Geological Field Trips

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Tectono-stratigraphic evolution of the Southern sector of the Calabria-Peloritani Chain: state of knowledge

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Tectono-stratigraphic evolution of the Southern sector of the Calabria-Peloritani Chain: state of knowledge

86° Congresso Nazionale della Società Geologica Italiana - Arcavacata di Rende (CS), 18-20 settembre 2012

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Peloritani main ridge, with Rocca Novara peak (1,340 m a.s.l.) to the right. In the background, the Mount Etna (3,328 m).

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Safety

Individuals or groups can make the geological excursion alone or accompanied by the authors of this guidebook.

- The geotour can be completed in three days by off-road vehicles and in nine days on foot. The hazard-level is medium to high.
- The excursion is divided into three itineraries. It starts at the small cliff of the scenic Punta Tono (at sea level), in the North-East of the Milazzo Peninsula (Central-Northern Peloritani Chain - Sicily, Italy). After a trip of about 250 km, it ends in Portella Mandrazzi (1,125 m a.s.l. - Central-Southern Peloritani Chain), the boundary between the Peloritani and Nebrodi Mts. and watershed of the sources of the Torrente Fondachelli (third tract of the T.te Patrì-Fantina-Fondachelli) in the East and Torrente Novara (second tract of the T.te Mazzarrà-Novara-Paratore) in the West.
- Milazzo Peninsula is approximately 30 km from Messina rail-station, and is accessible by public transport.
- The itinerary utilises dirt roads, trails and asphalt roads.

On the first day (Itinerary 1), the tour begins at Capo Tono (Stop 1.1) along the “Angonia Beach” road on the Western slope of the Milazzo Peninsula, accessible by off-road vehicles and a small trail to the North on foot. The Angonia Beach to Colle Makkarruna (Santa Lucia del Mela Castle - Stops 1.2 and 1.3) tract runs along the “Viale Sicilia” road, the SS 113 and the SP 65. The geotour continues along the Santa Lucia del Mela–Mandanici Road (Stop 1.4a and b) which is asphalted up to the San Nicola junction. However, it is narrow and steep in places. The road becomes a very windy and steep, changing into a dirt trail, up to Pizzo Rosarello (1,025 m a.s.l.) and Pizzo Croce (1,214 m a.s.l.), a SE-NW trending ridge forming the watershed between the T.te Floripotema in the east and the T.te Mela in the West (Stops 1.5a and b to 1.7). The geotour continues along the Pizzo Rosarello-T.te Cerasiera private trail (Stop 1.8) that quickly drops in altitude to 150 m a.s.l. The first day of the geotour ends with the last stop (Stop 1.9), in the right side of the T.te Santa Lucia valley bottom, and with the geo-cultural visit of the Santa Lucia del Mela Arab-Medieval Hamlet (Stop 1.10).

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In the second day (Itinerary 2), the trip begins by following the SS 113. The itinerary starts on the SP 93 Rodì-Milici asphalt road (Stop 2.1) and continues South along the dirt road of the Torrente Patrì-Fiumara Santa Venera–Fiumara Floresta valley bottom (Stops 2.2 to 2.4). It proceeds along the Patrì-Fantina asphalt road (Stops 2.5 to 2.7) up to the Fantina-Ruzzolino confluence and, going South, it reaches the Raiù ruins (Stop 2.8) along the steep dirt versants of the homonymous torrent. It then crosses the T.te Fantina to the East and continues up to Mt. Cipolla (757 m a.s.l.) (Stops 2.9a-c). It ends in Novara di Sicilia Village proceeding along SP 95 Fantina-San Marco and SS 185 Mazzarrà-Novara di Sicilia. The second day ends with the geo-cultural visit of the Novara di Sicilia Medieval Hamlet (Stop 2.10).

On the third day (Itinerary 3) the field trip starts from the SS 165-SP 95 junction (Stop 3.1) and continues along the older Novara di Sicilia–Fantina asphalt road and the dirt access road to North of Rocca Novara (or Rocca Salvatesta, 1,340 m a.s.l.) (Stop 3.2). The geotour ends along the SS Novara di Sicilia-Portella Mandrazzi (Stops 3.3 to 3.5).

The entire Geological Field Trip takes place amidst the spectacular and diverse Sicilian landscape, comprised of the luxuriant vegetation, the impervious versants, the wild and arid peaks and the ancient ruins for which Sicily is world-famous. The blue of the sky and of the Tyrrhenian Sea blend in perfect harmony with the iridescent greens of vegetation and hot browns of soil which paint this beautiful "*Terra del Sole*".

The best periods to undertake this field trip are from the end of August to mid-November and from March to mid-June, when the climate is mild and the panoramic view is clear. In springtime the region is covered by a spectacular blossoming of vegetation. In late June and July to August the weather is hot and sunny; at other times of the year, Sicily can be subject to heavy rainfall and therefore landslides can be a hazard.
- In all seasons a waterproof coat/jacket is recommended.
- All participants require comfortable hiking boots.
- A rucksack is necessary to carry rain protection, spare clothing (T-shirt or a fleece/sweater), apacked lunch, water and snacks.
- From June to September sun protection and hats are recommended as the fierce sun provides the danger of heat-stroke.

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- In spring and summer vipers and their bites provide a possible danger.
- Each vehicle must carry one basic first aid kit.
- Mobile/cellular phone coverage is good overall, although in some places it may be absent.
- The emergency telephone numbers for Police are 112 and 113.
- The emergency telephone number for ambulance is 118.
- The State Forest Corps of the Barcellona Pozzo di Gotto Detachment telephone number is + 39 090 9703595.

Hospitals

Milazzo
- Presidio Ospedaliero “Villaggio Grazia”, Contrada Grazia - Tel. (+39) 090 9290111

Barcellona P. G.
- Nuovo Presidio Ospedaliero “Cutroni Zodda”, Via Cattafi - Tel. (+39) 090 97511

Other first-aid stations

Milazzo
- *First Aid*, Contrada Grazia - Tel. (+39) 090 9295262
- Guardia Medica, Via G. B. Impallomeni 45 - Tel. (+39) 090 9281158
- Croce Rossa Italiana, Via Crispi - Tel. (+39) 090 9221695/(+39)090 9241762

Santa Lucia del Mela
- Guardia Medica, Piazza Milite Ignoto - Tel. (+39) 090/935072

Barcellona P. G.
- *First Aid*, Via Cattafi - Tel. (+39) 090 9751686/682

Castroreale
- Guardia Medica, Via Siracusa - Tel. (+39) 090 9746051

Fondachelli
- Guardia Medica, Via Patrì - Tel. (+39)0941 651207

Fantina
- Guardia Medica, Via dell’Olmo - Tel. (+39) 0941 654043

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Novara di Sicilia
- Guardia Medica, Via Nazionale 10 - Tel. (+39) 0941 650446
- Servizio Medicina Ospedaliera, Via Nazionale 10 - Tel. (+39) 0941 650295

Food & Beverage Options

Santa Lucia del Mela
- Restaurant *Pellegrino*, Piazza Milite Ignoto 10 – Tel. (+39) 090 935092
- Restaurant *La Siesta*, Via Mandre 3 – Tel. (+39)090 935835
- Restaurant *La Forchetta del Castello*, Contrada Filicusi – Tel. (+39) 090 935186
- Restaurant *La Trota*, Contrada Bellone – Tel. (+39) 090 9359417
- Trattoria *La Pergola*, Contrada Timpanara - Tel. (+39) 090 935266
- Trattoria *La Gastronomia*, Via Serri 49 – Tel. (+39) 090 935636
- Pizzeria *Buon Gusto*, Viale dei Pini – Tel. (+39) 090 9359737
- *Pizzeria dell'Arco*, P.za Milite Ignoto 30 – Tel. (+39) 090 9359746

Fondachelli
– Restaurant *La Vecchia Botte*, Via Mulino Vecchio 1 - Tel. (+39) 0941 654083
- Restaurant *l'Usignolo*, Via XX Giugno 2 - Tel. (+39) 0941 651356

Novara di Sicilia
- Confectionery *Scuderi*, Via Nazionale 105 – Tel. (+39) 0941 650580
- Bar *Angelina*, Via Nazionale 151 – Tel. (+39) 0941 650100
- Bar Confectionery *Buemi*, Via Nazionale 240 – Tel. (+39) 0941 650382
- *Slainte Pub* – Via Duomo 3 - Tel. (+39) 333 2344765
- Restaurant *La Pineta* – P.za M. Bertolami - Tel. (+39) 0941 65052
- Farm holidays *Girasole* – Contrada Greco - Tel. (+39) 0941 650812

Cultural Heritage Sites

Santa Lucia del Mela
- Cathedral (11th century)
- San Nicola Church (13-14th c.)
- Castle (14th c.)
- Santa Maria dell'Annunziata Church (15th c.)
- San Michele Arcangelo Church (15th c.)
- Basile-Vasari Palace (16th c.)
- Madonna della Neve Shrine (17th c.)
- Church and Crypt of Capuchins (17th c.)
- Bishop's Palace (17th c.)

Novara di Sicilia
- The "Sperlinga" Mesolitich station, Contrada Sperlinga
- Abbey Santa Maria La Noara (12th c.),
- San Francesco Church (13th c.)

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- Cathedral (16th c.)
- Annunziata Church (16th c.)
- Sant'Antonio Abate Church (16th c.)
- San Giorgio Church (17th c.)
- Ex Cistercian Convent (17th c.)
- San Nicolò Church (17th c.)
- Town Hall, ex Oratory San Filippo Neri (17th c.)
- Stancanelli Palace (18th c.)
- Salvo Risicato Palace (18th c.)
- Suor Teresa Fontana's House (18th c.)
- Anthropological Museum (2004)
- Territorial Museum (2007)

Fondachelli - SS. Angeli Custodi Church (1956)
Fantina - Maria SS. della Provvidenza Church (18th c.)

Service Stations

Santa Lucia del Mela
- SP, Contrada Pattina - Tel. (+39) 090 9359772

Castroreale
- GRS, Via Cesare Battisti - Tel. (+39) 090 9746115

Fondachelli
- TAMOIL, Via XX Giugno

Novara di Sicilia
- Q8, Via Carusa - Tel. (+39) 0941 650141

Accommodation

Santa Lucia del Mela
- Farm holidays *Parra*, Contrada Bassovalle - Tel. (+39) 360 531699

Fondachelli
- Farm holidays *La Valle della Luna*, Via XXIV Maggio - Tel. (+39) 0941 651114
- Farm holidays *Villa dell'Antico Gelso,* Via Rubino 114 - Tel. (+39) 0941 81529

Novara di Sicilia
- B&B *Noa*, Via Nazionale, 410 - Tel. (+39) 333 2345695/(+39) 0941 650974
- B&B *Sganga Kondè King*, Via Nazionale 163 - Tel. (+39) 0941 650526/(+39) 338 2696111
- Residence *Nucaria*, Via Benigno Salvo 10 and14 - Tel. (+39) 3394177737

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Program Summary

On the occasion of the 86th National Congress of the Italian Geological Society (Arcavacata di Rende - CS, September 2012), a geotour in the Northern-Central and Central Peloritani Chain (NE Sicily, Italy) has been organized.
The tour provides an update of the knowledge of structure, composition and evolution of crystalline basements and sedimentary covers of the Southern Sector of the Calabria-Peloritani Chain, illustrated by the recent CARG project, Sheet 587 Milazzo - 600 Barcellona Pozzo di Gotto (2011) of the Geological Map of Italy. The results of this investigation integrate and detail the specific geological aspects with an innovative multi-disciplinary approach already outlined in the Sheet 601 Messina–Reggio di Calabria (2008) by the same authors. Both geological maps have been developed thanks to years of field work and enhanced by chronostratigraphical, structural, petrological, sedimentological and geomorphological analyses. They have been integrated with very intensive sampling which is fundamental to distinguish the several basement nappes and understand the complicated geodynamic evolution of this edifice since Pre-Paleozoic times.
Specifically, the itinerary highlights the geometry, tectonic features, structures and composition of crystalline basements and sedimentary covers. New petrological data from rocks characterizing the examined basements are also provided. Hypotheses of evolutionary models of the illustrated Alpine units and comparisons with other Calabria-Peloritani Chain and internal Betic Chain (Spain) units are provided.

The geotour includes 26 Stops in the framework of a scenic and spectacular landscape.
The Field Trip takes place in a large area characterized by the presence of several valleys that, as a whole, show structure and composition of almost all the Peloritani tectono-stratigraphic units.

The itinerary focuses on geological and petrological peculiarities of: i) the already recognized Aspromonte and Mandanici units; ii) the recently recognized Mela and Piraino units, both of which extensively cropping out in this field trip area; iii) the Fondachelli unit, which is still debated; iv) the San Marco d'Alunzio unit, which has been studied petrographically for the first time.

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Riassunto

In occasione dell'86° Congresso Nazionale della Società Geologica Italiana (Arcavacata di Rende - CS, 18-20 Settembre, 2012) è stata promossa la realizzazione di un itinerario geologico nella parte centro-settentrionale e centrale della Catena Peloritana. Esso propone l'aggiornamento delle conoscenze su struttura, composizione ed evoluzione dei basamenti cristallini e delle coperture sedimentarie mesozoico-paleogeniche del settore meridionale dell'arco Calabro-Peloritano, dettagliatamente illustrate dalla recente cartografia del Progetto CARG relativa al Foglio 587 Milazzo - 600 Barcellona Pozzo di Gotto (2011), della Carta Geologica d'Italia, il quale integra e raffina, anche con le sue Note Illustrative, quanto in maniera innovativa era stato riconosciuto e delineato dagli stessi autori nel Foglio 601 Messina-Reggio di Calabria (2008).
La lunga e articolata storia geologica caratterizzante l'area dell'itinerario, che si estende dal paleo-Proterozoico al Paleogene, è stata responsabile di un'importante e varia geo-diversità preservata in un ricco patrimonio geologico e morfologico e nelle correlate unicità e peculiarità storico-culturali.

Il geotour occupa la parte centro-settentrionale e centrale della Catena Peloritana. Si percorre in tre giorni, articolato in tre differenti itinerari, delineati, discussi e illustrati nella presente Guida.

- Nel primo giorno, l'***Itinerario 1***, che include 10 Stops, si sviluppa nel territorio di *Milazzo (sul livello del mare) - Pizzo Rosarello (1.025 m s.l.m.) - Pizzo Croce (1.214 m s.l.m.)*, partendo dalla costa centrale tirrenica, a N e raggiungendo il tratto centro-orientale della dorsale principale Peloritana, a S. Esso è finalizzato alla conoscenza sia dei carateri geologici e petrologici delle unità tettono-stratigrafiche più elevate della Catena Peloritana, quali *le unità dell'Aspromonte, del Mela e di Piraino,* sia della composizione delle *coperture sedimentarie da oligo-mioceniche a oloceniche*, discordanti su di esse. L'itinerario si concentra su: geometrie; contatti tettonici per sovrascorrimento e per faglia; testimonianze di eventi plutonici e metamorfici da proterozoici a cambriani, fenomeni di mobilizzazione anatettica varisica ed evidenze di una sovrimpronta alpina, nell'unità dell'Aspromonte; testimonianze di un evento eo-varisico in facies eclogitica e di una riequilibrazione metamorfica varisica, di tipo barroviano, in facies da anfibolitica a scisti verdi, nell'unità del Mela; zoneografia varisica Ercino-tipo prograda, variabile da metamorfiti di basso fino a medio grado, nell'unità di Piraino. Gli Stops prendono in considerazione anche correlati aspetti morfologici e geo-culturali, tipici siciliani.

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- Nel secondo giorno, l'***Itinerario 2***, che comprende 11 Stops, si sviluppa lungo il territorio compreso tra il *Torrente Patrì* a N, e *Monte Cipolla (757 m s.l.m.)* a S, partendo da pochi chilometri di distanza dalla costa tirrenica fino alla Catena Peloritana centro-meridionale. Il suo scopo è quello di far conoscere i caratteri geologici e petrologici delle unità tettono-stratigrafiche intermedie e profonde della Catena Peloritana, quali le *unità di Mandanici, Fondachelli e San Marco d'Alunzio e le relazioni geometriche tra queste e le coperture sedimentarie da oligo-mioceniche a oloceniche,* discordanti su di esse. In Particolare, il geotour permette di evidenziare la differente composizione ed evoluzione geologica di queste unità di basso grado metamorfico che, sebbene siano chiaramente mostrate dagli stessi caratteri di campagna, sono ancora oggi oggetto di interpretazioni controverse, per le quali si continua a mettere insieme rocce con differenti composizione ed evoluzione geologica (ISPRA: F° 613 *Taormina*; F° 599 *Patti*; F° 598 *Sant'Agata di Militello*).

Topographic map of North-Eastern Sicily showing the 27 Stops of the Sicilian Field Trip of the 86th National Congress of the Italian Geological Society (1:250.000 scale, Istituto Geografico De Agostini, Novara, 1993).

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Detti dibattiti non sono stati, fino a oggi, supportati da dettagliate ricostruzioni dell'evoluzione tettono-metamorfica di queste unità, secondo la quale rocce dell'unità di Piraino *Auct.* non possono essere ascritte all'unità di Mandanici, così come quelle dell'unità del Mela *Auct.,* o dell'unità di Fondachelli *Auct*., non possono essere incluse, rispettivamente, nelle unità dell'Aspromonte e di Longi-Taormina (o di San Marco d'Alunzio). Ciò è anche chiaramente dimostrato dalla differente geometria di ciascuna delle nove unità tettoniche formanti la Catena Peloritana terziaria, cui si aggiungono, quali elementi chiave, la presenza di contatti primari per sovrascorrimento e di lembi di vario spessore di coperture da mesozoiche a paleogeniche sulle unità suddette, ovviamente mancanti sulle unità polimetamorfiche, di medio-alto grado dell'Aspromonte e di medio grado del Mela. Anche l'Itinerario 2 comprende la visita a siti geo-culturali.

- Nel terzo giorno, l'***Itinerario 3*** presenta 5 Stops, concentrati nella Catena Peloritana centrale, da *Novara di Sicilia (650 m s.l.m.) a Portella Mandrazzi (1.125 m s.l.m.)*, intorno a Rocca Novara (1.340 m s.l.m.), particolarmente dedicato a geometria, struttura e composizione della "*formazione di Rocca Novara*", considerata nella cartografia geologica relativa al F° 600 Barcellona Pozzo di Gotto, la *copertura meso-cenozoica dell'unità di Fondachelli*. Sono anche discusse e illustrate le relazioni tra detta formazione e il deposito oligo-miocenico del flysch di Capo d'Orlando, in quanto "Rocca Novara" secondo Bonardi et al. (1982) risulterebbe costituita da olistoliti di calcari mesozoici inclusi nel conglomerato rosso della fm. di Stilo-Capo d'Orlando, discordante sulle metamorfiti dell'unità di Fondachelli.
A supporto dei temi discussi, nella presente guida geologica sono stati inseriti nuovi dati petrologici, realizzati su rocce caratterizzanti i basamenti esaminati. La guida si chiude con ipotesi di modelli evolutivi comprendenti le unità illustrate, inquadrate nel contesto evolutivo della Catena Calabro-Peloritana, e comparate con simili unità interne della Cordigliera Betica (Spagna).

Parole Chiave: *Orogeni alpini del Mediterraneo centro-occidentale; Catena Calabro-Peloritana; Itinerario Geologico; Progetto CARG; Basamenti Cristallini e Coperture sedimentarie; Caratteri Geologici e Petrologici; Evoluzione Paleo-Proterozoica - Paleogenica.*

Abstract

This Geological Field Trip has been conceived on the occasion of the 86th National Congress of the Italian Geological Society (Arcavacata di Rende - CS, September 18th-20th, 2012). The tour provides to most update knowledge on structure, composition and evolution of crystalline basements and Mesozoic-Paleogene sedimentary covers of the Southern sector of the Calabria-Peloritani Chain, discussed and illustrated by the recent CARG Project relating to the Sheet 587 *Milazzo* - 600 *Barcellona Pozzo di Gotto* (2011) of the Geological Map of Italy, and corresponding Illustrative Notes. The results of this investigation integrate and detail the specific geological aspects already described in the Sheet 601 *Messina–Reggio di Calabria* (2008) by the same authors, with an innovative multi-disciplinary approach.
The significant geo-diversity of the area of this Field Trip is a result of a long and complex geological history, from the Paleo-Proterozoic to the Paleogene, responsible for a rich geological and morphological heritage and related historical/cultural uniqueness and peculiarity. The geotour is concentrated in the Central-North and Central Peloritani Chain. It lasts three days and develops along three different itineraries, described and illustrated by this Field Trip Guidebook.

- The first day, ***Itinerary 1***, which includes 10 Stops, explores the *Milazzo (on sea level) – Pizzo Rosarello (1,025 m a.s.l.) - Pizzo Croce (1,214 m a.s.l.) region* extending from the Tyrrhenian coast to the Central-Eastern Peloritani main ridge. It is devoted to the knowledge of geological and petrological features characterizing the higher Peloritani Chain tectono-stratigraphic units of the *Aspromonte, Mela, Piraino units and the discordant Oligo-Miocene to Holocene sedimentary cover.* It focuses on: geometries; overthrusting and fault contacts; Aspromonte unit Proterozoic to Cambrian plutonic and metamorphic records, Variscan mobilization phenomena and Alpine overprint evidences; Mela unit Eo-Variscan eclogite facies rocks affected by a Variscan Barrovian-type metamorphic re-equilibration; Piraino unit Variscan Hercyno-type low- to medium-grade metamorphic prograde zoning. The Stops also involve corresponding aspects of the typical Sicilian morphological and geo-cultural Heritage.
- The second day, ***Itinerary 2***, which includes 11 Stops, follows along the *Torrente Patrì to Mt. Cipolla (757 m a.s.l.)* region, which extends from a few kilometres from the Tyrrhenian coast up to the Central Peloritani Chain. Its topics include the geological and petrological features of the middle to lower Peloritani Chain

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tectono-stratigraphic units of the *Mandanici, Fondachelli and San Marco d'Alunzio units*, and the geometric relationships between them and the higher tectonic elements of Aspromonte, Mela and Piraino units and of the discordant *Oligo-Miocene to Holocene sedimentary covers.* In particular, this itinerary focuses on the different composition and geological evolution of these last defined low-grade units; despite their geological features, which are well evident in the field, they are still now the object of controversial interpretations. The consequence of this is that rocks which are different in evolution and composition are still associated with each other (ISPRA, Sheet 613 *Taormina*; Sheet 599 *Patti*; Sheet 598 *Sant'Agata di Militello*). These debates are not supported by the detailed reconstruction of their specific tectono-metamorphic evolution, which indicates that the rocks of the Piraino unit *Auct*. can not be included in the Mandanici unit, and those of the Mela unit *Auct.* or the Fondachelli unit *Auct*. can not be included in the Aspromonte unit and in the Longi-Taormina unit (or San Marco d'Alunzio unit), respectively. This is demonstrated by the geometry of the nine tectonic units forming the Tertiary Peloritani Chain, in addition to the presence of the overthrusting contacts and of the different in thickness slices of original Mesozoic to Paleogene covers on them. The latter obviously not present a top the polymetamorphic high- to medium-grade Aspromonte unit and on the medium-grade Mela unit. In the Itinerary 2 Geo-Cultural sites are also included.

- The third day, ***Itinerary 3***, is organized with 5 Stops concentrated in the Central Peloritani Chain, from *Novara di Sicilia (650 m a.s.l.) to Portella Mandrazzi (1,125 m a.s.l.)* region around the Rocca Novara (1,340 m a.s.l.). It is particularly dedicated to the *geometry, structure and composition of the Rocca Novara fm.*, considered, in the Sheet 600 *Barcellona P.G.*, as a Fondachelli unit Meso-Cenozoic cover. The relationships between this formation and the Oligo-Miocene Capo d'Orlando flysch are also discussed and illustrated. The Rocca Novara fm. was previously interpreted by Bonardi et al. (1982) as Mesozoic "olistholiths" inside the red conglomerate of the Stilo-Capo d'Orlando fm., transgressive on the Fondachelli unit metamorphics.

In support of the discussed themes, new petrological data from rocks characterizing the examined basements are also given. Hypotheses of evolutionary models of the illustrated Alpine Units in the framework of the Southern sector of the Calabrian-Peloritani Chain and comparisons with internal Betic (Spain) units are also provided.

Key words: *Central-Western Mediterranean Alpine Orogens; Calabria-Peloritani Chain; Geological Field Trip; CARG Project; Crystalline Basements and Sedimentary Covers; Geological and Petrological features; Palaeo-Proterozoic to Paleogene Evolution.*

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1. Geomorphology

The North-Eastern corner of the largest Mediterranean Island (Fig. 1) with the ancient name of "Trinacria" (from Greek *treis*=three and *àkra*=headlands) shows a variable and discontinuous morphology related to its complex geological evolution. Very different from the rest of the territory, this particular Sicilian area is occupied by the Peloritani Mts. Geographically, the Peloritani Mts. extend west from the Peloro Cape (also called Punta del Faro), in the extreme North-West of the Messina Straits, to the Torrente Novara–Portella Mandrazzi limit (Fig. 2). However, geologically, they continue to the West and include the Eastern Nebrodi Mts. up to the Taormina-Sant'Agata di Militello alignment.

These mountains, together with the *Calabrian Coastal Chain, Sila, Serre* and *Aspromonte Massifs*, form the Calabria-Peloritani Chain.

Fig. 1 - Historic Geographic Map of Sicily. Title: *Siciliae Regnum*. Period: 1589-1595. Author: Gerard Mercator, Reproductive technique: copperplate engraving. Regional Universitary Library of Messina.

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Fig. 2 - Geographic Map *"Territorio dello Stretto"*: detail of the Peloritani Mts. (Glimas I.G.M., Firenze - 1885). The rectangular box defines the area of the Sicilian Field Trip of the 86th National Congress of the Italian Geological Society.

The Peloritani Chain (from Greek, *pelorios or peloros*=gigantic) and the surrounding area are considered a very important Mediterranean naturalistic environment, with particular geographic and geological features at the base of a rich and varied geo- and bio-diversity.

The Peloritani Chain (PC) is delimited by the Tyrrhenian and Ionian Seas to the North and to the East, respectively, by the Alcàntara Valley to the South (which separates it from Mt. Etna), and by the Maghrebian Chain units forming the remaining Nebrodi Mts., to the West. It shows a very heterogeneous morphology, which, going towards the inside of the map is made up of:

- Ionian and Tyrrhenian coasts. The former, extending from the Peloro Cape (Figs. 3a and b) to the Taormina Cape (Fig. 3c) with a rectilinear N-S trend, is characterized by long beaches cut by the very narrow San Raineri Peninsula and the Alì, Sant'Alessio, Sant'Andrea and Taormina promontories. The latter, extending from the Peloro Cape to Sant'Agata di Militello-Acquedolci (Fig. 3d), exhibits a disjointed NE-SW trend marked by an irregular alternation of long and wide beaches and promontories, of which, the Milazzo Peninsula is the most important. The morphology of the coast is also characterized by the two brackish lagoon systems (also designated natural reserves) of the Peloro Cape, in the Ionian coast (North-West of Messina Straits) comprising the Ganzirri (Fig. 3a) and Faro Lakes, and of the Marinello Lakes, located on the Central Tyrrhenian coast;
- a crystalline hilly to mountainous inland consists of Proterozoic to Paleozoic metamorphics and plutonics, and is unconformably covered by Lower Miocene to Recent sedimentary deposits and cut by deep valleys. The reliefs exhibit steep versants, acute peaks (Fig. 4) and marine terraces which differ in height;
- an interconnecting and hierarchized hydrographic network, characterized by seasonal and torrential watercourses (*Fiumara* – F.ra; *Torrente* – T.te).

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Fig. 3a - Peloritani Northern Ionian coast: panoramic view of the Ganzirri Lake in the Peloro Cape Lagoon System (Natural Reserve). In the background the Calabrian coast can be observed. Loc.: Panoramica dello Stretto Road. North-Eastern Peloritani Mts.

The Peloritani main ridge (Fig. 4), with an average altitude of 1,000 m a.s.l., defines the watershed and extends, with NE-SW direction, from Dinnammare (1,127 m a.s.l.) to Montagna Grande (1,374 m a.s.l.) continuing, with an E-W trend to join, with the Maghrebian Chain units.

Fig. 3b - Peloritani Eastern Tyrrhenian coast: panoramic view of the extreme eastern Peloritani coast, starting from Peloro Cape, in the Messina Straits. In the background the Calabrian coast can be observed. Loc.: Panoramica dello Stretto – Faro – SS 113 road. North-Eastern Peloritani Mts.

The territory along which the geotour follows is made up of **three different morphological zones:**

- ***the mountainous zone*** (Fig. 5a), in the South, corresponding to the intermediate tract of the Peloritani main ridge formed, from NE to SW, by Mt. Poverello (1,279 m a.s.l.), Pizzo Acqua Menta (1,110 m a.s.l.), Pizzo Croce (1,214 m a.s.l.), Pizzo Acqua Bianca (1,210 m a.s.l.), Pizzo

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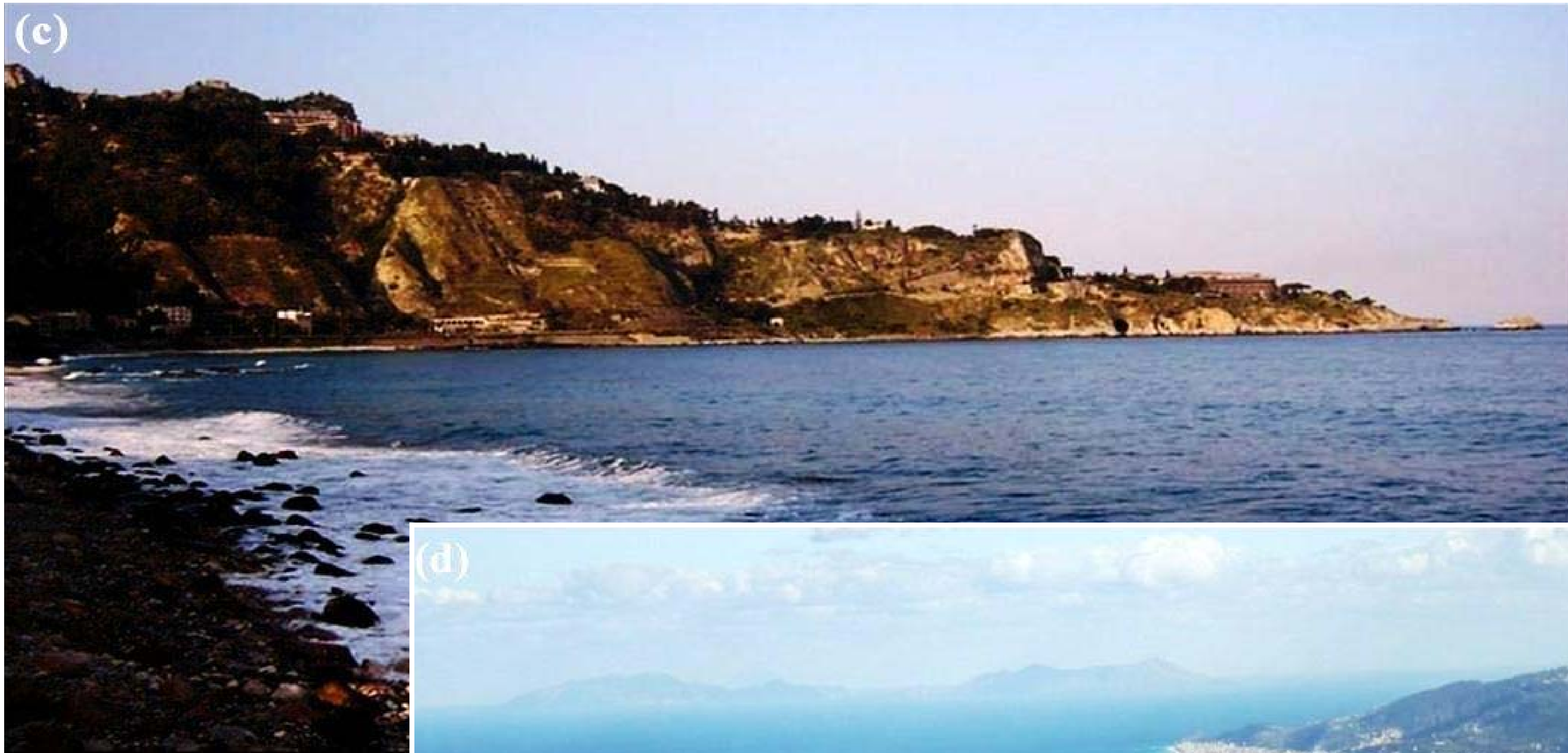

Fig. 3c – View from South of the Taormina Promontory, in the Ionian coast (Messina et al., 2010). Loc.: Northern Giardini Naxos. South-Eastern Peloritani Mts.

Fig. 3d - Panoramic view of d'Orlando Cape - Sant'Agata di Militello North-Western coast of the Peloritani Chain. Nebrodi Park. Loc.: Mt. San Fratello peak. Eastern Nebrodi Mts.

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Fig. 4 - Panoramic view of the Peloritani acute peaks (1,200-1,400 m a.s.l.) and deep valleys. In the background, the smoking Mt. Etna (3,350 m) is visible (Macaione et al., 2010). Loc.: Central Peloritani Mts.

Mualio (1,200 m a.s.l.), Pizzo Batteddu (1,228 m a.s.l.), Montagna di Vernà (Pizzo Polo, 1,287 m a.s.l.), Montagna Grande (1,374 m a.s.l.) and Rocca Novara (1,340 m a.s.l.). From this main ridge, secondary ridges diverge decreasing in altitude towards the Tyrrhenian Sea forming, from E to W, the watershed of the T.te Floripotema (22 km,30.15 sq. km), T.te Mela (24.6 km, 64.97 sq. km), T.te Patrì-Fantina-Fondachelli and T.te Mazzarrà-Novara-Paratore. The high reliefs consist of crystalline basement units, wereas the Northern hills are formed by Miocene

Fig. 5a - Panoramic view of the mountainous zone in the South, corresponding to the intermediate tract of the Peloritani main ridge. Loc.: right slope of the F.ra Santa Venera. Central Peloritani Mts.

to recent sedimentary covers, cut by river terraces at about 4-6 km from the coast;

- ***the plain zone*** (Fig. 5b), made up of the Milazzo-Barcellona P.G. Plain, consists of recent sedimentary covers and shows three main marine terraces (110-130 m; 70-90 m; 25-40 m, a.s.l.);

- ***the coastal zone*** (Fig. 5b) forms the Milazzo Peninsula and the two physiographic units of the

Fig. 5b - Panoramic view of the Milazzo-Barcellona P.G. Plain and of the Milazzo Peninsula.

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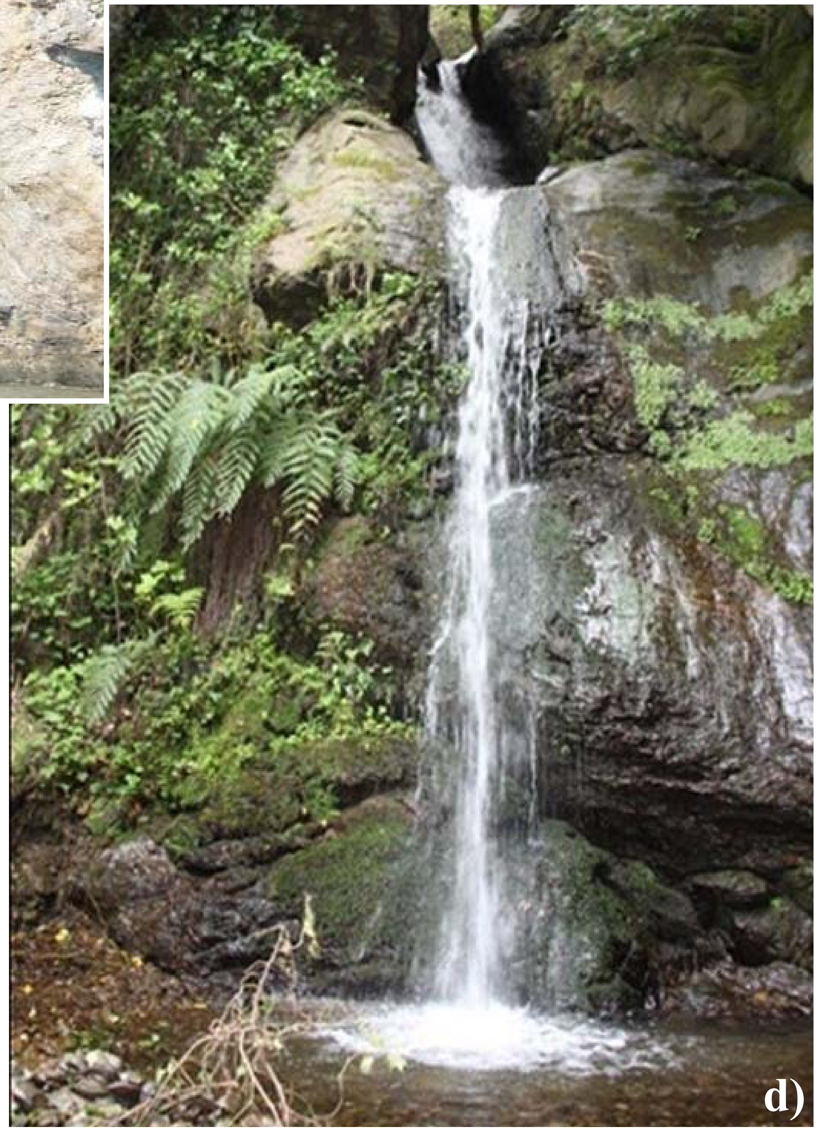
Fig. 5c - The *"Cave of gold"* Geosite, ancient seat of pirates, within Upper Messinian coralgal limestones. Loc.: Punta Trefiletti, North-East of Milazzo Peninsula. Northern Peloritani Mts.



Milazzo Cape - Peloro Cape unit, in the East, and the Milazzo Cape - Calavà Cape unit in the West. The Eastern and Western coasts of the Peninsula border the Milazzo and Patti Gulfs, respectively.
The four above defined river basins are dominated by spectacular landscapes with hypogeal karst phenomena (canyons and caves, Fig. 5c), beautiful waterfalls (Fig. 5d), small natural oases with endemic and endangered flora (Fig. 5d) and fauna.

Fig. 5d - Vallone Avvelenato Geo-Biosite: beautiful *"Schicciu a Saìtta"* waterfall, with a rare Peloritani location of the endemic and endangered *Woodwardia radicans* (Torre, 2012). Loc.: T.te Mela. Central-Northern Peloritani Mts.

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2. Geological setting

2.1 Calabria-Peloritani Chain (CPC)

Distinct structural domains can be distinguished in the Mediterranean orogenic belt, which runs from Southern Apennines to Sicily: the foreland domains are represented by the Apulian Block in the North and the Pelagian Block in the South, belonging to the Adria and Africa plates, respectively (Fig. 6). They have been separated since the Permo-Triassic period, by the oceanic crust of the Ionian Sea (Lentini et al., 2006). The Apenninic-Maghrebian Orogenic Belt is located between two oceanic crusts: the old Ionian crust, presently subducting beneath the Calabria-Peloritani Chain, and the new crust of the opening Tyrrhenian Sea.

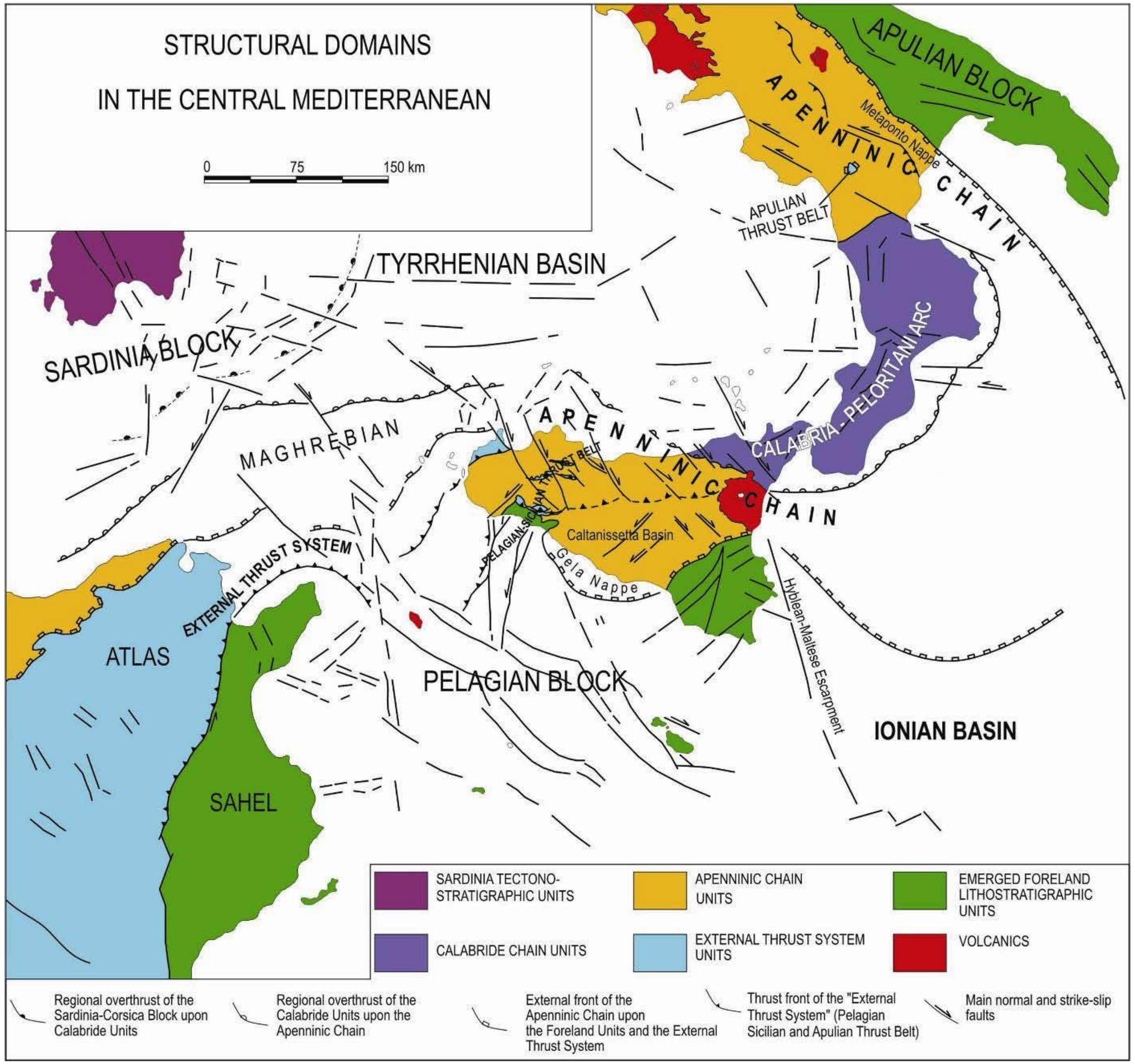

Fig. 6 - Regional outline of the structural domains in the Central Mediterranean (after Lentini et al., 1996, modified by Lentini et al., 2009).

