma; **Maineri et al.**, in prep.: 8.5).

Bouillin et al. (1994) using fission tracks data revealed a fast denudation of the eastern part of the Mt. Capanne that occurred around 2 Ma, and that is probably due to the detachment and the eastward sliding of the cover. The previous data are in disagreement with the conclusions of **Maineri et al**. (1999; in prep.), which studied and dated (6.7-6.8 Ma) the sericitisation of the Neogene dikes at the Buraccio Quarry ("eurite" Auctt.), and interpreted this phenomenon as the result of fluid flow channeled through the low angle Central Elba Fault (CEF) during its eastwards movement. According to the last hypothesis, the Mt. Capanne denudation would have been older, and contemporaneous to the monzogranite emplacement.

Maineri et al. (in prep.), also dated the La Serra - Porto Azzurro pluton at about 6.0 Ma ($^{40}Ar/^{39}Ar$).

FE-ORES OF EASTERN ELBA

Many papers deal with the famous Fe mineralisations of the Elba Island, which were exploited since about the 8th-7th century B.C. until 1981 (**Savi**, 1836; **Strüver**, 1869; **vom Rath**, 1870; **Fabri**, 1887; **Lotti**, 1886; 1887; 1901; 1928; **De Launay**, 1906; **Pullè,** 1921; **Stella**, 1933; **Debenedetti**, 1951; 1953; **Beneo**, 1952; **Cocco** and **Garavelli**, 1954; **Gilliéron**, 1959; **Dimanche**, 1971; **Calanchi et al**., 1976; **Tanelli**, 1995; **Orlandi** and **Pezzotta,** 1997).

In the last thirty years, the magnetite-prevalent ores associated to the skarn bodies of the Calamita Promontory and Cannelle-Torre di Rio area have been described by **Dimanche** (1971) and **Tanelli** (1977). **Deshamps** (1980) and **Deshamps et al.** (1983) studied the hematite±pyrite mineralisations of Rio Marina-Rialbano area;

The epigenetic or syngenetic-metamorphic origin of the Elba-Fe ores has been discussed by **Tanelli** (1983), **Tanelli** and **Lattanzi** (1986), **Zuffardi** (1990) and **Lattanzi et al.** (1994): a) the "plutonistic epigenetic" models considered the intrusions only as the heat sources, which favoured the circulation of hydrothermal fluids (e.g. **Lotti**, 1929; **Stella**, 1933; **Debenedetti**, 1951; **Beneo**, 1952; **Penta**, 1952; **Gillieron**, 1959; **Marinelli**, 1959b; 1983; **Dechomets**, 1985); b) the "syngenetic/hydrothermal-metamorphic" models acknowledge the importance of the Apenninic tectonomagmatic event in metamorphosing and partly remobilising sedimentary and/or hydrothermal sedimentary protores of Triassic and/or Paleozoic age (e.g. **Bodechtel**, 1964b; 1965; **Deschamps et al**., 1983; **Lattanzi** and **Tanelli**, 1985).

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