The orogenic belt, represented by a multilayer allochthonous edifice, is composed of the Calabria-Peloritani Chain **(CPC)** tectonically overlying the Apenninic-Maghrebian Chain **(AMC),** which in turn overthrusts the Late Miocene and Pliocene top-levels of a deep seated thrust system, originating from the deformation of the innermost carbonates of the Foreland Domains (external thrust system). The **AMC** (Fig. 6) tectonic units derive from the orogenic transport of sedimentary sequences during Oligo-Miocene

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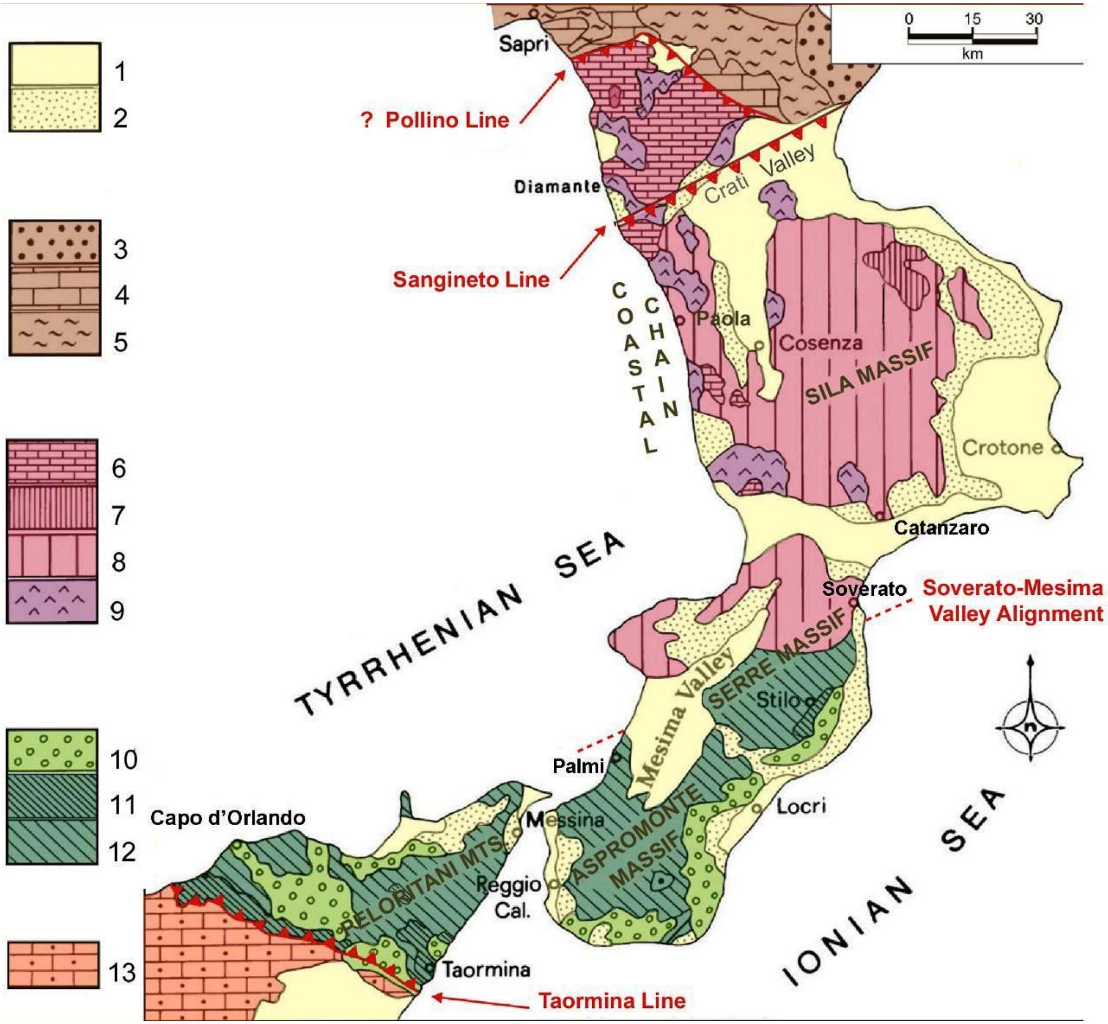
times, deposited in paleogeographical domains located between the European and the Afro-Adriatic plates.
The Meso-Cenozoic basinal units, that compose the AMC, belong to two main groups of sequences, originally located on the Alpine Tethys and the Ionian oceanic crusts, separated by the Panormide continental crust.
The **CPC** (Fig. 7), which connects the NW-SE trending Apennines to the E-W trending Sicilian and African

Fig. 7 - Tectonic sketch map of the Calabria-Peloritani Chain (after Macaione et al., 2010, modified).



Legend: 1. Alluvial and beach deposits (Holocene); Etna volcanics (Middle Pleistocene-Holocene). **2**. Clastics and evaporites (Upper Tortonian-Pliocene). **3-5. Apenninic Chain: 3.** Clastics of the Cilento Group (Langhian-Lower Tortonian); **4**. External mainly carbonate units (Upper Triassic-Serravallian); **5**. Lucanian oceanic units (Upper Jurassic-Burdigalian). **6-9. Calabria-Peloritani Chain, Northern Sector. Continental crust units: 6**. Lungro-Verbicaro and Cetraro units (Middle Triassic-Aquitanian); **7**. Paludi fm. (Upper Oligocene-Lower Miocene) and Sila unit sedimentary cover (Upper Triassic?-Lower Cretaceous); **8**. Sila (pre-Paleozoic and Paleozoic), Castagna (pre-Paleozoic and Paleozoic) and Bagni (Paleozoic) units basements; Oceanic crust units: **9**. Diamante-Terranova, Monte Reventino-Gimigliano and Malvito (Upper Jurassic-Lower Cretaceous) units. **10-12. Calabria-Peloritani Chain, Southern sector. 10**. Floresta calcarenites (upper Burdigalian-lower Langhian), Antisicilide complex (Upper Cretaceous-Lower Miocene) and Capo d'Orlando flysch (upper Oligocene-lower Burdigalian). Continental crust units: **11**. Stilo (Calabria - Upper Triassic?-Aquitanian), Fondachelli (Sicily - lower Kimmeridgian-Oligocene?), San Marco d'Alunzio (Sicily - Upper Triassic-Eocene); Longi-Taormina (Sicily - Upper Triassic–lower Oligocene?); Capo Sant'Andrea (Sicily-lower Lias-Lower Eocene) units sedimentary covers; **12**. Stilo (Calabria-Paleozoic), Aspromonte (Calabria and Sicily – Paleo-Proterozoic - Cambrian and Paleozoic), Cardeto, Africo (Calabria - Paleozoic), Mela, Piraino, Mandanici, Alì, Fondachelli, San Marco d'Alunzio, Longi-Taormina and Capo Sant'Andrea (Sicily - Paleozoic) unit basements. **13**. Maghrebian Chain flysch basin units (Upper Jurassic-Burdigalian).

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Maghrebids, extends from North Calabria to North-East Sicily, with a controversial north tectonic limit, traditionally ascribed to the Sangineto line (Amodio-Morelli et al., 1976) but recently attributed to the Palinuro left transcurrent fault (Finetti, 2005; Finetti et al., 2005), or to the Pollino line (Perrone et al., 2006), and with the Southern boundary corresponding to the so called transpressive Taormina line (Scandone et al., 1974).
The CPC, constructed in the Tertiary during collisional phases between the Eurasia and Africa plates, is formed by a stack of continental and oceanic crust units (Amodio-Morelli et al., 1976; Bonardi et al., 1976a, b, 1996, 2001, 2004). Several controversial paleogeographical reconstructions have been proposed in the last ten years. According to Finetti et al. (2005) and Lentini et al. (2006) the continental tectonic units of the CPC derive from the delamination of the original European margin, during the Balearic stage (Oligocene-Early Miocene), contemporaneous with the rotation of the Sardinia-Corsica block and the opening of the Western Mediterranean Basin.
According to one of the current opinions, the continental CPC units derived from the Jurassic-Cretaceous Mesomediterranean microplate, which, originally located between the Europe and Africa plates, divided the Western Tethys Ocean in the Piemontese-Ligurian-Nevado-Filabride branch, in the North, and the Lucanian-Maghrebian branch, in the South (Guerrera et al., 1993; Martin-Algarra et al., 2000; Bonardi et al., 2002, 2003, 2008; Perrone et al., 2006, 2008; Careri et al., 2004). The oceanic crust units originated from the Tethys Ocean branch, between this microplate and the main plates (Bonardi et al., 1976a, b, 1996, 2001, and references therein).
At the Mediterranean-scale (Fig. 8) the CPC shows compositional, structural and tectono-metamorphic correlations with Central-Western Mediterranean internal tectonic units (Internal Zone) exposed in North Africa (Kabylias and Rif) and in South Spain (Betic Cordillera), also considered to have originated from the Mesomediterranean microplate (Frizon de Lamotte et al., 2000; Martin-Algarra et al., 2000; Michard et al., 2002; Bonardi et al., 2003; Careri et al., 2004; Perrone et al., 2006).

In the CPC, the Northern and Southern sectors (Bonardi et al., 1996; Messina et al., 1996a) or subterranes (Bonardi et al., 2001, 2004), diversified as a result of the Alpine evolution, have been recognized in the North and South of the Soverato-Mesima Valley alignment crossing the Serre Massif, in Calabria. They become kinematically independent in the Cretaceous-Paleogene.

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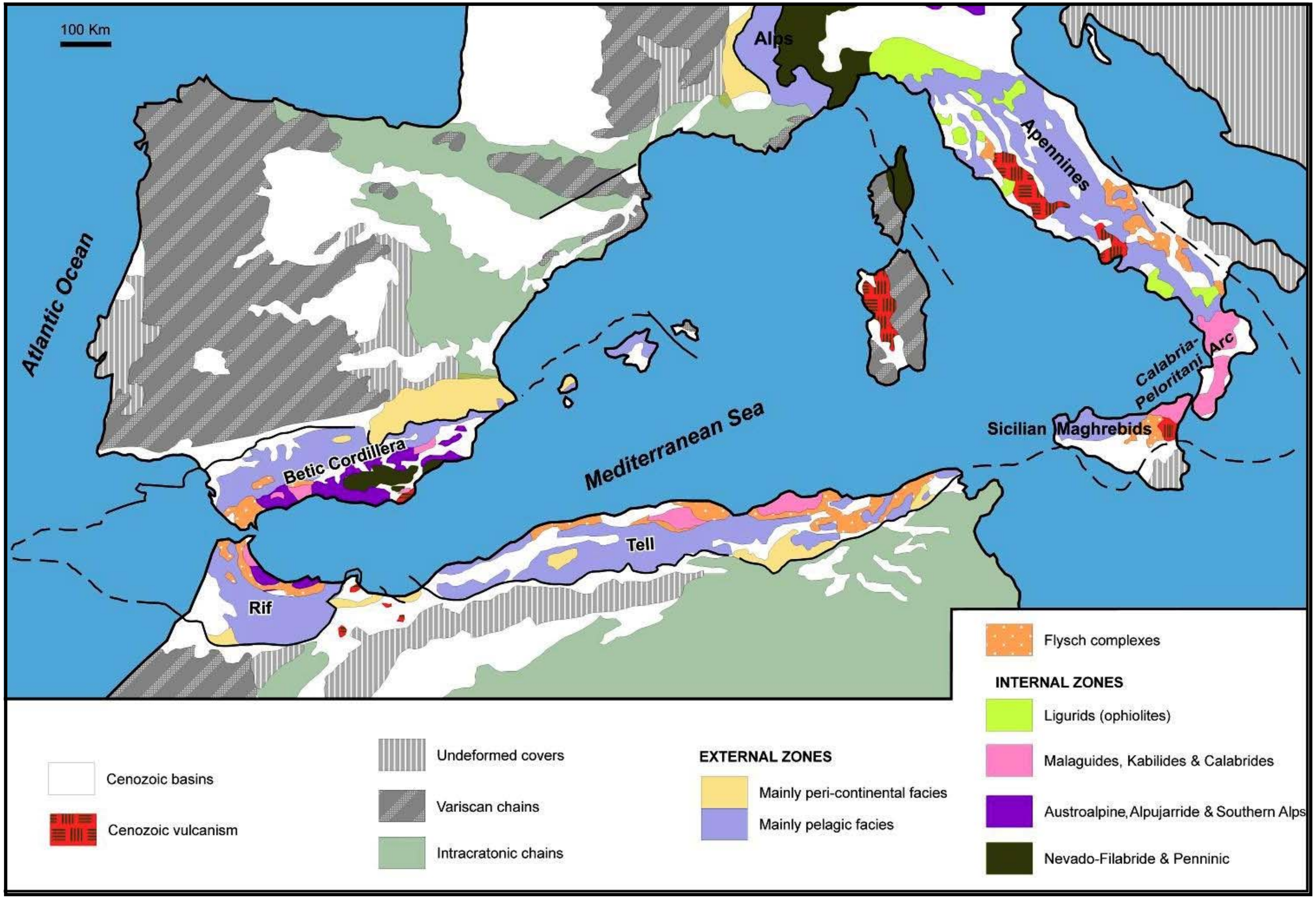

Fig. 8 - Geological sketch map of the Western segment of the Alpine Peri-Mediterranean Orogen (after Geologia de Espana, J.A. Vera - Ed. SGE-IGME, 2004, modified by Macaione et al., 2010).

The ***Southern sector*** (CPCSS) forms the bulk of the Serre Massif and the Aspromonte Massif, in Southern Calabria, and the Peloritani Mts. in North-East Sicily (Figs. 9a and b).

The CPCSS structural setting consists of a stack of twelve Africa-verging continental crust units (Messina & Macaione, 2010; Messina et al., 2010; Carbone et al., 2011) that, from top to bottom, are:

- ***Stilo, Aspromonte, Cardeto*** and ***Africo units*** in Calabria (Figs. 9a and b);

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- ***Aspromonte, Mela, Piraino, Mandanici, Alì, Fondachelli, San Marco d'Alunzio, Longi-Taormina and Capo Sant'Andrea units*** in Sicily (Figs. 9a and b).

The units are made up of Pre-Variscan and Variscan basements and some of the latter preserve a Meso-Cenozoic cover.

Since the early Oligocene, the Balearic stage (Lentini et al., 2006) gave rise to the nappe stacking, implying cataclastic effects to localized metamorphic re-equilibrations, recorded in the Aspromonte and Cardeto units basements (Bonardi et al., 1992, 1996, 2008; Messina et al., 1990, 1992, 1996a, 2004a, b; Platt & Compagnoni, 1990), in the Africo unit (Heymes et al., 2008, 2010) and in the Alì unit basement and cover (Atzori et al., 1995).

Late Oligocene-Early Miocene siliciclastic turbidites of the Capo d'Orlando flysch (Lentini et al., 1995) unconformably covered and sealed the CPCSS crystalline units. The flysch is interpreted as a thrust top basin deposit developed after the main emplacement of the CPCSS units and, subsequently, involved in further tectonic phases.

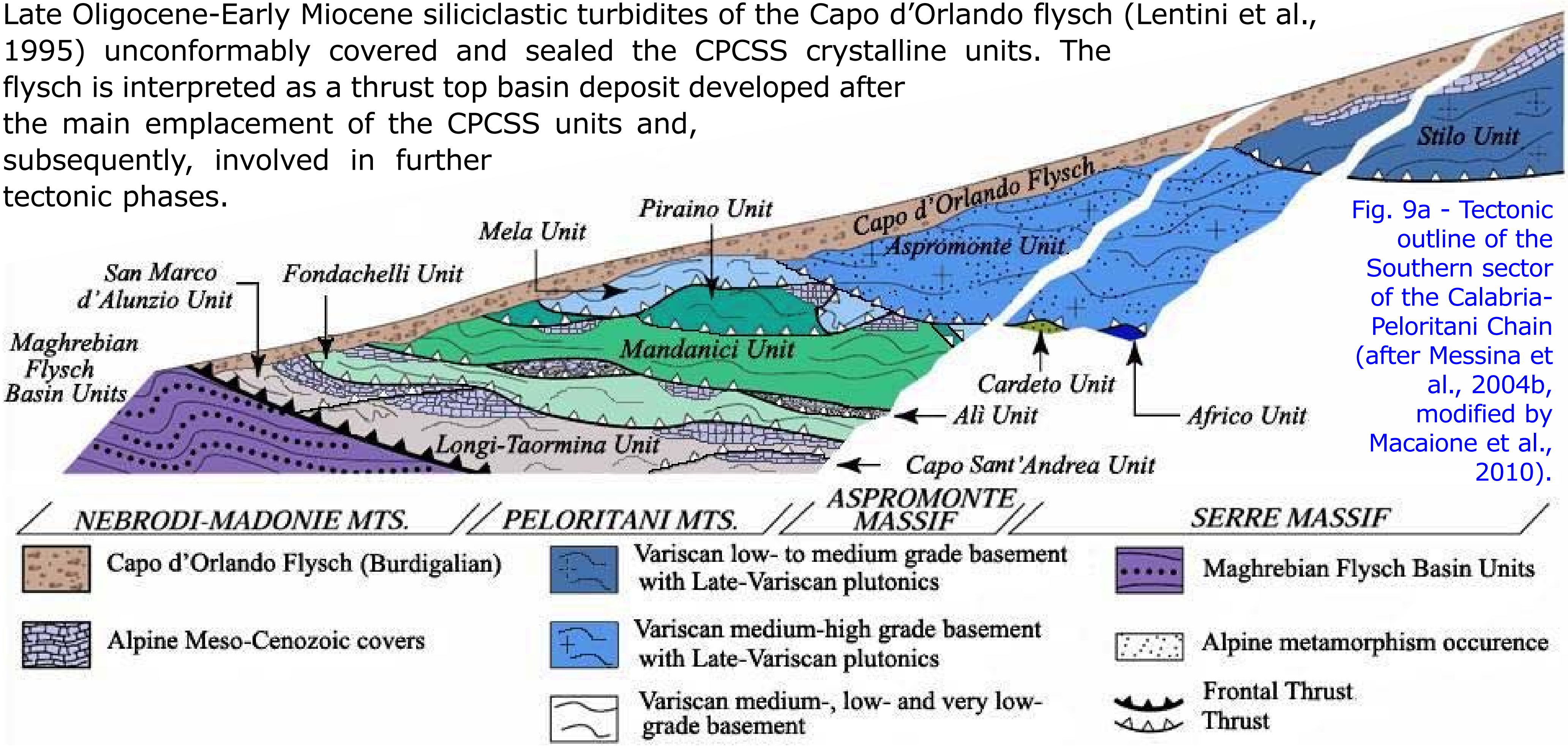

Fig. 9a - Tectonic outline of the Southern sector of the Calabria-Peloritani Chain (after Messina et al., 2004b, modified by Macaione et al., 2010).

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Since Early Miocene, further tectonic activity affected the CPCSS edifice during the orogenic transport onto the AMC and, since Middle Miocene, as consequence of the Tyrrhenian back-arc basin development.
The whole edifice is a result of polyphasic tectonics, in which the thrust system has been affected by decoupling of the sedimentary cover, and by breaching of the nappes sequence. Lower-Middle Miocene to Recent deposits unconformably cover both crystalline and terrigenous units, further affected by Plio-Pleistocene and Recent fault systems (Lentini et al., 2000a, b; APAT, 2008; ISPRA, 2011; Carbone et al., 2008, 2011).

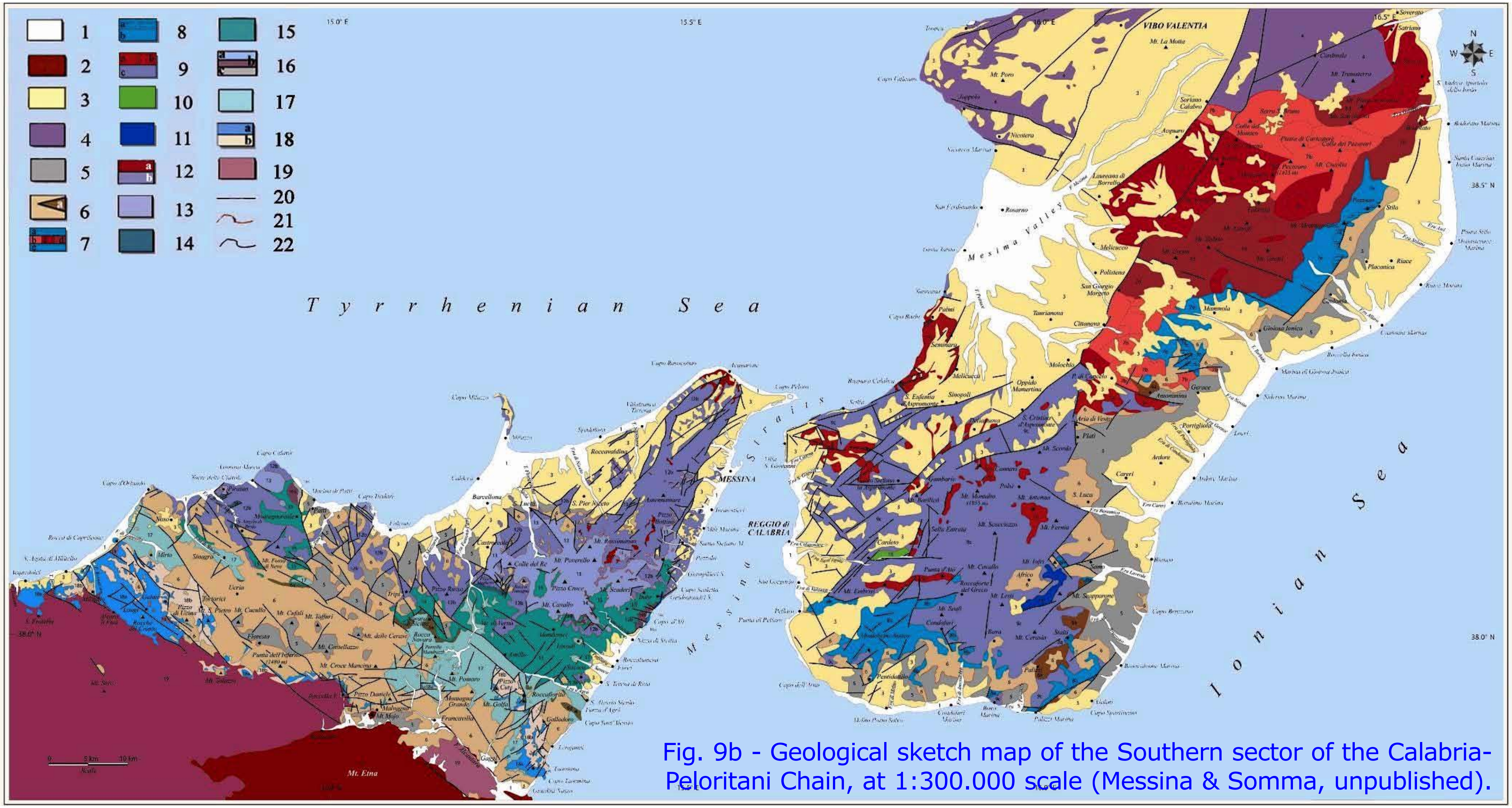

Fig. 9b - Geological sketch map of the Southern sector of the Calabria-Peloritani Chain, at 1:300.000 scale (Messina & Somma, unpublished).

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Legend fig. 9b: **1.** Alluvial and beach deposits (Holocene). **2.** Etna volcanics (Middle Pleistocene - Holocene). **3.** Middle Miocene-Pleistocene deposits. **Northern sector of the Calabria Peloritani Chain**. Continental crust unit. 4. Sila unit: undifferenziated basement. **Southern sector of the Calabria Peloritani Chain**. Upper Cretaceous-Middle Miocene sedimentary covers: **5.** Floresta calcarenites (Upper Burdigalian–Lower Langhian) and Antisicilide unit - varicoloured clays (Upper Cretaceous). **6.** Capo d'Orlando flysch (Upper Oligocene-Lower Burdigalian). Calabria continental crust units. **7** and **8.** Stilo unit: **7a** and **8a.** Meso-Cenozoic cover (**7a.** Upper Triassic-Lower Miocene; **8a.** Jurassic-Lower Oligocene); **7b, c, d, e; 8b.** Paleozoic basement: **7b, c, d.** Late Variscan plutonics (**7b.** post-tectonic two mica+Al-silicates±cordierite leucomonzogranites to granodiorites; **7c.** biotite±muscovite monzogranites to granodiorites; **7d.** amphibole±biotite granodiorites to gabbros) (Upper Carboniferous-Permian); **7e.** and **8b.** Paleozoic basement (**7e** and **8b.** Variscan LT greenschist to LT amphibolite facies metamorphics; **7e.** Late Variscan amphibolite facies hornfels); **9.** Aspromonte unit Proterozoic and Paleozoic basement: **9a.** and **b.** Late Variscan plutonics (**a.** post-tectonic two mica+Al-silicate±cordierite leucomonzogranites to leucotonalites; **b.** post to syntectonic granodiorite to gabbro; **a** and **b** with a localized Alpine greenschist to amphibolite facies metamorphism) (Upper Carboniferous-Permian); **c.** Variscan metamorphics with Pre-Variscan granulite relics (Pan-African granulites with Late Pan-African intermediate to acidic plutonics, both affected by a Variscan LT granulite to LT amphibolite facies metamorphism and by an Alpine greenschist to amphibolite facies overprint) (Paleo-Proterozoic - Cambrian). **10.** Cardeto unit: Paleozoic basement (Variscan low-grade metamorphic with a HT greenschist facies overprint). **11.** Africo unit: Paleozoic basement (Variscan low-grade metamorphics with a HT greenschist facies overprint). **Peloritani continental crust units**. **12.** Aspromonte unit Proterozoic and Paleozoic basement: **a.** Late Variscan plutonics (post-tectonic Al-silicate+cordierite+two mica leucomonzogranites to leucotonalites with a localized Alpine greenschist to amphibolite facies metamorphism) (Upper Carboniferous-Permian); **b.** Variscan metamorphics with pre-Variscan granulite relics (Pan-African granulites with Late Pan-African intermediate to acidic plutonics, both affected by a Variscan LT granulite to LT amphibolite facies metamorphism and by an Alpine greenschist to amphibolite facies overprint) (Paleo-Proterozoic - Cambrian). **13.** Mela unit: Paleozoic basement (Eo-Variscan eclogite facies metamorphics with a Variscan amphibolite to greenschist facies re-equilibration). **14.** Piraino unit: Mesozoic cover (Upper Triassic?-Aalenian); Paleozoic basement (Variscan greenschist to amphibolite facies metamorphics). **15.** Mandanici unit: Mesozoic cover (Upper Triassic-Lower Lias); Paleozoic basement (Variscan LT to HT greenschist facies metamorphics). **16.** Alì unit: **a** and **b.** Mesozoic cover (Middle? Upper Triassic-Cretaceous) affected by a subgreenschist facies metamorphism; **c.** Paleozoic basement (Devonian-Lower Carboniferous) (Variscan low grade (?) metamorphics with an Alpine subgreenschist facies overprint). **17.** Fondachelli unit: **a.** Meso-Cenozoic cover (Lower Kimmeridgian-Oligocene?); **b.** Paleozoic basement (Variscan chlorite zone of greenschist facies metamorphics). **18.** San Marco d'Alunzio, Longi-Taormina and Capo Sant'Andrea units: **a.** Meso-Cenozoic cover (San Marco d'Alunzio unit, Upper Triassic–Eocene; Longi-Taormina unit, Upper Triassic–Lower Oligocene?; Capo Sant'Andrea unit, Lower Lias–Lower Eocene); **b.** Paleozoic basements (Cambrian-Lower Carboniferous) (Variscan metamorphics: greenschist facies in the San Marco d'Alunzio unit; subgreenschist to greenschist facies in the Longi-Taormina unit; subgreenschist facies in the Capo Sant'Andrea unit). **19.** Maghrebian flysch basin units (Upper Jurassic–Lower Miocene). **20.** Fault. **21.** Overthrust. **22.** Undifferentiated tectonic boundary.

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On the basis of the composition and the evolutionary history of each CPCSS Alpine unit, the following features have been recognized:

- ***a Proterozoic or older crystalline basement in the Aspromonte unit,*** affected by three metamorphic (Pan-African HT granulite facies; Variscan Bosost-type LT granulite to LT amphibolite facies; Alpine Barrovian-type HT greenschist to LT amphibolite facies) and three intrusive (Paleo-Proterozoic within-plate tholeiitic ultramafics; Late-Pan-African orogenic peraluminous intermediate to acidic plutonics; Late-Variscan orogenic basic-intermediate to acidic meta- to meso-peraluminous plutonics) processes. The unit is devoid of a Meso-Cenozoic sedimentary cover;

- ***Paleozoic sedimentary-volcanic sequences*** (from Cambrian to Early Carboniferous) *in the remaining units,* some of them preserving remnants of original Mesozoic to Paleogene (Middle Triassic to Early Miocene) sedimentary covers (lacking in the Cardeto, Africo and Mela units).
Among these latter tectonic elements, *the Mela unit records a polymetamorphism* (an Eo-Variscan eclogite facies and a Variscan Barrovian-type amphibolite facies re-equilibration), whereas *the other units record peculiar-Variscan polyphase monometamorphic processes* (with a prograde zoning, from LT greenschist facies to oligoclase+almandine zone of greenschist facies in the Mandanici unit, to staurolite+oligoclase zone in the Piraino unit, up to sillimanite+muscovite zone in the Stilo unit; under LT greenschist facies in the Fondachelli and San Marco d'Alunzio units, and up to subgreenschist facies in the Longi-Taormina and Capo Sant'Andrea units);

- ***Additional evolutionary processes affected the Stilo unit*** (both Late-Variscan orogenic intermediate to acidic meso- to peraluminous plutonic process and up to hornblende *hornfels* facies contact metamorphism), and the *Cardeto*(?), *Africo* and *Alì units* (an Alpine polystage metamorphic overprint which locally completely mask the Pre-Alpine features, occurred under HT greenschist in the Cardeto unit, under greenschist in the Africo unit and sub-greenschist facies in the Alì unit).

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2.2 Peloritani Chain tectono-stratigraphic units

In the Peloritani Chain, the geological mapping (APAT, 2008; ISPRA, 2011; Carbone et al., 2008, 2011) confirms the presence of the newly recognized Mela and Piraino units of Messina et al. (1997, 1998, 2004b), the Fondachelli unit of Bonardi et al. (1976b, 1996) and the San Marco d'Alunzio, Longi-Taormina and Capo Sant'Andrea units of Lentini and Vezzani (1975) and Lentini et al. (2000b), detailing their geological and petrographic features.
This field trip illustrates geometries, structures, compositions and metamorphic evolution of the *Aspromonte, Mela, Piraino, Mandanici, Fondachelli* and *San Marco d'Alunzio units* and related Meso-Cenozoic deposits, which crop out in the studied areas. It also describes relationships between these Peloritani Chain units and the unconformable Oligo-Miocene to Recent sedimentary covers, as well as the neotectonic features, that affected the Peloritani edifice.

2.2.1 Aspromonte unit (AsU)

The ***Aspromonte unit*** (Bonardi et al., 1979) extensively crops out from the homonymous massif, in Southern Calabria, to the Northern Peloritani Mts. in Sicily (Fig. 9b). In Calabria, the AsU extends from Taureana-Antonimina in the North to Bova Marina in the South, geometrically interposed between the overlying low- to medium-grade Stilo unit (Crisci et al., 1983; Bonardi et al., 1984) and the underlying low-grade Cardeto (Bonardi et al., 1980b; Messina et al., 1996a) and Africo (Bonardi et al., 1979) units, with thickness of about 2,000 m (Mt. Montalto 1956 m a.s.l.). It is also present in the Montebello Ionico tectonic window (Southern Aspromonte Massif).
In Sicily the AsU crops out North of Guidomandri- d'Orlando Cape alignment with thickness of about 1,200 m. It is the highest tectonic unit and commonly overlies the Mela unit and subordinately all the other tectonic units, except the Longi-Taormina and Capo Sant'Andrea units (APAT, 2008; Carbone et al., 2008, 2011, and references therein; Macaione et al., 2010; ISPRA, 2011).

Devoid of a Meso-Cenozoic cover, the Aspromonte unit consists of a Paleo-Meso-Proterozoic ultramafic plutonic (and metamorphic?) basement, affected by a Pan-African HT granulite facies metamorphism and intruded by Late-Pan-African orogenic intermediate to acidic plutonics. This basement was also involved in a Variscan LT granulite to LT amphibolite facies metamorphic re-equilibration, intruded by a late-Variscan orogenic basic-intermediate to acidic plutonics and affected by a localized Alpine MHP greenschist to MP amphibolite facies metamorphic overprint (Messina et al., 2004b; Macaione et al., 2010).

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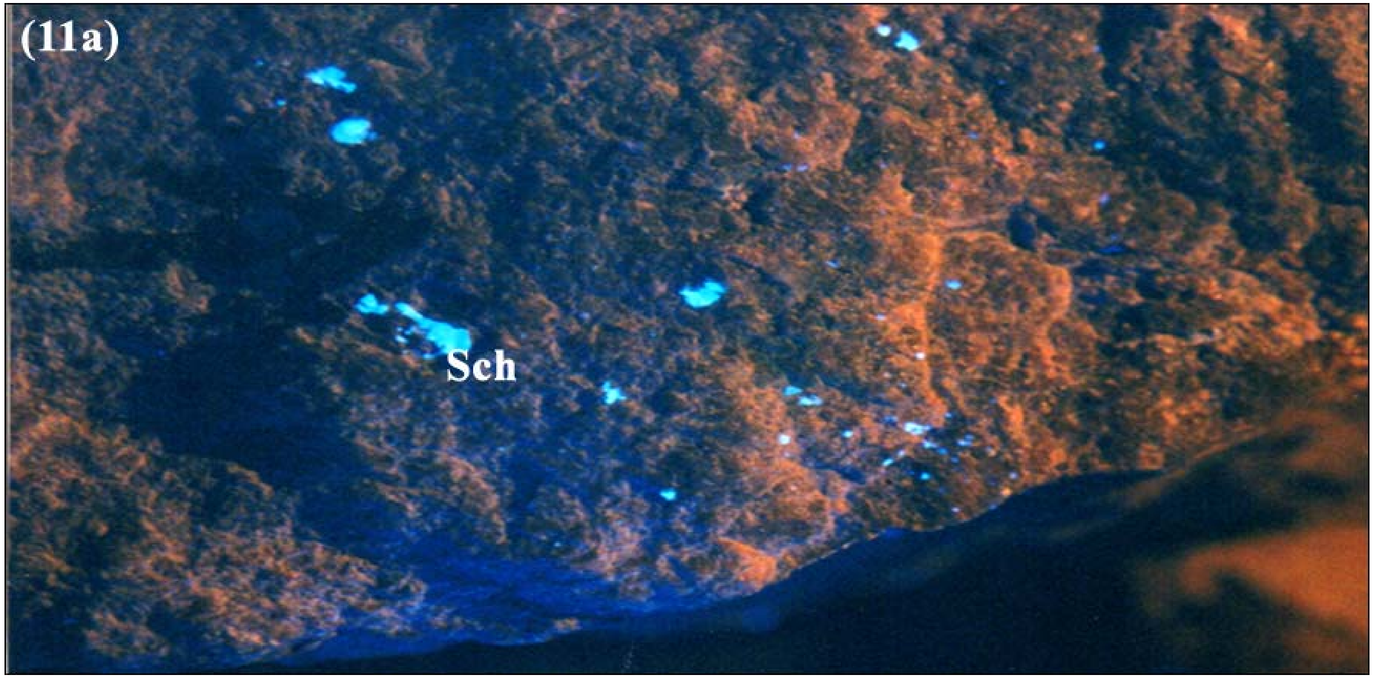
A ***Paleo-Meso-Proterozoic ultramafic plutonic event*** (Messina et al., 2004a, 2010; Carbone et al., 2008, 2011; Macaione et al., 2010) is indicated by preserved Pre-Variscan relict *metaperidotites* (Fig. 10a), *metapyroxenites* (Fig. 11a) and *metahornblendites* which range from meter-sized lenses to bodies many hundreds of meters in size. This magmatism, dated at 1771–1562 Ma in metahornblendites (U/Pb titanite age; De Gregorio et al., 2003), exhibits a within-plate tholeiitic affinity (Macaione et al., 2010).

A ***Neo-Proterozoic granulite metamorphic event*** is recorded in the same metaultramafic rocks and in acidic *cordierite+garnet+K-feldspar granulite* lenses, both ascribed to the Pan-African event, dated at 800-600 Ma ($^{39}Ar/^{40}Ar$ amphibole age; De Gregorio et al., 2003) in hornblende cores of the above mentioned metahornblendites. The Pan-African



Figs. 10a and 11a - Aspromonte unit. Pan-African metaultramafics relics after Paleo-Proterozoic plutonics: **10a)** metaperidotite with partial Variscan amphibolite and Alpine greenschist facies re-equilibrations; **11a)** metric block of garnet metapyroxenite with primary Proterozoic synplutonic scheelite (Sch) deposit, with a partial Variscan amphibolite facies and a weak Alpine greenschist facies re-equilibration (mesoscopic view under Wood’s lamp ultraviolet rays). Loc.: Badiazza Valley, North-East Peloritani Mts. (**10a**); Larderia, North-East Peloritani Mts. (Saccà collection, Messina University) (**11a**).

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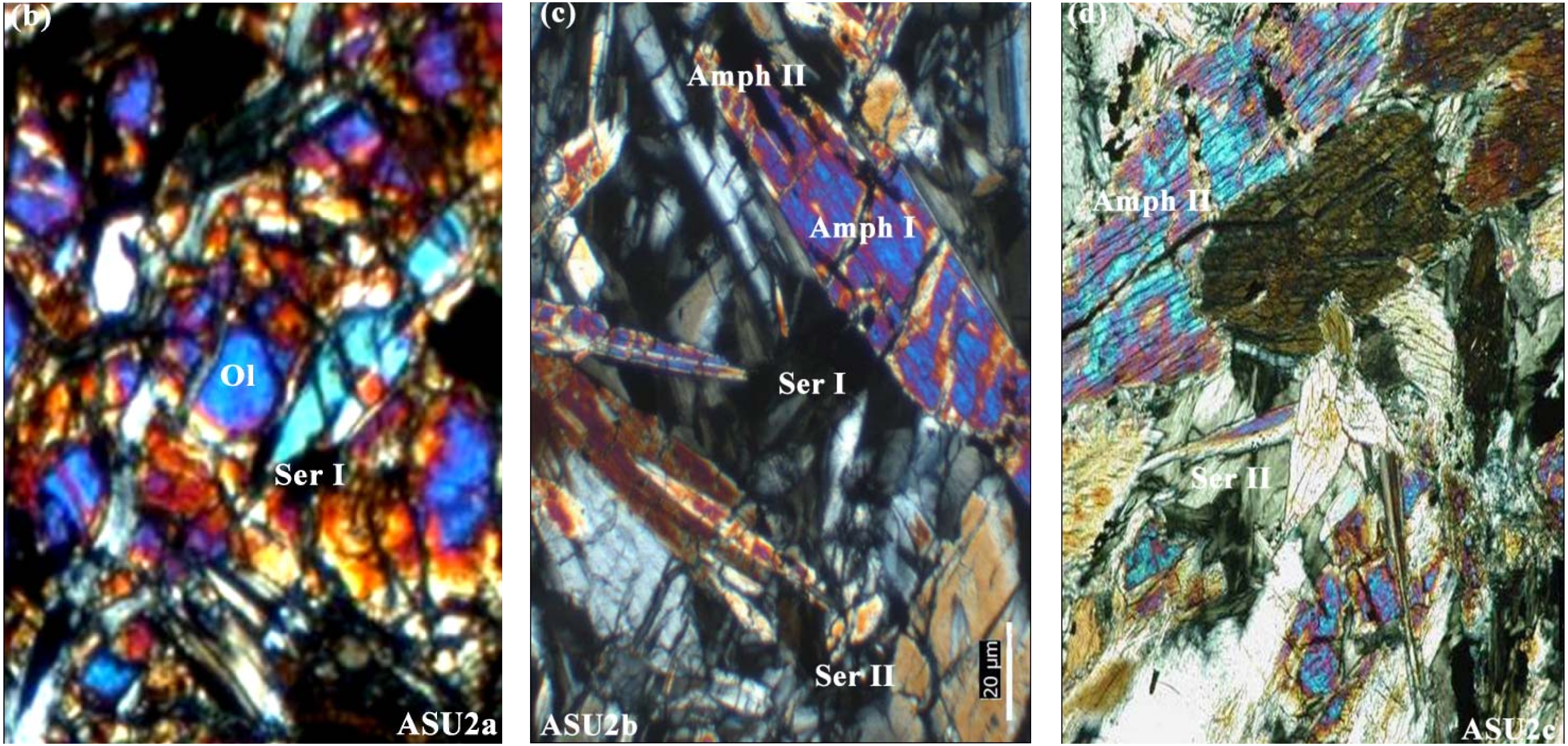
granulite ultramafic associations were marked by *forsterite*(Fo_{78})-*enstatite*(XMg=0.96-0.99)-*magnetite paragenesis* in metaperidotites (Fig. 10b) and by *orthopyroxene-plagioclase-garnet (scheelite) paragenesis* in metapyroxenites (Figs. 11b and c) (Messina et al., 1996b).



Figs. 10b to d – Aspromonte unit. Photomicrographs of the re-equilibrated Pan-African metaperidotites of Fig. 10a: **b)** Pan-African forsterite (Ol) porphyroclast partly replaced by Variscan antigorite (Ser I); **c)** Variscan porphyroclastic anthophyllite (Amph I), derived from the almost replaced Pan-African enstatite, recrystallized at the rim in an Alpine acicular tremolite (Amph II), and Variscan antigorite (Ser I) recrystallized in Alpine small-sized Fe-antigorite plagues (Ser II); **d)** Alpine matrix made up of prevalent tremolite (AmphII), Fe-antigorite (Ser II) and subordinate chlorite. Samples: ASU2a, b, c. Crossed Polars (CP), 45x. Loc.: Badiazza Valley. North-Eastern Peloritani Mts.

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These rocks were involved in a partial *Variscan LT granulite facies re-equilibration,* and part of them also by a localized *greenschist facies Alpine metamorphic overprint*. The former re-equilibration is indicated by the *anthophyllite*[XMg=0.78-0.81]+*antigorite*[XMg=0.93-0.96]+*magnetiteII* paragenesis in metaperidotites (Fig. 10c) (Macaione et al., 2010), as well as by the *orthopyroxene+plagioclase = clinopyroxene+Ca-garnet+quartz* reaction which occurred in the metapyroxenites under T=700°C and P=0.9-1.0 GPa (Figs. 11c and d). The latter re-equilibration is marked by Alpine *tremolite*[XMg=0.90-0.95]-*Fe-antigorite*[XMg=0.84-0.90]-*clinochlore*[XMg=0.90-0.91] paragenesis in metaperidotites (Figs. 10c and d) (Macaione et al., 2010), and by Alpine *amphibole-chlorite-garnet (scheelite?)* paragenesis in metapyroxenites (Figs. 11c to f).
In the metahornblendites, the Pan-African metamorphism is dated in the preserved hornblende core and the Variscan re-equilibration in the hornblende rims. The metahornblendites were also locally affected by a partial to pervasive Alpine overprint (Macaione et al., 2010).

A ***Neo-Proterozoic-Cambrian orogenic plutonic event*** is indicated by the presence of an intermediate to acidic Variscan metaplutonic series, augen gneisses prevailing, dated at 600-520 and at 572-537 Ma (U/Pb zircon ages; Schenk & Todt, 1989 and Micheletti et al., 2007, respectively), in Variscan augen gneisses and attributed to a Late Pan-African event (Messina & Macaione, 2010). The series exhibits calc-alkaline affinity and is peraluminous (Ferla & Rotolo, 1992; Ferla, 1994). It is made up of metatonalite to metaleucomonzogranite bodies and of metaaplopegmatite and subordinate metagabbro dykes (Messina et al., 1996a, 2004b; Carbone et al., 2008, 2011).
A ***Middle-Late Carboniferous metamorphic event***, which pervasively affected both Pan-African metamorphics and Late-Pan-African plutonics, is ascribed to the Variscan event and dated at 314 Ma in paragneisses (Rb/Sr mica age in, Bonardi et al., 2008), and at 340 Ma in amphibolites ($^{39}Ar/^{40}Ar$ amphibole age; De Gregorio et al., 2003).
The ***Variscan metamorphic basement*** is formed by *gneisses* up to a kilometer in extension, which locally grade to *schists* including meter-thick lenses of *amphibolites, gneissic amphibolites and* relics of Pan-African metaultramafics (*metaperidotites*, *metapyroxenites* and *metahornblendites)*, with alternation of layers of *silicate marbles*, *Ca-silicate fels* and *quartzites* (Paleo-Proterozoic). A *metatonalite to metaleucogranite series* in large bodies and dykes, where augen gneisses prevail, forms 40% of the AsU outcrops (Neo-Proterozoic-Cambrian).
The ***Variscan tectono-metamorphic evolution*** was articulated during two main deformation phases (Dv_1 and Dv_2 or Dv_n and Dv_{n+1}). Of these phases, only the former was accompanied by a syn- to post-kinematic, plurifacial and Bosost-type metamorphism, responsible for a retrograde zoning from LT granulite to LT amphibolite facies. The unit is reversed: in Sicily, it shows high- grade rocks to the North (North-West in

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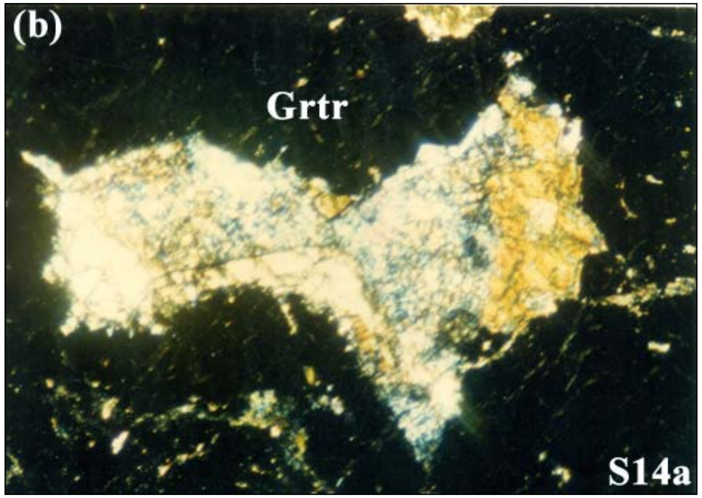
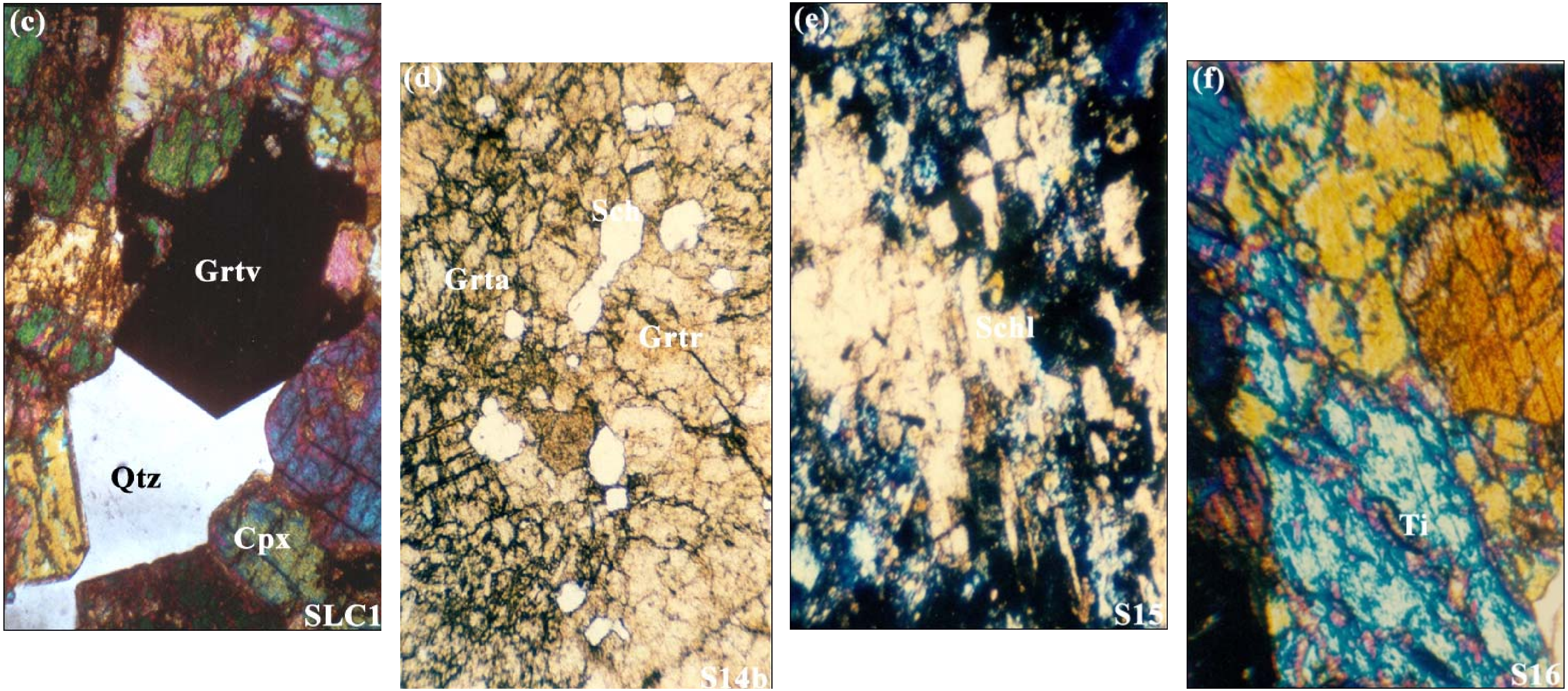


Figs. 11b to f – Aspromonte unit. Photomicrographs of the re-equilibrated Pan-African metapyroxenites of Fig. 11a: **b)** Pan-African preserved large Ca-garnet (Grtr) and Variscan pseudomorphosis of white mica on former plagioclase; **c)** Variscan augite(Cpx)+Fe-garnet(Grtv)+quartz(Qtz) paragenesis (after orthopyroxene+ plagioclase reaction); **d)** Pan-African large Ca-garnet (Grtr), including idioblastic scheelite (Sch), recrystallized along Alpine shear planes in very small garnet (Grta) and chlorite; **e)** broken and/or recrystallized scheelite and garnet along Alpine shear planes; **f)** chlorite+uncoloured amphibole+titanite(Tit) (after Variscan clinopyroxene) and quartz along Alpine shear planes. Samples: S14a, SLC1, CP, 60x (b, c); S14b, Plane Polarized Light (PPL), 45x (d); S15, S16, CP, 60x (e, f). Loc.: Larderia. North-East Peloritani Mts.



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Calabria), and medium-grade lithotypes to the South (South-East in Calabria). At the meso- and microscale the rocks, which commonly exhibit a crenulated Fv_{1m} (Fv_{nm}) main foliation, are marked by anatectic phenomena with mobilization of leucosomes and melanosomes in the Bagnara-Scilla (Calabria) to the Calavà Cape (Sicily) band. In the other areas, gneisses and schists show late- to post-Fv_{1m} centimeter sized blastesis of Mg-cordierite, prismatic sillimanite, garnet, staurolite, Fe-cordierite, andalusite, depending on the specific metamorphic zone (Messina *et* al., 1996a, 2004b; Carbone et al., 2008, 2011; Macaione et al., 2010).
A ***Carboniferous–Permian plutonic event*** is indicated by several plutonic bodies intruding the Variscan basement, dated at 290 Ma (Rb/Sr mica age; Rottura et al., 1990) and ascribed to the Late Variscan.
The ***Variscan plutonic basement*** is made up of syn- (only in Calabria) to post-tectonic bodies, ranging in composition from gabbros and diorites (in Calabria) to leucomonzogranites, and of felsic and mafic dykes (the latter only in Calabria), which represent the latest intrusions. In Sicily, intrusions have *two mica+sillimanite+andalusite+cordierite leucotonalite to leucomonzogranite* compositions and contain melatonalitic microgranular inclusions and medium- to high-grade metamorphic xenoliths. An intersected network of felsic dykes, with prevailing aplo-pegmatites, and of rare mafic dykes, represents the latest intrusions.
A ***Late Oligocene metamorphic overprint***, indicated by a grain-size reduction and a recrystalization of Variscan metamorphics, Pre-Variscan relics and Late Variscan plutonics along localized kilometer-thick shear zones, is dated at 28-22 Ma (Rb/Sr mica age, Bonardi et al., 2008) and ascribed to the Alpine event (Bonardi et al., 1984, 1992, 1996, 2008; Messina et al., 1990, 1992, 1996a, 2004b; Platt & Compagnoni, 1990; Heymes et al., 2008, 2010).

The overprint created four zones at different grades of re-equilibration (*pervasive, partial, weak, soft)*, locally showing a gradual transition (about 25 km around Badiazza Valley - Messina, 1998a; Bonardi et al., 2008; Macaione et al., 2010). In the pervasive overprinted zone, five deformation phases (Da_1–Da_5) have been recognized, three of them accompanied by syn- to post-kinematic metamorphism ascribed to two different stages of re-equilibration. The first, syn- to post-Da_1, stage developed a Barrovian-type HT greenschist facies metamorphism defined by almandine-kyanite-chloritoid paragenesis. The second, syn-Da_2 to post-Da_3, stage was responsible for the Fa_{2m} main and the Fa_3 foliations, developed a LT amphibolite facies metamorphism indicated by biotite-oligoclase-almandine paragenesis.

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Overthrusting contacts, mainly sub-horizontal in orientation, are present at the bottom of the unit (Figs. 12a and b), along the overthrusts of the AsU on the underlying units, responsible for LT and LP meter-thick (max 10 m) cataclastic to mylonitic bands accompanied by retromorphosis and locally also remobilized or recrystallized metallic deposits.

Fig. 12a – Relationships between Aspromonte unit and Mela unit. Alpine overthrusting contact between the Variscan augen gneisses of the Aspromonte unit (AsU) and the underlying Variscan relict garnet schists of the Mela unit (MeU), forming a decametric cataclastic band accompanied by hydrothermal phenomena with sulphide and Fe-oxide deposits. Loc.: Northern slope of Mt. Ficherelle. Central Peloritani Mts.

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Fig. 12b – Relationships between Aspromonte unit and Fondachelli unit. Alpine overthrusting contact between the Variscan augen gneisses of the Aspromonte unit (AsU) and the underlying Variscan graphite phyllites of the Fondachelli unit (FU), forming a cataclastic band of about twenty metres in thickness. Loc.: Western slope of Montagna di Vernà. Central Peloritani Mts.

The ***AsU field markers***, *not present in the other tectonic units, are:*

- Pan-African metaultramafic relics (metaperidotites, metapyroxenites, metahornblendites);
- Variscan metaplutonics (prevailing augen gneisses);
- Variscan anatectic mobilization (migmatites);
- Late-Variscan syn- and post-tectonic (the last are present only in the Stilo unit) plutonics;
- strong Alpine metamorphic overprint (not always recognizable in the field).

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2.2.2 *Mela unit (MeU)*

The ***Mela unit*** (Messina et al., 1997) extensively crops out in the Peloritani Mts., from Giampilieri Marina on the Ionian coast to Capo d'Orlando, on the Tyrrhenian side (Fig. 9b), in an area ascribed by Bonardi et al. (1979, 1996) to the Aspromonte unit. The MeU is sandwiched between the overlying high- to medium-grade Aspromonte unit and either the underlying low- to medium-grade Piraino unit or, rarely, Mandanici unit. Its maximum thickness has been estimated to be about 800 m in Pizzo Croce (1,214 m a.s.l.) (Carbone et al., 2008, 2011). The MeU basement, as the other Peloritani Chain units, is locally unconformably covered by the Oligo-Miocene Capo d'Orlando flysch (Fig. 13).

Fig. 13 – Mela unit. Sandstones of the Oligo-Miocene Capo d'Orlando flysch (COF), which unconformably covers the two mica+garnet marbles of the Mela unit (MeU). Loc.: North of Rocca Timogna. Central Peloritani Mts.

The MeU devoid of a Meso-Cenozoic cover, is made up of a basement characterized by a Paleozoic sequence affected by an Eo-Variscan eclogite facies metamorphism, followed by a Variscan Barrovian-type amphibolite to HT greenschist facies metamorphic re-equilibration (Messina et al., 1997, 2004b; Compagnoni et al., 1998).

The ***Paleozoic sequence,*** from top to bottom, consists of Na-within plate basalts, carbonate and siliceous pelagites, pelitic-arenaceous succession and intermediate to acidic volcanics, and is typical of a passive continental margin. The sequence is ascribable to a transitional crust (Carbone et al., 2011).

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The ***Variscan metamorphic basement*** is made up of layers, up to a kilometer in extension, of *paragneisses* grading to *schists* (Fig. 14a) both characterized by the occurrence of centimeter *relict garnet*, and including meter-thick lenses of *relict andesine gneissic amphibolites*, bodies of *relict K-feldspar orthogneisses* which can be many hundreds of meters thick and meter-thick concordant *feldspar-rich leucogneisses*. The MeU is capped by thick *marbles* (Fig. 14b), several tens of meters in thickness, which include *amphibolized eclogite* bodies and layers of *quartzites* up to some meters.

The ***tectono-metamorphic evolution*** developed in two stages. The first, Eo-Variscan in age (349 Ma through $^{39}Ar/^{40}Ar$ amphibole dating; De Gregorio et al., 2003), is documented by symplectites of clinopyroxene+hornblende after omphacite destabilization in the amphibolized eclogites, and by the association of quartz+oligoclase±biotite after garnet destabilization in the same rocks and in the paraderivates (Compagnoni et al., 1998). The second metamorphic stage, Variscan

Fig. 14a - Mela unit. Folded Variscan Fv_{3m} main foliation in relict garnet schists to large static (from post-Dv_3 to post-Dv_4,) blastesis of staurolite±kyanite±sillimanite+new garnet+cordierite+andalusite. Loc.: West of Pizzo Ilici. Eastern Peloritani Mts.

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Fig. 14b - Mela unit. Panoramic view of two mica+garnet marbles (400-500 meters in thickness) (MeU). Loc.: Colle del Re (1,180 m a.s.l.). Central Peloritani Mts.

in age (310-315 Ma through $^{39}Ar/^{40}Ar$ amphibole dating; De Gregorio et al., 2003), was responsible for a polyphase (Dv_1–Dv_4; the first three accompanied by metamorphism) Barrovian-type LT amphibolite to HT greenschist facies metamorphic re-equilibration. At the meso- and microscale the rocks show a strongly crenulated Fv_3 main foliation which wraps up and rotates the relict garnet and is cut by kyanite, staurolite, (sillimanite only at the microscale), new garnet, cordierite and andalusite porphyroclasts (Messina, 1998a, b; Messina et al., 1997, 1998, 2004b; Macaione et al., 2012b).

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Alpine shear planes, varying in thickness and very widespread in the MeU, were responsible for brittle to mylonitic deformations, of which, the latter were accompanied by LT retrograde recrystallizations, such as margaritic sericite after Variscan alumosilicates (kyanite, sillimanite and andalusite) and chlorite±epidote±opaques after Variscan biotite, garnet or amphibole.

Overthrusting contacts (Figs. 15a and b), at the upper and the lower boundaries of the unit, are defined by cataclastic bands up to 20 m thick, responsible for a strong alteration of minerals and hydrothermal remobilizations and/or recrystallization of polymetallic and carbonatic deposits.

Fig. 15a – Relationships between Mela unit and Aspromonte unit. Alpine overthrusting contact between the Variscan augen gneisses of the Aspromonte unit (AsU) and the underlying two mica+garnet marbles of the Mela unit (MeU). Loc.: T.te San Nicola. Central Peloritani Mts.

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Fig. 15b – Relationships between Mela unit and Piraino unit. Alpine overthrusting contact between the Variscan marbles of the Mela unit (MeU) and the underlying Variscan dark-pearl graphite phillytes of the Piraino unit (PU). The contact is marked by a cataclastic band several metres in thickness. Loc.: Madonna del Lume. Central-Western Peloritani Mts.

The ***MeU field markers are***:
- very thick two mica±garnet marble layers, locally including up to centimeter-sized silicate lenses;
- amphibolized eclogites;
- fine grained relict garnet- and muscovite-rich paragneisses and schists, showing a strongly crenulated Fv_{3m}, foliation cut by centimeter sized static blastesis of kyanite, staurolite, new garnet, cordierite and andalusite;
- relict andesine gneissic amphibolites;
- important polymetallic deposits (Ag-rich galena, scheelite, chalcopyrite, pyrite and pyrrhotite).

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2.2.3 Piraino unit (PU)

The ***Piraino unit*** (Messina, 1998b; Messina et al., 1998) crops out continuously from Nizza di Sicilia village on the Ionic coast, to the Piraino village on the Tyrrhenian coast (Fig. 9b), where the unit was recognized for the first time. The PU is geometrically interposed between the overlying Mela unit (Figs. 16a and a[1]) or, in some locations, the Aspromonte unit (Fig. 16b), and the underlying Mandanici unit or, in some locations, Fondachelli or San Marco d'Alunzio units. It has a thickness ranging from 10 m up to 500 m, and crops out in areas previously ascribed to the Mandanici unit by Bonardi et al. (1979, 1996).

In the Sheet Barcellona P.G.-Milazzo, going West, the PU crops out along the F.ra Dinarini (near Mandanici village) – T.te Mela (high valley) - Pizzo Mualio – T.te Fondachelli – T.te Novara alignment. The geo-petrographic study and the surveys carried out for the map Sheet 587-600 have contributed, in a significant way, to the enhancement of the knowledge of the areal extension, composition and evolution of this latest recognized Peloritani Chain unit.

The PU consists of a basement defined by a Paleozoic sedimentary-volcanic sequence affected by a Variscan metamorphism responsible for a LT greenschist to LT amphibolite facies prograde zoning, and of a Mesozoic cover (Messina et al., 1998, 2004a, b; Cecca et al., 2002; Carbone et al., 2008, 2011).

The ***Paleozoic sequence*** refers to a pelitic-arenaceous succession intercalated by basic volcanics.

The ***Variscan metamorphic basement*** is made up of many hundreds of meters thick layers of *dark-grey graphite phyllites* grading to *metarenites,* which include bodies of *quartzites* many meters in thickness, and meter-thick lenses of *pale-green amphibolitic schists*.

The ***Variscan tectono-metamorphic evolution*** developed during four deformation phases (Dv_1-Dv_4), the first three accompanied by a syn- to post-kinematic Abukuma-type metamorphism, and were responsible for a prograde zoning from chlorite zone of greenschist facies to staurolite-oligoclase-almandine zone of amphibolite facies. At the meso- and microscale the rocks show a Fv_{2m} main foliation imprinted by a narrowly-spaced and not penetrative crenulation cleavage Fv_3 defined by sericite+chlorite and/or biotite, according to the zoning, on which Mn- to Fe-garnet porphyroblasts (Fig. 16 a[1]) commonly occur, in addition to chlorite and/or biotite and or staurolite static blastesis (Messina, 1998b; Messina et al., 1998, 2004b).

The ***Mesozoic cover***, from bottom to top, is composed by a Pseudo-Verrucano succession of *siltites*, *sandstones* and *conglomerates* (Late Triassic? - Hettangian), *dolostones* (Jurassic?), *limestones, marls, sandstones* and

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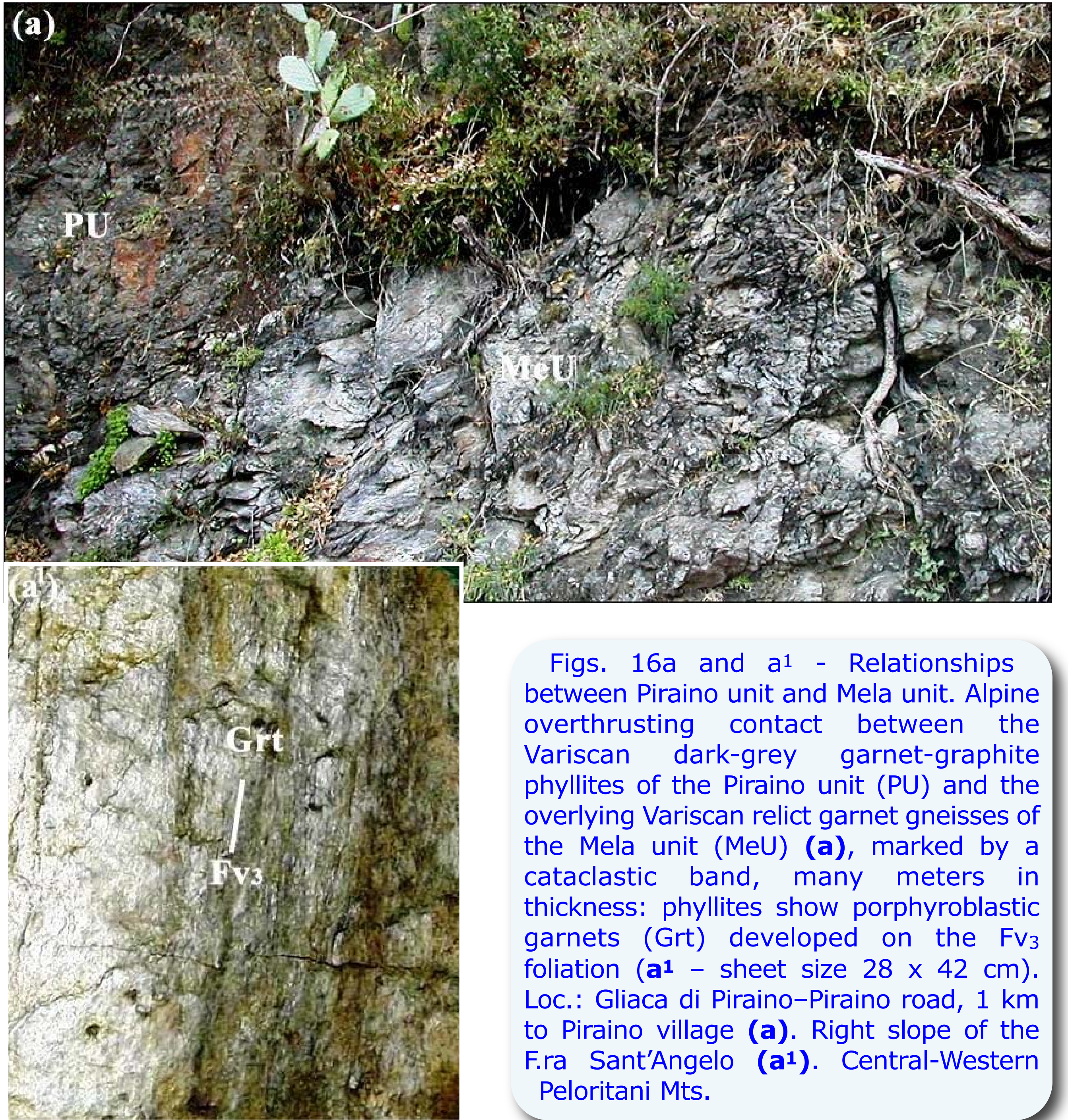

Figs. 16a and a¹ - Relationships between Piraino unit and Mela unit. Alpine overthrusting contact between the Variscan dark-grey garnet-graphite phyllites of the Piraino unit (PU) and the overlying Variscan relict garnet gneisses of the Mela unit (MeU) **(a)**, marked by a cataclastic band, many meters in thickness: phyllites show porphyroblastic garnets (Grt) developed on the Fv_3 foliation (**a¹** – sheet size 28 x 42 cm). Loc.: Gliaca di Piraino–Piraino road, 1 km to Piraino village **(a)**. Right slope of the F.ra Sant'Angelo **(a¹)**. Central-Western Peloritani Mts.

siltites (Middle Lias – Aalenian. Cecca et al., 2002). Meter-thick slices of *limestones* and *dolostones* crop out along the dirty road from Mandanici up to Pizzo Mualio, about 3,5 km from the village.

Alpine shear planes are widespread in the unit, responsible for brittle deformations accompanied by cataclasis and retrocessions.

Overthrusting contacts, at the top and the bottom of the unit (Figs. 16a, b and c), define cataclastic bands decameters in thickness, marked by retromorphosis of minerals and rarely by *sulphides, Fe-oxides and Fe–hydroxides* deposits.

The ***PU field markers are:***

- prevalent garnet-bearing dark-grey graphite phyllites and metarenites with static blastesis up to post Fv_3 of chlorite, biotite, chloritoid, garnet and staurolite (according to the zoning);
- dark grey phyllitic quartzites;
- pale-green amphibolitic schists.

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Fig. 16b - Relationships between Piraino unit and Aspromonte unit. Alpine overthrusting contact between the Variscan dark-grey garnet-graphite phyllites of the Piraino unit (PU) and the overlying Variscan augen gneisses of the Aspromonte unit (AsU). The contact is marked by a cataclastic band, several meters in thickness. Loc.: right slope of the F.ra Santa Venera. Central Peloritani Mts.

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2.2.4 Mandanici unit (MaU)

The ***Mandanici unit*** (Bonardi et al., 1976b) crops out continuously for about 250 sq. km, from Scaletta Zanclea – F.ra d'Agrò area on the Ionian coast, to the F.ra Naso on the Tyrrhenian side, reaching 500 m in thickness (Fig. 9b). It is tectonically overlaid by the Piraino unit and to a lesser extent by the Mela and the Aspromonte units, and overthrusts the Fondachelli and the San Marco d'Alunzio units (Messina, 1998a, b; Messina et al., 1998, 2004b; Carbone et al., 2008, 2011).

The MaU is made up of a basement composed of a Paleozoic sedimentary-volcanic sequence affected by a Variscan metamorphic prograde zoning, from LT greenschist facies to the beginning of the amphibolite facies, and by a thin Mesozoic cover.

The ***Paleozoic sequence*** is composed of a pelitic-arenaceous-carbonatic succession with rare intercalations of basic volcanics and acidic volcanoclastites.

The ***Variscan metamorphic basement*** consists of layers of *grey-green to leaden phyllites* (Figs. 18a and b), many kilometers in extension, grading to *metarenites*, intercalated with meter-thick bodies of *whitish-grey quartzites* and lenses of *green-blue actinolitic schists* and localized kilometer-thick bodies of *porphyroids* (Figs. 17a and b). In the uppermost part of the sequence levels of *banded white mica marbles*, many hundreds of meters thick, are also present.

The ***Variscan tectono-metamorphic evolution*** is characterized by three main deformation phases (Dv_1–Dv_3), the first two were accompanied by syn- to post-kinematic metamorphism responsible for the development of chlorite zone of greenschist facies to oligoclase-almandine zone of amphibolite facies prograde zoning. At the meso- and microscale the rocks show a crenulated Variscan Fv_{2m} main foliation, transposed rarely along a thin, incipient and spaced Fv_3 foliation in the most metapelitic types. Fv_1 is always evident and static blastesis develop up to post Dv_2.

The ***Mesozoic cover*** outcrops in small slices along the T.te Pagliara – F.ra Santa Venera - Tripi village alignment. It consists of Upper Triassic - Lower Lias *limestones*, *dolostones*, *sandstones* and *evaporites* (Carbone et al., 2008, 2011).

Alpine shear planes were responsible for brittle to mylonitic deformations, accompanied by cataclasis with alteration of minerals to a low-T recrystallization, respectively.

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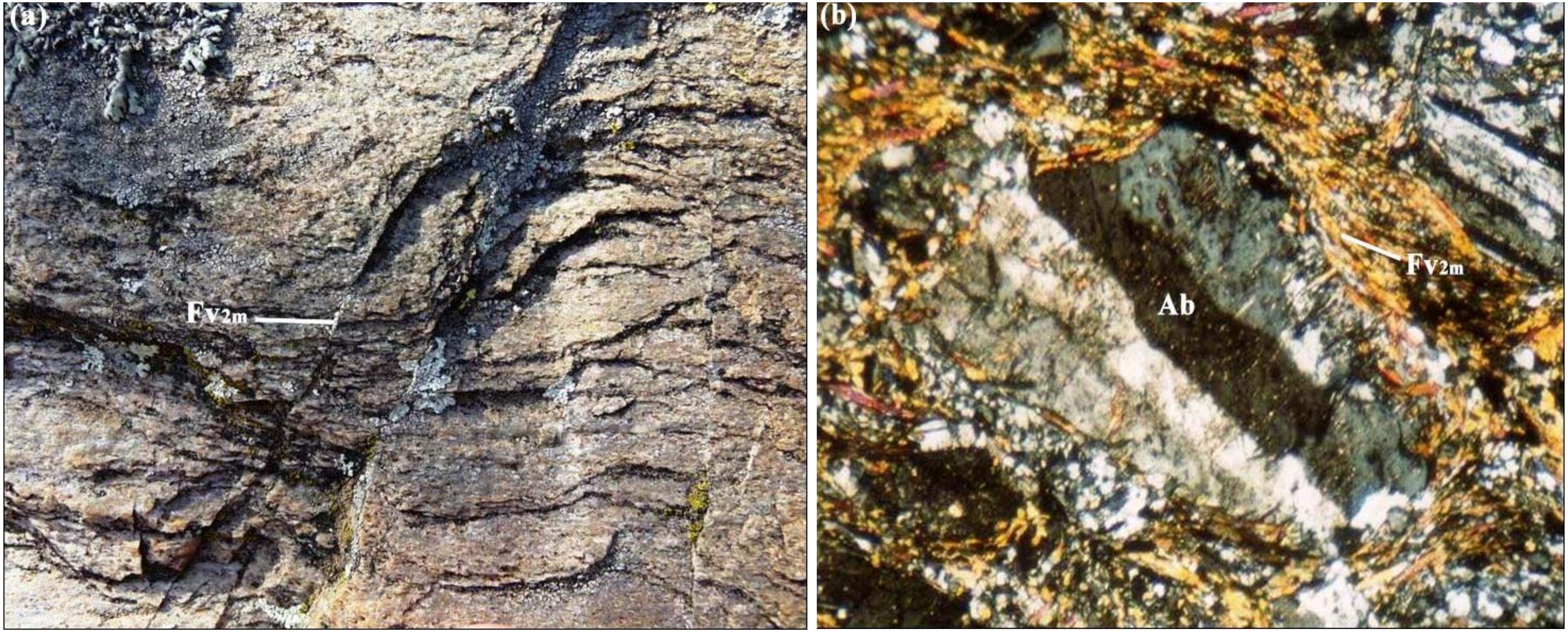

Figs. 17a and b - Mandanici unit: Variscan porphyroids from biotite-zone. Variscan grey two mica porphyroid with a crenulate Fv_{2m} foliation **(a)**. Photomicrograph of albite porphyroclast (Ab) wrapped by the Fv_{2m} main foliation defined by fine-grained white mica+chlorite+biotite+quartz+opaques **(b)**. Sample Md1. CP, 45x (from Messina & Macaione, 2010). Loc.: left slope of the T.te Pagliara. Eastern Peloritani Mts.

Overthrusting contacts, at the top and the bottom (Figs. 18a and b, 19a) of the unit, are defined by cataclastic bands reaching up to 30 m in thickness, accompanied by retromorphosis of minerals (Carbone et al., 2011).

Polymetallic *stratabound and stratiform* ***mineral deposits***, including noble metals, remobilized and/or recrystallized during the Variscan metamorphism and Alpine tectogenesis, or Plio-Pleistocene hydrothermal processes, are one of the most important features of all the MaU lithotypes.

The ***MaU field markers are:***

- phyllites and metarenites showing medium to low crystallinity and variable color, from grey-green if they

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contain chlorite, silver-grey if they have abundant white mica, to leaden if they include biotite, with the less crenulated Fv_{2m} main foliation and small, up to post-Fv_2, static blastesis;
- green-pale blue fine-grained actinolitic schists;
- chlorite to biotite porphyroids;
- fine-grained banded marbles containing white mica (muscovite or paragonite).

Figs. 18a and b – Panoramic view of the Alpine tectonic pile made up of Aspromonte, Piraino and Mandanici units. Alpine cataclastic band approximately 10 meters in thickness, including few meters of ochre Variscan augen gneisses of the Aspromonte unit (AsU), which thrust over meter-thick layers of dark-grey Variscan graphite-garnet phyllites of the Piraino unit (PU). These latter units, in turn, tectonically rest on a Variscan silver-grey phyllites **(b)** of the Mandanici unit (MaU). Loc.: left slope of the T.te Novara, near Tripi Village. Central Peloritani Mts.

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2.2.5 Fondachelli unit (FU)

The ***Fondachelli unit*** (Bonardi et al.,1976b), corresponding to a part of the Galati nappe of Ogniben (1960) and of the San Marco d'Alunzio unit of Lentini & Vezzani (1975), crops out for about 230 sq km from F.ra d'Agrò Valley on the Ionian coast, to Rocca di Caprileone on the Tyrrhenian coast. The unit is commonly sandwiched between the overlying Mandanici unit (Fig. 19a) and the underlying San Marco d'Alunzio unit, and its maximum thickness has been estimated to be about 600 m. It is also tectonically covered by Piraino, or Mela, or Aspromonte units and locally also overlies the Longi-Taormina unit (Fig. 19b). The tectonic contacts are well evident along the F.ra d'Agrò – T.te Fantina–Fondachelli – F.ra Sant'Angelo - Rocca di Caprileone alignment.

The FU is made up of a basement, characterized by a Paleozoic sedimentary-volcanic sequence affected by a Variscan LT greenschist facies metamorphism, and of a thick Meso-Cenozoic cover.

The ***Paleozoic sequence*** consists of a pelitic-arenaceous succession with rare carbonate and intercalations of mafic volcanics.

The ***metamorphic basement*** is made up of a monotone alternation of *black-pearl graphite-rich phyllites, metarenites and quartzites* (Figs. 20a and b*)*, with localized *blue-green metadiabases* and very rare *metacarbonates.*

Fig. 19a - Fondachelli unit. Alpine overthrusting contact between the Variscan black-pearl phyllites of the Fondachelli unit (FU) and the overlying Variscan silver-grey phyllites of the Mandanici unit (MaU) marked by a folded meter-thick cataclastic and mineralized band. Loc.: right slope of the F.ra Santa Venera. Central Peloritani Mts.

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The ***Variscan tectono-metamorphic evolution*** is marked by four deformation phases (Dv_1-Dv_4), the first three accompanied by a chlorite-zone of greenschist facies metamorphism. At the meso- and microscale the rocks show a crenulated Variscan Fv_{2m} main foliation cut, at about 80°, by a thin and spaced Fv_3 foliation.

The ***sedimentary cover***, according to our new interpretation on the basis of the above defined mapping project, consists of the ***Meso-Cenozoic Rocca Novara stratigraphic succession*** cropping out along the Forza d'Agrò, in the Ionian side, to Raccuia – Novara di Sicilia (Central Peloritani Mts.) alignment, with a thickness of about 170 m. It is overturned and entirely exposed along the Southern slope of the Rocca di Novara as well as in San Basilio area.

Fig. 19b - Fondachelli unit. Alpine overthrusting contact between the Variscan black-pearl phyllites of the Fondachelli unit (FU) and the underlying Lower Lias oolitic limestones of the Longi-Taormina unit cover (LTU). Loc.: Mt. Galfa. Eastern Peloritani Mts.

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Alpine shear zones, responsible for mylonitic deformations, are widespread in the FU, also accompanied by recrystallization along a new Fa_{my} foliation mimetically developed on the Variscan Fv_2 foliation, obliterating previous structures. They are defined by a very fine grained recrystallization of LT minerals, and by a remobilization and recrystallization of *sulphides, sulphates, Fe-oxides* and *Fe-hydroxides* deposits (Messina et al., 2004b).
Overthrusting contacts, on the upper and the lower boundaries of the FU (Figs. 19a and b), are defined by cataclastic bands of approximately 20 m in thickness, responsible for the alteration of minerals and hydrothermal phenomena with remobilizations or newly formed metallic and carbonatic deposits.

The ***FU field markers are:***
- very low crystallinity;
- typical and homogeneous black-pearl color of the graphite-rich phyllites, metarenites and quartzites;
- blue-green metadiabases;
- widespread Alpine and Plio-Pleistocene hydrothermal phenomena responsible for sulphides and Fe-oxides and Fe-hydroxides deposits.

2.2.6 Fondachelli unit Meso-Cenozoic cover

Rocca Novara unit

The Novara unit (Truillet, 1961), or Rocca Novara unit (Lentini & Vezzani, 1975), is an Upper Jurassic-Oligocene sedimentary sequence cropping out along the Forza d'Agrò (on the Ionian coast, North of Taormina) to Ucria ESE-WNW alignment, through Novara di Sicilia.
According to Bonardi et al. (1976b) and Amodio Morelli et al. (1976), the Novara succession belongs to the Stilo unit, which represent the uppermost tectonic element of the CPA cropping out in Southern Calabria made up of a Paleozoic basement (Variscan low to medium-grade metamorphics intruded by Late Variscan plutonics) and a Meso-Cenozoic cover. The Lentini & Vezzani (1975) and Atzori et al. (1977) consider the Rocca Novara unit a tectonic horizon between the basements of the San Marco d'Alunzio and Mandanici units.
These two interpretations result in different reconstructions of the Novara unit geological evolution: in the first, it overlaps with the top of the CPA Southern sector and represents the only fragment of European provenance; in the second, the unit is not considered the innermost cover of the entire edifice. Atzori et al. (1977) define an original succession including, from the base to the top: metamorphics of the San Marco d'Alunzio unit; Tithonian grey limestones; whitish *Aptycus* and *Calpionella* bearing marly limestones ascribed to Lower

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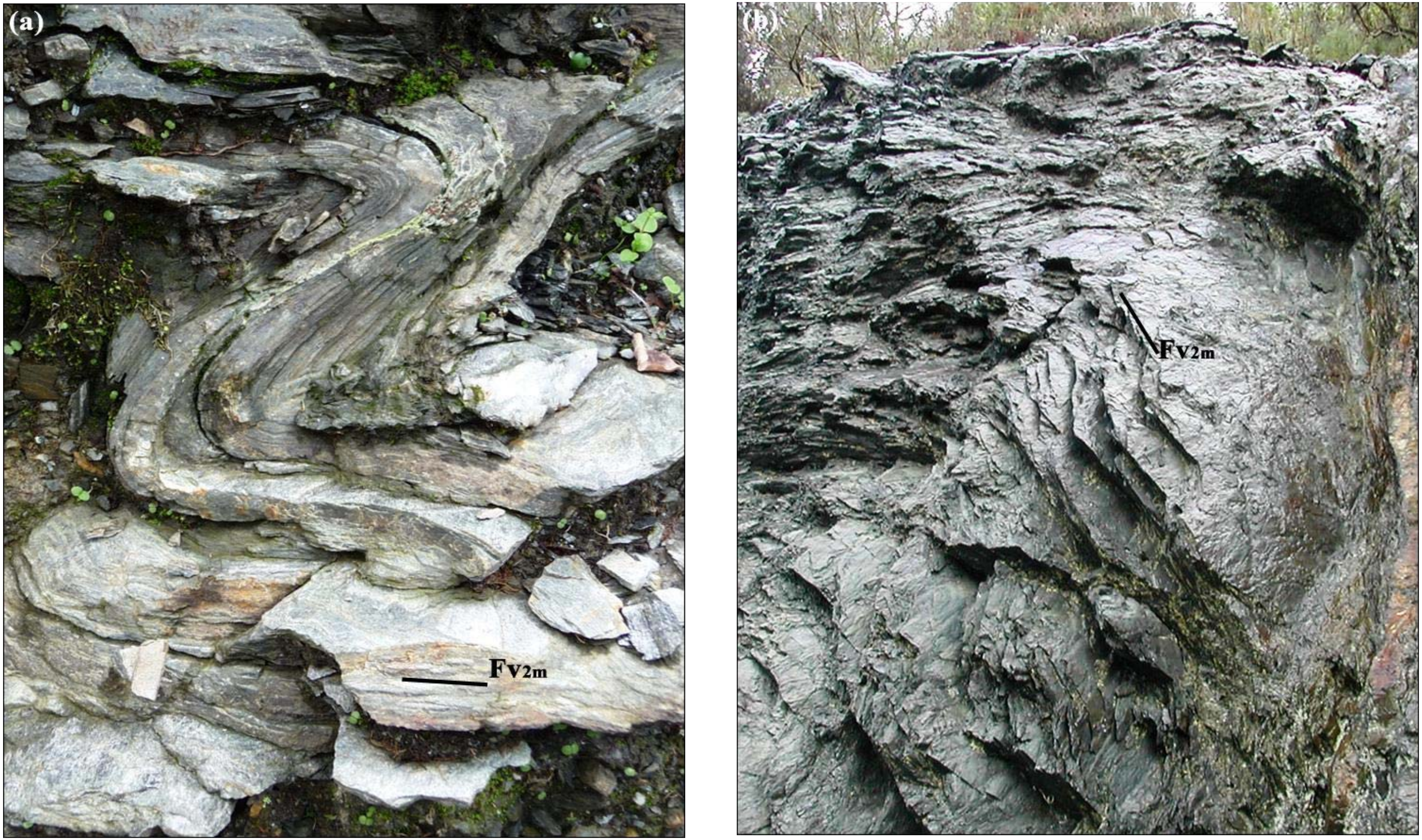

Figs. 20a and b – Fondachelli unit: Variscan chlorite quartzites. Black-pearl chlorite+sericite quartzites up to a few meters in thickness showing the folded Fv_{2m} foliation. Loc.: right slope of F.ra Santa Venera **(a)**; North of km 17 of the SS 185 **(b)**. Central Peloritani Mts.

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Cretaceous; 30 m thick greenish or red silvery silty marls in Scaglia facies, upgrading to an alternation of yellowish sandstones and marly siltstones, ascribed to Cretaceous-Eocene. This latter in turn upgrades to a red polygenic conglomerate, matrix supported, rich of high- and medium-grade metamorphic clasts and of granites, which upwards progressively prevail over carbonatic and schistose lithotypes; the uppermost level is represented by the phyllites of the Mandanici nappe.

The red conglomerate crops out along a WNW-ESE oriented alignment, extending from Raccuia to Sant'Alessio Cape, but it is commonly correlated to the above-defined Mesozoic outcrops. Several authors (Truillet, 1961; Bonardi et al., 1980a; Caliri et al., 1993; Catalano et al., 1996; Lentini et al., 2000b) consider it as a discordant syn-orogenic deposit for its geometric position, sometimes directly at the top of various Calabride crystalline units.

In the almost complete succession, even if overturned, of the Southern side of Rocca Novara, Atzori et al. (1977) consider the red conglomerate as a deposit originally at the top of the Rocca Novara succession. It marked a fast increase of detritic sedimentation, coarsening gradually. They did not interpret it as a transgressive deposit on the metamorphics, but as a marginal facies comparable with coeval deposits such as the Frazzanò flysch, but more internal corresponding to a basin margin in quick uplift or to the front of a tectonic overthrusting.

Mesozoic-Paleogene succession

According to the new interpretation, the Mesozoic-Paleogene succession of the Novara unit corresponds to a mainly overturned sequence, tectonically interposed between the San Marco d'Alunzio unit metamorphics at the bottom and the Fondachelli unit basement at the top. It is affected by detachments, and repeated slices, which are sometimes transformed into a tectonic breccia.

In the considered area, the Rocca Novara fm. crops out along the T.te Paratore (right slope) - Novara di Sicilia - Mt. Porcospino (Fondachelli-Fantina) NNW-SSE oriented alignment. It is well exposed in Mt. Santa Croce, Novara di Sicilia and Poggio Campi (West of San Basilio). Other minor blocks are prevalently situated North-East of the main alignment.

The formation is composed of grey or light brown crystalline massive limestones, dolostones and carbonate breccias. The limestones are frequently oolitic and sometimes well-bedded, especially in the lower levels where they are not affected by dolomitization. The massive limestones are made up of a grain-supported grainstone containing peloids, gastropoda, foraminifera (*Trocholina* sp.), but mostly algae, such as *Clypeina sulcata*, and subordinately *Campbelliella striata* and *Salpingoporella* sp.. This algae association indicates a Lower

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Kimmeridgian-Lower Berriasian range, but it is typical of Middle Tithonian. These lithotypes form the reliefs of Mt. Santa Croce, part of Novara di Sicilia village, and of Mt. Porcospino (North of Fondachelli). The thickness of the formation ranges from few meters up to 150 m. The described lithotypes evolve upwards into:

- greyish fine-grained marly limestones in medium-thin strata. They crop out in small meter-thick slices north-West of Novara di Sicilia and in Contrada Poma, East of the same village. They contain macrofauna of aptycus and sponge spicules, and microfauna constituted by Calpionellids and Radiolaria, ascribable to the Lower Cretaceous; in analogous levels Truillet (1968) indicates a Tintinnids microfauna of Berriasian age. Atzori et al. (1977) ascribe it to the Rocca Novara unit;
- green or red silty sliverly marls in Scaglia facies, in very thin strata (1-2 cm), with bottom marks and tracks of *Inoceramus*. The marls gradually pass into a rhythmic alternation of yellowish graded sandstones and marly siltstones, exposed in 5 to 50 cm strata. This interval is ascribed to Upper Cretaceous-Eocene (Atzori et al., 1977; Lentini et al., 2000b). The maximum thickness is 30 m (South-Eastern slope of Rocca Novara, at the base of the Tithonian limestones, with clear overturned position).

The relief of Poggio Campi is made up by numerous south-verging tectonic sheets of Mesozoic limestones.

The environment is typical of carbonate platform drowned since Lower Cretaceous. The age of the entire succession is Upper Jurassic-Eocene.

Red conglomerate

In the considered area, the red conglomerate formation is exposed between the T.te Fantina in the East and T.te Paratore in the West and is always associated with the above-described Mesozoic succession.

The red conglomerate is a polygenic deposit from matrix to grain-supported with generally rounded elements composed of various grade metamorphics, granitoids and Mesozoic limestones. The matrix, made up of reddish and (to a lesser extent) green shales and of dark siltites, shows a marked fissility produced by thin boudinage lamination and a pervasive cleavage.

Near San Basilio village, an overturned alternation of graded arkosic sandstones and greyish shales in thin strata is exposed. It represents a transitional facies to the red conglomerate. It is correlated to the deposits cropping out on the Southern side of the Rocca Novara described by Atzori et al. (1977), where the overturned succession evolves from sandstone to conglomerate, increasingly richer in crystalline elements. The thickness is about 100-150 m, the formation is fossil barren and, from its stratigraphic position, is ascribed to Lower Oligocene(?).

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2.2.7 San Marco d'Alunzio unit (SMU)

The ***San Marco d'Alunzio unit*** (Lentini and Vezzani, 1975) crops out in the Southern Peloritani Mts., from the high tract of the Agrò Valley, on the Ionian coast, to the San Marco d'Alunzio-Sant'Agata di Militello area, on the Tyrrhenian side (Fig. 9b), where it reaches a thickness of about 600 m. Usually interposed between the overlying Fondachelli unit (Fig. 21) and the underlying Longi-Taormina unit, in some localities it is overlaid by all the higher Peloritani Chain units. The tectonic contacts are exposed well along the T.te Fondachelli - T.te Novara alignment in the Central Peloritani Mts. and along the San Salvatore di Fitalia - San Marco d'Alunzio - Sant'Agata di Militello alignment in the Western Peloritani Mts. On the Southern side of the Peloritani Chain, the SMU sometimes directly tectonically overlies the Apenninic-Maghrebian units (Monte Soro unit).

The SMU consists of a basement characterized by a Paleozoic volcanic-sedimentary sequence affected by a Variscan low T and P greenschist facies metamorphism, and of a condensed Meso-Cenozoic cover with repeated gaps.

The ***Paleozoic sequence*** consists of a succession of prevailing acidic volcanoclastics alternating with pelitic-arenaceous layers and subordinate intercalations of basic volcanics.
The ***Variscan metamorphic*** basement is made up of meters to hundreds of meters in thickness pink *acidic metavolcanics* (Fig. 22a) where *porphyroids* prevail, *dark-bluish graphite slates* (Fig. 22b) and *phyllites, pink-violet metarenites*, *grey-pink quartzites, ochre talc-schists* and *dark-violet metabasites*.
The ***Variscan tectono-metamorphic evolution*** is characterized by four deformation phases (Dv_1-Dv_4), which the first three accompanied by a typical chlorite zone of greenschist facies metamorphism. At the meso- and microscale the rocks show a strongly crenulated Variscan Fv_{2m} main foliation, which is cut by a thin spaced Fv_3 foliation in the most pelitic types.
The ***Meso-Cenozoic cover*** is composed of *pseudo-verrucano facies arenites* and *conglomerates*; *limestones* and *dolomitic limestones*; *Medolo facies limestones* and *marls*, *massive limestones*, *Rosso Ammonitico facies limestones*, *Scaglia facies marly limestones* and *marls*, *carbonate breccias*. The age of the cover is Lower Jurassic-Eocene (Lentini & Vezzani, 1975; Lentini et al., 2000a, b).
Alpine shear planes, up to many kilometers in extension, are widespread in the unit. responsible for cataclastic phenomena up to low-T and P mylonitic effects, with remobilizations and/or depositions of *sulphides, sulphates, carbonates, Fe-oxides* and *Fe-hydroxides*. In the mylonites the new Fa_{my} foliation, mimetic on the Fv_2, completely obliterates the previous structures.

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Overthrusting contacts (Fig. 21) are marked by cataclastic bands that exceed 20 m in thickness at the top and the bottom of the unit, accompanied by hydrothermal processes with remobilizations and/or new metallic and carbonate deposits.

The ***SMU field markers are:***
- *low crystallinity;*
- *polychrome lithotypes;*
- *abundant metavolcanics with prevailing porphyroids.*

The general features of the SMU are similar to those of the Longi-Taormina and Capo Sant'Andrea units. Numerous authors considered the three units as subunits of the Longi-Taormina unit of Amodio-Morelli et al. (1976) and Bonardi et al. (1976b). They, delimited at the top and the bottom by primary tectonic contacts, differ in geometry, metamorphic grade of basements and characteristics of the Meso-Cenozoic cover.

Fig. 21 - San Marco d'Alunzio unit. Alpine overthrusting contact band, a few meters in thickness, between the Variscan black-pearl phyllites of the Fondachelli unit (FU) and the underlying pink acidic metavolcanics of the San Marco d'Alunzio unit (SMU). The band shows a strong cataclasis and hydrothermal phenomena with mineral (?) deposits. Loc.: right slope of the F.ra Novara. Central Peloritani Mts.

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Fig. 22a - San Marco d'Alunzio unit: Variscan pink acidic metavolcanics. Layer of pink metavolcanics, many meters in thickness, showing the crenulated Variscan Fv_{2m} foliation. Loc.: North slope of Pizzo Torno. Central-Southern Peloritani Mts.

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Fig. 22b – San Marco d'Alunzio unit: Variscan dark-bluish graphite slates. Detail of a many meter-thick layers of dark-bluish graphite slates, with quartz layers delineating the folded Fv_{2m} main foliation. Loc.: East of Pizzo Torno. Central-Southern Peloritani Mts.

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2.3 Upper Oligocene-Lower Miocene terrigenous succession

This succession includes the ***Capo d'Orlando flysch deposits*** which rest unconformably on all the basement units of the Peloritani Chain, sealing the related tectonic contacts. The formation also extends marginally at the top of the innermost chaotic units of the Apenninic-Maghrebian Chain. It preserves the original contacts on both edifices and is tectonically overlaid by the backthrusting varicoloured clays of the Peloritani Chain, even if cut in various tectonic slivers.

2.3.1 Capo d'Orlando flysch

The Capo d'Orlando flysch crops out extensively from Taormina, on the Ionian coast to the Sant'Agata di Militello village, on the Tyrrhenian coast. It is well exposed between the Raccuia and Capo d'Orlando villages and in discontinuous outcrops in the Patti and Barcellona Pozzo di Gotto areas. It is absent, or found only in limited exposures, in the Central-Eastern Peloritani Chain. The present distribution of the flysch is the result of the activation in the Tortonian of compressional transcurrent dextral faults, which greatly deformed the geometry of the Lower Miocene thrust system and they are still active.

According to Lentini & Vezzani (1975, 1978), the Capo d'Orlando flysch consists of the Oligo-Miocene terrigenous cover resting unconformably on all the already piled tectonic units. It represents the progression of the detritic sedimentation started in the Eo-Oligocene basin with the Frazzanò flysch. Consequently, the Capo d'Orlando flysch shows the characteristics of the post-orogenic molasse-type deposit compared with the onlap of the various Calabride units, evolving upward to a flyschoid facies correlated to more recent tectonic phases. The age is Chattian-Lower Burdigalian (Lentini et al., 1995a, 2000b).

The ***Capo d'Orlando flysch is a conglomeratic-arenaceous-pelitic sequence*** characterized by three heteropic lithofacies: the prevalently basal conglomerate, the arenaceous and (to a lesser extent) the pelitic or pelitic-arenaceous lithofacies. In the area considered here, the conglomeratic and arenaceous lithofacies crop out. The formation, which generally rests unconformably on the Aspromonte unit, lies with on-lap geometry on all the crystalline units, sealing the contacts.

The ***conglomeratic lithofacies*** is represented by *clasts* which vary in size from 2 to 50 cm, sometimes up to 1 m. They are polygenic, grain-supported, with rare calcareous clasts, and with a chaotic structure. The conglomerate is massive and/or organized in amalgamate 1-3 m banks; they mostly constitute channelized bodies with erosive base. The thickness varies from some tens metres up to 250 m. The arenaceous and/or

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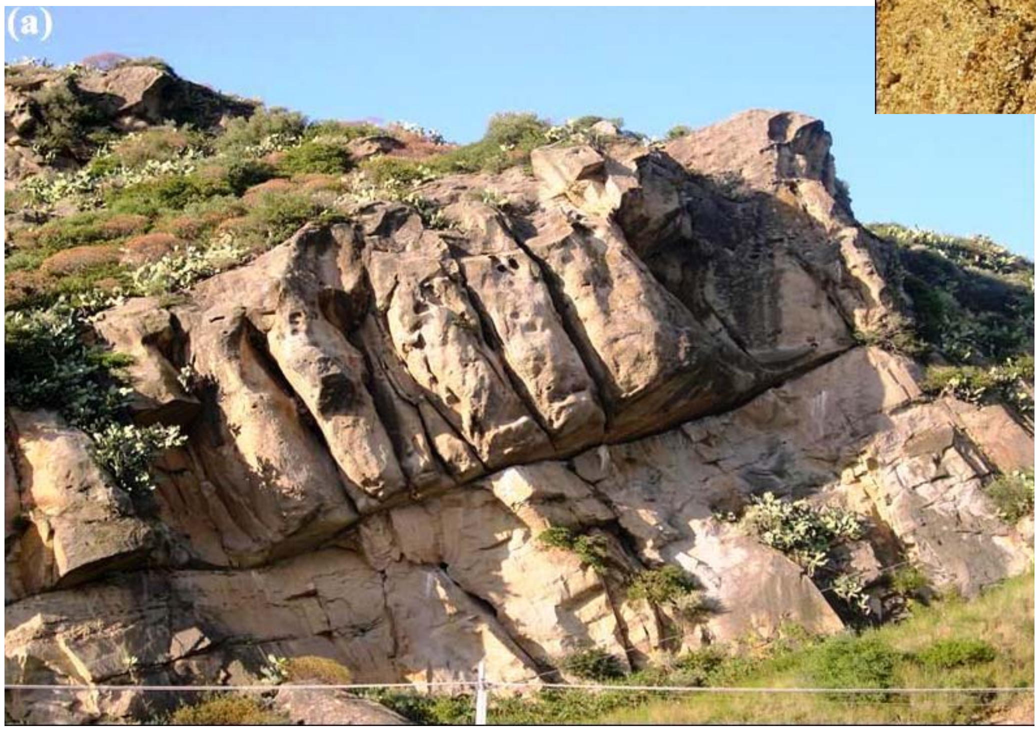
ruditic levels are fossil barren; on the basis of stratigraphic position the age is Upper Oligocene.

The ***arenaceous lithofacies*** consists of *grey-yellowish coarse-grained sandstones* (Figs. 23a and b, and 24), cropping out in medium to thick strata, interbedded with medium to thin *argillaceous-marly* horizons. The sandstones are graded and/or laminated, with Bouma sequences Ta-c or Tb-c, and bottom and ripple marks. The composition ranges from lithic to two feldspar (K-feldspar and plagioclase) arkoses, with abundant micas (Carmisciano & Puglisi, 1979). This lithofacies is the most common in the studied area, extending continuously West of the Tindari-Novara di Sicilia alignment, and in various slices in the rest of the territory. It reaches up to 350 m in thickness.

Figs. 23a and b - Oligo-Miocene to Miocene sedimentary covers: Oligo-Miocene Capo d'Orlando flysch. Many meters thick blocks of grey-yellowish sandstones (a); detail on (b). Loc.: right slope of the T.te Timeto, East of Patti. Western Peloritani Mts.



The age of the formation is defined on the basis of biostratigraphic data from the literature (Lentini et al., 1995a; Catalano & Di Stefano, 1996; Lentini et al., 2000b).

The argillaceous-arenaceous basal levels of this lithofacies are characterized by associations of typical Chattian species such as *Dictyococcites bisectus*, *Helicosphaera euphratis*, *Cyclicargolithus floridanus*, *C. abisectus*, *Sphenolithus moriformis* and *S. ciperoensis*. In the upper layers, an Aquitanian association is defined by the presence of rare *Helicosphaera carteri* and *Sphenolithus delphix*. In the map sheet "Taormina" the upper argillaceous interval of the pelitic lithofacies (not cropping out in the map Sheet "Milazzo-Barcellona P.G."), immediately under the contact with the varicoloured clays, contains lower Burdigalian nannoflora such as *Helicosphaera carteri*, *Discoaster deflandrei*, *Sphenolithus moriformis*, *S. conicus*.

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Fig. 24 - Oligo-Miocene to Miocene sedimentary covers. Panoramic view, from the bottom to the top, of the Oligo-Miocene Capo d'Orlando flysch (arenaceous lithofacies, COF), the Cretaceous varicoloured clays (VC), the Lower-Middle Miocene Floresta calcarenites (FC). Loc.: North-West of San Basilio village. Central Peloritani Mts.

2.4 Cretaceous Antisicilide tectonic unit

The Antisicilide tectonic unit (Ogniben, 1969), originally belonging to the Sicilide unit of the Apenninic-Maghrebian Chain, is at present time a north-verging nappe resting above the Calabro-Peloritani edifice. It is characterized mainly by chaotic clayey volumes named varicoloured clays of the Peloritani Chain (Carbone et al., 2008), which

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tectonically overlie the Capo d'Orlando flysch and, locally, the crystalline basements of the Aspromonte and Mela units. They crop out in more or less isolated klippen, but the large diffusion in all the Southern sector of the Calabria-Peloritani Chain indicates that this nappe was widely distributed before the erosional processes.

2.4.1 Varicoloured clays of the Peloritani Mts.

The clays crop out in the studied area, preserved in the morphotectonic depressions oriented along the N-S, NW-SE and NE-SW main fault systems.

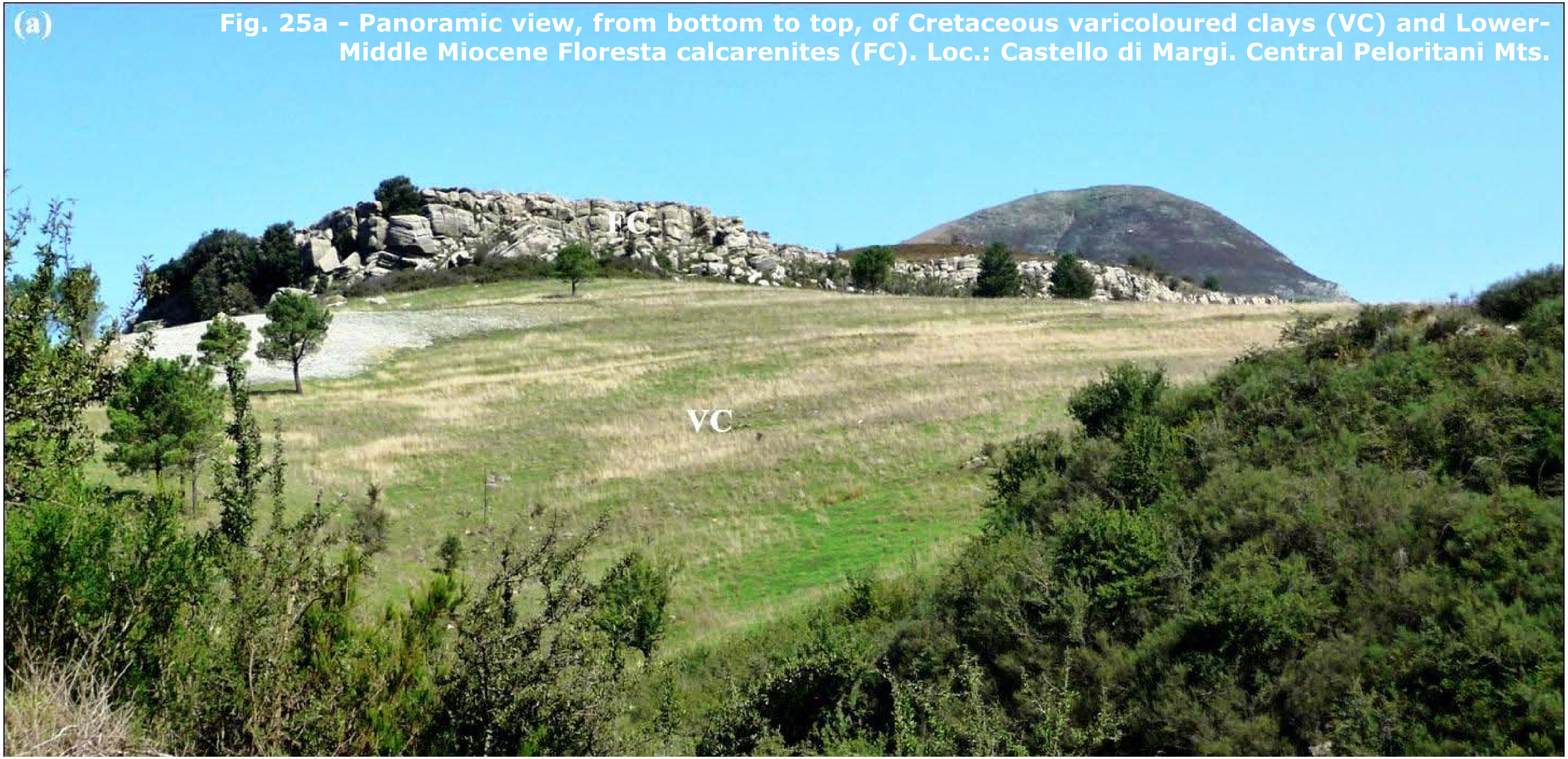

Fig. 25a - Panoramic view, from bottom to top, of Cretaceous varicoloured clays (VC) and Lower-Middle Miocene Floresta calcarenites (FC). Loc.: Castello di Margi. Central Peloritani Mts.

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The unit rests mainly on the Capo d'Orlando flysch, and locally on the Aspromonte unit metamorphics. Following a progressive reduction in thickness and in close proximity to the Capo d'Orlando flysch, the unit lies directly over the Mela unit schists, South-East of the Castroreale–Santa Lucia del Mela alignment, between Pizzo Muliciano and Mt. Pione (South of Santa Lucia del Mela village), and between Mt. Santa Croce and Pizzo Soglio-Pizzo Pennati (East of Castroreale village). The upper limit is characterized by the unconformable contact of Middle Miocene to Pleistocene formations.

The ***formation*** is characterized by chaotic *polychrome clays* (Figs. 24 and 25a) with local intercalations of *radiolarites* (Fig. 25b) in thin strata (northern versant of Mt. Bammina) of blackish, jaspery limestones and thin argillaceous-arenaceous layers. Fragments of *white micrites* and *grey carbonatic siltites* which range in size from one to ten centimeters across. Slices of *nummulitic limestones*, as well as blocks of *yellowish quartz-sandstones* ranging from one meter to many tens of meters in size, are also present locally, compositionally

Fig. 25b – Radiolarite (Rd) layers, a few meters in thickness, within Cretaceous varicoloured clays. Loc.: North of Mt. Bammina, Central Peloritani Mts.

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comparable to those of the Numidian flysch but ascribable to this one. The quartz-sandstones crop out at Piano di Santo Cono and between Cascina Mastroeni and Mt. Castellacci (East of Santa Lucia del Mela).
In regards to the age of the unit, Leonardi (1965), on the basis of the fossil fishes recognized in the bituminous schists of Floresta, and Campisi (1977), on the basis of the *Rotalipora*, *Guembelina*, *Ticinella* and *Pithonella* associations found in the upper biocalcarenites, assigned a Cenomanian age. In the map sheets *"Messina-Reggio di Calabria"* and *"Randazzo"*, the scant nannofossil associations, made up of *Arkhangelskiella cymbiformis*, *Braarudosphaera bigelowii*, *Calculites obscurus*, *Ceratolithoides aculeus*, *Micula concava*, *M. decussata*, *Watznaueria barnesae*, indicate a Campanian age. The thickness does not exceed 100 m.

2.5 Lower-Middle Miocene terrigenous succession

The ***Floresta calcarenites formation*** consists of arkosic sandstones with more or less abundant fossiliferous carbonate clasts (Carmisciano et al., 1981; Carbone et al., 1993), which unconformably rest, with gentle down lap, on the Cretaceous varicoloured clays, or sometimes on the Capo d'Orlando flysch and rarely on the basement. Consequently, this formation is an autochthonous deposit which seals the tectonic contact between the Capo d'Orlando flysch and the Antisicilide unit, postdating at late Burdigalian the orogenic transport of the nappe. Although reduced to isolated outcrops, as a result of erosion, it is diffusely present on both sides of the Peloritani Mts. (Guerrera and Wezel, 1974; Lentini et al., 1987, 2000).
Above the calcarenites, a horizon of Middle Miocene argillaceous marls stratigraphically lies. They have named by Caliri et al. (1993) the Monte Pitò marls.

2.5.1 Floresta calcarenites
In addition to the Floresta area, the formation is well exposed between Montalbano Elicona and Basicò, at Mt. Bammina, and between Furnari and Campogrande. The cliff of Castello di Margi (Fig. 25a), in the Castroreale area, is a peculiar outcrop of this formation.

The formation consists of white-grey biocalcarenites (Fig. 26a), *sometimes crossbedded, with algae, bryozoans and amphistegines and of glauconitic arkoses with spathic cement in strata from 20 cm up to 2 m in thickness, alternated with thin argillaceous and/or marly horizons. The coarser-grained layers show erosive contacts at the base; sometimes channelized bodies and slumps can be observed.*

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Fig. 26a – Oligo-Miocene to Miocene sedimentary covers. A block of white-grey calcarenite, a few decimeters in thickness, belonging to Lower-Middle Miocene Floresta calcarenites. Loc.: North-West of San Basilio village. Central Peloritani Mts.

They are petrographically *arkosic sandstones* with a varying abundance of *bioclasts*, together with angular quartz, micas, feldspars and metamorphic clasts. The bioclasts are represented by algae, bryozoans, bivalves, pectinides and benthonic foraminifera.

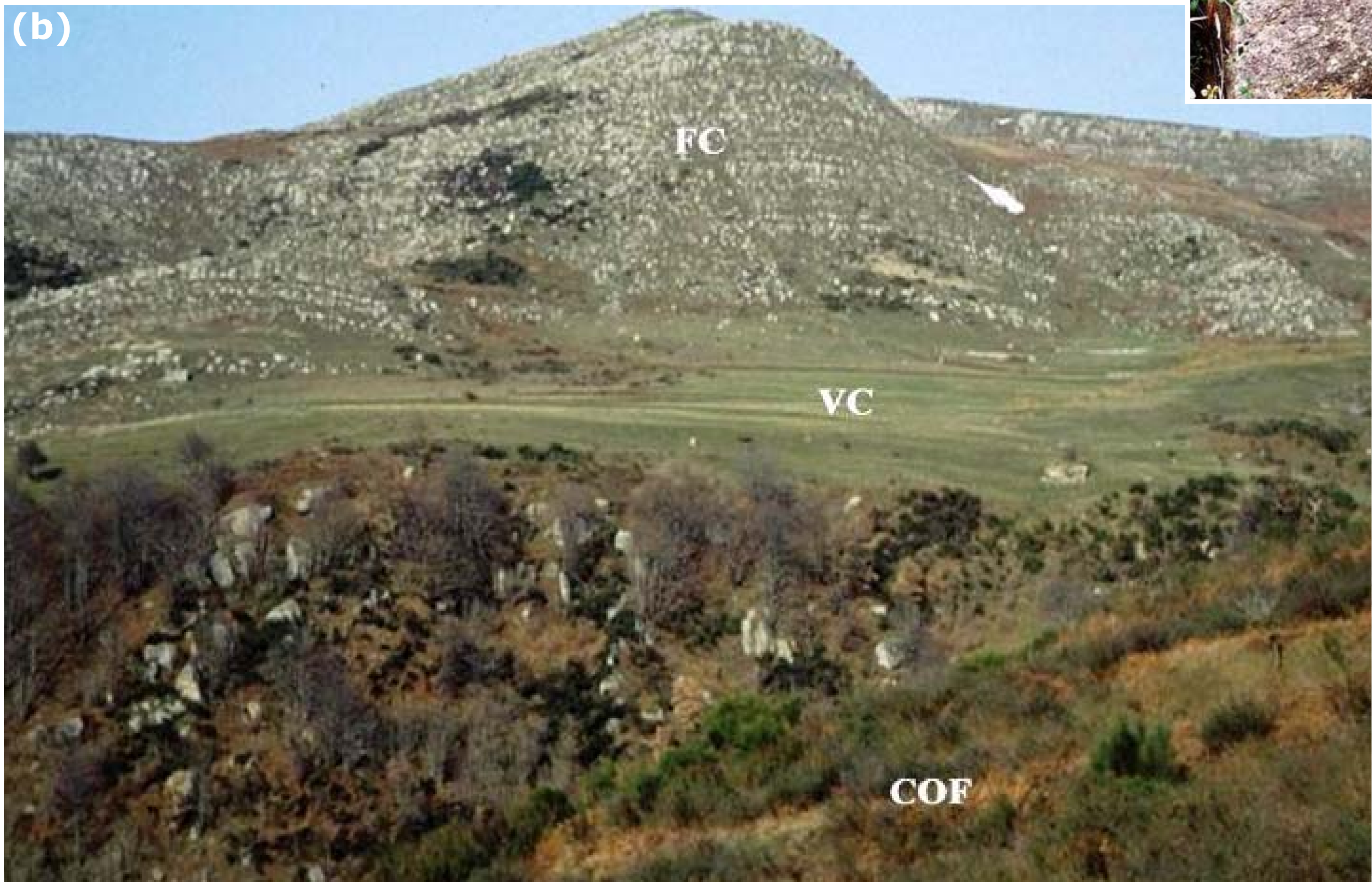

Fig. 26b - Panoramic view, from bottom to top, of the Oligo-Miocene Capo d'Orlando flysch (arenaceous lithofacies; COF), the Cretaceous Antisicilide unit (varicoloured clays; VC) and Lower-Middle Miocene Floresta calcarenites (FC). Loc.: Mt. Polverello, some kilometers East of Floresta village. Central-Eastern Peloritani Mts.

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Carbone et al. (1993) recognized, in all the outcrops, three facies correlated to different bathimetric conditions and to eustatic variations. The ***first facies*** *is constituted* by *carbonate platform bryozoans and rhodolites-bearing biolithites*, extending in scattered remains along the peri-Tyrrhenian versant from Patti to San Pier Niceto. The ***second facies*** is formed by cross-stratified *calcarenites*, diffused on the Northern versant of Maraffino (South of Falcone village) up to surroundings of Messina. The ***third facies***, more extended between Floresta and Novara di Sicilia areas, is characterized by *arkosic sandstones* in big banks with down lap geometry, which indicate a provenance from north of the sediments. Therefore, the quoted authors reconstructed both the original paleoenvironment and the tectono-sedimentary evolution. In the early Langhian, owing to an eustatic fall (*lowstand*), the internal areas emerged and the carbonatic products deriving from the erosion together with those of the crystalline substratum produced the clastic-organogenous sediments particularly extended in the Southern areas.

The lower limit of the unit is sharp and unconformable, on top of the variegated clays. The upper limit, where preserved by erosion, is gradual and continuous with the Mt. Pitò marls and/or coincides with the current topographic surface. The thickness ranges between at least 10 m up to 200 m.

Carbone et al. (1993) highlighted associations of *Globigerinoides trilobus*, *Paragloborotalia siakensis* and *P. acrostoma*, in the basal levels, indicative of the late Burdigalian age. In the upper levels faunal associations of *G. irregularis*, *Praeorbulina glomerosa glomerosa* and *P. glomerosa circularis* define a Langhian age. Associations of *Helicosphaera carteri*, *H. ampliaperta*, *Sphenolithus belemnos* nannofossils, in the basal levels, and of *Sphenolithus heteromorphus* and *Helicosphaera ampliaperta* in the mid-upper ones, confirm the attribution to the late Burdigalian-Langhian period.

2.5.2 Monte Pitò marls

The formation consists of a pelitic-arenaceous alternation made up of marls, clays and fine-grained sandstones with thin plane-parallel stratification.

Besides in Mt. Pitò (South of Basicò), good exposures of this unit occur North-West of Basicò (Fig. 27). West of Mt. Pitò fine-grained sands and grey-blue silty clays, with rare centimeter-sized intercalations of sandstones, crop out. The same formation is present at the top and on the Southern versant of Mt. Bammina.

The faunal content is represented by nannoflora composed of *Sphenolithus heteromorphus, Helicosphaera walbersdorfensis*, *Cyclicargolithus floridanus, Discoaster musicus*, *D. moorei*, *D. variabilis*, and of foraminifera characterized by *Orbulina suturalis* and *O. universa* in the upper region, which allows the formation to be ascribed to a late Langhian-early Serravallian age (Carbone et al., 1993).

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The characteristic facies and the microfaunal content with prevalent planktonic associations assign this deposit to a distal marine environment. Its large bathymetry compared to that of sedimentation of the Floresta calcarenites, is correlated to an eustatic uplift which occurred during the Langhian (Carbone et al., 1993; Lentini et al., 1995a). The thickness ranges from a few meters up to 60 m.

Fig. 27 - Panoramic view of the South-Eastern slope of Mt. Bammina, where the late Burdigalian-early Langhian Floresta calcarenites fm. (FC) and late overlying Langhian-early Serravallian Monte Pitò marls fm. (MPM) are downfaulted toward SE. Loc.: North-West of San Basilio village. Central Peloritani Mts.

2.6 Middle-Upper Miocene clastic and evaporitic succession

The ***upper Langhian-lower Messinian deposits*** (***San Pier Niceto fm***., Carbone et al., 2008) are preserved within downfaulted areas, along both the Tyrrhenian and Ionian coasts, separated by a modern NE-SW oriented horst structure, upon which a few depositional remnants are scattered.

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Fig. 28 - Arenaceous-pelitic lithofacies of the Middle-Upper Miocene San Pier Niceto fm. Loc.: East of Furnari village. Central-Western Peloritani Mts.

They consist of repeated horizons of conglomerates (Fig. 28), *interbedded with arenaceous-argillaceous layers, arranged in North-West dipping foresets and downlapping onto the substratum. The upper portion of the sequence consists of arenaceous-argillaceous alternations, forming a top-set geometry, and dates at the late Tortonian–early Messinian*.

The analysis of facies distribution and tectonics demonstrate that the overall geometry of the middle Serravallian-lower Messinian sequence is that of an original fan-delta, controlled by tectonics and eustasy. The conglomerate distribution reflects the arrangement of structural paleodepressions, originated from Serravallian faulting, connected to the initial phases of Tyrrhenian opening.

Along the north-facing slopes of the Nebrodi-Peloritani ridge, from Santo Stefano di Camastra through the largest outcrop on the Milazzo Peninsula to Rocca Valdina and Rometta, there is a number of exposures of upper Tortonian-lower Messinian reefoidal carbonates and calcareous breccias (Grasso & Pedley, 1997).
The evaporites (Gessoso-Solfifera Fm. Auct.) are correlated to the salinity crisis of the Mediterranean Basin, which occurred in the late Messinian. Their distribution is limited to

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the peripheral zones of the Peloritani Chain, cropping out both in the external areas (Ionian side) and in the retro-chain zones (Tyrrhenian side). The succession is reduced and lacunose, characterized by thin layers of carbonates and sulphates.

In the considered area the succession is represented by the evaporitic limestone. The more extensive outcrops are localized between Barcellona P.G. and Pace del Mela.

2.7 Lower Pliocene-middle Pleistocene succession

The ***Pliocene*** and ***Pleistocene deposits*** are preserved in downfaulted areas, adjacent to the modern coastline. They were deposited within structural depressions and then successively modified by Recent tectonics.

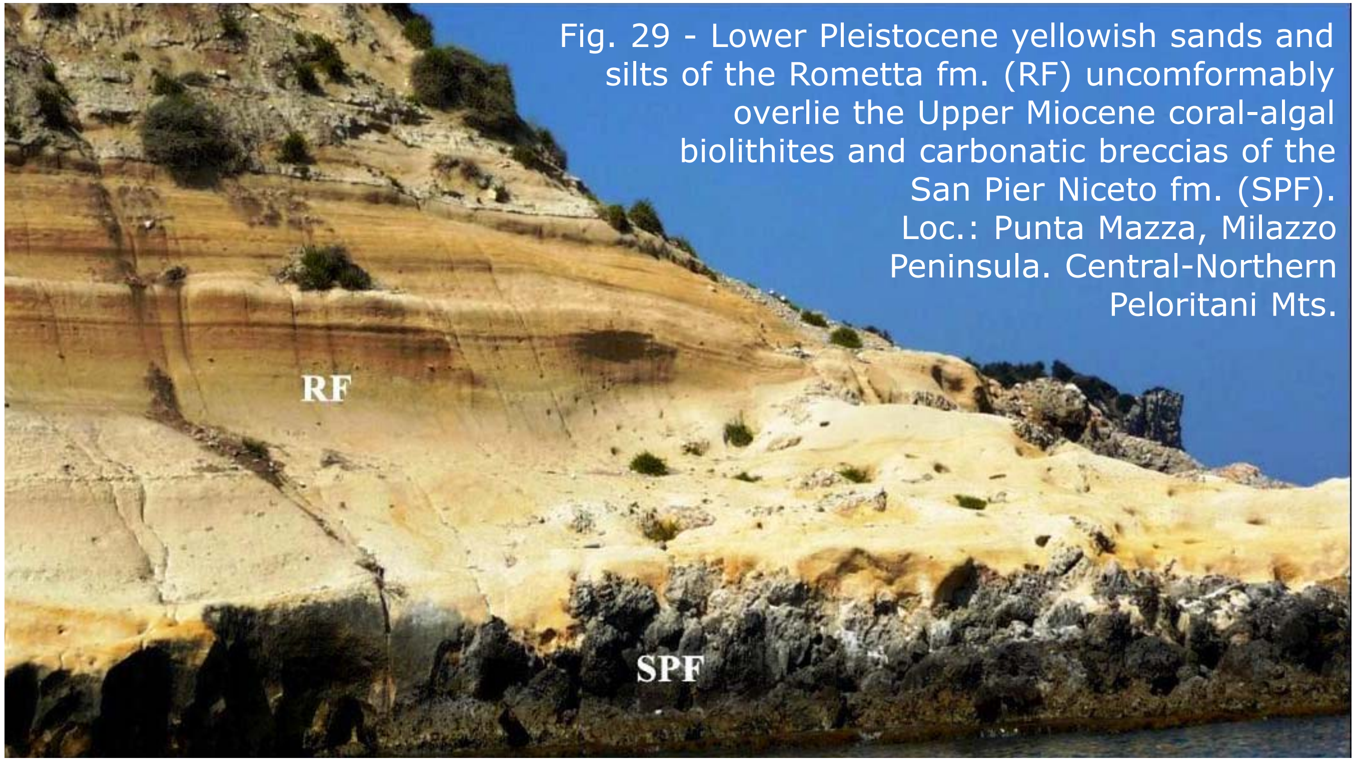

Fig. 29 - Lower Pleistocene yellowish sands and silts of the Rometta fm. (RF) uncomformably overlie the Upper Miocene coral-algal biolithites and carbonatic breccias of the San Pier Niceto fm. (SPF). Loc.: Punta Mazza, Milazzo Peninsula. Central-Northern Peloritani Mts.

The ***Lower Pliocene sediments*** are composed of *white marls* (*Trubi*), deposited during the rising of the sea-level, following the Messinian salinity crisis.
The ***Plio-Pleistocene deposits*** (Fig. 29) consist of *shallow-water calcarenites*, *sands* and *clays,* and form distinct cycles, unconformably covering the substratum and filling depocentres which originated during the Messinian.

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In chronological order, the following formations are recognized:
- *sandy marls* and *sands* (Massa Santa Lucia fm. - middle Pliocene);
- *biodetrital calcarenites*, *fossiliferous sands* (Rometta fm.), *clays* and *sandy clays* (Spadafora fm.), *organogenous calcarenites* with thin clayey levels and coral limestones (San Corrado calcarenites) (Upper Pliocene-middle Pleistocene).

2.8 Middle Pleistocene-Holocene deposits

The ***middle Pleistocene-Holocene succession*** (Fig. 30) consists of marine terraced deposits and active strandlines (beaches).
Transitional to continental deposits represented by *conglomerates*, *sands* and *gravels* (Ghiaie e sabbie di Messina fm., middle-upper Pleistocene); *inactive alluvial terraced deposits*, undergoing pedogenesis or terracing developed during different pulses of the glacial-eustatic activity; *alluvial and littoral deposits* constitute the wide Milazzo-Barcellona P.G. Plain; *active alluvial deposits* grade laterally into slope detritus and alluvial fan deposits; *eluvium* and *colluvium*; *gravity deposits* and some large and active mass-movements; and *slope debris*.

Fig. 30 - Panoramic view of Holocene marine terraces (AS), lower Pleistocene yellowish sands and silts of the Rometta fm. (RF) and upper Miocene coral-algal biolithites and carbonatic breccias of the San Pier Niceto fm. (SPF). The latter uncomformably covers the Variscan migmatites of the Aspromonte unit (AsU). Loc.: Punta Mazza, Milazzo Peninsula. Central-Northern Peloritani Mts.

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Itinerary

First Day

Itinerary 1: Milazzo Peninsula – Colle Makkarruna - Pizzo Rosarello – Pizzo Croce - Torrente Cerasiera – Torrente Mela – Santa Lucia del Mela

Themes: Geology and petrology of the Aspromonte, Mela and Piraino units (Southern sector of the Calabria-Peloritani Chain). Discordant Oligo-Miocene to Miocene sedimentary covers and overthrust of the Cretaceous Antisicilide unit.

Stop 1.1. Punta Tono – North-West Milazzo Peninsula.

The Milazzo Peninsula. Aspromonte unit Proterozoic and Paleozoic high-medium grade polymetamorphic basement: Variscan anatectic phenomena in gneisses and metahornblendites (migmatitic zone) after Pan-African granulites.

Geological Map: Milazzo (Sheet 587) – Barcellona Pozzo di Gotto (Sheet 600), 1:50.000 scale - CARG Project.

Milazzo Peninsula

Situated in the Central-Northern Peloritani Mts., the Milazzo Peninsula extends out into the Tyrrhenian Sea with S-N direction, for approximately 7.5 km and reaches 135 m of elevation (Mt. Trinità). It is characterized by the presence of the homonymous city which expands from the isthmus between the peninsula and the Barcellona Pozzo di Gotto alluvial plain to the Milazzo Cape.

This area is known for two contrasting characters: its spectacular and scenic geomorphological landscape and its severe hydrocarbon and electromagnetic pollution.

The peninsula is bounded by steep coast-line that is in contrast with the gentle, sometimes flattened morphology of the rest of the peninsula. The Southern area is densely populated and contains a port (Fig. 1.1a); the South-West coast shows a large beach (Figs. 1.1b and c). The cape promontory shows an articulated shape (Fig. 1.1d).

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Fig. 1.1a - The South-Eastern area of Milazzo Peninsula, densely populated and containing the port. Loc.: Central-Northern Peloritani Mts.

Fig. 1.1b - The South-West coast of Milazzo Peninsula showing a large beach. Loc.: Central-Northern Peloritani Mts.

Fig. 1.1c - Panoramic view at sunset of the South-West side of Milazzo Peninsula with the *Norman Castle* (Castrum) built a top of Mt. Trinità. (135 m a.s.l.). Loc.: Central-Northern Peloritani Mts.

Fig. 1.1d - The Milazzo Cape with the large *marine terrace* (70 m a.s.l.) situated on fossiliferous carbonate deposits (Upper Pliocene-Middle Pleistocene) covering the Aspromonte unit Variscan medium-high-grade metamorphics and dipping towards Punta Messinese. Loc.: Milazzo Peninsula. Central-Northern Peloritani Mts.

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The peninsula is characterized by the presence of scenic and actively eroding sub-vertical cliffs and the top of the promontory exhibits two orders of marine terraces and narrow sandy shores. Its northern extremity, the Milazzo Cape, consists of a large marine terrace (70 m a.s.l.) sited on fossiliferous carbonate deposits (Upper Pliocene-Middle Pleistocene) covering the Variscan high-medium grade metamorphics of the Aspromonte unit, dipping towards Punta Messinese (Fig. 1.1d) in the North-West and Punta Mazza (Fig. 1.1e) in the North-East.

The Milazzo Peninsula is made up of the Aspromonte unit Variscan migmatitic basement, intruded by Late-Variscan peraluminous plutonic small bodies and dykes and covered by Late Miocene and Quaternary deposits.

Fig. 1.1e - *Punta Mazza*, on North-Eastern side of Milazzo Cape: **A** - medium to high grade metamorphics of the Aspromonte unit, **B** - Upper Miocene biolithitic facies and carbonate breccias; **C** - Pleistocene marly sands; **D** - marine terrace. Loc.: Milazzo Peninsula. Central-Northern Peloritani Mts.

The Late Miocene deposits consist of grey-whitish limestones containing corals, algae and mollusks, lying unconformably on the metamorphic basement. Often this level is represented by a breccia characterized by large calcareous elements and sandwiched between the basement and the Quaternary deposit.
Yellowish calcareous sands, attributed to the Early Quaternary, rest unconformably on both metamorphics and Late Miocene bioherms.
The highest order of marine terraces is represented by a gentle surface dipping northwards from 85 to 50 m a.s.l., consisting of shallow water sands and conglomerates (Tonnara to Cala Sant'Antonio; Punta Salto del Cavallo to Punta Cirucco zones). These deposits allowed Charles Depéret to introduce in 1918 the *Piano Milazziano*, successively ascribed, by Hearty et al. (1986), to the Tyrrhenian.
A second order of marine terraces is located between 45 and 28 m a.s.l.

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The area is affected by a post-Pleistocene uplift. Originally it was a small island.
On the Milazzo Peninsula, surf karren (Punta Gamba di Donna) and hypogean structures set in the migmatites ("Golden Cave" and "Punta Grottazza Cave") are also present.

The city derived from the expansion of ancient settlements, unified in the course of centuries. It involves three areas: the High City, or the historic center with the Medieval Hamlet, the castle and the most important monuments; the Low City, or the present urban center, which extends from the port area to the archaeological ruins of the Greek *Mylai* (716 B.C.); the City of the plain, which is the recently built-up area with several farming quarters.
Due its strategic and scenic geographic position between the Messina Straits and the Aeolian Islands, Milazzo was a center of important civilizations and theater of famous historic events, from the Caio Duilio (260 B.C.) to the Corriolo Battles (1860). The latter was the most important battle of the Garibaldi Army, and occurred during the unification of Italy (1860).
Several examples of Bronze, Iron, Greek and Roman Age settlement are still preserved both in the historic centre of the High City, and in the surrounding areas. Under the Arab domination, the city was fortified with a very important castle (the Castrum, Fig. 1.2) and reinforced its commercial and farm economy. During the Norman, Suevian and Aragonese periods, the castle was enlarged and in the Aragonese and

Fig. 1.2 - Panoramic view looking North-West of the *Castrum* of Milazzo defense system, sited on the Variscan migmatitic basement of the Aspromonte unit, which constitutes the Mt. Trinità (135 m a.s.l.). Loc.: Milazzo Peninsula. Central-Northern Peloritani Mts.

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Spanish periods surrounded by two different walls, transforming this architectural complex into a fortified citadel. Other significant architectural structures in Renaissance to Baroque Styles characterize Milazzo City. The fortified citadel is composed of the Mastio Federiciano (XI and XII centuries), Giurati Palace (XII c.), Benedictine Monastery (XV c.) and Aragonese (XV c.) and Spanish (XVI c.) walls.
The most important monuments are: the Castle, the Cathedral (1608), the Shrine of San Francesco di Paola (1482-1626), the Cave Shrine of Sant'Antonio da Padova (1221), the Church of Madonna del Rosario (XVI-XVII c.), the Convent of the Dominicans (XVIII c.), the churches of San Giacomo (XV c.), Santa Maria Maggiore (XVII c.) and Carmine (XVII c.) and the Archaeological Antiquarian Museum.

Aspromonte unit Variscan migmatites
The Aspromonte unit (AsU) is interpreted as a reversed Variscan mid-lower continental crustal segment, made up of metamorphic and intrusive rocks, preserving evidence of a Proterozoic evolution including granulite metaultramafics, and affected by a localized Alpine low- to medium-grade metamorphic overprint. The Variscan evolution of the basement was responsible for a retrograde Bosost-type LT granulite to LT amphibolite facies metamorphic zoning.

Variscan migmatitic rocks characterize the zone typify the Scilla-Bagnara (South-West Calabria)–Rasocolmo Cape–Milazzo Peninsula-d'Orlando Cape (Northern Peloritani Mts.) belt of the Aspromonte unit basement.
Previous investigations have been undertaken in some remobilized rock sites (Ferla & Negretti, 1969; D'Amico et al., 1972; Atzori et al., 1975; Messina & Ioppolo, 1982).

Current research on the Punta del Tono migmatites of the Milazzo Peninsula (Stop 1) provides an integrated petrological and geochronological study (Macaione et al., 2012a), the first results of which are reported here. Kilometers of Variscan mobilized gneissic bodies, which include amphibolite (s.l.) lenses up to several meters thick, crop out in this area. Both types of rocks show ***flebitic to stromatitic structures*** (Figs. 1.3a and b), developing along the Variscan Fv_{1m} main foliation (or Fv_n=last pervasive foliation) and are locally crenulated. The migmatites are affected by centimeter- to meter-thick Alpine shear planes and by E-W Plio-Pleistocene fault systems (Fig. 1.3c), both of which are responsible for cataclastic effects (the former also for retrogressive processes). Micrite and sparite calcite systems fill the multiple fractures (Fig. 1.3d) some of which also include Pliocene fossils. Breccias of migmatites are also present (Fig. 1.3e).

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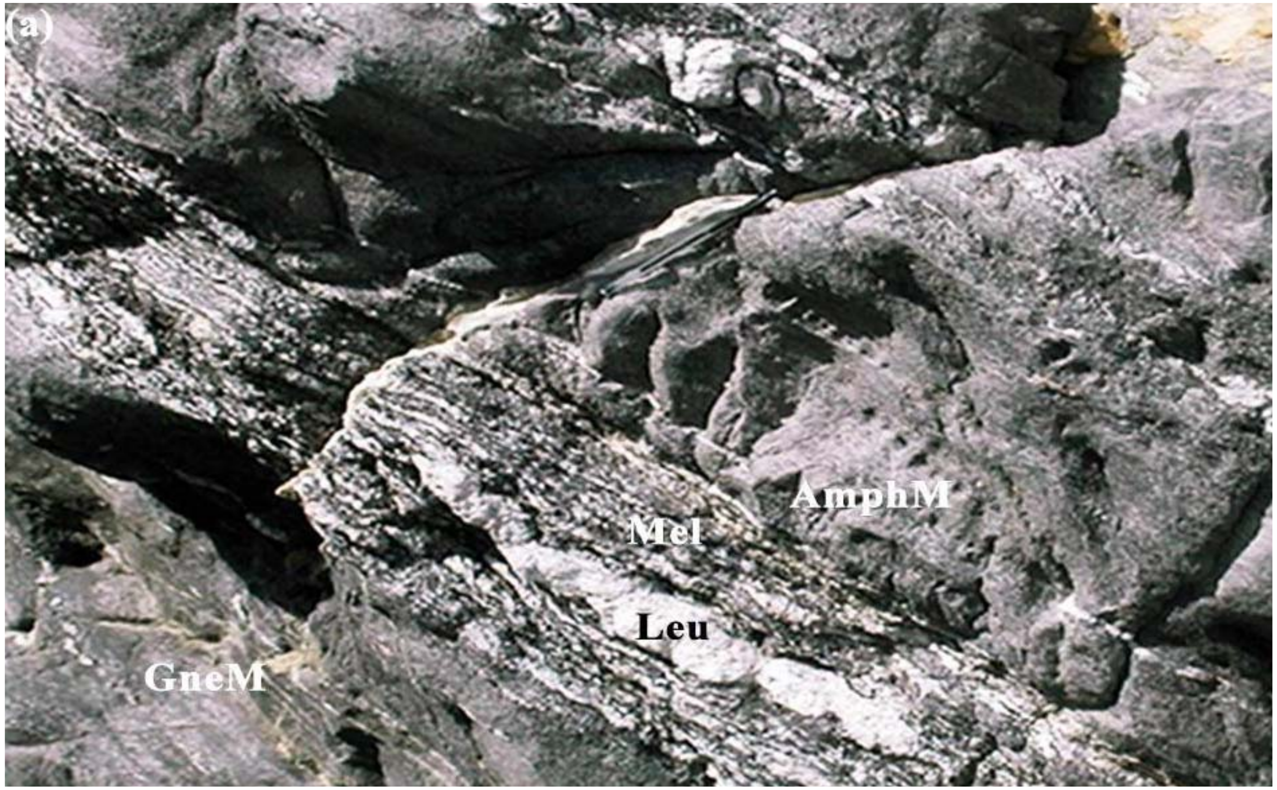
Fig. 1.3a - Aspromonte unit Variscan *metatexites* (after Pan-African HT granulites) showing stromatitic structures: Gneissic (GneM) and amphibolitic (AmphM) mesosomes; quartz+ feldspars±muscovite leucosomes (Leu) and biotite melanosomes (Mel). Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.



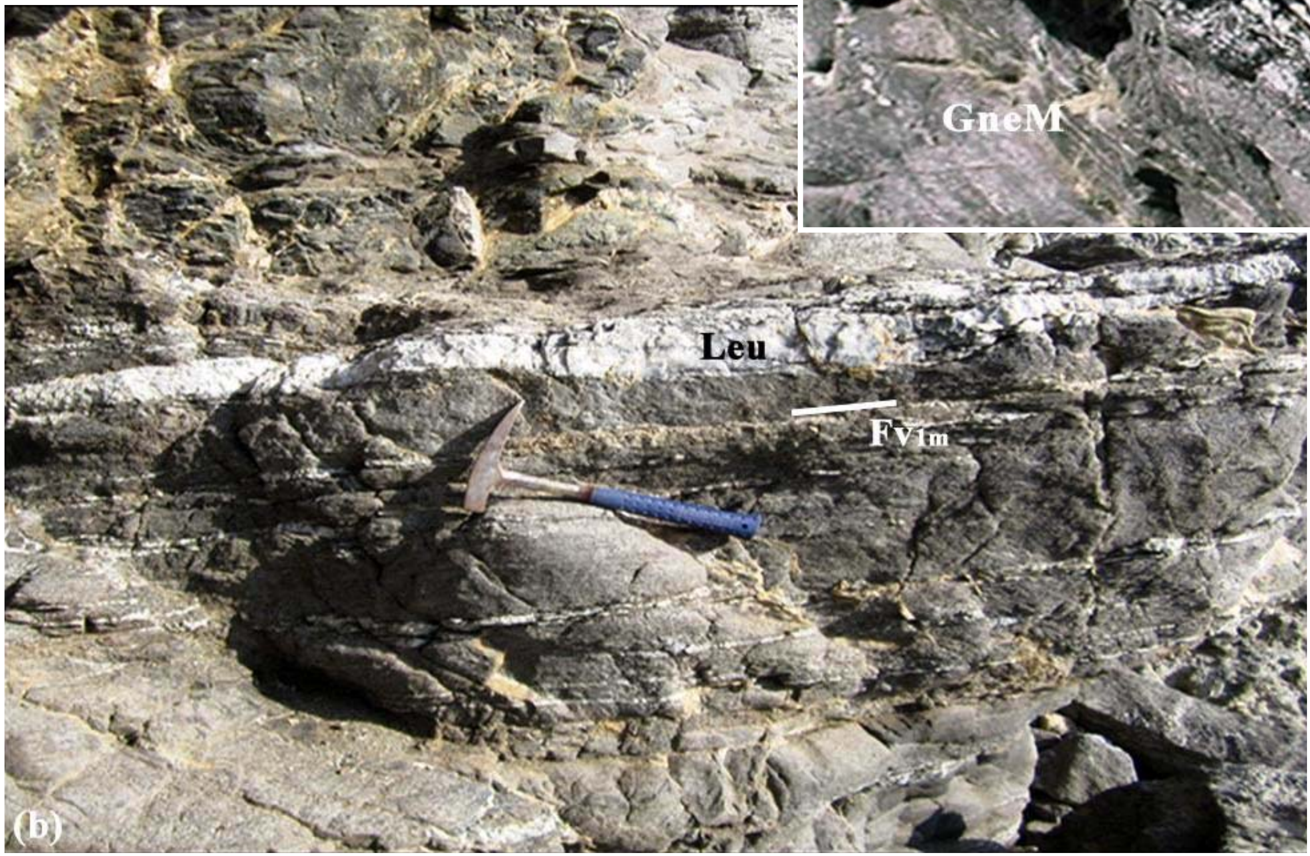


Fig. 1.3b - Aspromonte unit Variscan metatexites (after Pan-African HT granulites): millimeters to tens of centimeters in thickness *quartz+feldspars±muscovite* leucosomes (Leu) oriented along the Fv_{1m} main foliation. Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.

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Fig. 1.3c - Aspromonte unit Variscan metatexites (after Pan-African HT granulites): *gneisses and amphibolites* (s.l.) in migmatitic facies affected by an E-W reverse fault responsible for cataclasis. Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.

Figs. 1.3d and e - Aspromonte unit Variscan metatexites (after Pan-African HT granulites): *multiple fractures filled by calcite* **(d)**; *breccias* of plurimeter-thick migmatitic blocks **(e)**. Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.

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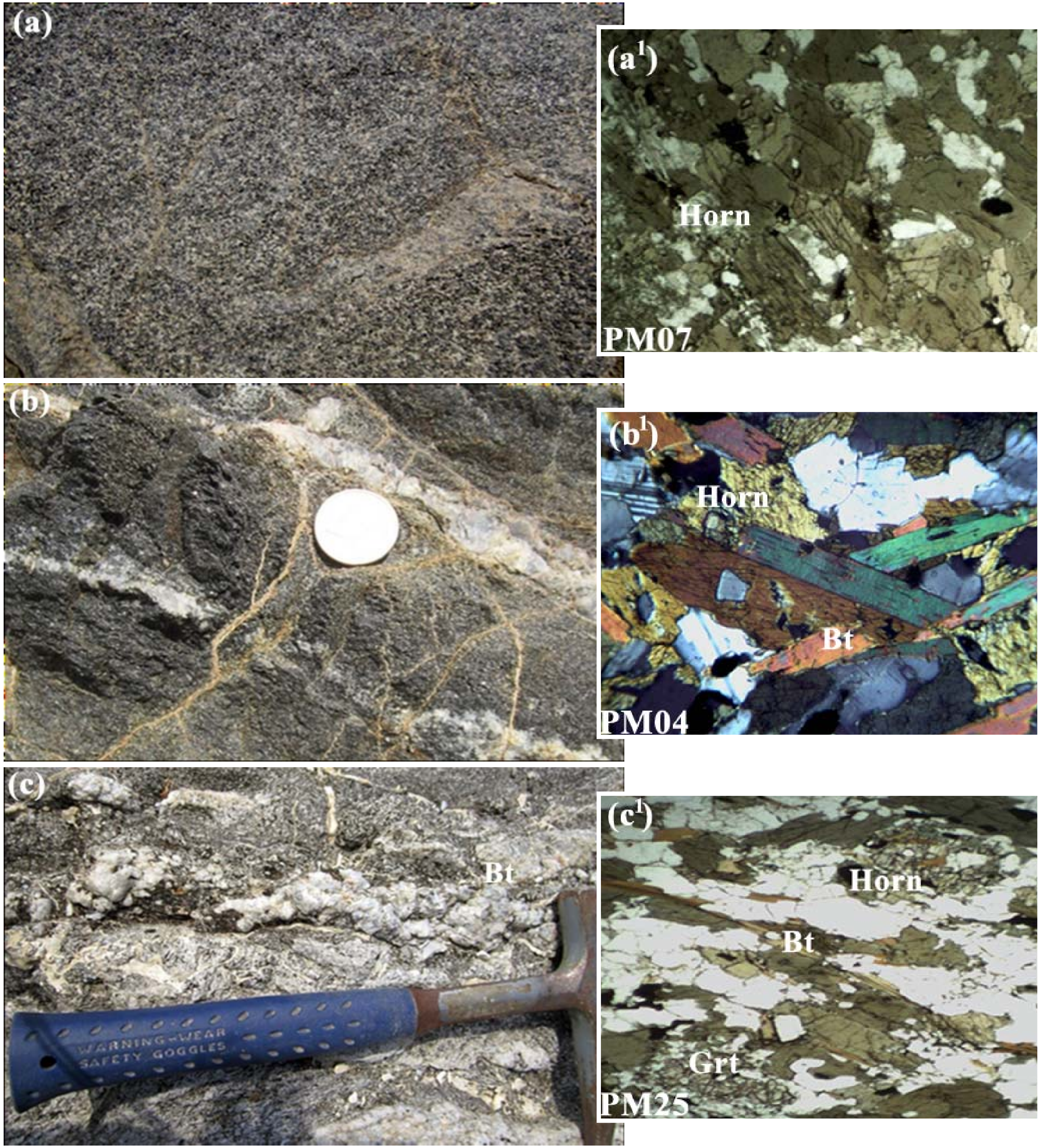

Meso- and microstructures indicate that preserved *massive metahornblendites* (or hornblende rich amphibolites – Horn 80-90% - Fig. 1.4a) and *poorly oriented equigranular medium-fine grained biotite gneisses* (Fig. 1.5a) are *mesosomes* of all mobilized lithotypes described below.

Figs. 1.4a to c - Aspromonte unit: representative mineralogical and textural variation in Variscan migmatites (after Pan-African HT mafic granulites). Mesostructures: massive *meta-hornblendites* (80-90% of hornblende - mesosome) (a); poorly-banded biotite±garnet *amphibolites* (b); banded biotite±garnet *gneissic amphibolites* **(c)**. Same scale in **(a)** and **(b)**. Photomicrographs: granoblastic/polygonal hornblende(Horn)+bitownite/labradorite+ quartz metahornblendite **(a1)**; lepido-/diablastic and granoblastic/polygonal hornblende(Horn)+biotite(Bt)+anorthite/ oligoclase+quartz amphibolite **(b1)**; granoblastic and lepido-/diablastic labradorite/andesine+biotite(Bt)+ hornblende(Horn)+almandine(Grt) gneissic amphibolite. Samples: PM07, PPL **(a1)**; PM04, CP **(b1)**; PM25, PPL **(c1)**. 45x. Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.

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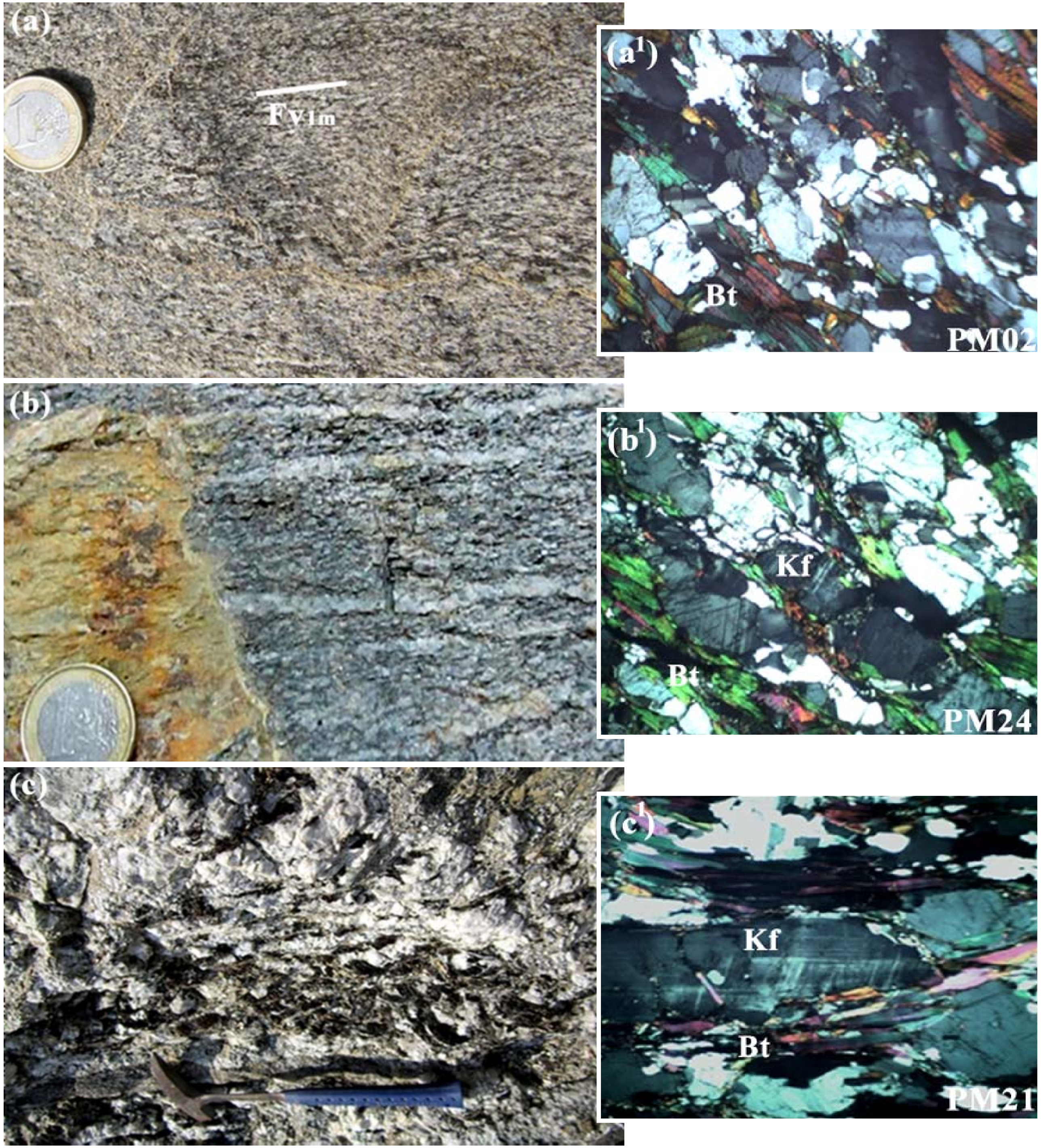

In the ***gneissic rocks,*** the differing intensity of mobilization is indicated by layers of *quartz+plagioclase±K-feldspar±muscovite leucosomes*, sub-millimeter to many tens of centimeters in thickness, which extend parallel to the main foliation and are rimmed by *biotite melanosomes*.
The varyingly mobilized rocks, which are also irregularly distributed, differ in grain-size, structure and composition.

Figs. 1.5a to c - Aspromonte unit: representative mineralogical and textural variation in Variscan migmatites (after Pan-African HT acidic granulites).
Mesostructures: *poorly-oriented biotite gneisses* (mesosome) **(a)**; *poorly-banded biotite±garnet gneisses* **(b)**; *banded biotite±garnet±K-feldspar± muscovite gneisses* **(c)**.
Photomicrographs: grano/xenoblastic quartz+andesine/oligoclase+biotite(Bt) gneiss **(a1)**; granoblastic and lepido-/diablastic quartz+andesine/oligoclase+ K-feldspar(Kf)+biotite gneiss **(b1)**; grano-/lepidoblastic quartz+oligoclase+K-feldspar(Kf)+biotite(Bt)+garnet gneiss **(c1)**. Samples: PM02 (a1); PM24 (b1); PM21 **(c1)**. CP, 45x. Loc.: Punta del Tono, North-West of Milazzo Peninsula. Central-Northern Peloritani Mts.

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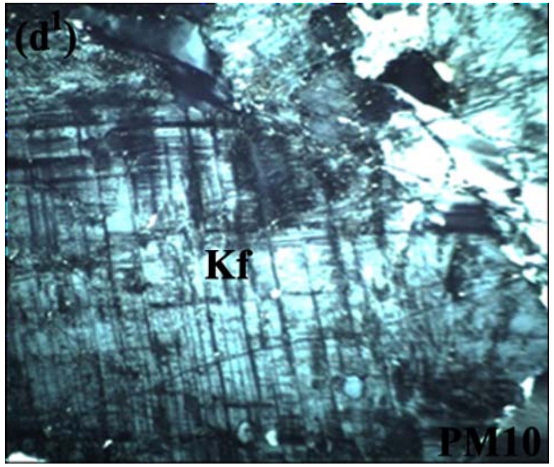
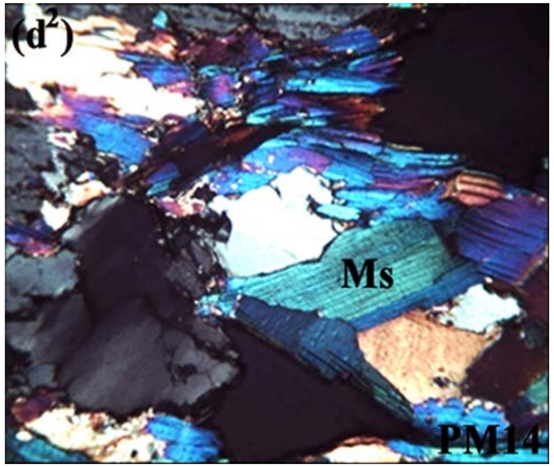
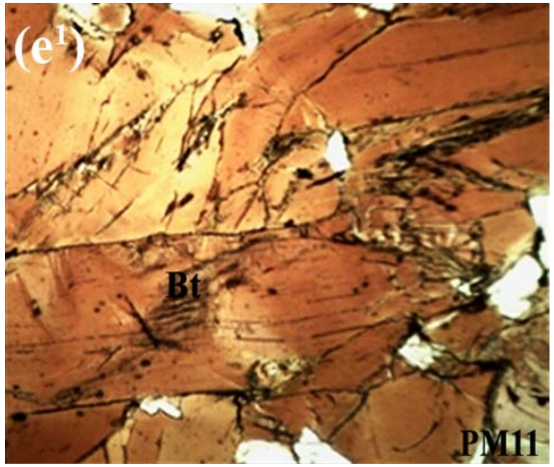
They range:

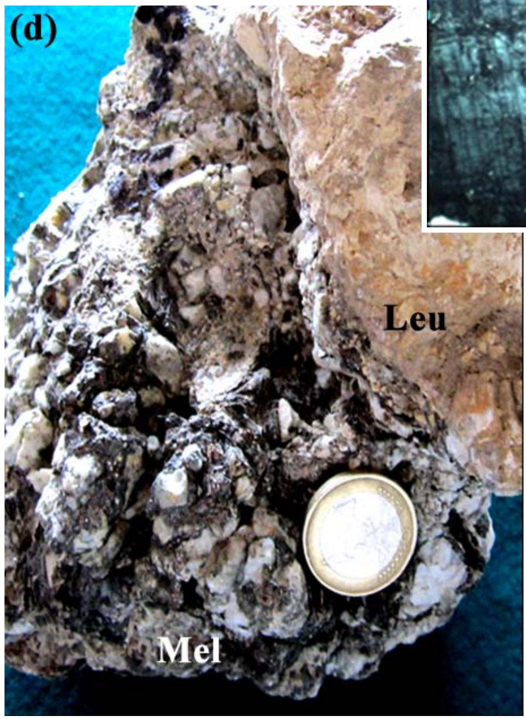
- in the metamafics (s.l.), from *massive metahornblendites* (Fig. 1.4a) to *less-banded biotite±garnet amphibolites* (Fig. 1.4b), to *banded biotite±garnet gneissic amphibolites* (Fig. 1.4c);
- in the gneisses, from the *less-oriented biotite gneisses* (Fig. 1.5a) to *less-banded biotite±garnet gneisses* (Fig.1.5b), to *banded biotite±garnet±K-feldpar±muscovite gneisses* (Fig.1.5c), up to *trondhjemitic and leucogranodioritic quartz+plagioclase±K-feldspar±muscovite leucosomes* (Fig. 1.5d) and *biotite melanosomes* (Fig. 1.5e);
- rare centimeter-thick *garnet-biotite-sillimanite-plagioclase glomerocrysts* are considered *restites*.

Mineral chemistry analyses indicate the following compositions.









Figs. 1.5d and e – Aspromonte unit: Variscan metatexites. Mesostructures: trondhjemitic and leucogranodioritic *quartz+plagioclase+K-feldspar+muscovite leucosomes* **(d)** and cumulate *biotite melanosomes* **(e)**. Microphotographes: granoblastic/polygonal quartz+oligoclase+K-feldspar **(d1)**; lepidoblastic/diablastic quartz+oligoclase/albite+muscovite **(d2)** leucosomes; lepidoblastic/diablastic biotite+quartz melanosome **(e1)**. Samples: PM10, CP, 60x **(d1)**; PM14, CP, 45x **(d2)**; PM11, PPL, 45x **(e1)**. Loc.: Punta del Tono, North-West Milazzo Peninsula. Central-Northern Peloritani Mts.

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In the ***metahornblendites***, ***amphibolites*** and ***gneissic amphibolites***:
- *amphibole* changes from *tschermakitic*-(XMg=0.51) and *Mg-hornblende*(XMg=0.50-0.58), to *Fe-tschermakitic*-(XMg=0.41-0.42) and *Fe-hornblende*(XMg=0.43-0.45), to *Fe-pargasitic hornblende*(XMg=0.41), respectively;
- *plagioclase* varies from An_{81-54} in the metahornblendites, to An_{91-25} in the amphibolites, up to An_{62-37} in the gneissic amphibolites. Each mafic rock type exhibits both Pre-Variscan granulite facies relict compositions and Variscan amphibolite facies re-equilibrated compositions.
- *garnet* is Ca-almandine (X_{Alm}=66-59, X_{Grs}=27-18) in the gneissic amphibolites;
- *biotite* has annitic compositions [XFe=0.46-0.49 and 0.49-0.52] in the amphibolite and gneissic amphibolites, respectively.

In the ***less-oriented***, ***less-banded*** and ***banded gneisses***:
- *plagioclase* varies from An_{33-29}, to An_{31-27}, to An_{28-26}, respectively;
- *biotite* shows annitic compositions [XFe = 0.53-0.50, 0.49-0.48 and 0.49-0.43, respectively];
- *garnet* is Mn-rich almandine (X_{Alm}=64-57, X_{Sps}=31-22) in the less banded and banded gneisses, respectively;
- *muscovite*, where is present, is very close to the pure end member with Si=3.00-3.09 (a.p.f.u.).

In the ***leucosomes***:
- *plagioclase* shows values of An_{32} indicating relict andesine, and a range of An_{26} to An_{6} of Variscan oligoclase-albite compositions;
- *K-feldspar* is orthoclase (Ab_{5-7}, Or_{93-95});
- *muscovite* shows composition very close to the pure end member with Si=2.98-3.08 (a.p.f.u.).

In the ***melanosomes***:
- *biotite* shows annitic [XFe=0.53-0.46] composition.

Analyses of major, trace and rare earth elements from representative *gneissic and amphibolitic mesosomes*, *mobilized rocks, leucosomes* and *melanosomes,* are in progress (Geological Survey of Reston VA Laboratory - USA).
In the Scilla migmatites, the hornblende-rich amphibolites show MORB character (Messina & Ioppolo, 1982).
The AsU Variscan metatectic phenomena have not been dated by the time of the publication of this guide. Attempts are in progress to define the age of this particular zone which is marked by mesosome and neososome features, and also to confirm or modify the complex evolution reconstructed by the authors through U/Pb monazite and zircon dating from the recognized rocks. In this context it is important to add that the first results on the gneissic rocks and related mobilized types indicate ***magmatic zircon cores*** that suggest a plutonic genesis for their protoliths.

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The defined geological, structural and compositional dates, included in the context of the AsU evolutional history, indicate that the AsU migmatitic rocks were affected by up to four Variscan progressive and continuous stages (steps):
- the first, which occurred during the start of the Variscan Dv_1 (or Dv_n) deformation, was responsible for a retrograde re-equilibration of *Neo-Proterozoic ultramafic and acidic granulite paleosome* into *amphibolite facies Variscan metahornblenditic* (probably partly re-equilibrated) and *gneissic mesosome*;
- the second stage developed contemporaneously with Dv_1, creating the *leucosomatic and melanosomatic veins*, parallel to the Fv_1 main foliation (or up to the late-Dv_1, on the basis of the development of some granoblastic-polygonal/diablastic textures). The time-span of anatexis corresponds to the thermal peak of metamorphism identified in this layer of the Variscan AsU mid-lower crustal segment;
- the third stage, correlated to the post-Dv_1 deformation phase, was responsible for the *start of cooling and exhumation* of the AsU, recorded in the rocks by the crystallization of late muscovite and low An-content plagioclase, which reaches albitic compositions in the leucosomes;
- the fourth stage, resulting from the Dv_2 (or Dv_{n+1}) compression, was the origin of the *crenulation* and *boudinage of veins*.

Stop 1.2. Colle Makkarruna (370 m a.s.l.), Santa Lucia del Mela Castle.

Overview of the geometry of the Central Peloritani Chain. Relationships between the Oligo-Miocene (Capo d'Orlando flysch) and Miocene (San Pier Niceto formation. and evaporites) deposits. Overthrusts of the Cretaceous varicoloured clays (Antisicilide unit) of the Peloritani Mts. Relationships between basement rocks of the Aspromonte unit (Variscan augen gneisses) and that of the underlying Mela unit (Variscan marbles).
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

The Stop 1.2 is located on the Tyrrhenian side of the Peloritani ridge. From the Colle Makkarruna, beautiful geological landscapes can be observed.
To the North, the ***Milazzo-Barcellona Plain*** broadly extends, limited only by the spectacular Tyrrhenian coast.
Looking to the West, the ***tectono-stratigraphic succession exposed along the Mela Valley*** is made up of (from bottom of the sequence and going to the North): metamorphic rocks of the Mela unit, Capo d'Orlando flysch, Antisicilide unit and San Pier Niceto fm. (Fig. 1.6a).

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The Mela unit is characterized by a quarried large marble body (Fig. 1.6a). The Oligo-Miocene Capo d'Orlando flysch lies unconformably at the top (Pizzo Lando, 619 m a.s.l). This flysch is dipping toward the north below the Antisicilide unit, which is characterized by a gentle morphology. Conglomerates and sands of the Middle-Upper Miocene San Pier Niceto fm. rest unconformably on top the nappe (Fig. 1.6a).

Fig. 1.6a - Panoramic view westwards from the Colle Makkarruna (Santa Lucia del Mela Castle): the *Mela unit* (**A)** with quarried Variscan marbles (**A_1**). From the top of Pizzo Lando downwards the Upper Oligocene-Lower Burdigalian *Capo d'Orlando flysch* (**B**) crops out. The flysch is dipping toward North and underthrusting the Cretaceous *varicoloured clays of the Antisicilide unit* (**C**). The sandy and conglomerate deposits of the Middle-Upper Miocene *San Pier Niceto* fm. (**D**) unconformably rests on the Antisicilide unit. In the picture an overthrust (**t**) and a stratigraphic boundary (**s**) are also delineated. Loc.: left slope of the T.te Mela. Central-Northern Peloritani Mts.

Looking to the East, ***on the right side of the Floripotema-Serrapotamo confluence***, the Capo d'Orlando flysch, which rests on the Mela unit, is dipping with the help of faults below the Antisicilide unit, which is characterized by yellowish quartzarenite blocks located inside the clayey terranes. Sandstones and clays of the San Pier Niceto fm. are widely exposed (Fig. 1.6b).
In the background, some flat surfaces which can be observed correspond to marine terraces.

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Fig. 1.6b - Panoramic view toward North-East from the Colle Makkarruna (Santa Lucia del Mela Castle): from the right to the left we can observe the Mela unit (**A**) cropping out in the left side of T.te Floripotema; the hills on the opposite side of the valley are made up of the Upper Oligocene-Lower Burdigalian Capo d'Orlando flysch (**B**), which underthrust the Cretaceous varicoloured clays of the Antisicilide unit (**C**); the Middle-Upper Miocene San Pier Niceto fm. (**D**) lies in uncomformity over the Antisicilide unit. In the picture an overthrust (**t**) and a stratigraphic boundary (**s**) are also delineated. Loc.: T.te Floripotema. Central-Northern Peloritani Mts.

Stop 1.3. Colle Makkarruna - Contrada Filicusi (370 m a.s.l.), Santa Lucia del Mela-Mandanici Road.

Aspromonte unit Proterozoic and Paleozoic high-medium grade polymetamorphic basement: Variscan augen gneisses, after Late Pan-African orogenic plutonics.

Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

In the area of this geotour, the ***Aspromonte unit Variscan augen gneisses*** (after Late Pan-African plutonics) crop out as bodies up to a kilometers extension, reaching up to 500 m in thicknesse in the Pizzo Polo peak (1,287 m a.s.l.) of the Montagna di Vernà, South of Fondachelli village and in the Mazzarrà – Tripi area (Fig. 1.7a). At the meso- (Fig. 1.7b) and microscale (Fig. 1.7c) the augen gneisses are grey in colour, and exhibit an inequigranular coarse-grained and oriented texture along the Variscan Fv_{1m} main foliation.

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These metaplutonics exhibit porphyroclastic texture characterized by magmatic K-feldspar relics (up to 6 cm across) including reabsorbed zoned plagioclase and biotite, surrounded by a Variscan medium-grained matrix of biotite, quartz, oligoclase, new K-feldspar and rarely also sillimanite. The augen gneisses, which range from leucotonalites to leucogranites in composition, contain concordant leuco-orthogneisses (Late Pan-African aplitic and pegmatitic dykes) and polymetamorphic schlieren (Pan-African metaultramafics re-equilibrated in the Variscan) and to a lesser extent ultramafic meta-dykes. Augen gneisses are associated with small bodies of Variscan biotite±muscovite metagranodiorites to metamonzogranites and also cut by many systems of Late Variscan aplo-pegmatitic dykes. Augen gneisses show mobilization phenomena along the Scilla-Bagnara (Calabria) – Capo d’Orlando (Sicily) migmatitic belt, with the formation of both coarse-grained quartz+oligoclase+K-feldspar leucosomes and biotite melanosomes.

Figs. 1.7a to c - Aspromonte unit: *Variscan augen gneisses* (after Late Pan-African plutonics) bodies up to a kilometer in extension **(a)**. Mesostructure: Fv_{1m} main foliation, defined by biotite+quartz+plagioclase which surrounds the centimeter-sized magmatic K-feldspar porphyroclasts **(b)**. Microphotograph: detail of the large magmatic poikiloclastic K-feldspar (microcline) including reabsorbed plagioclase and quartz **(c)**. Sample MZ4. CP, 60x. Loc.: left slope of the T.te Mazzarrà. Central Peloritani Mts.

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The augen gneisses commonly show evidence of Alpine deformation with varying intensity, responsible for cataclastic effects, with the widespread retrocession of biotite in chlorite (in the grey-green augen gneisses of the right slope of the T.te Pietralonga and T.te San Nicola, South-West of Pizzo di Sughero), to mylonisis with the formation of a mylonitic Fa_{my} foliation (in the left slope of T.te Patrì), up to a metamorphic overprint (with differing intensities of re-equilibration up to a pervasive Alpine recrystallization) originating white-silver phengite+almandine leuco-orthogneisses, oriented along the Alpine Fa_{2m} foliation (in the T.te Mandri and T.te Mazzarrà); and rarely also contain pink porphyroclastic K-feldspar.

In the ***Colle Makkarruna -*** *Contrada Filicusi area, South of Santa Lucia del Mela* (Stop 1.3), the overthrusting contact between the overlying Aspromonte unit Variscan augen gneisses, intruded by Late Variscan pegmatites, and the underlying Mela unit Variscan marbles developed a large cataclastic contact band (Figs. 1.8a and b).

The *augen gneisses* and *aplo-pegmatitic dykes* were affected by an Alpine re-equilibration, which was responsible for the transposition of dykes *along* the Alpine Fa_{2m} main foliation. The overprint recrystallized (with a reduction in overall grain size) both rocks, which were converted into two Alpine orthogneisses, different in both colour and grain size (Figs. 1.8a and b).

In the augen gneisses the Fa_{2m} main foliation is defined by *phengit*e(after Variscan biotite)+ *quartz+albite/(oligoclase rim)* and cuts the Variscan *microcline poikil*oclasts (such as the Fa_1), which recrystallized with a sub-granular texture (Fig. 1.8c). The same minerals are also present in the felsic dykes. The overthrusting contact resulted in a ductile deformation accompanied by the fracturing of the Alpine minerals. Late micro-faults accentuated the chaotic texture.

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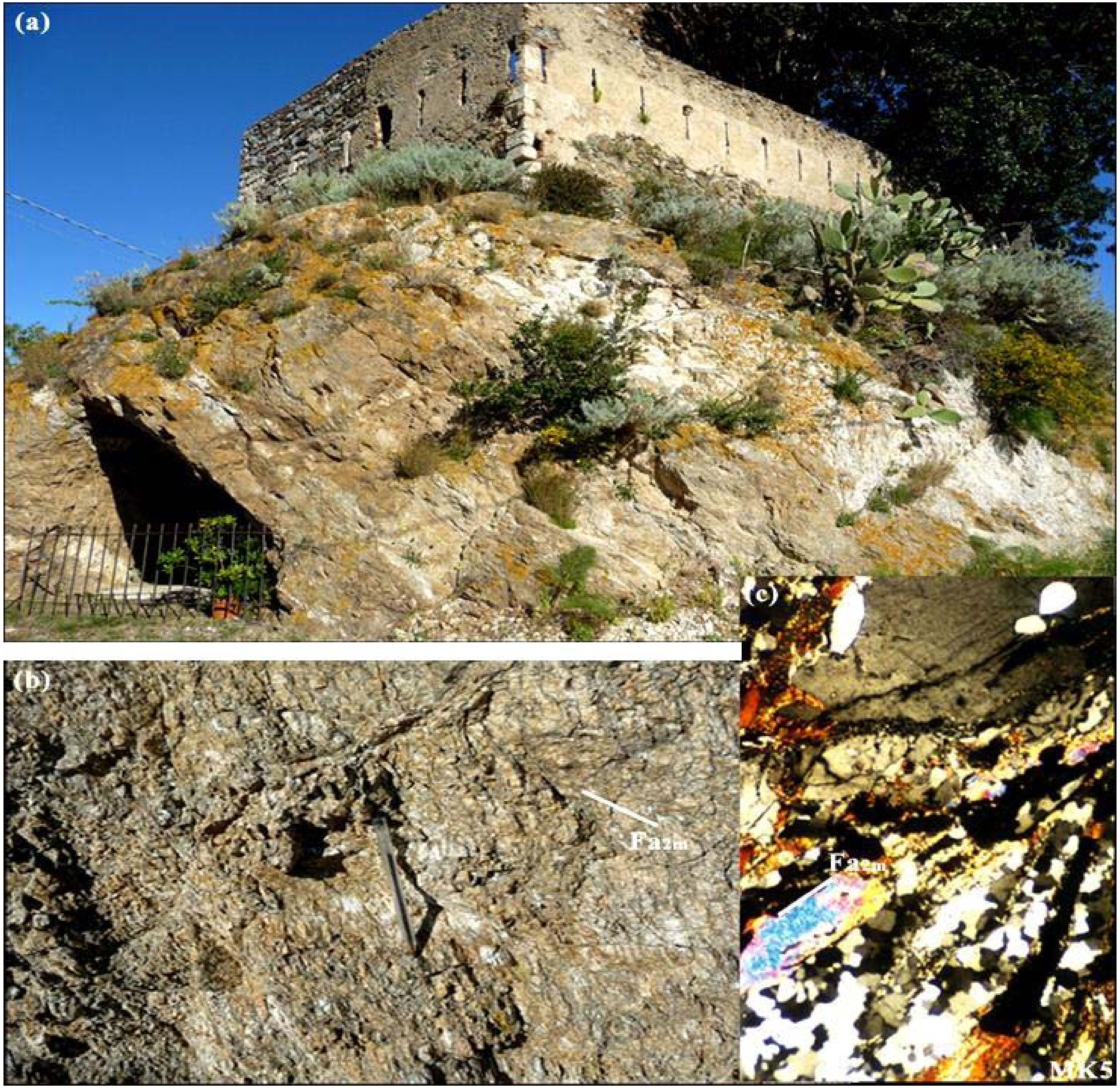

Figs. 1.8a to c - Aspromonte unit: *Alpine leuco-orthogneisses* (after Variscan augen gneisses intruded by Late Variscan pegmatitic dykes) along a ductile cataclastic band, several meters in thickness, formed by the overthrusting contact with the underlying Mela unit (Stop 1.4) marbles (**a**): mesostructure of the Alpine Fa2m main foliation affected by cataclasis (**b**); Photomicrograph showing the Alpine Fa2m main foliation, defined by newly formed phengite(after Variscan biotite) +quartz+albite/(oligoclase rim), cutting the poikiloclastic K-feldspar, which recrystallizes with a sub-granular structure (**c**). Sample MK5. CP, 60x. Loc.: Colle Makkarruna, Santa Lucia del Mela - Mandanici road. Central-Northern Peloritani Mts.

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Stops 1.4a and b. Mt. Melia (686 m a.s.l.), Santa Lucia del Mela - Mandanici Road.

a) Mela unit Paleozoic medium-grade polymetamorphic basement: Variscan muscovite±biotite±garnet marbles. **b)** Fault contact between the overlying Aspromonte unit Variscan augen gneisses (after Late-Pan-African plutonics) and the underlying Mela unit Variscan marbles.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

The Mela unit is capped by *two mica±garnet marbles* (which extend for many kilometers and can be several tens of meters thick) which form a large SE-NW metacarbonate belt in the Central Peloritani Mts., stretching from the Ionian coast to the Tyrrhenian coast. This belt represents the largest Calabria-Peloritani Chain outcrop of marbles.
In the area of the geotour, going towards the West, the MeU Variscan marbles extend from the T.te Floripotema (Fig. 1.9a) – Pizzo Croce to T.te Mazzarrà. In the T.te Mela and T.te Floripotema, the marbles are object of uncontrolled mining and extraction (Fig. 1.6a).
The marbles are commonly isoclinally folded and show a strongly crenulated Variscan Fv_{3m} main foliation (Fig. 1.9b). Prevalently whitish-grey, with a less-banded medium to fine grained texture, they are characterized by the presence of centimeter-thick silicate lenses (*two mica+quartz+plagioclase*) (Fig. 1.9b). Locally (in the right slope of the T.te Cavallo) they are white and show a medium-grained massive texture. At the microscale they show *calcite+quartz±plagioclase±garnet±biotite*, which develop along the Fv_{3m} foliation, pseudomorphs of *epidote* on pre-Variscan plagioclase (Fig. 1.9c), and to a lesser extent *biotite+quartz* on Pre-Variscan garnet, are also present, supporting the Eo-Variscan age.
Marbles contain large horizons and lenses of *relict garnet amphibolitized eclogites* and *quartzite bodies*, up to one hundred meters thick. They were affected by Alpine shear planes responsible for widespread mylonitic to LT recrystallizations. The MeU marbles, such as all the Mela unit lithotypes, are rich in polymetallic deposits.

Along the ***Santa Lucia del Mela -** Mandanici road, about 600 m North to the Mt. Melia (686 m a.s.l.) (Stop 1.4a)* the *MeU Variscan marbles* crop out. In the Northern area they are overlain by the Aspromonte unit augen gneissic bodies (Stop 1.3). In spite of the cataclasis of the contact band, the folding or crenulation of the Fv_{3m} foliation in whitish-grey fine-grained marbles (Fig. 1.10a) are well evident. Going towards the South, marbles locally include small lenses of relic garnet amphibolites and gneissic amphibolites.

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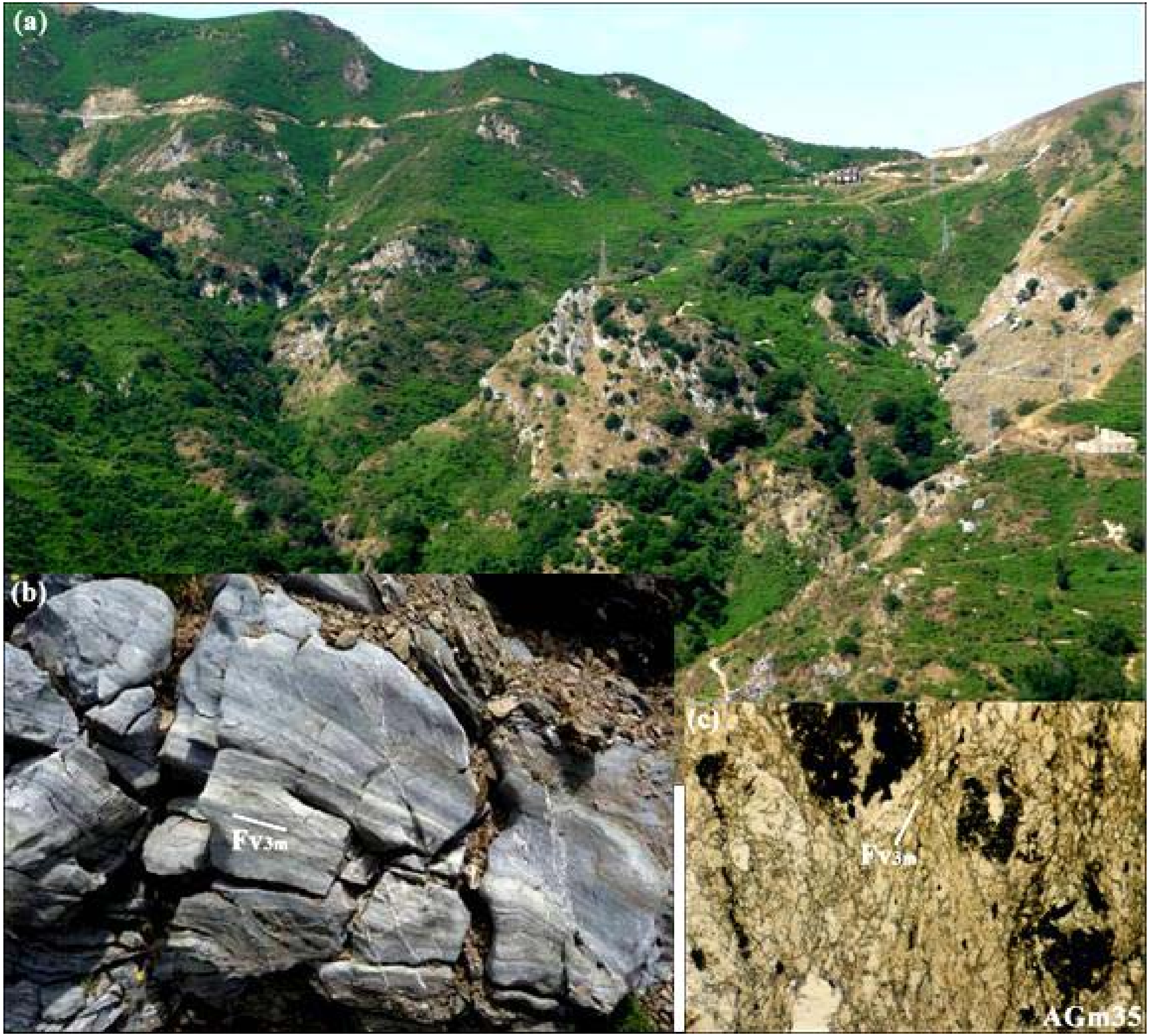

Figs. 1.9a to c - Mela unit: Variscan *muscovite+garnet marbles*. 700 meter-thick muscovite±garnet marbles, which extend for many kilometers **(a)**. Mesostructure: whitish-grey banded MeU marble showing the Fv_{3m} main foliation **(b)**. Photomicrograph: detail of the Fv_{3m} main foliation, defined by calcite+quartz+muscovite, which surrounds pseudomorphs of epidote on pre-Variscan plagioclases **(c)**. Sample AGm35. PPL, 45x. Loc.: left slope of the upper Floripotema Valley. Central-Northern Peloritani Mts. **(a)**; Pizzo Croce-Mandanici road. Central-Northern Peloritani Mts. **(b, c)**.

At ***Mt. Melia (Stop 1.4b)***, ***the fault contact*** between the overlying Aspromonte unit Variscan augen gneisses intruded by discordant Late Variscan pegmatites and the underlying Mela unit marbles is well exposed (Fig. 1.10b).

Fig. 1.10a - Mela unit: Variscan Fv_{3m} foliation in the fine-grained Variscan muscovite marbles. Loc.: North of Mt. Melia (686 m a.s.l.), along the Santa Lucia - Mandanici road. Central-Northern

Fig. 1.10b - *Reverse SW-NE fault contact* between the overlying Aspromonte unit Variscan augen gneisses (Aug), intruded by discordant Late Variscan pegmatites (Peg), and the underlying Mela unit Variscan marbles (Mar). This contact was responsible for a strong cataclasis and retrogression processes in all lithotypes. Loc.: Mt. Melia (686 m a.s.l.), along Santa Lucia del Mela - Mandanici road. Central-Northern Peloritani Mts.

Stop 1.5a. Piano di Palitti, North-West Pizzo Muliciano (660 m a.s.l.), Santa Lucia del Mela - Mandanici Road.

Recent tectonics in the Peloritani Mts. *Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.*

The panoramic view of ***Piano di Palitti*** provides a clear example of ***Recent tectonics*** connected to the opening of the Tyrrhenian Sea (post-Middle Miocene).

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The flat morphology is related to the varicoloured clays of the Antisicilide unit that originally overthrust the Capo d'Orlando flysch in the Burdigalian. At present time the Antisicilide Nappe is downfaulted toward the North-West, and preserved in a structural depression, bounded to the South by the Mela unit (normal fault) and to the North-West by the Capo d'Orlando flysch (high angle reverse fault) (Fig. 1.11). This structure can be explained with a previous thrust that cuts the original structure.

Fig. 1.11 - Piano di Palitti is located in a *NE-SW oriented half-graben*. The Mela unit **(A)** is downfaulted and the flattened morphology is occupied by the varicoloured clays of the Antisicilide unit **(B)**. The opposite side is made up of the Capo d'Orlando flysch **(C)**, whose boundary is represented by a high angle reverse fault **(f)**, breaching the previous overthrust of the Antisicilide unit. Loc.: North-West Pizzo Muliciano. Central-Northern Peloritani Mts.

Stop 1.5b. Pizzo Muliciano (660 m a.s.l.), Santa Lucia del Mela - Mandanici Road.

Overthrusting contact between the Aspromonte unit basement (Variscan gneisses after Pan-African granulites, including concordant muscovite-leucogneisses after Late Pan-African pegmatites and cut by discordant Late-Variscan pegmatites) and Mela unit basement (Variscan relict garnet-schists after Eo-Variscan eclogite facies rocks).
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

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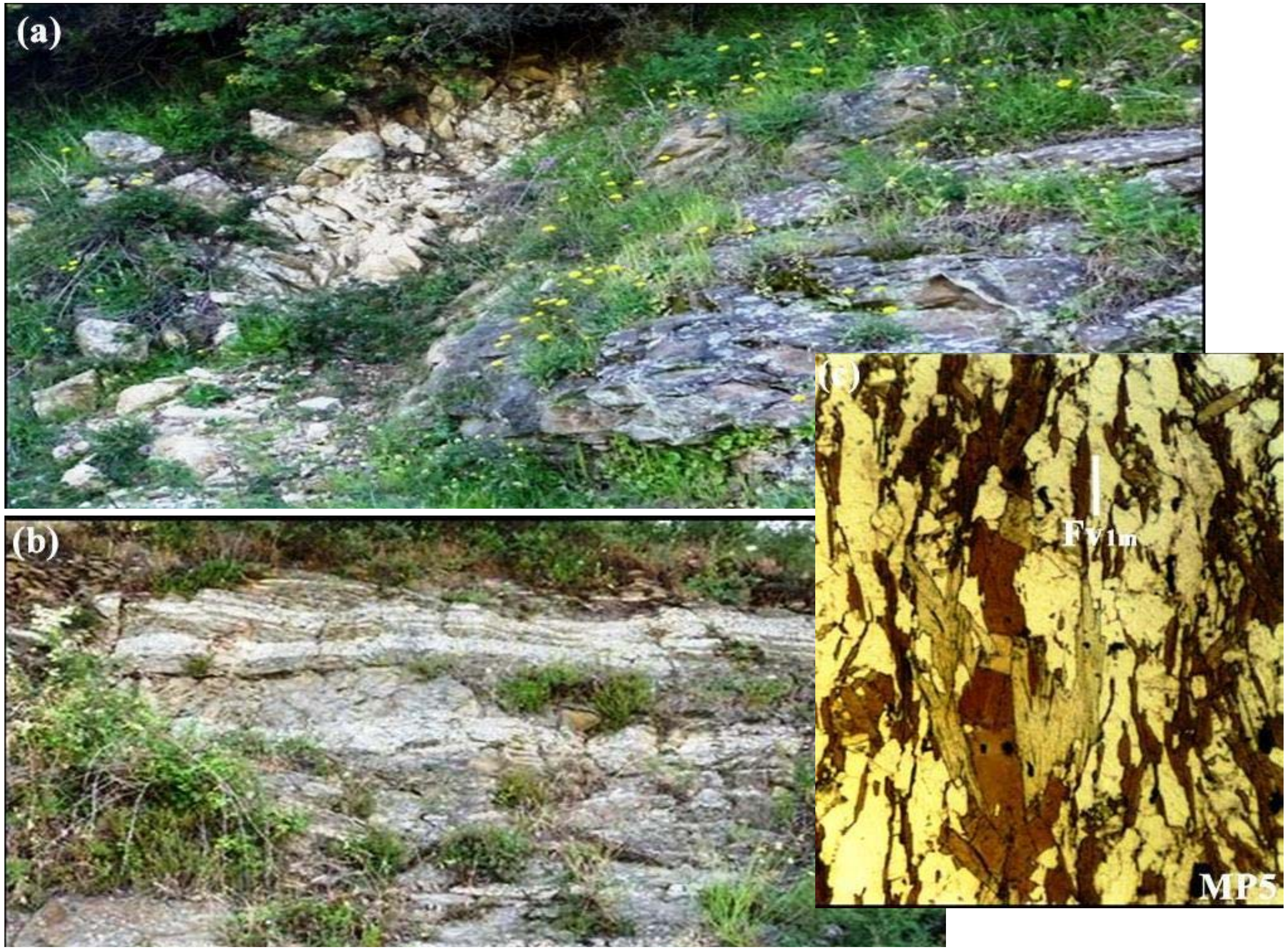
Variscan high- to medium-grade gneisses grading to gneissic schists, both after Pan-African granulites, crop out discontinuously at *Pizzo Muliciano* (Figs. 1.12a and b), in the left slope of the Torrenti Patrì and Fondachelli and along SP 95. They are locally intruded by Late-Variscan felsic plutonics, as both small bodies and dykes.

At *Pizzo Muliciano (Stop 1.5b), within a large cataclastic band characterizing the overthrusting contact between the overlying Aspromonte unit and the underlying Mela unit* (Stop 1.6), Variscan gneisses are grey with an oriented medium- to fine-grained texture along the Variscan Fv_{1m} (or Fv_{nm}) foliation, locally crenulated. They contain concordant Variscan leucogneisses (after Late Pan-African pegmatites), up to many centimeters in thickness, and are intruded by discordant Late-Variscan pegmatite dykes (Figs. 1.12a and b).



Microscopically, the *gneisses* exhibit grano-lepidoblastic/diablastic structure defined by the syn- to post-Dv_1 growth of *quartz+oligoclase/andesine±K-feldspar+biotite+sillimanite* (Fig. 1.12c).

Figs. 1.12a to c - Aspromonte unit high- to medium-grade basement within a meter-thick Alpine overthrusting band: *Variscan biotite gneisses* (after Pan-African granulites) **(a)**, including *concordant Variscan muscovite-rich leucogneisses* (after Late Pan-African pegmatites) **(b)**, and intruded by *discordant Late-Variscan pegmatites* **(a)**. All lithotypes show Alpine cataclastic effects. Photomicrograph: granoblastic quartz+oligoclase+biotite along the Fv_{1m} **(c)**. Sample MP5. PPL, 45x. Loc.: Pizzo Muliciano, Santa Lucia del Mela - Mandanici Road. Central-Northern Peloritani Mts.

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Late and rare *muscovite* is also present. The *leuco-orthogneisses* show medium- to coarse-grained, granoblastic to polygonal texture defined by *oligoclase+quartz+K-feldspar+muscovite* and a smaller amount of *biotite*. The coarse grained *pegmatites* are *muscovite-rich*. The Alpine cataclasis was strong and affected all the lithotypes. Ductile deformations are locally also related to the E-W fault system.
The Aspromonte unit Variscan gneisses in the remaining outcrops differ in grain size and composition.

The ***AsU Variscan tectono-metamorphic evolution*** developed in two deformation phases (Dv_1 –Dv_2) of which only the former was syn-metamorphic and responsible for a retrograde Bosost-type LT granulite facies to LT amphibolite facies metamorphic zoning. Dv_1 originated the main foliation Fv_{1m}, defined by quartz+plagioclase+biotite and, depending on the zoning, also by sillimanite±muscovite, whereas garnet±staurolite±cordierite±andalusite show a late- to post-Dv_1 growth. Dv_2 produced a crenulation cleavage of the Fv_{1m}. The highest grade zone, which is defined by the biotite-sillimanite-K-feldspar-garnet-(Mg-Fe)cordierite mineral association, developed under condition of T=680°C and P=0.5 GPa (thermobaric peak), typical of granulite-amphibolite facies transition. The lowest grade zone, characterized by the oligoclase-staurolite-andalusite-Fe-cordierite mineral association, and PT conditions of T=550°C and P<0.4 GPa, is typical of the beginning of an amphibolite facies (Messina et al., 1996a, 2004b).
A weak to pervasive Alpine metamorphic overprint affected the above-defined rocks in the left slope of Vallone Pietralonga and north of Serra di Spadolelle (left slope of the middle tract of the T.te Mela).

Stop 1.6. 3 km after Pizzo Muliciano, along the Santa Lucia del Mela-Mandanici Road.

Mela unit Paleozoic medium-grade polymetamorphic basement: Variscan relict garnet schists, after Eo-Variscan eclogite facies rocks, with static blastesis of ±kyanite±sillimanite+staurolite+cordierite+andalusite+garnet.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

Paragneisses grading to *micaschists (*after Eo-Variscan eclogite facies rocks), both characterized by the occurrence of *garnet porphyroclasts,* are the most common Mela unit rock types which extensively and continuously crop out in the visited area, from the T.te Floripotema to the East, up to the T.te Patrì to the West, and reach up to 500 m in thickness. They include lenses, many meters in thickness, of foliated *relict andesine gneissic amphibolites* and *relict k-feldspar orthogneisses*, in bodies and dykes.

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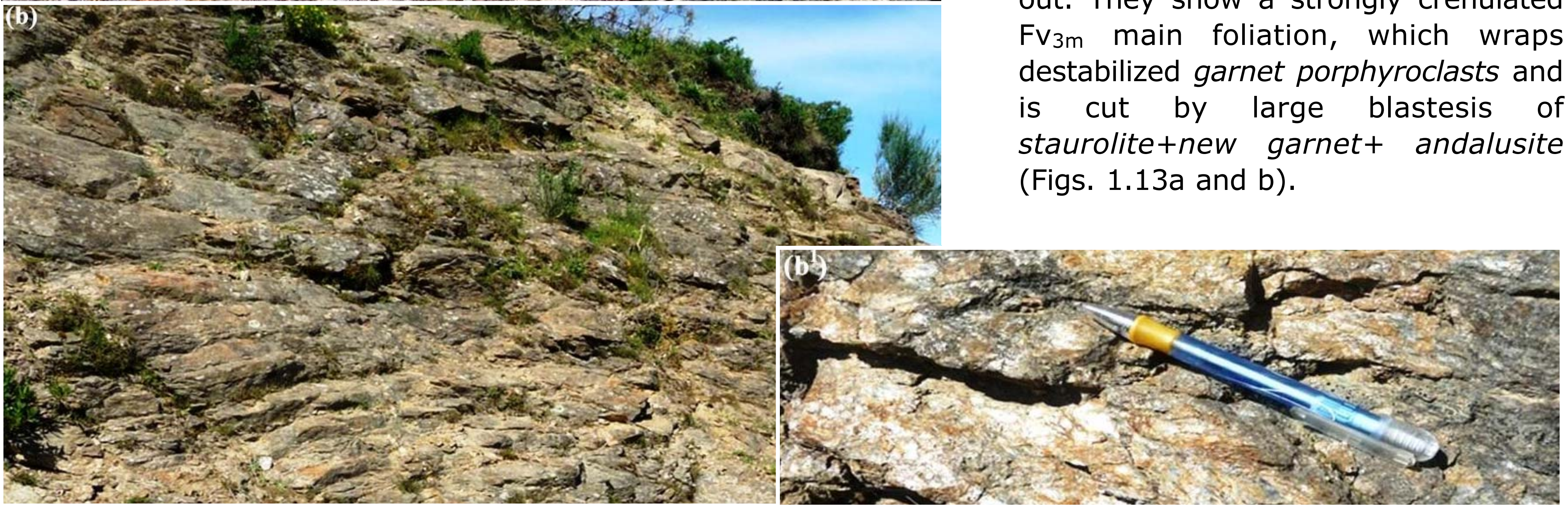
Fig. 1.13a - Mela unit: detail of Fig. 1.13b showing a Variscan *relict garnet (Grtr) schist*, (after an Eo-Variscan eclogite facies rock), with static blastesis of staurolite(St)+new garnet(Grt)+andalusite(And). Loc.: 3 km from Pizzo Muliciano, Santa Lucia del Mela - Mandanici Road. Central-Northern Peloritani Mts.

3 km after the overthrusting contact between the Aspromonte and Mela unit (Pizzo Muliciano, Stop 1.5b), along the Santa Lucia del Mela - Mandanici Road, muscovite-rich schists (Stop 1.6) crop out. They show a strongly crenulated Fv_{3m} main foliation, which wraps destabilized *garnet porphyroclasts* and is cut by large blastesis of *staurolite+new garnet+ andalusite* (Figs. 1.13a and b).



Figs. 1.13b and b1 - Mela unit: Variscan relict garnet schists (after Eo-Variscan eclogite facies rocks) with post-Dv_3 to Dv_4 kyanite+sillimanite+staurolite+garnet+cordierite+andalusite. Loc.: 3 km after Pizzo Muliciano, Santa Lucia del Mela - Mandanici Road. Central-Northern Peloritani Mts.

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Four main deformation phases have been recognized in the MeU schists, the first three being syn-metamorphic. The most important is the D_{V3}, which was responsible for the regional transposition foliation (Fv_{3m}), mainly defined by the preferred orientation of *white mica+biotite+quartz+oligoclase*. Microscopically, the relict garnet (Grtr), wrapped up by the crenulated main foliation Fv_{3m}, consists of a core crowded with opaques and a rim mainly retrogressed in a *plagioclase±quartz±biotite* (Fig. 1.13c). An important post-Fv_3 static metamorphic event was marked initially by porphyroblastic *staurolite* (Figs. 1.13c and f), rare *kyanite* (Fig. 1.13d), and local *fibrolitic sillimanite* (Fig. 1.13e); and later by *cordierite* (Fig. 1.13e), *new garnet* (Fig. 1.13g), *albite rims* around syn-kinematic plagioclase and large *poikiloblastic andalusite* (Fig. 1.13h).
Mineral chemistry indicates that: *plagioclase* is *oligoclase* (An_{19-28}) with a local *albite* rim (An_{3-9}); *biotite* has annitic compositions [XFe=0.54-0.64]; relict and newly formed g*arnet* is almandine with a composition which changes slightly from core (X_{Alm}=60-79, X_{Grs}=4-30, X_{Sps}=0-14) to rim; *muscovite* is very close to the pure end member, with Si=3.05-3.12 (a.p.f.u.) in the core and Si = 3.00 in the rim (Macaione et al., 2012b).
The ***MeU Variscan tectono*-metamorphic evolution** developed in two stages. The first stage is documented by garnet+omphacite relics in the mafic rocks (Stop 1.7) and by garnet relics in micaschists and paragneisses. During the second stage, these minerals are partially re-equilibrated in amphibolite facies symplectites, and more precisely, the clinopyroxene+hornblende association from omphacite destabilization and the quartz+oligoclase±biotite association after garnet destabilization.

The Eo-Variscan metamorphic stage was prograde, beginning in epidote amphibolite facies and continuing up to the baric peak of the eclogite facies under conditions of T=600°C and P=1.6 GPa (Compagnoni et al., 1998).
The second stage was characterized by four deformation phases (Dv_1–Dv_4), which the first three responsible for a retrograde Barrovian-type metamorphism, from kyanite-staurolite-garnet zone of amphibolite facies, which took place under conditions of T=600-550°C and P between 0.6 and 0.4 GPa, to andalusite-cordierite-albite zone of greenschist facies, which developed at T=500°C and P<0.4 GPa (Messina et al., 1997, 1998, 2004b).
Previous geochronological data support the complex polystage tectono-metamorphic evolution of the Mela unit: *an early stage*, dated *at* 349 Ma ($^{40}Ar/^{39}Ar$ amphibole, De Gregorio et al., 2003), has been ascribed to an Eo-Variscan, most likely eclogite facies, event; and *a later stage*, dated at 315 Ma ($^{40}Ar/^{39}Ar$ amphibole, De Gregorio et al., 2003) has been attributed to the amphibolite facies Variscan event.

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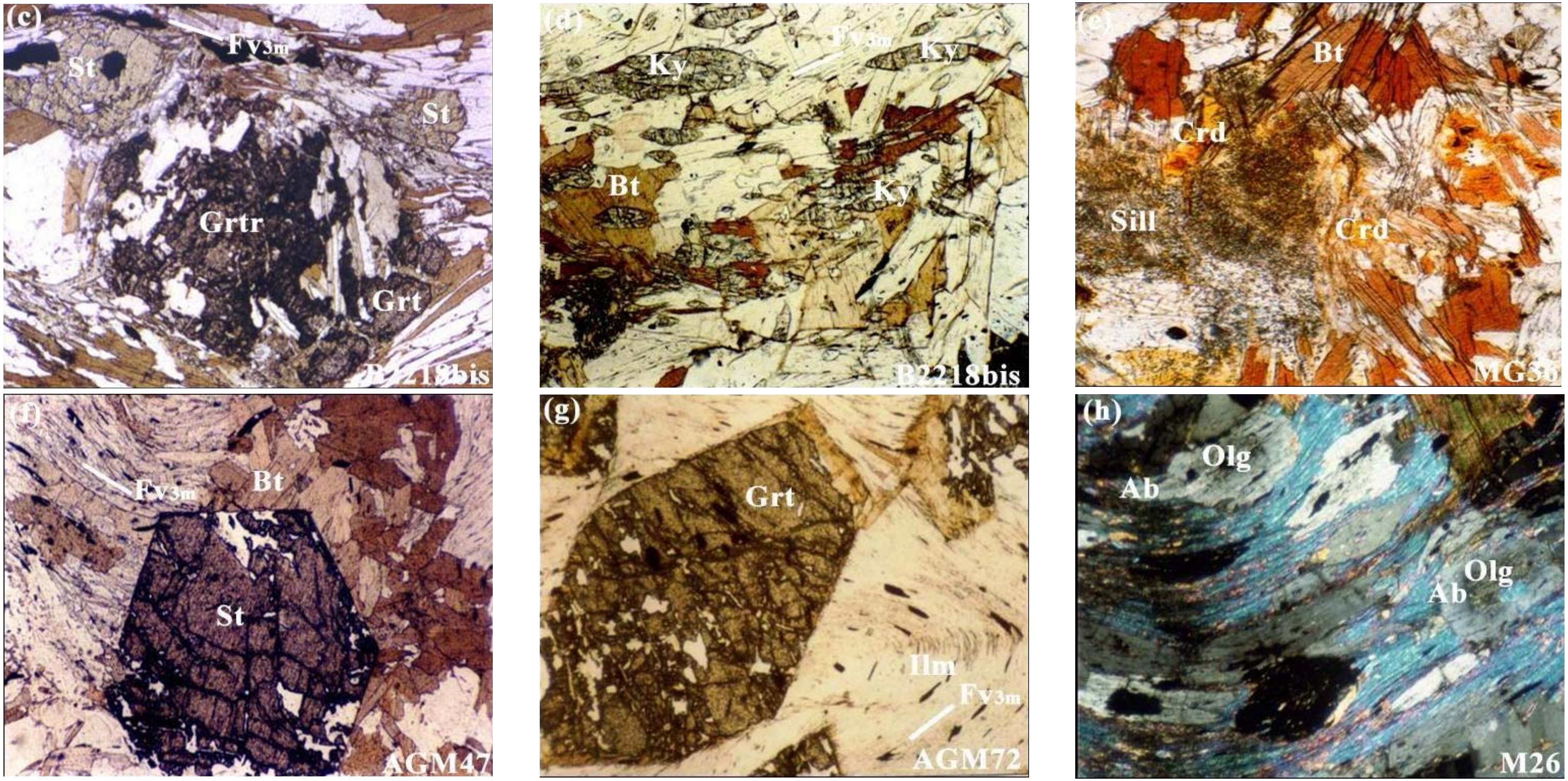

Figs. 1.13c to h - Mela unit: Variscan *relict garnet schists* (after Eo-Variscan eclogite facies rocks). Photomicrographss: relict garnet (Grtr), with a re-equilibrated quartz+biotite+oligoclase rim, wrapped up by the Variscan Fv_{3m} main foliation defined by micas. Post-Fv_{3m} staurolite (St) and second garnet generation (Grt) are also evident **(c)**; kyanite (Ky) and biotite (Bt) are overgrowing on the Fv_{3m} main foliation **(d)**; fibrolite (Sill), biotite (Bt) and late cordierite (Crd) **(e)**; porphyroblasts of staurolite (St), biotite (Bt) **(f)** and second garnet generation (Grt) (g) overgrowing the folded Fv_{3m} main foliation defined by mainly muscovite and transposed post-Fv_1 ilmenite; late albite rim (Ab) around oligoclase (Olg) included, with muscovite, within centimeter-sized peciloblastic andalusite **(h)**. Samples: B2218bis, PPL, 60x **(c)** and **(d)**; MG36, PPL, 45x (e); AGM47 (f) and AGM72 (g), PPL, 60x; M26, CP, 45x (h). Loc.: Pizzo Rosarello - Pizzo Croce road. Central-Northern Peloritani Mts. **(c, d, f, g)**; Piraino village. North-Western Peloritani Mts. **(e)**; F.ra Colonnina. Eastern Peloritani Mts. **(h)** (after Messina & Macaione, 2010).

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In order to better understand the tectono-metamorphic evolution of the Mela unit, and especially to know whether the eclogite facies metamorphism is Pre-Variscan or Eo-Variscan in age, an *in situ* U-Th-Pb dating of zircon and/or monazite by LA-ICP-MS is in progress (Macaione et al., 2012b).

Stop 1.7. Pizzo Rosarello (1,026 m a.s.l.) - Pizzo Croce (1,214 m a.s.l.), Santa Lucia del Mela - Mandanici Road.

Mela unit Paleozoic medium-grade polymetamorphic basement: Variscan relict garnet-amphibolites from Eo-Variscan eclogites.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

The Paleozoic volcanic sequence which characterized the Mela unit basement was marked by two main volcanic cycles. The first is a mafic series, documented by the Na-alkaline within plate metabasalts (Messina et al., 2004b; Macaione et al., 2012b), represented by the Eo-Variscan eclogites re-equilibrated into Variscan *relict garnet amphibolites* (Compagnoni et al., 1998). The second is an acidic series, represented by the Variscan relict K-feldspar two-mica orthogneisses and Variscan relict feldspars leucogneisses.

In the ***Pizzo Rosarello – Pizzo Croce ridge*** (Figs. 1.14a and b), proceeding along the *Santa Lucia del Mela - Mandanici Road, several bodies of Variscan relict garnet amphibolites after Eo-Variscan eclogites crop out within thick marble layers* (Stop 1.7). They are green to grey-green, fine to medium grained, from massive, to less oriented up to oriented texture along the Fv_{3m} foliation, which commonly wraps up relict garnets. These amphibolitic bodies are also widespread as meter-thick lenses in paragneisses and micaschists. They constitute the most abundant metamafics characterizing the basements of the CPC units.

The ***Mela unit Variscan amphibolites*** *exhibit a large range of structure and composition* (Figs. 1.14b to i). The development of different mineral assemblages in these medium-high pressure rocks is related to the diverse intensities of deformation during their Variscan re-equilibration, and not to original differences of bulk-rock chemistry. Microscopically, the following types of Variscan amphibolites (s.l.) have been recognized in the MeU, starting from the most preserved lithotypes showing eclogite facies minerals, to the most re-equilibrated types:
- the *relict garnet clinopyroxene amphibolite* (Fig. 1.14d) is the most preserved metamafic rock (*amphibolitized eclogite*). It is massive to weakly oriented and made up of *diopside+labradorite/oligoclase+Mg-*

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Figs. 1.14a to c - Mela unit: Variscan *relict garnet amphibolites* (after Eo-Variscan eclogites.). Bodies of Variscan relict garnet amphibolites outcrop for many hundreds of meters in extension, along the Pizzo Rosarello-Pizzo Croce ridge **(a)**; mesoscopic features of the previous amphibolites showing a grey-green colour and a poorly oriented porphyroclastic texture, characterized by millimeter-sized relict garnet replaced at the rim by a quartz+plagioclase corona **(b)**; mesoscopic features of a MeU amphibolite which exhibits centimeter-sized relict garnet destabilized in quartz+plagioclase **(c)**. Loc.: Pizzo Rosarello-Pizzo Croce ridge. Central-Northern Peloritani Mts. **(a, b)**; T.te San Filippo Eastern Peloritani Mts. **(c)**.

hastingsite(Mg#=0.70) symplectitic association from the destabilization of *omphacite*, and of *oligoclase+quartz+biotite* association from the destabilization of *garnet*. Omphacite was completely re-equilibrated, because it has not yet been observed, whereas in these rock-types garnet was replaced only at the rim by *quartz+plagioclase+biotite* corona. *Epidote* and *titanite* are accessories included in the relic garnet, where rare amphibole is also present;

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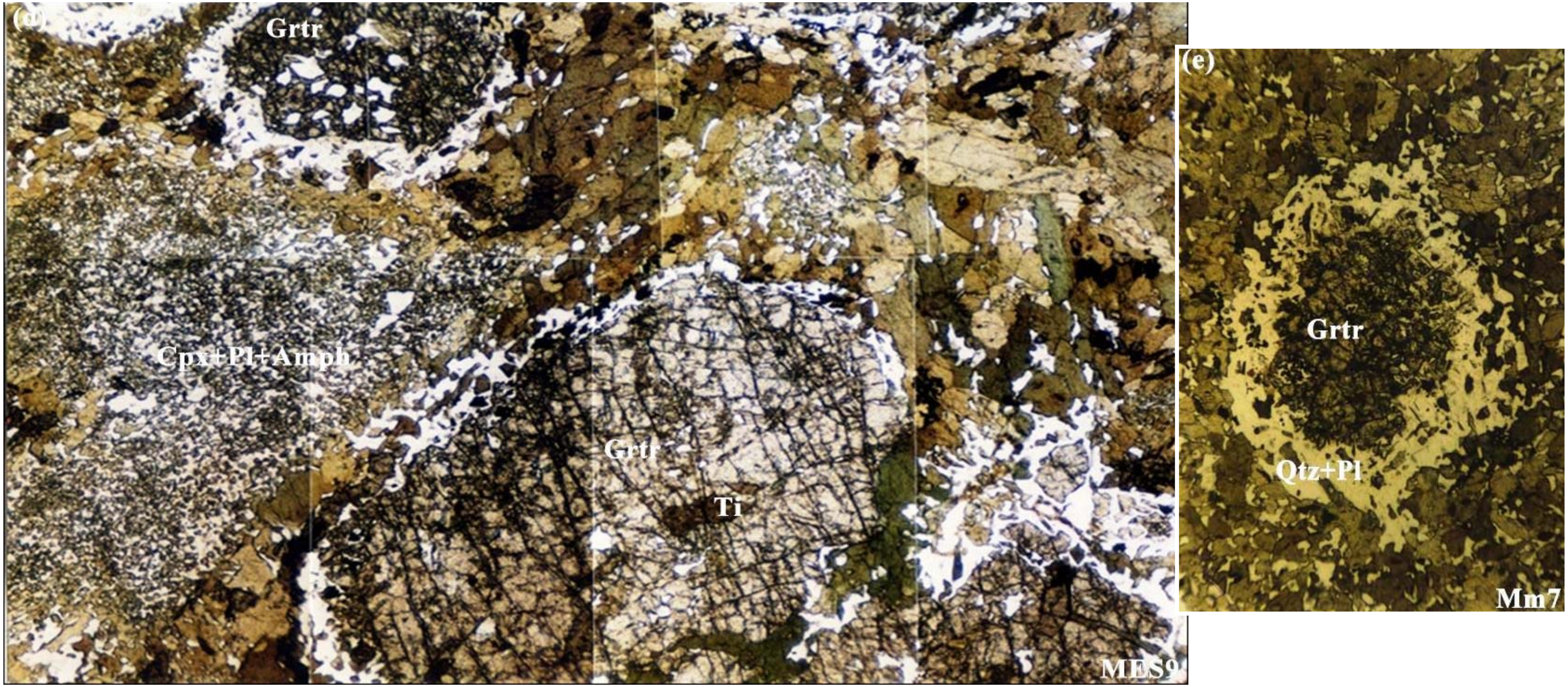

Figs. 1.14d and e - Mela unit: Variscan amphibolites (after Eo-Variscan eclogites). Photomicrographs: *relict garnet-clinopyroxene amphibolite* consisting of centimeter-thick Eo-Variscan relict garnet (Grtr) replaced at the rim by a quartz+plagioclase (Qtz+Pl) corona in a Variscan poorly-oriented matrix made up of diopside+labradorite /oligoclase+Mg-hastingsite (Cpx+Pl+Amph) symplectites from the destabilization of omphacite. Titanite (Ti) is the prevalent accessory **(d)**; relict garnet amphibolite made up of Eo-Variscan destabilized porphyroclastic garnet (Grtr) within a Variscan granoblastic to polygonal medium-fine grained matrix, formed by oligoclase+quartz association after garnet and hornblende+oligoclase association (without clinopyroxene) after omphacite **(e)**. Samples: MES9 (d); Mm7 (e). PPL, 60x. Loc.: Pizzo Rosarello - Pizzo Croce ridge. Central-Northern Peloritani Mts.

- the *relict garnet amphibolite* (Fig. 1.14e) is massive and shows a partly destabilized *porphyroclastic garnet* in a granoblastic to polygonal medium- to fine-grained matrix, defined by the same symplectitic association described above, without clinopyroxene;

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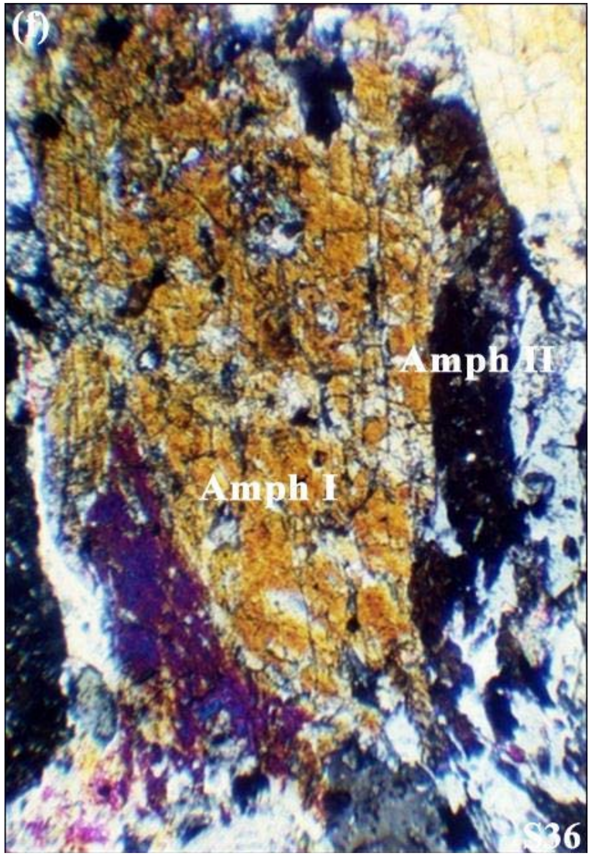

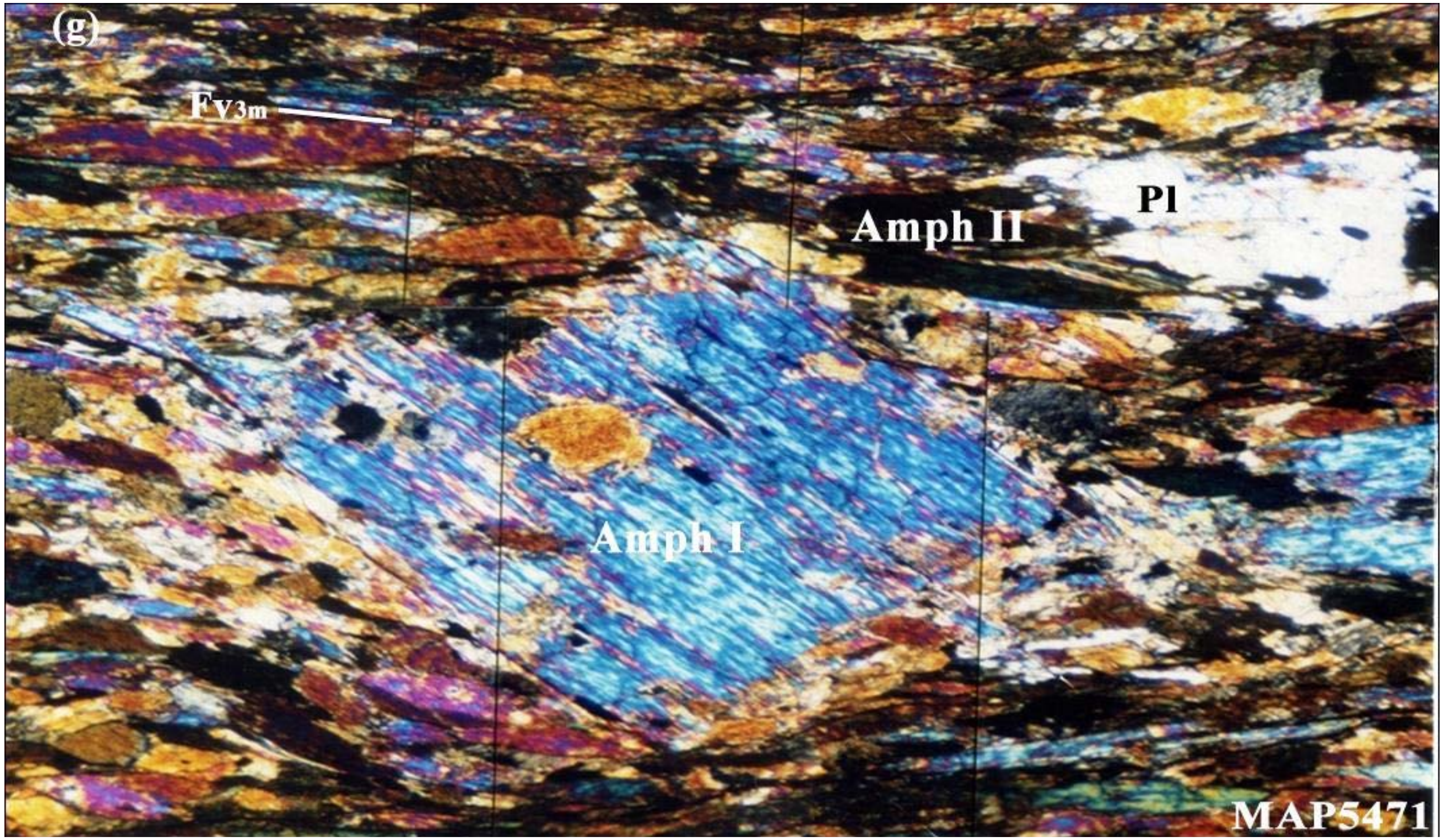

Figs. 1.14f and g - Mela unit: Variscan amphibolites after Eo-Variscan eclogites. Photomicroographs: *gneissic amphibolite* showing a porphyroclastic structure characterized by large post-Dv2 hornblende (Amph I) recrystallized at the rim (Amph II) with subgranular-structure, along the Fv_{3m} main foliation, alternated to quartz-plagioclase domains (probably after the garnet destabilization) **(f)**; hornblende-rich amphibolite, which has a porphyroclastic structure, defined by large post-Dv2 hornblende (Amph I) recrystallized at the rim with sub-granular structure along the Fv_{3m} main foliation, in an oriented matrix defined by syn-Dv_3 hornblende (Amph II) and zoned plagioclase (Pl). Ilmenite, apatite and zircon are the accessories **(g)**. Samples: S36 (f); MAP5471 (g). CP, 60x. Loc.: Pizzo Croce. Central-Northern Peloritani Mts. (f); left slope of the T.te Fiumedinisi. Eastern Peloritani Mts. **(g)**.

- the *gneissic amphibolite* (Fig. 1.14f) shows a porphyroclastic texture defined by large post-Dv_2 *hornblende*, recrystallized at the rim, with a sub-granular structure, along the Fv_{3m} main foliation, alternated with *quartz-plagioclase domains* (probably after the garnet destabilization);
- the *hornblende-rich amphibolite* (Fig. 1.14g) shows a foliate porphyroclastic texture defined by large post-

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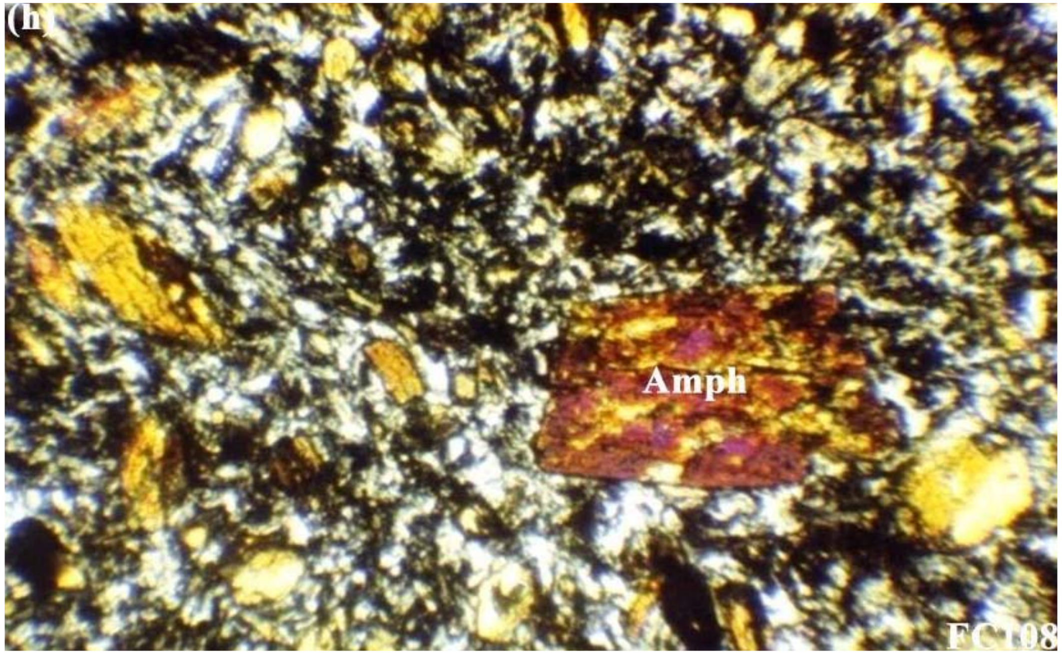
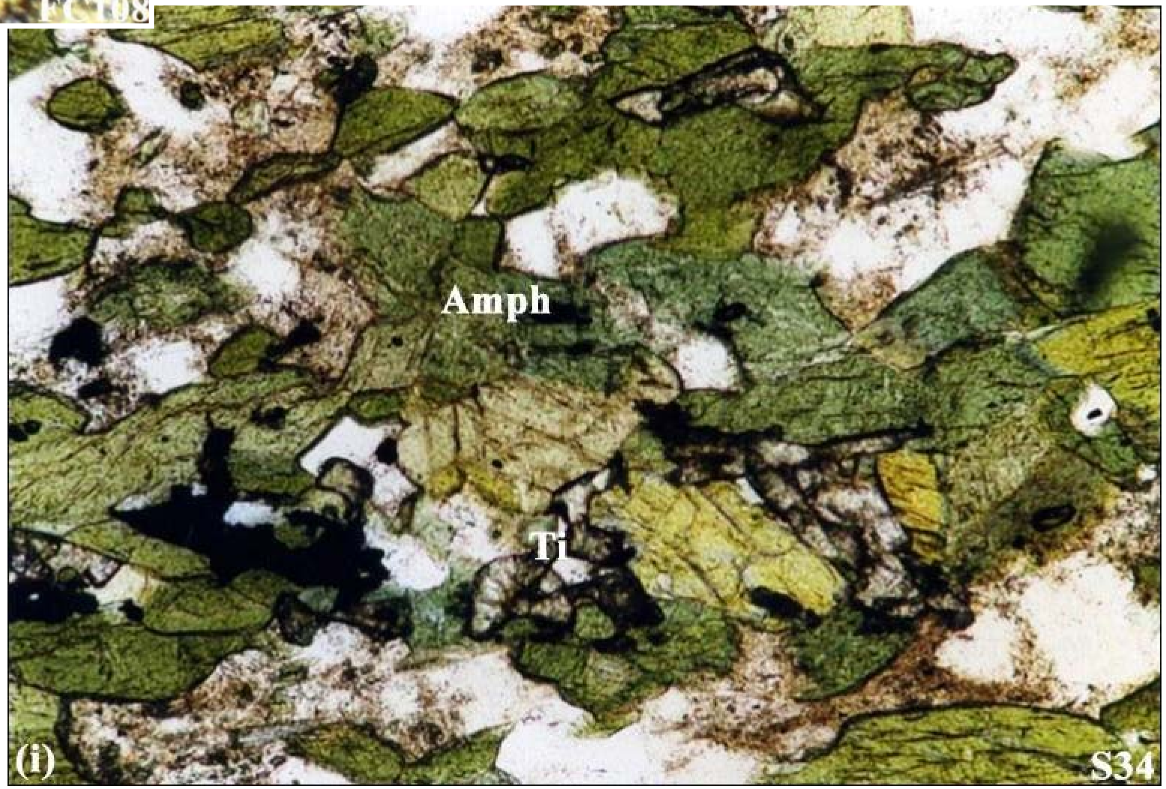


Dv$_2$ *hornblende*, recrystallized at the rim, with a sub-granular structure, along the Fv$_{3m}$ main foliationin, in addition to *zoned plagioclase. Ilmenite, apatite* and *zircon* are accessories;
- the *fine-grained gneissic amphibolite* (Fig. 1.14h) exhibits an oriented micro-porphyroblastic structure defined by *quartz+plagioclase+garnet+ amphibole+opaque* aggregates along the Fv$_{3m}$ main foliation, cut by small post-Dv$_3$ *hornblende*;
- the *medium-fine grained amphibolite* (Fig. 1.14i) has massive granoblastic to polygonal structure with post-Dv$_3$ hornblende, plagioclase and quartz. The accessory titanite is abundant.



Figs. 1.14h and i - Mela unit: Variscan amphibolites after Eo-Variscan eclogites. Photomicrographs: *fine-grained gneissic amphibolite* exhibiting a porphyroblastic structure defined by oriented quartz+plagioclase+garnet+amphibole+opaque aggregates along the Fv$_{3m}$ main foliation, which is cut by small post-Dv$_3$ hornblende (Amph) (**h**); *medium- to fine-grained amphibolite* showing a massive structure made up of granoblastic to polygonal post-Dv$_3$ hornblende (Amph), plagioclase and quartz. Titanite (Ti) is abundant (**i**). Samples: FC108, CP (**h**); S34, PPL (i). 60x. Loc.: left slope of the F.ra Colonnina. Eastern Peloritani Mts. (h); Pizzo Croce. Northern-Central Peloritani Mts. (**i**).

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The early (Eo-Variscan) metamorphic stage was prograde, beginning in epidote amphibolite facies condition, continuing up to the garnet-omphacite eclogite facies baric peak (T=600°C and P=1.6 GPa; Compagnoni et al., 1998). *The presence of titanite instead of rutile and the apparent stable occurrence of hornblende with the eclogite assemblage suggest that the lower limit of the eclogite facies has been only just surpassed* (Macaione et al., 2012b).

Stop 1.8. Pizzo Rosarello - Torrente Cerasiera dirt road.

Tectonic window of the Piraino unit Paleozoic low- to medium-grade basement: Variscan dark-grey chlorite-garnet phyllites.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

In the ***Mela unit tectonic window of Pizzo Rosarello - Torrente Cerasiera,*** *West to Pizzo Rosarello – Pizzo Croce ridge, crops out the low- to medium-grade basement of the Piraino unit. The predominant lithotypes are the Variscan dark-grey graphite-garnet phyllites grading to metarenites in banks up to 100 meters in thickness (Fig. 1.15).*

They are well evident along the dip dirt road that links the Pizzo Rosarello to T.te Cerasiera, where mesoscopically phyllites and metarenites show porphyroblastic texture with the Fv_{2m} main foliation being crenulated and cut by a thin Fv_3. Depending on the metamorphic zoning, porphyroblasts of chlorite, chloritoid, biotite, garnet (always present) and staurolite, up to a millimeter across, can be found.

Fig. 1.15 - Piraino unit: Variscan phyllites from chlorite-garnet zone. *Dark-grey chlorite+graphite+garnet phyllites*. Loc.: Pizzo Rosarello – T.te Cerasiera dirt road, about 1 km South-West of Pizzo Rosarello. Central-Northern Peloritani Mts.

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In the Sheet Barcellona P.G. - Milazzo, the Piraino unit crops out for about 15 sq km, with thickness up to 500 m. In the South-Eastern area of the geotour, it is found between the confluence of the T.te Fantina and F.ra Santa Venera. In the North, it is found on the eastern slope of Pizzo Rainoso, and in the South, at the confluence of the Torrenti Tripi-Mazzarrà and Cavallo. It is interposed between the overlying Mela unit (marbles and schists), and locally the Aspromonte unit (augen gneisses and gneisses), and the underlying Mandanici unit (phyllites, metarenites and related cover).
The LT greenschist to LT amphibolite facies prograde zoning is observable in localized areas of the geotour territory such as in the F.ra Santa Venera and in the left slope of the T.te Fantina, because of the intense Alpine tectonics. *White mica+chlorite+garnet phyllites* and metarenites are exposed East of Pizzo Rainoso, North of Mandra Pulario (South-East of Rocca Timogna), in the left slope of the Vallone Cugno di Mezzo (South-East of Bafia) and South-West of Pizzo di Sughero. *Biotite+garnet±chloritoid phyllites* crop out South of Mt. Pizzicari and *garnet+albite/oligoclase±staurolite phyllites* can be found along the valleys between Pizzo Croce and Pizzo Rainoso, South of Pizzo Mualio, in the right slope of the F.ra Santa Venera and in the left slope of the T.te Fantina.

The ***PU Variscan tectono-metamorphic evolution*** took place during four deformation phases (Dv_1-Dv_4), the first three accompanied by a Abukuma-type metamorphism (Messina, 1998b; Messina et al., 1998, 2004b).
The Dv_1 produces the first foliation Fv_1, defined by white mica+chlorite with quartz-albite domains. It is rarely evident but well preserved in the microlithons. The same minerals, together with ilmenite, crystallize up to post-Fv_1, continuing to develop in the Dv_2 deformation phase, along the main foliation Fv_{2m}. Ilmenite is transposed on Fv_{2m} (Fig. 1.16a) and, depending on the zoning, garnet±chloritoid(Fig. 1.16b)±biotite grow as porphyroblasts until post-Fv_2. The Dv_3 developed a crenulation cleavage originating a third, thin, not penetrative and spaced Fv_3 foliation, marked by chlorite+white mica in the chlorite zone (Figs. 1.16a and b), and biotite in the other zones (Figs. 1.16c to e). The garnet develops up to post-Fv_3, reaching up to a centimeter across in size, showing a post-Dv_3 rim (Figs. 1.16c and d). In the highest grade zone, post-Fv_3 staurolite also crystallizes (Fig. 1.16d).
According to the mineral associations, the thermobaric peak in each zone is post-Dv_3, under a temperature ranging from 400 (chlorite-Mn-garnet-chloritoid paragenesis of the LT greenschist facies) to 550°C (oligoclase-Fe-garnet-staurolite paragenesis of the LT amphibolite facies) and at pressures <0.4 GPa (absence of kyanite). The Alpine shear zones, very widespread in the entire unit, were responsible for cataclastic to mylonitic effects, accompanied by rare deposits of sulphides, Fe-oxides and Fe-hydroxides.

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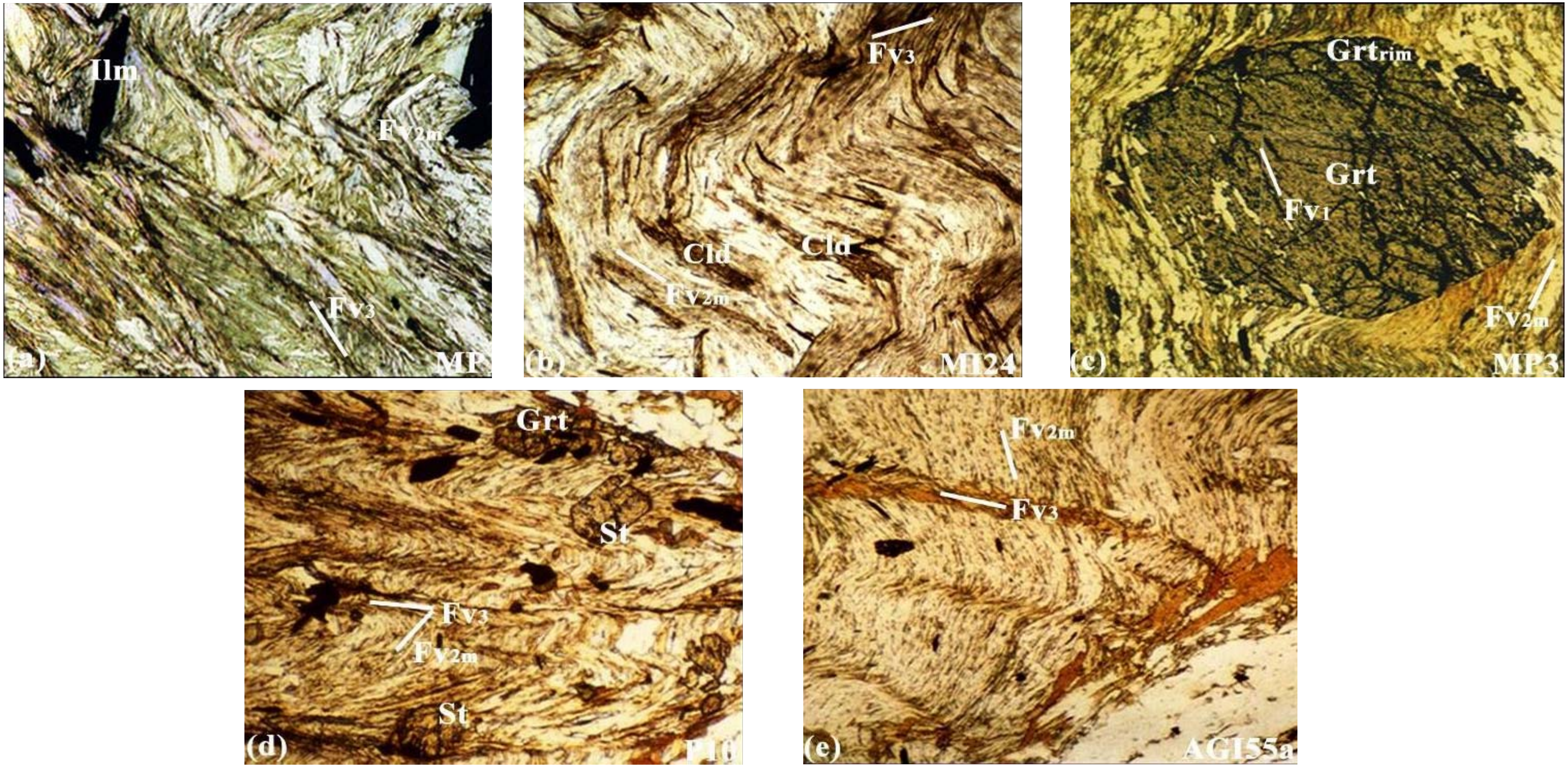

Figs. 1.16a to e - Piraino unit: Variscan *chlorite to staurolite garnet phyllites*. Photomicrographs: Variscan Fv_{2m} main foliation defined by chlorite+white mica+quartz (a and b) or biotite+white mica+quartz **(c - e)**, deformed by *a later penetrative crenulation cleavage Fv_3* at high angle (80°) with respect to the main foliation, defined by the transposition or recrystallization of chlorite **(a, b)** and/or biotite **(c-e)**, depending of the zoning. Post-Fv_1 ilmenite (Ilm) is transposed along the main foliation **(a)**; post-Fv_2 chloritoid(Cld) (altered in quartz+white mica+opaques) is transposed on the Fv_3 foliation (b); syn-Fv_1 to post-Fv_3 Mn- to Fe-garnet (Grt) showing a post-Dv_3 (Grtrim) rim **(c)**; post-Fv_3 garnet (Grt) and staurolite (St) **(d)**. Samples: MP1 **(a)**, MP3 **(c)**, P10 **(d)** and AGI55a **(e)**, PPL, 60x; MI24, PPL, 45x (b). Loc.: Sant'Orsola, Piraino village. Central-Western Peloritani Mts. **(a)** (from Messina et al., 2004b); South of Mt. Pizzicari Central Peloritani Mts. **(b)**; Burcano, Piraino village. Central-Western Peloritani Mts. **(c)**; West of Pizzo Faleco. Eastern Peloritani Mts. **(d)**; Santa Marta, Piraino village. Central-Western Peloritani Mts. **(e)**.

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Stop 1.9. Torrente Santa Lucia river bed.

Mela unit Paleozoic low- to medium-grade basement: Variscan muscovite+biotite+garnet marbles with epigean and hypogean macro-karst and hydrothermal phenomena (geo-morphosites).

Moving back toward Saint Lucia del Mela village, along the Pizzo Croce-Pizzo Rosarello-Colle Makkarruna ridge (Mandanici - Santa Lucia del Mela Road), the turn off for San Nicola locality, to the West (at the beginning of the asphalted road), leads to the F.ra del Mela. Moving up the steeply sided Mela valley, it arrives at the F.ra Santa Lucia, right tributary affecting very-thick levels of Mela unit marbles.
The Santa Lucia valley shows spectacular geological and morphological landscapes. The valley, still preserved from anthropic modification i.e., quarries, roads etc., contains gorges, canyons and in the narrow passages, three levels of fluvial cave systems (Fig. 1.17) and widespread hydrothermal sulphide deposits

Fig. 1.17. Mela unit: Variscan two mica marbles. *A Santa Lucia fluvial cave system* with the external opening (2-3 m in diameter) at about 1 m above the actual river bed. Loc.: right slope of the F.ra Santa Lucia. Central-Northern Peloritani Mts.

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Stop 1.10. Santa Lucia del Mela Hamlet.

Geo-cultural visit of the Arab-Medieval Hamlet of Santa Lucia del Mela.

The territory of Santa Lucia del Mela, between the catchment areas of the Torrenti Muto, Floripotema and Mela, has strongly influenced the evolution of human settlement in the area.
The ***name "Mela" derived from the Greek "melas" which means "black, dark" and which is aimed at the widespread presence of dark green amphibolitized eclogite lenses*** included in whitish marbles and silver-grey schists and gneisses (Mela unit) widely outcropping along the slopes of the three above defined torrents.
The well preserved elegant hamlet, that from the Colle Makkarruna (387 m a.s.l.) where the Arab-Swabian Castle rises, gradually sloping down to the Milazzo Plain.

The oldest traces of settlement found in this area are located along the lines of the watersheds of the main rivers (e.g. Mt. Lanzaria and Pizzo Lando - Late Bronze Age - IV century B.C.) and in the river-bed of the T.te Mela (Contrada Cattera - Roman necropolis).
In Roman times this area had a strategic importance, as witnessed by the fact that nearby stood the famous Temple of Diana Facellina (*Phacelinus Siciliae juxta Peloridem, confinis Templo Dianae*), cited by various historical sources and still the subject of studies and geo-archaeological research (Saporetti, 2008). Another archaeological mystery is the reservoir of *Naulochus*, used as a refuge by Roman ships in the battle of 36 B.C., and probably located in a marshy area, now lost, at the mouth of the T.te Floripotema.
The current hamlet of Santa Lucia del Mela, however, seems to be the result of the Arab, Norman, Swabian and Aragonese influences.
The most symbolic monument of the area is the Castle (Fig. 1.18), which consists of three towers, triangular (remains of a lunette), cylindrical and rectangular, rebuilt by the Aragonese in 1322, on a Palatium that already existed. The towers are made up of irregular polychrome blocks of Mela and Aspromonte units metamorphics, Floresta calcarenites, Capo d'Orlando sandstones, Pliocene fossiliferous limestones, Aeolian lavas and subordinate in amount red bricks. According to historical data, it was the Arabs whobuilt it on top of Colle Makkarruna (Makrun in Arab, means "perched, attacked"). In 1675, the square tower of the Castle was transformed in the Sanctuary of the Madonna delle Neve, which contains, among other things, the beautiful marble statue of Antonello Gagini (1529, Fig. 1.18a). It also housed an extensive library with incunabula,

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Fig. 1.18. The Santa Lucia del Mela Medieval Hamlet. *The Arab-Swabian Castle* erected on the Colle Makkarruna (387 m a.s.l.). The cylindrical tower is made up of irregular blocks of polychrome local and Aeolian rocks and bricks. Loc.: Santa Lucia del Mela. Central-Northern Peloritani Mts.

liturgical and philosophical texts (XVI-XVII c.) connected to an old seminary, a study center that has hosted celebrities such as the Calabrian philosopher Pasquale Galuppi (1770-1846) and the abbot Antonio Scoppa (1763-1817).

Many monuments characterize the urban centre: the Cathedral (XI - XVII c.), rich in works of art and considered one of the most important cathedrals of the Sicily, containing paintings, plates and stone monuments of Filippo Jannelli (1621-1696), Fra Felice of Sambuca (1734-1805), Deodato Guinaccia (1510-1585), Ignazio Marabitti (1719-1797; Fig. 1.18b), Valerio Villareale (1773-1854), Pietro Novelli (1603-1647), Domenico Gagini (1420-1492), in addition to the incorrupt body of the Prelate Archbishop Antonio Franco (1626 and close to beatification); the Church of San Nicola (XIII-XV c., Fig. 1.19) with a churchyard in giacato (typical medieval flooring consists of local river pebbles) and with the valuable statue of San Nicola di Bari of Andrea Calamech (XVI c.); the Church of Santa Maria Annunziata (XV c.), also famous for the imperious 32 m high bell tower, for the valuable painting of the Madonna delle Grazie (XV c.) of an unknown artist and the remains of mass graves visible below the churchyard; the ruins of the Church of San Michele Arcangelo (XV c.); the Church and Convent of the Sacro Cuore, with its impressive cloister consists of 24 sandstone columns; the Church of Immacolata, the Convent and the Crypt of Padri Cappuccini (XVII c.), where are preserved valuable works of Fra Felice of Sambuca and mummified bodies of many noble "luciesi", the Palazzo Vescovile (1609-1613) hosting the "*Diocesan Museum of the Prelature nullius*" and artistic works of famous painters such as Antonello de Saliba, pupil of Antonello da Messina; and the Basile-Vasari Palace (XVII c.) in Baroque style (Fig. 1.20), which was the residence of the famous poet and futurist painter Ruggero Vasari (1898-1968).

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The well preserved architectonic and decorative lapideus materials characterizing the Santa Lucia del Mela monumental complex, as well as that of other Peloritani ancient urban centers, are strictly correlated to the period of construction or restoration of the architectonic element. The local Capo d'Orlando sandstones, Floresta fm. calcarenites and Pliocene fossiliferous limestones have been used, as external and internal decorative elements, in all periods. Aeolian dark lavas are typical of Arab-Norman Age (very common in the Federician structures), as it is evident in the Castle and in the bell towers of the San Nicola Church (XIII c., Fig. 1.19) and Annunziata Church (XV c.), because in this latter the tower is inherited from Arab period. Since Late Middle Age the San Marco d'Alunzio pink to grey limestones and dolostones (Middle-Upper Lias), and calcareous Rosso Ammonitico (Malm) have been common used in the Peloritani sacral architecture, as it is possible to observe in the reconstructed elements, during the XVII c., of the Cathedral and Annunziata Church. Calabrian ophiolitic serpentinites decorate parts of the Cathedral and San Nicola Church. Since the Renaissance to Baroque Epoch, Tuscany polychrome limestones and marbles have been used, particularly the white saccharoidal Carrara marble and the yellow Siena marble (Cathedral, Santa Maria dell'Arco Church and Sanctuary of Madonna della Neve), in addition to beautiful alabasters, calcareous breccias and polychrome limestones of South Sicily.

Figs. 1.18a and b - The Santa Lucia del Mela Medieval Hamlet. *The "Madonna della Neve" statue* (1529, Antonello Gagini) in Carrara marble, sited in the homonymous Sanctuary (**a**); in the Cathedral, at the base of *San Marco Evangelista table* (1581, Deodato Guinaccia), the beautiful *Ecce Homo pink alabaster sculpture* (1771, Ignazio Marabitti) is present (**b**). Loc.: Santa Lucia del Mela. Central-Northern Peloritani Mts.

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Fig. 1.19 - The Santa Lucia del Mela Medieval Hamlet. *The Church of San Nicola* (XIII c.), with the Arab bell tower (XI c). Loc.:Santa Lucia del Mela. Central-Northern Peloritani Mts.

Fig. 1.20 - The Santa Lucia del Mela Medieval Hamlet. *The façade of the Basile-Vasari Palace* (XVII c.) with arches, doorposts and architrave of portals and windows decorated with Capo d’Orlando sandstones. Loc.: Santa Lucia del Mela. Central-Northern Peloritani Mts.

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Second Day

Itinerary 2: SP 93 Rodì-Milici - Torrente Patrì - Fiumara Santa Venera – Torrente Fantina – Fiumara Floresta - Torrente Raiù – Mt. Cipolla - Novara di Sicilia

Themes: Stratigraphic-structural features and petrology of the Mandanici, Fondachelli and San Marco d'Alunzio units. Geometry. Overthrusting contacts and fault contacts. Relationships between Oligo-Miocene to Quaternary deposits.

Stop 2.1. Pietre Rosse locality, North of Rodì village, SP 93 Rodì - Milici.

Structural setting of the area, originated by neotectonic activity.
Geological Map: Carta Geologica della Provincia di Messina, 1:50.000. Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

Looking South: in the near-distance we can observe the gentle morphology of the Cretaceous varicoloured clays (Antisicilide unit), and in the far-distance, the Capo d'Orlando flysch partially uplifted respect to the Antisicilide unit (Fig. 2.1). On the left side of the view the Late Miocene and Quaternary covers are downfaulted eastwards along a N-S oriented fault.

Fig. 2.1 - Panoramic view of the *cretaceous varicoloured clays* (Antisicilide unit, VC), characterized by a gentle morphology. They are down faulted respect to the Oligo-Miocene Capo d'Orlando flysch (COF), on which the nappe originally overthrusts. Loc.: Pietrerosse, along the SP 93. Northern Peloritani Mts.

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Stop 2.2. Torrente Patrì - Fiumara Santa Venera confluence.

Mela, Piraino, Mandanici and Fondachelli units tectonic pile. Overthrusts.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

The T.te Patrì and its right tributary the F.ra Santa Venera constitute a natural cross-section that highlights the entire tectonic setting of the Peloritani Chain, excluding the Alì, Longi-Taormina and Capo Sant'Andrea units.
In fact, South of Milici village (South of the Stop 2.1) and along the left slope of the T.te Patrì, alternations of Aspromonte unit Variscan medium-fine grained gneisses grading to subordinate gneissic schists and augen gneisses crop out. They are unconformably covered by the Oligo-Miocene Capo d'Orlando flysch and overthrust the Variscan marbles, paragneisses and schists of the Mela unit.
At the confluence of the T.te Patrì with its right tributary F.ra Santa Venera, laminated Variscan *whitish muscovite±biotite±garnet marbles* of the Mela unit, many meters in thickness, overthrust the Variscan *dark graphite+garnet phyllites* of the Piraino unit; this latter, in turn, tectonically rests onto the Variscan *silver-grey chlorite-muscovite phyllites* of the Mandanici unit. In this very limited area the original geometries between these tectonic units are evident (Figs. 2.2a and b).

Fig. 2.2a - Overthrusting between the Variscan whitish *muscovite+biotite+garnet marbles* of the Mela unit (MeU) and the underlying *Variscan dark graphite+garnet phyllites* of the Piraino unit (PU). Loc.: T.te Patrì – F.ra Santa Venera confluence (38°03'00.0'' N, 015°12'35.8'' E, altitude 310 m a.s.l.). Central-Northern Peloritani Mts.

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Fig. 2.2b - Overthrusting between the Variscan *dark graphite+garnet phyllites* of the Piraino unit (PU - more evident in Fig. 2.2a because of vegetation cover) and the underlying Variscan *silver-grey phyllites* of the Mandanici unit (MaU). Loc.: T.te Patrì – F.ra Santa Venera confluence, 500 m South of Stop 2.2a. Central-Northern Peloritani Mts.

Stop 2.3. Left slope of the Fiumara Santa Venera.

Mandanici unit Paleozoic low- to medium-grade metamorphic basement: Variscan green-silver chlorite phyllites.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

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In the map sheet "Barcellona P.G." the MaU lies in the Central-Southern part of the map, extending for about 25 sq km and reaching up to 500 m in thickness, from Santa Lucia Valley in the South-East, to Tripi village in the South-West. The main overthrusting contacts are clearly evident at the top with: the Piraino unit biotite+garnet phyllites, South-East of Rocca Timogna and in the right slope of the Santa Venera valley (Western versant of Mt. Ficherelle); the Mela unit paragneisses and micaschists, in the intermediate Mela Valley; the Aspromonte unit augen gneisses, on the northern slope of Pizzo Polo, North of Fantina village. At the bottom, the MaU overthrusts the Fondachelli unit graphite phyllites, metarenites and quartzites along both slopes of the F.ra Santa Venera and in the left slope of the T.te Fantina, and the San Marco d'Alunzio unit polychrome slates and phyllites in Portella Fossa Lupa (South of Pizzo Mualio).
In this area, the MaU can be seen with both the basement and the cover (Monte Ficherelle fm.).

500 m South the Stop 2.2, *the MaU Variscan phyllites grading to metarenites crop out in banks extending for several kilometers with thicknesses up to 100 m or more* (Fig. 2.2b). *These lithotypes are widespread in both slopes of the F.ra Santa Venera and T.te Patrì-Fantina* (Stop 2.6).
Their color varies from *silver-green* in the *muscovite+chlorite* types to *silver-grey* in the *muscovite* types, up to *grey-leaden* in the *biotite* lithotypes, with crystallinity that increases from the *muscovite+chlorite* to *biotite phyllites*. Mesoscopically, they show the Variscan Fv_{2m} main foliation, commonly crenulated, and a porphyroblastic texture which, according to the zoning, is characterized by syn- to post-Fv_1 and/or to post-Fv_{2m} blastesis of *chlorite*, *epidote*, *biotite*, *chloritoid* and *garnet*, which is less evident in the lower grade lithotypes. Alpine cataclastic to mylonitic effects are diffuse. These effects are responsible for retrogressive processes and localized LT mylonitic recrystallizations.

In the MaU, mono- and polymetallic (Zn, Cu, Fe, Pb, As, W, Ag, Au, etc.) deposits are widespread in a quartz and/or fluorite and/or calcite gangue, both as primary Paleozoic syn-sedimentary and exhalative volcanogenic deposits, remobilized during the Variscan regional metamorphism and the Alpine tectonics. The most important metallic deposits are recognized along the overthrusting contact between the Mandanici unit and the overlying Mela unit or the underlying Fondachelli unit (Fig. 2.3). Hydrothermal Plio-Pleistocene deposits are also present (Carbone et al., 2011 and reference there in; Cosenza et al., 2012).

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Fig. 2.3 - Mandanici unit. Alpine cataclastic band, many meters in thickness, along the overthrusting contact between the Variscan *grey-silver phyllites* of the Mandanici unit (MaU) and the underlying Variscan *black-pearly phyllites* of the Fondachelli unit (FU). Along the contact, *hydrothermal phenomena* are responsible for sulphides, sulphates, Cu-carbonates (azurite and malachite), Fe-oxides and Fe-hydroxides deposits. Loc.: Case Malasà, right slope of the F.ra Santa Venera. Central Peloritani Mts.

The MaU Variscan tectono-metamorphic evolution developed during three main deformation phases (Dv_1 – Dv_3), of which the first two were accompanied by syn- to post-kinematic metamorphism responsible for a prograde zoning, from the LT greenschist facies to the beginning of the amphibolite facies.
The Dv_1 originated the Fv_1 foliation, which is defined by muscovite+chlorite+albite (Figs. 2.4a and b), and, according to the zoning, also by localized biotite and snowball Mn- (Fig. 2.4b) to Mn-Fe-garnet (Figs. 2.4c and e).

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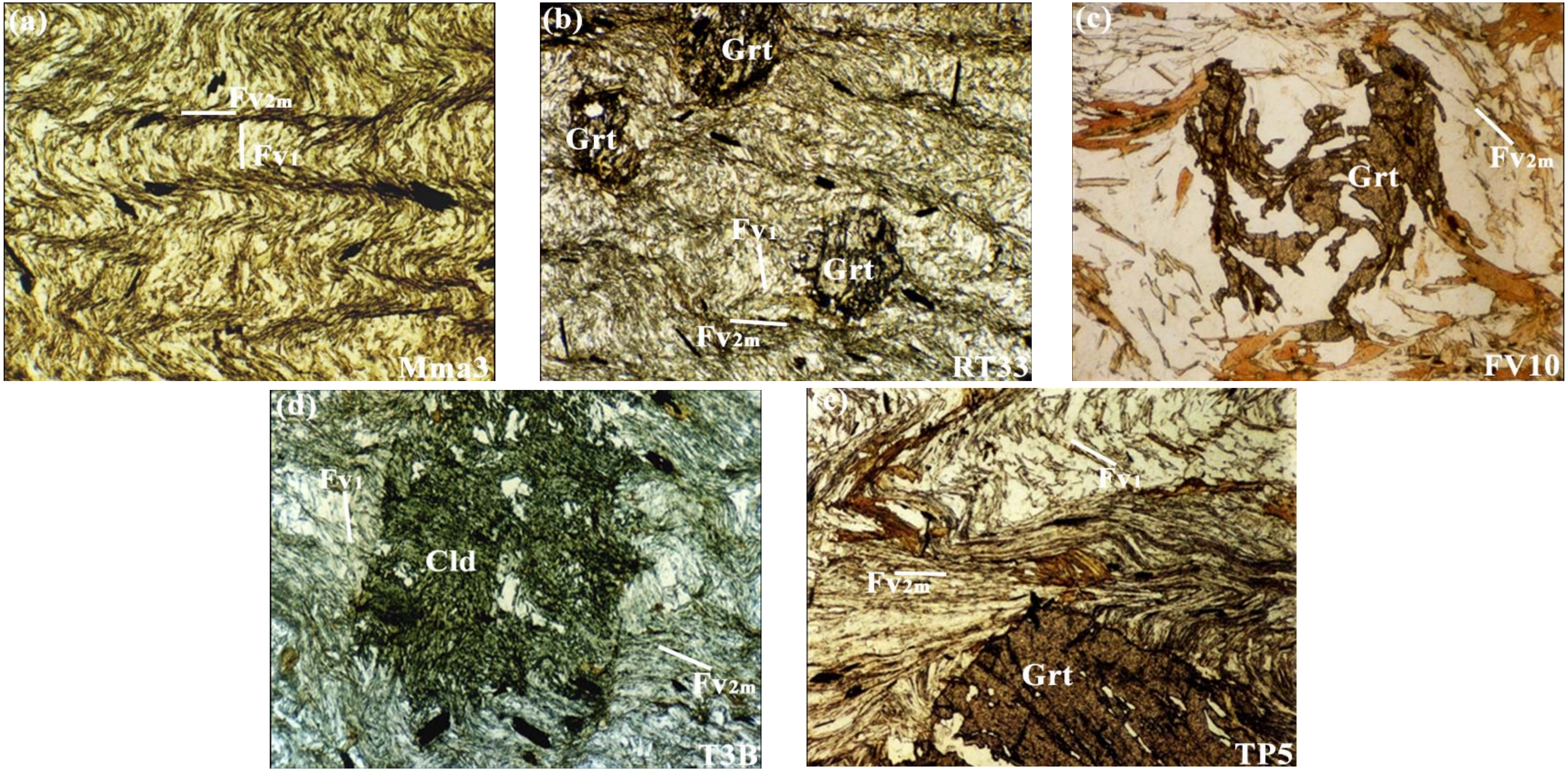

Figs. 2.4a to e - Mandanici unit: Variscan phyllites. Photomicrographs: preserved *Variscan Fv_1 foliation*, defined by chlorite+sericitic muscovite+quartz+albite in the chlorite zone (**a** and **b**), or by biotite+muscovite+albite/oligoclase+quartz in the other zones (**c** to **e**), in addition to a localized snowball Mn-**(b)** to Mn-Fe-garnet (**c**, **e**). The Fv_1 is overprinted by the crenulation cleavage Fv_{2m}, originating the main foliation, oriented at about 90° with respect to the first foliation, and defined by muscovite+chlorite (**a** and **b**) and/or biotite (**c** to **e**), depending on the zoning. Garnet develops from syn-Fv_1 to post-Fv_2 (**b**, **c** and **e**) and changes in composition from chlorite zone **(b)** to garnet-oligoclase zone **(e)**, whereas chloritoid grows in the post-Fv_2 **(d)** in the biotite zone. Samples: Mma3 **(a)**, FV10 **(c)** and T3B (d), PPL, 60x; RT33 **(b)** and TP5 (e), PPL, 45x. Loc.: right slope of the T.te Fiumedinisi. Eastern Peloritani Mts. **(a)** (from Messina et al., 2004b); Vallone Pulario, West of Pizzo Ruggeri. Central-Northern Peloritani Mts. **(b)**; right slope of the F.ra Santa Venera. Central Peloritani Mts. (**c** and **d**); Pagliara village, South-East of Mandanici. Eastern Peloritani Mts. **(e)** (from Messina & Macaione, 2010).

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In the post-Dv_1 porphyroblasts of chlorite, muscovite and biotite develop, in addition to ilmenite, epidote and Mn-Fe- or Fe-garnet.
The Dv_2 was responsible for the Fv_{2m} crenulation cleavage, which is the main foliation, oriented at about 90° with respect to the first foliation, and is defined by muscovite, chlorite (Figs. 2.4a and b), albite, biotite (Figs. 2.4c to e), Fe-garnet and oligoclase (Fig. 2.4e), depending on the zoning. The same minerals develop up to post-Dv_2, in addition to chloritoid (Fig. 2.4d), which grows in the biotite zone. Consequently, garnet develops with a snowball structure from syn-Fv_1 to post-Fv_2 (Figs. 2.4b, c, e), whereas chloritoid grows in the post-Fv_2 (Fig. 2.4d).
The Dv_3 created an irregular spaced and not penetrative crenulation.
According to the first results of a mineral chemistry study and phase relations, the thermobaric peak occurred in each zone during the Dv_2 which, as a whole, realized under T<400°C with P of about 0.2 GPa suggested by the muscovite-Mn-garnet-chlorite paragenesis typical of chlorite zone of greenschist facies, to T= 550°C and P around 0.3 GPa indicated by the Fe-garnet-oligoclase paragenesis typical of the greenschist to amphibolite facies transition.

Mandanici unit Mesozoic sedimentary cover: Monte Ficherelle fm.
Various sedimentary lithotypes are exposed in discontinuous and limited slices between the Mandanici and Piraino units, along the Mt. Pizzicari-Mandanici village alignment (South-Eastern sector of the map Sheet “Barcellona P.G.”), and South of Mt. Ficherelle on the right side of the T.te Fantina. The strong deformation which has affected these exposures does not permit the reconstructon of the original stratigraphic sequence. These deposits, previously ascribed to the Novara Unit (Truillet, 1961), or to the Rocca Novara Unit of Lentini & Vezzani (1975), and interpreted as the Mandanici unit sedimentary cover, or as the Alì unit Mesozoic cover (APAT, 2008), represent the original Mandanici unit sedimentary cover (ISPRA, 2011). The wider slices crop out North-East of Mandanici (Pizzo Ilici) (Figs. 2.5a and b), along the T.te Cavallo North of Mandanici village, upstream of the confluence between the T.te Dinarini and T.te Iadizzi, and on the South-western side of Mt. Ficherelle (in the right slope of the T.te Fantina) (Figs. 2.5c and d). Smaller slices are exposed in the slope of the F.ra Dinarini and South of Mt. Pizzicari (Contrada Floresta).

The Monte Ficherelle fm. is made up of prevailing pinkish vacuolar evaporitic dolostones, yellowish limestones and sandstones, yellowish and greyish cargneules, which sometimes contain gypsum. These last are cataclastic and crossed by thick system of fractures filled by carbonates (Fig. 2.5e).

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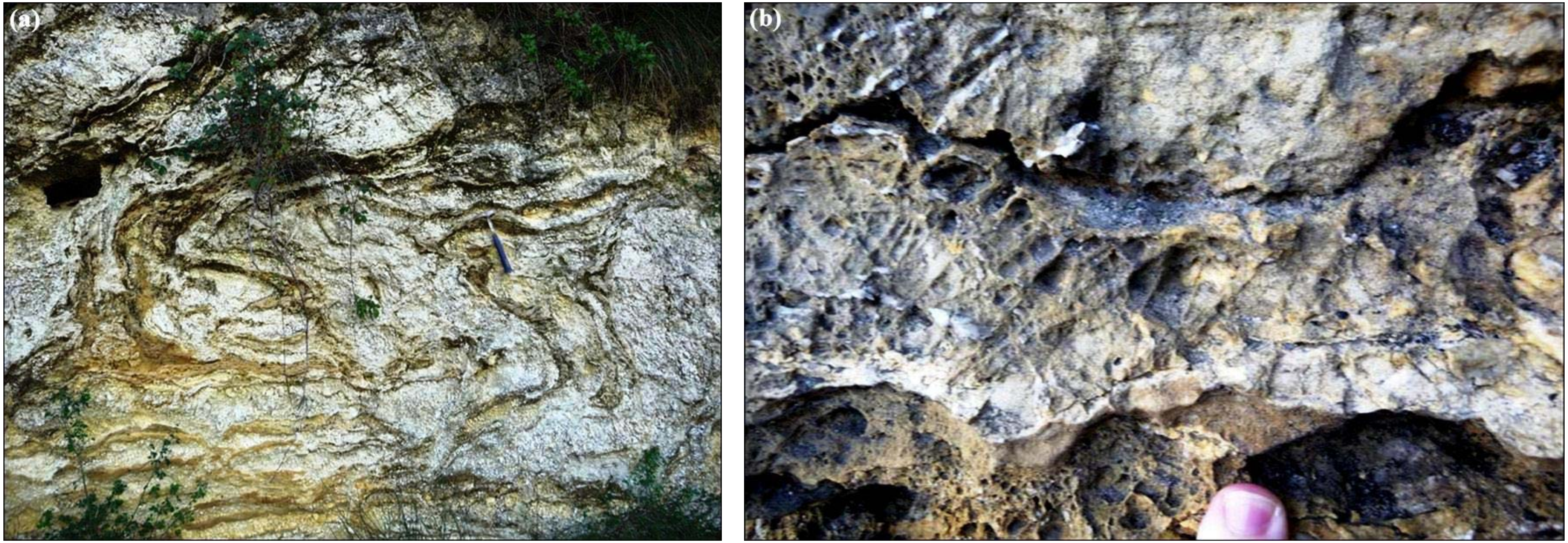

Figs. 2.5a and b - Mandanici unit: *Mesozoic sedimentary cover*. Upper Triassic whitish micro-selenite gypsum rock with disharmonic folds (**a**); Upper Triassic yellowish cargneules with planar texture (**b**). Loc.: North-East of Mandanici village (Pizzo Ilici).

The limits of the formation are poorly defined because of their lenticular shape, the strong tectonics and the vegetative cover. The formation lies disconformably on the Mandanici unit phyllites. The upper boundary is determined by the tectonic contact with the Piraino unit phyllites, and at Pizzo Ilici (North-East of Mandanici village) with some thin slices of the Aspromonte unit augen gneisses.
The real thickness of the formation ranges from 10 to 50 m. The apparent thickness because of tectonic repetition (Pizzo Ilici) can reach 150-200 m. As fossilized faunal content is absent, the deposition environment could be marine and/or transitional.
The formation is attributed to Upper Triassic?–lower Lias, for correlation with similar lithotypes (evaporitic dolostones and cargneules) of the Alì unit.

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Fig. 2.5c - Mandanici unit: Mesozoic sedimentary cover. High *angle overthrusting* contact between the Variscan black-pearl graphite+garnet phyllites of the Piraino unit (PU) and the underlying Mesozoic evaporitic cover *(yellowish gypsiferous cargneules)* of the Mandanici unit (MaU). Loc.: South-West of Mt. Ficherelle, in the right slope of the T.te Fantina. Central Peloritani Mts.

Figs. 2.5d and e - Mandanici unit: Mesozoic sedimentary cover. Upper Triassic? marly limestones, alternating to siliciferous clays and fine-grained sandstones **(d)**; alternating levels of Upper Triassic limestones and gypsiferous cargneules, crossed by fracture systems filled by carbonates **(e)**. Loc.: South-West of Mt. Ficherelle, in the right slope of the T.te Fantina. Central Peloritani Mts. **(d)**; left slope of the Vallone Carbonara (South of Castello di Margi). Central Peloritani Mts. **(e)**.

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Stop 2.4. Right slope of the Fiumara Santa Venera, near the confluence with the Fiumara Floresta.

Fondachelli unit Paleozoic low-grade metamorphic basement: Variscan black-pearl phyllites and metarenites.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

Along the left slope of the F.ra Santa Venera (Sheet 600 - Barcellona P.G.), South of Stop 2.3, the overthrusting contact between the Variscan *silver-grey phyllites* of the Mandanici unit and the underlying Variscan *black-pearl phyllites* and quartzites of the Fondachelli unit can be observed (Fig. 2.6a).

The FU phyllites *grading to metarenites are well evident in the right slope of the F.ra Santa Venera* (Fig. 2.6b)*, at the confluence with the F.ra Floresta. Phyllites, metarenites and quartzites, in a monotonous alternation, stain both slopes of the F.ra Santa Venera with their black-pearl colour, and continue along to the T.te Fantina - Montagna di Vernà - Serra Pasaleo (South of Montagna di Vernà) aligneament up to the T.te Novara-Paratore, for about 20 sq km and with thickness up to 500 m, often forming entire reliefs* (Fig. 2.6c).

Fig. 2.6a - Fondachelli unit. Meter-thick *Alpine cataclastic tectonic band* affecting the folded Variscan black-pearl quartzites of the Fondachelli unit (FU) and the overlying Variscan *silver-grey phyllites* of the Mandanici Uni (MaU). Loc.: left slope of the middle tract of the F.ra Santa Venera. Central Peloritani Mts.

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Figs. 2.6b and b1 - Fondachelli unit: Variscan metarenites. A bank, many hundreds of meters in extension, of Variscan black-pearl metarenites crops out in the right slope of the F.ra Santa Venera. They show a banded texture along the crenulated Fv_{2m} main foliation defined by heterogeneous in grain-sized quartz-rich levels. Centimeter-thick quartz layers (Qtz), parallel to the crenulated main foliation, are also common. Loc.: right slope of the F.ra Santa Venera, near the confluence with the F.ra Floresta (38°01'59.5'' N, 015°13'23.4'' E; altitude 395 m a.s.l.). Central Peloritani Mts.

Other overthrusting contacts at the top of the FU basement with the overlying *muscovite+chlorite phyllites* of the Mandanici unit are well exposed in the left slope of the T.te Fantina; with the augen gneisses of the Aspromonte unit, at Montagna di Vernà, on the North-Eastern slope of Mt. Licciardi, and along the San Marco-Fantina road. The tectonic contact at the bottom with slates and phyllites of the San Marco d'Alunzio unit is exposed between the Fantina village and Mt. Licciardi. On the South-West slope of the Mt. Muscià, the FU basement is unconformably covered by the Capo d'Orlando flysch.

At the mesoscale *phyllites*, *metarenites* and *quartzites* show a very fine grained and a crenulated Variscan Fv_{2m} main foliation (Fig. 2.6b1). Quartz veins are very abundant (Fig. 2.6b1). At the microscale the Fv_{2m} foliation, which is defined by *chlorite+white mica+quartz±albite+graphite*, is affected by a crenulation cleavage and

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transposed in a thin Fv_3 foliation oriented at about 90° with respect to the main foliation, marked by the same minerals but where the graphite prevails (Figs. 2.7a, b, d, d[1]). The Alpine tectonics were the origin of widespread mylonitic effects along shear zones (Fig. 2.7c) and of remobilization and recrystallization of metallic deposits, such as *galena, sphalerite, chalcopyrite, magnetite, pyrrhotite, tetraedrite*, in a *quartz±fluorite±siderite±ankerite gangue*, as in the left slope of the F.ra Santa Venera (Case Malasà - Fig. 2.3).

Fig. 2.6 c - Fondachelli unit. Variscan black-pearl phyllites, metarenites and quartzites cropping out in the Mandale locality, with a thickness of about 500 m. In the foreground *alluvial conoid deposits* can be observed. Loc.: right slope of the F.ra Santa Venera. Central Peloritani Mts.

The ***Variscan FU tectono-metamorphic evolution*** took place during four main deformation phases (Dv_1 – Dv_4), of which the first three were syn-metamorphic and responsible for a LT greenschist facies process.

The Dv_1 originated the Fv_1 foliation, wihch is not evident in the field. The Dv_2 was responsible for the pervasive Fv_{2m} main foliation, defined by sericite+chlorite+quartz+albite (Fig. 2.7a) and which transposed post-Fv_1 ilmenite. The Dv_3 originated a crenulation cleavage of the Fv_2 with the formation of a thin Fv_3 defined by the same minerals, but where graphite prevails (Figs. 2.7a, b, d[1]).

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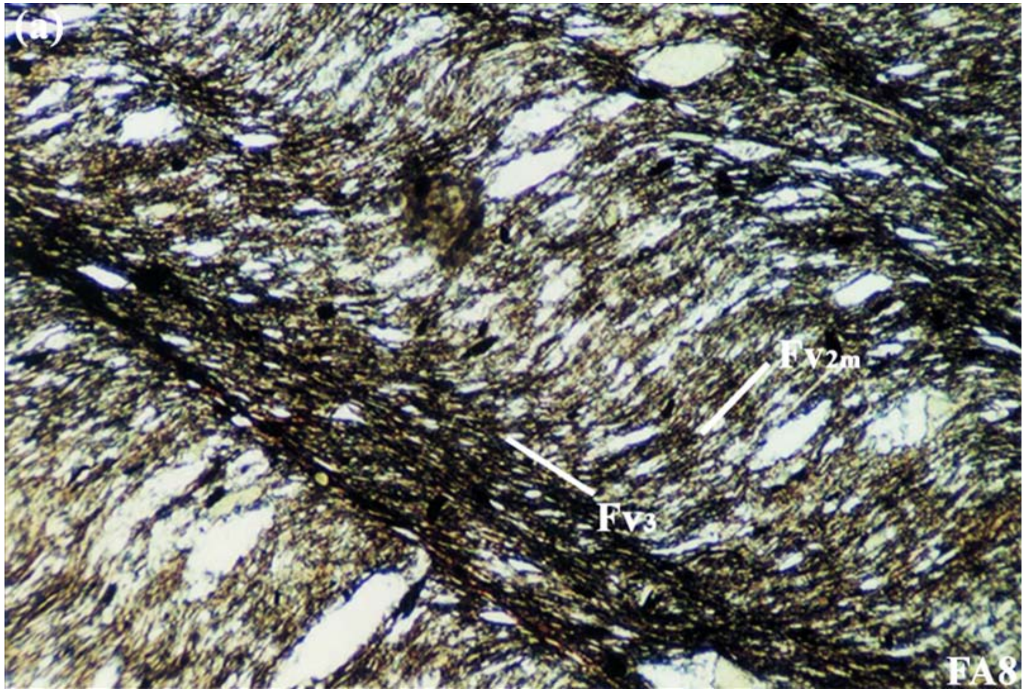
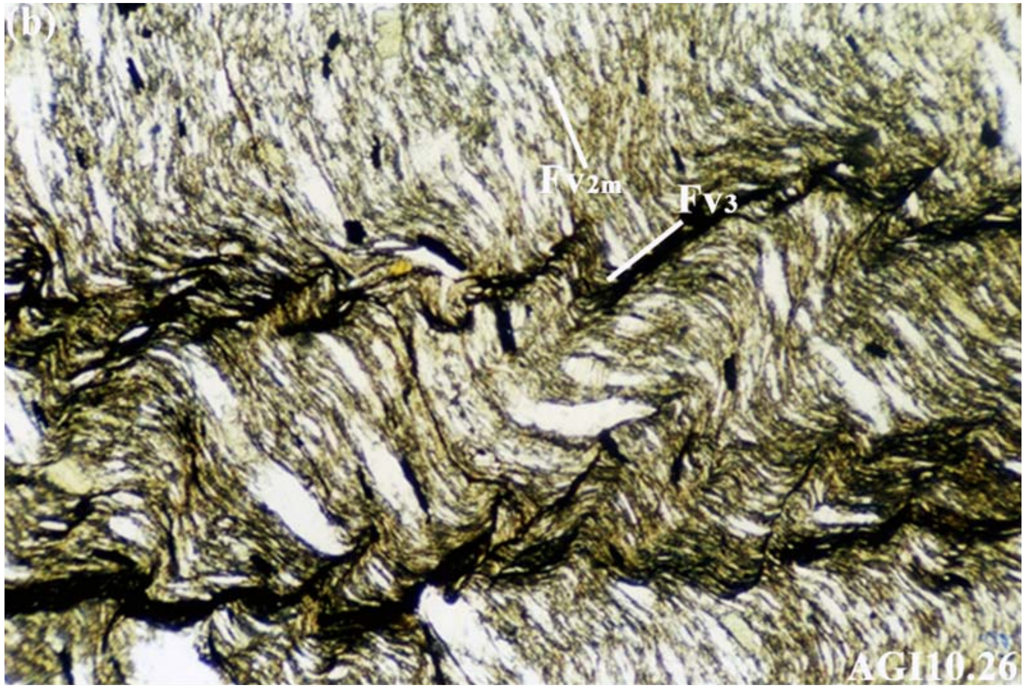
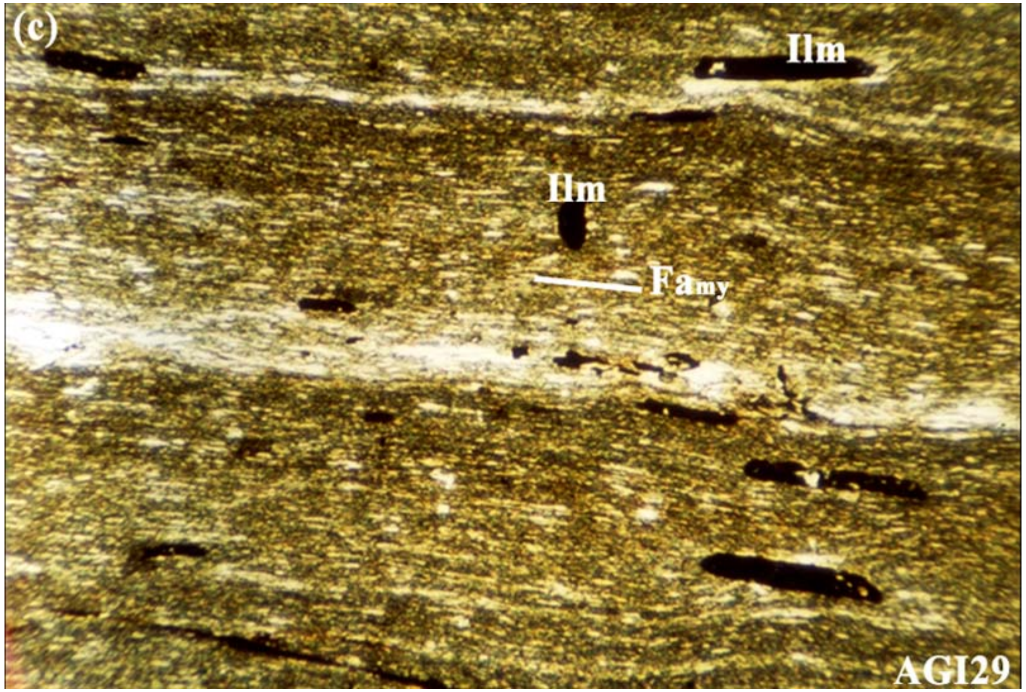


Fig. 2.7a to c - Fondachelli unit: Variscan *graphite-chlorite phyllites*. Photomicrographs: Variscan Fv_{2m} main foliation defined by chlorite+sericite+quartz+graphite+albite and transposed post-Fv_1 ilmenite. Small-sized of post-Fv_{2m} white mica and chlorite are olso present A crenulation cleavage Fv_3, overprints, at about 90°, the main foliation and is marked by the transposition and recrystallization of the same Fv_{2m} minerals, with abundant graphite (**a** and **b**); the Fv_3 was further affected by Dv_4 asymmetric microfolds rotated at about 45° with respect to the third foliation **(b)**; Alpine mylonitic foliation Fa_{my} responsible for a very fine-grained recrystallization of graphite, chlorite, white mica and quartz, wraps up imenite (Ilm) porphyroclasts **(c)**. Samples: FA8 **(a)**; AGI10.26 **(b)**; AGI29 (c). PPL, 60x. Loc.: left slope of the F.ra Santa Venera. Central Peloritani Mts. (**a** and **b**); left slope of the T.te Fantina. Central Peloritani Mts **(c)**.





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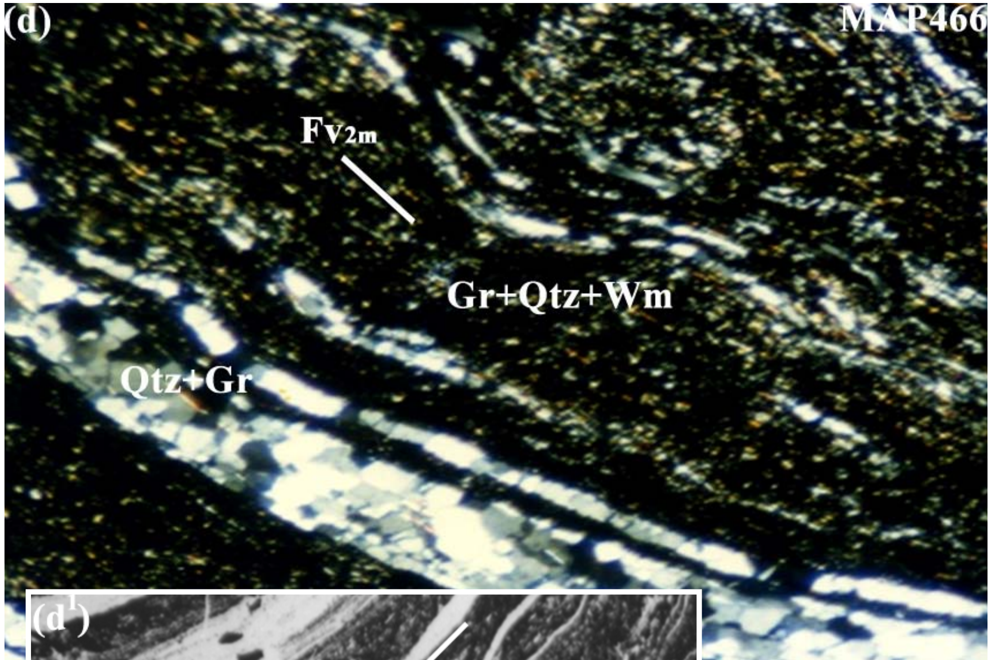
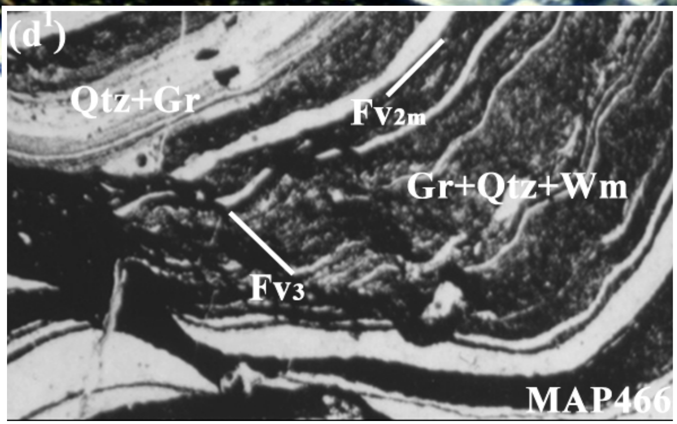
According to the mineral associations, the thermobaric peak occurred during the Dv_2, which realized under T<420°C and P between 0.2-0.3 GPa, suggested by the white mica-chlorite-albite paragenesis typical of chlorite zone of greenschist facies (Messina, 1998b; Messina et al., 2004b).





Figs. 2.7d and d[1] - Fondachelli unit: Variscan *graphite-chlorite quartzite*. Photomicrographs: Variscan Fv_{2m} main foliation defined by alternate layers of quartz+graphite (Qtz+Gr) and of graphite, quartz and white mica (Gr+Qtz+Wm) (**d**, **d[1]**). The thin and unpenetrative cleavage Fv_3 is defined by transposed graphite, and develops at about 90° with respect to the Fv_{2m} main foliation (**d[1]**). Sample: MAP 466. CP, 60x (**d[1]**); PPL, 45x (**d[2]**). Loc.: left slope of the F.ra Santa Venera. Central Peloritani Mts.

Stop 2.5. Torrente Patrì valley-bottom road - Milici - Fantina asphalt road junction (left hydrographic slope of the Torrente Patrì-Fantina).

Piraino unit Paleozoic low- to medium-grade metamorphic basement: Variscan dark-grey biotite+garnet+graphite phyllites (biotite-garnet zone). *Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600). 1:50.000 scale - CARG Project.*

Backon the asphalted road that runs along the T.te Patrì–Fantina riverbed in the left slope, connecting Milici to Fantina villages, alternations of low-grade rocks, mainly consist of phyllites grading to metarenites continue to prevail. Careful and detailed observations of the colour, grain-size, texture and minerals characterizing the different outcrops, in addition to geometries, folds and faults that affected them, allow to recognize phyllites and metarenites of the Piraino, Mandanici and Fondachelli units going to Fantina from Stop 2.5 to Stop 2.6 and Stop 2.7. The overthrusting contacts between them can be rarely evident along the road, but they can be well observed in the inner areas of the large and long slope.

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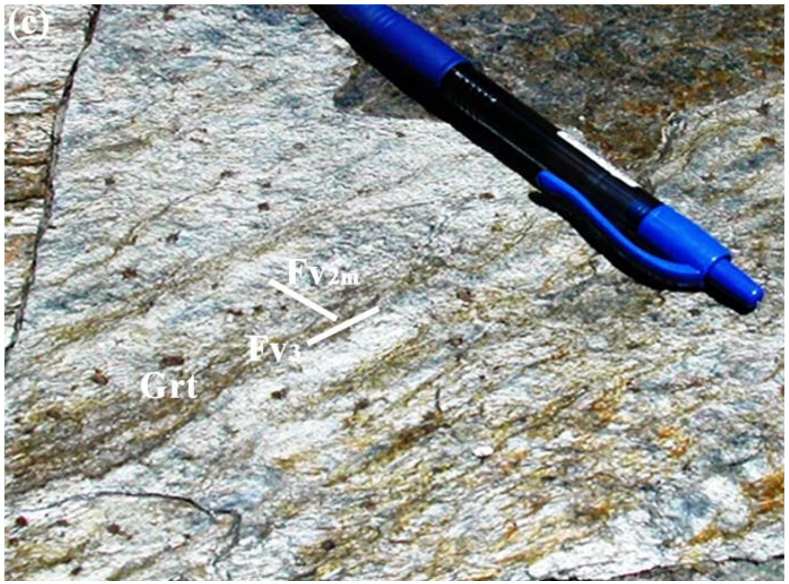
At the Stop 2.5, situated few meters South of the T.te Patrì valley bottom road – Milici - Fantina road junction, a many meters thick layer of ***dark-grey biotite+garnet+graphite phyllite of the Piraino unit crops out*** (Figs. 2.8a to c).



Figs. 2.8a to c - Piraino unit: Variscan *phyllites from the biotite-garnet zone*. Variscan dark-grey biotite+garnet+graphite phyllites cropping out in layers, many meters in thickness **(a)**, showing a porphyroblastic texture, with a fine-grained foliate matrix oriented along the Fv_{2m} main foliation and overprinted, at high angle (about 90°), by the thin spaced crenulation cleavage Fv_3 defined by biotite (**b**, **c**), on which millimeter-sized porphyroblasts of garnet (Grt) develop **(c)**. Loc.: T.te Patrì valley-bottom road - Patrì - Fantina road junction, (38°03'19.0" N, 015°11'25.1" E; altitude 268 m a.s.l.). Central Peloritani Mts.

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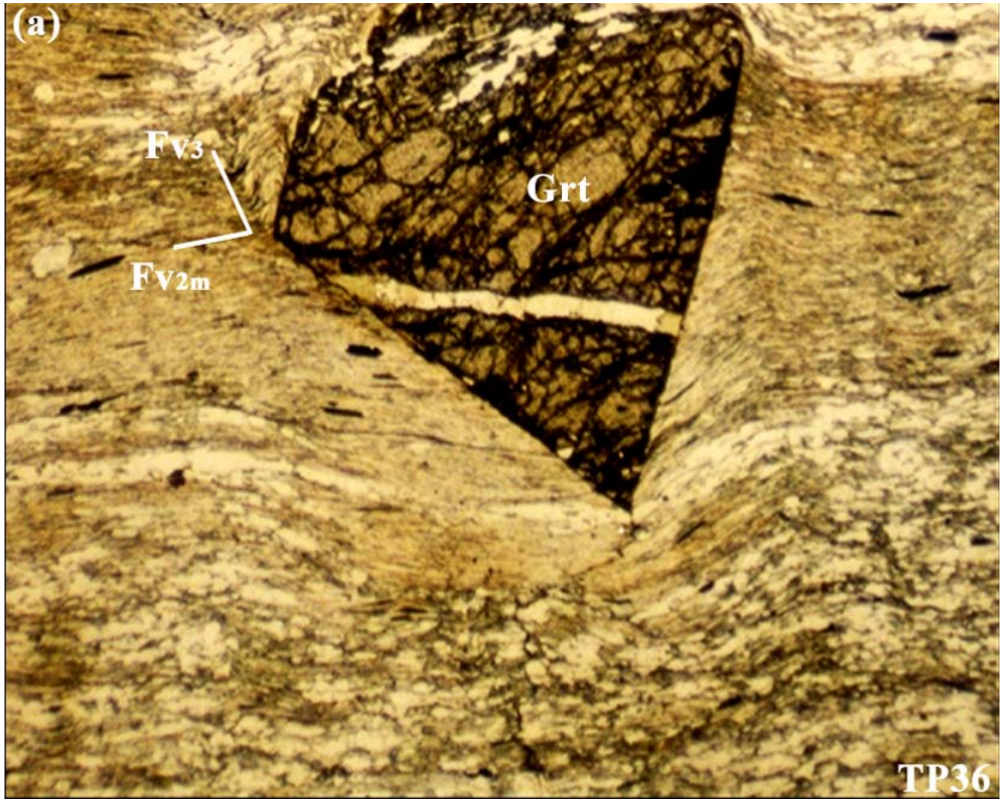
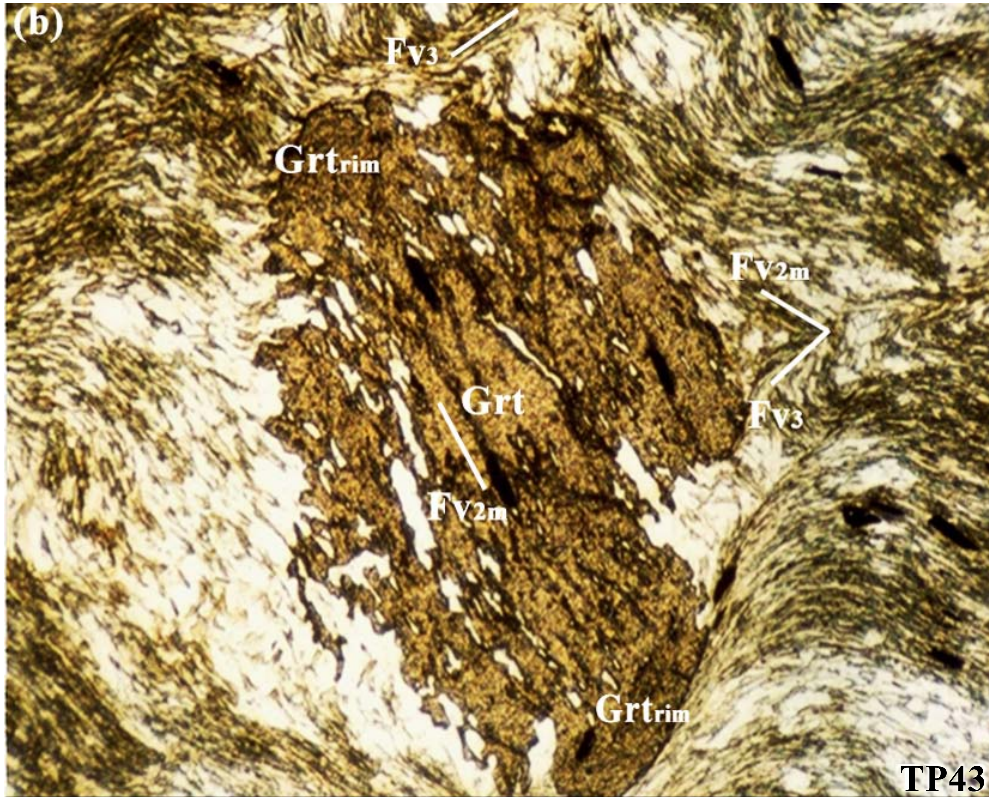
Phyllites exhibit a porphyroblastic texture, characterized by a fine grained foliated matrix oriented along the Fv_{2m} main foliation and overprinted, at about 90°, by the thin spaced crenulation cleavage, Fv_3, on which millimeter-sized *garnet* porphyroblasts develop (Figs. 2.8a to c). At the microscale, the Fv_2 main foliation, defined by prevalent *white mica* and by *quartz*, *biotite*, rare *albite* and transposed post-Fv_1 *ilmenite*, was deformed by a thin, spaced and non penetrative crenulation cleavage, Fv_3, characterized by recrystallized *biotite* (Figs. 2.9a, b). Syn-Fv_1 to post-Fv_3 *garnet* develops (Fig. 2.9a) preserving the Fv_2 foliation defined by *quartz*, and locally exhibiting a thin static Fe-rich post-Fv_3 rim (Fig. 2.9b).





Figs. 2.9a and b - Piraino unit: Variscan *phyllites from the biotite-garnet zone*. Photomicrographs: Variscan Fv_{2m} main foliation defined by prevalent white mica and by quartz, biotite, rare albite and transposed post-Fv_1 ilmenite, deformed by a thin, spaced and non-penetrative crenulation cleavage Fv_3, characterized by recrystallized biotite (**a** and **b**). Syn-Fv_1 to post-Fv_3 garnet (Grt), preserving the Fv_{2m} foliation defined by quartz (**a**), with a thin post-Fv_3 Fe-rich rim (Grtrim) (**b**), also develops. Samples TP36 (**a**) and TP43 (**b**). PPL, 60x. Loc.: T.te Patrì valley bottom road – Patrì - Fantina road junction. Central Peloritani Mts.

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Stop 2.6. 2 km South of Stop 2.5, Milici - Fantina road.

Mandanici unit Paleozoic low- to medium-grade metamorphic basement: Variscan silver-grey chlorite phyllites and metarenites (chlorite zone).
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

In the Stop 2.6, located about 2 km South of Stop 2.5, along Milici - Fantina road, ***Variscan silver-grey chlorite+muscovite*** *phyllites of the Mandanici unit crop out in banks up to 100 m in thickness* (Figs. 2.10a-c).

The phyllites show a fine-grained foliated texture oriented along a strongly crenulated Fv_{2m} main foliation (Figs. 2.10a to c). At the microscale the preserved Fv_1 foliation, mainly defined by *muscovite+chlorite+quartz* and rare *albite*, is overprinted, at high angle (about 90°), by the penetrative crenulation cleavage Fv_2, corresponding to the main foliation, characterized by recrystallized *chlorite* and *muscovite* and transposed post-Fv_1 *ilmenite* (Fig. 2.11).

Fig. 2.10a - Mandanici unit: Variscan *phyllites from the chlorite zone*. Bank of siler-grey chlorite+muscovite phyllites, up to 100 m in thickness. Loc.: Milici - Fantina road, 2 km South of the Stop 2.6. Central Peloritani Mts.

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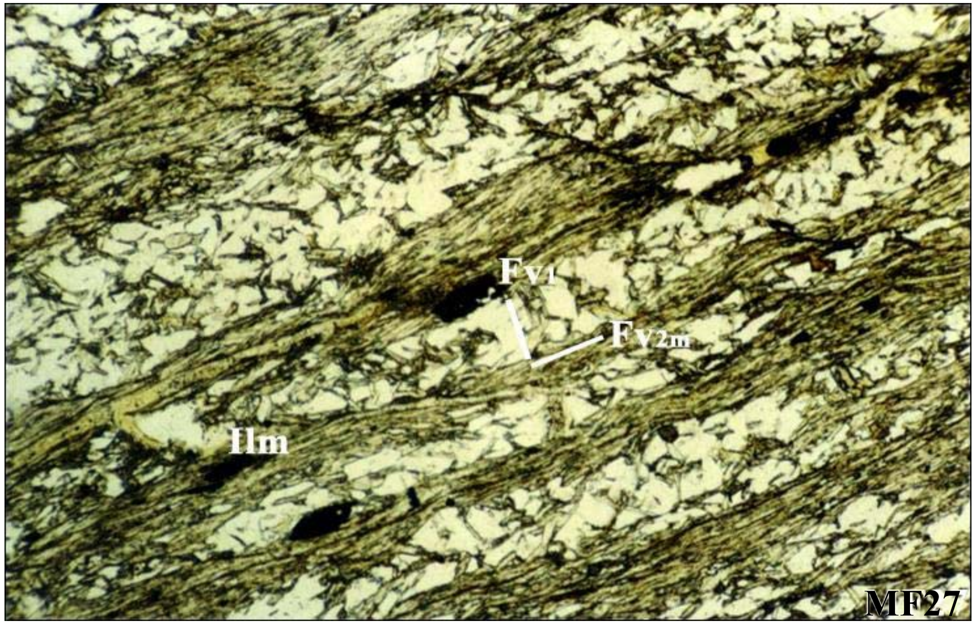
Figs. 2.10b and c - Mandanici unit: Variscan *phyllites from the chlorite zone.* Mesostructure of silver-grey chlorite+muscovite phyllites showing the crenulated Fv_{2m} main foliation (Fig. 2.10c shows a decimetric block). Loc.: Milici - Fantina road, 2 km South of the Stop 2.6. Central Peloritani Mts.

Fig. 2.11 - Mandanici unit: Variscan *phyllite from the chlorite zone*. Photomicrograph: preserved Variscan Fv_1 foliation, mainly defined by chlorite+muscovite+quartz, overprinted, at about 90°, by the penetrative crenulation cleavage Fv_2, corresponding to the main foliation, characterized by recrystallized chlorite and muscovite and transposed post-Fv_1 ilmenite (Ilm). Sample MF27. PPL, 60x. Loc.: Milici - Fantina road, 2 km South of Stop 2.6. Central Peloritani Mts.



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Stop 2.7. North of Fantina village, Milici - Fantina road.

Fondachelli unit Paleozoic low-grade metamorphic basement: Variscan black-pearl graphite phyllites.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

In the Stop 2.7, North of Fantina village, along the Milici - Fantina road, ***Fondachelli unit black-pearl graphite*** *phyllites, many meters in thickness, crop out* (Figs. 2.12a-c).

Phyllites have a very-fine grained foliated texture oriented along a crenulated Fv_{2m} main foliation (Figs. 2.12a to c). At the microscale the Fv_{2m} main foliation, which is defined by *graphite+sericite+chlorite+quartz*, was overprinted, at about 90°, by the crenulation cleavage Fv_3, characterized by *graphite* and a lesser amount of *chlorite, sericite* and *quartz* (Fig. 2.13).

Fig. 2.12a - Fondachelli unit: Variscan phyllites. *Black-pearl graphite phyllites*, locally grading to metarenites. Loc.: Milici - Fantina road, North of Fantina village (38°01’45.4’’ N; 015°10’59.4’’ E, altitude 382 m a.s.l.). Central Peloritani Mts.

DOI: 10.3301/GFT.2013.04

Figs. 2.12b and c - Fondachelli unit: Variscan metarenites. Mesostructures: *black-pearl graphite metarenites* **(b)** showing a crenulated Fv_{2m} main foliation **(c)**. Loc.: Milici-Fantina road, North of Fantina village (38°01’45.4’’ N; 015°10’59.4’’ E, altitude 382 m a.s.l.). Central Peloritani Mts.

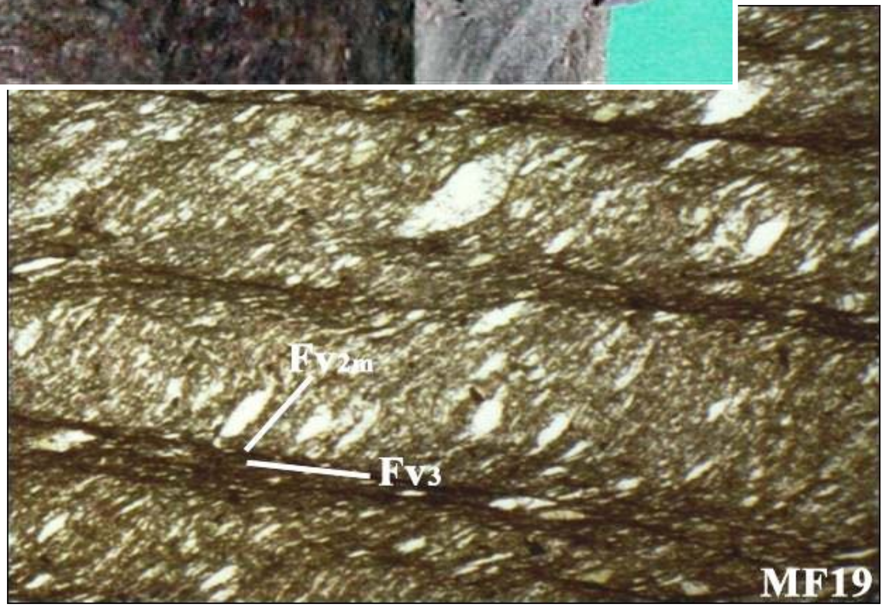

Fig. 2.13 - Fondachelli unit: Variscan phyllites. Photomicrograph: Variscan Fv_{2m} main foliation defined by graphite+sericite+chlorite+quartz, overprinted at about 90° by the *crenulation cleavage* Fv_3, characterized by graphite and subordinate chlorite, sericite and quartz. Sample MF19. PPL, 60x. Loc.: Milici - Fantina road, North of Fantina village (38°01’45.4’’ N; 015°10’59.4’’ E, altitude 382 m a.s.l.). Central Peloritani Mts.

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Stop 2.8. Raiù village.

Geo-cultural site: remains of the Medieval rural village along the homonymous torrent, where the San Marco d'Alunzio unit Paleozoic low-grade metamorphic basement crops out.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

Flooding phenomena have always characterized the Peloritani territory and they have intensified in last fifty years. The flood of January 1973, which affected the whole Peloritani territory, from the Tyrrhenian coast to the Ionian *coast, was responsible for the devastation of the entire hydrographic basin of the T.te Patrì-Fantina-Fondachelli and also claimed numerous victims as a result of* landslides in the area.

***One such area of devastation was the picturesque* medieval rural village of Raiù, situated along the homonymous torrent, which was destroyed by landslides** (Figs. 2.14a to c).
Today there are only remnants of the old urban structure, still throbbing with life (Figs. 2.14b and c).
While the course of the torrent has changed its structure, small, original beautiful corners are still preserved. The proximity of urban remnants to the water course, and the pleasing polychromy of the San Marco d'Alunzio unit rocks which outcrop there and in the alluvial deposits of the riverbed and the peculiar vegetation makes this geo-cultural site a place with particular aesthetic value, worthy of being preserved and enjoyed through targeted projectst its redevelopment.

Fig. 2.14a – The Geo-cultural site of Raiù village. The aspect of the *T.te Raiù*, before the heavy rains of the late autumnal season, characterized by the contrast among the different shades of green of the vegetation and the pink colour of alluvial sands and blocks originated by the San Marco d'Alunzio basement (porphyroids). In the background, the remains of the Raiù village. Loc.: T.te Raiù. Central Peloritani Mts.

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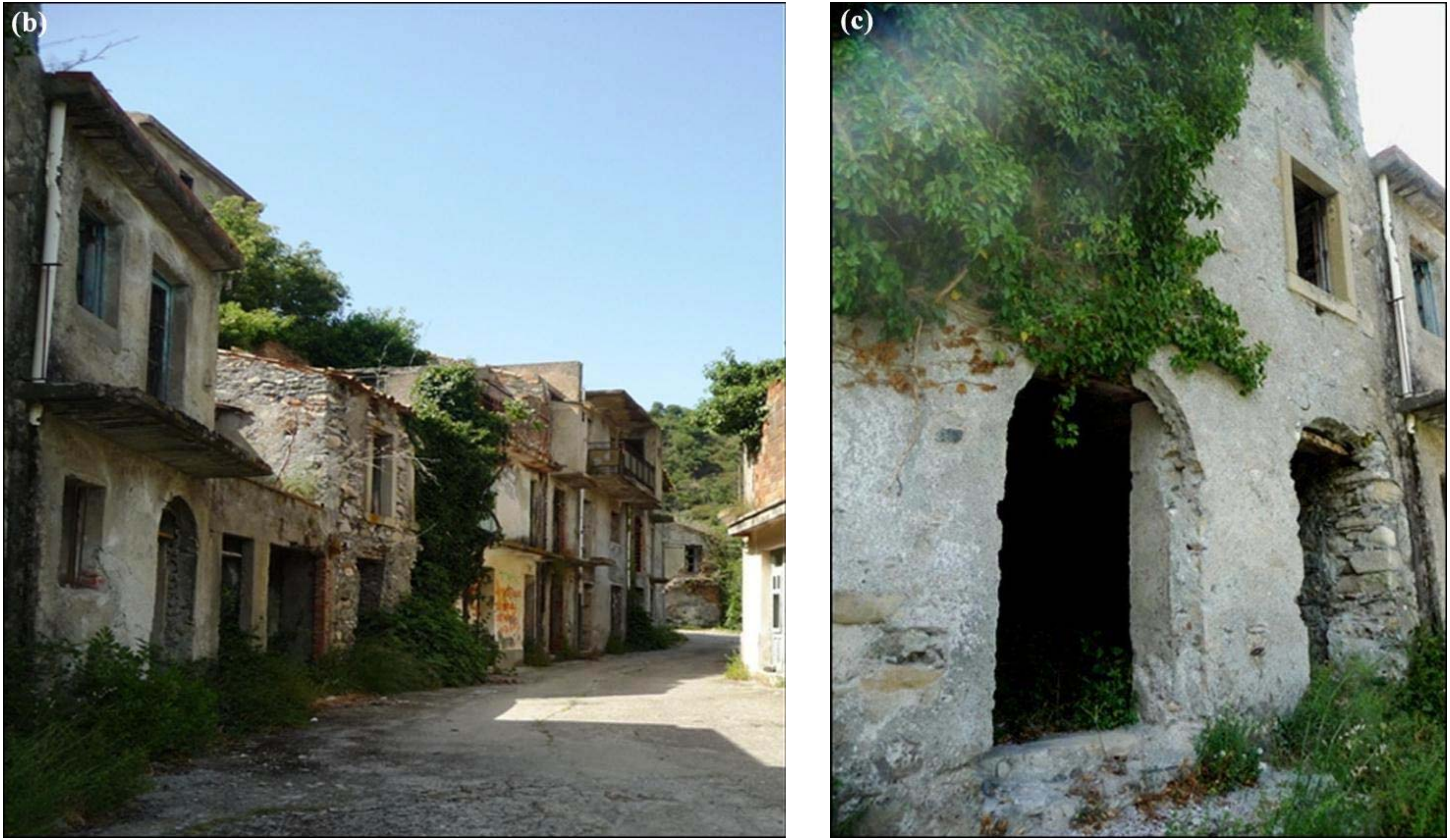

Figs. 2.14b and c - The Geo-cultural site of *Raiù village*. Urban remains of the medieval rural village situated along the homonymous torrent, where the polychrome San Marco d'Alunzio unit low-grade basement crops out. Loc.: Raiù village, altitude 464 m a.s.l.). Central Peloritani Mts.

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Stops 2.9a, b and c. Torrente Fantina – Mt. Cipolla (757 m a.s.l.) dirt road.

San Marco d'Alunzio unit Paleozoic low-grade metamorphic basement: Variscan pale-pink porphyroids (Stop 2.9a), dark-violet metabasalts (Stop 2.9b) and dark bluish-grey slates (Stop 2.9c).
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600). 1:50.000 scale - CARG Project.

Going towards the East from Raiù village (Stop 2.7) *we arrive at the T.te Fantina, where, in both slopes,* ***the San Marco unit low-grade basement continues to outcrop.*** *It forms the entire right slope and the Mt. Cipolla* (Stops 2.9a, b and c), *strongly destroyed by Aeolian structures.*

In the Sheet "Barcellona P.G.", the SMU, which is represented only by the basement, extends continuously from the T.te Dinarini in the South-East of sheet (near Mandanici) to the T.te Novara-Paratore in the South-West, for about 25 sq km and with a maximum thickness of 600 m. The overthrusting contacts between the SMU basement and the overlying units are well exposed between Carnale-Fantina villages and Mt. Licciardi, with the Fondachelli unit; at Portella Fossa del Lupo (right slope of the T.te Dinarini) and in the East of Mt. Casalotto (South of Basicò village), with the Mandanici unit; at Mt. Pietre Rosse and North of Caserma Prugnola, with the Mela and Piraino units; along the Eastern and Southern slopes of Pizzo Polo (Montagna di Vernà), with the Aspromonte unit. Locally, the SMU basement is covered unconfomably by the Capo d'Orlando flysch (between Mt. Casalotto and Serro Orsino; between Mt. Bammina and T.te Chiappera, and at Mt. Olivetta, South-East of Novara di Sicilia village.
Along the T.te Fantina–Mt. Cipolla dirt road, alternating successions of very-fine grained and polycrome slates, phyllites, metarenites and acidic and basic metavolcanics, meters in thickness and hundreds of meters in extension, can be observed (Figs. 2.15-2.19). *At the mesoscale, these rocks show the strongly crenulated Fv_{2m} foliation, crossed at about 90° by a Fv_3 foliation, which is well evident in the most pelitic types*.

At the **Stop 2.9a, *Variscan acidic metavolcanics*** crop out (Figs. 2.15a and b) showing pale-pink oriented micro-porphyroclastic texture (***porphyroids***). At the microscale they are made up of *albite* and *K-feldspar* porphyroclasts wrapped up by a Fv_{2m} main foliation (Fig. 2.18c). It is defined by alternating layers of *sericite+chlorite+graphite+opaques* (*ilmenite+hematite* prevailing) and *quartz+feldspars*, imprinted by the crenulation cleavage Fv_3 originating a thin foliation, defined by the same phyllosilicates and opaques.

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In analogous porphyroids of the Longi-Taormina unit, Lower Ordovician in age (Trombetta et al., 2004), a calc-alkaline affinity has been recognized (Ferla & Azzaro, 1978).
Acidic metavolcanics are the most representative SMU rock types in terms of abundance. They are widespread in all the unit, forming large bodies in the eastern slope of Pizzo Tornio, near the Contrada Pergotere (South of Santa Barbara village), West of Serro Parrini (East of Santa Barbara), and to South-West of Mt. Casalotto.

Figs. 2.15a and b - San Marco d'Alunzio unit: Variscan porphyroids. *Pale-pink porphyroid* **(a)** showing a porphyroclastic and oriented texture along a strongly crenulated Fv_{2m} main foliation **(b)**. Loc.: T.te Fantina – Mt. Cipolla dirt road (38°00'13.2'' N; 015°12'14.3'' E, altitude 531 m a.s.l.). Central Peloritani Mts.

At **Stop 2.9b, *Variscan metabasalts*** crop out (Figs. 2.16a and b) which have a typical dark violet foliate texture and pale-pink quartz veins. At the microscale they consist of *chlorite+sericite+graphite+opaques+calcite±talc* growing, in different quantitative ratios, along the strongly crenulated Fv_{2m} main foliation, or as pseudomorphic associations after completely replaced mafic mineral phases. A thin Fv_3 foliation, defined by the same phyllosilicates and opaques, is also present.
In similar metabasalts of the Longi-Taormina unit, of still debated age, a Na-alkaline within plate affinity has been recognized (Ferla & Azzaro, 1978).
The main SMU metabasitic bodies, locally associated to ochre colour talcschists, are present near Carnale locality (South-West of Fantina village), West of Pernina village (left slope of the T.te Fantina), and between Pizzo Scopettati and Mt. Olivetta (East of Novara di Sicilia village).

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Figs. 2.16a and b - San Marco d'Alunzio unit: Variscan metabasalts. *Dark-violet metabasalts* (**a** and **b**). Loc.: T.te Fantina – Mt. Cipolla dirt road (38°00'11.1'' N; 015°12'34.1'' E, altitude 682 m a.s.l.). Central Peloritani Mts.

At the **Stop 2.9c, *Variscan slates grading to metarenites*** are present (Figs. 2.17a and b), the former of which are dark bluish-grey, the latter greyish-pink. They show a foliated texture and, also at the mesoscale, a strongly crenulated Fv_{2m} main foliation crossed, at about 90°, by a Fv_3 foliation. At the microscale, the crenulated Fv_{2m} foliation is defined by *sericite+chlorite+albite+graphite+opaques*, in different quantitative ratios, and transposed post-Fv_1 *ilmenite*. Post-F_2 *chloritoid* and/or *chlorite* are also common. The Fv_3 foliation is defined by the same phyllosilicates and opaques (Figs. 2.18a and b).

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Figs. 2.17a and b - San Marco d'Alunzio unit: Variscan slates. *Dark bluish-grey slats* **(a)** showing a foliated texture along a strongly crenulated Fv_{2m} main foliation **(b)**. Loc.: T.te Fantina – Mt. Cipolla dirt road (500 m South of Stop 2.9b). Central Peloritani Mts.

Slates and metarenites alternating to quartzites are prevalent in the East of Pizzo Torno, at the bifurcation of the T.te Novara, South-West of Serro Parrini, North-West of San Basilio village (Contrada Crocetta), North-East of the Piano Vigna village (South of San Basilio village), South-West of Mt. Bammina, North of Pizzo Melia (West of Mandanici village) and North-West of Pizzo Daini.

The ***SMU Variscan tectono-metamorphic evolution*** took place during four main deformation phases (Dv_1-Dv_4), of which the first three syn-metamorphics and responsible for a greenschist facies metamorphism.
The Dv_1 was the origin of the Fv_1 foliation, locally preserved and defined by sericite+chlorite+quartz+albite+graphite. Post-Fv_1 ilmenite and chlorite also develop.

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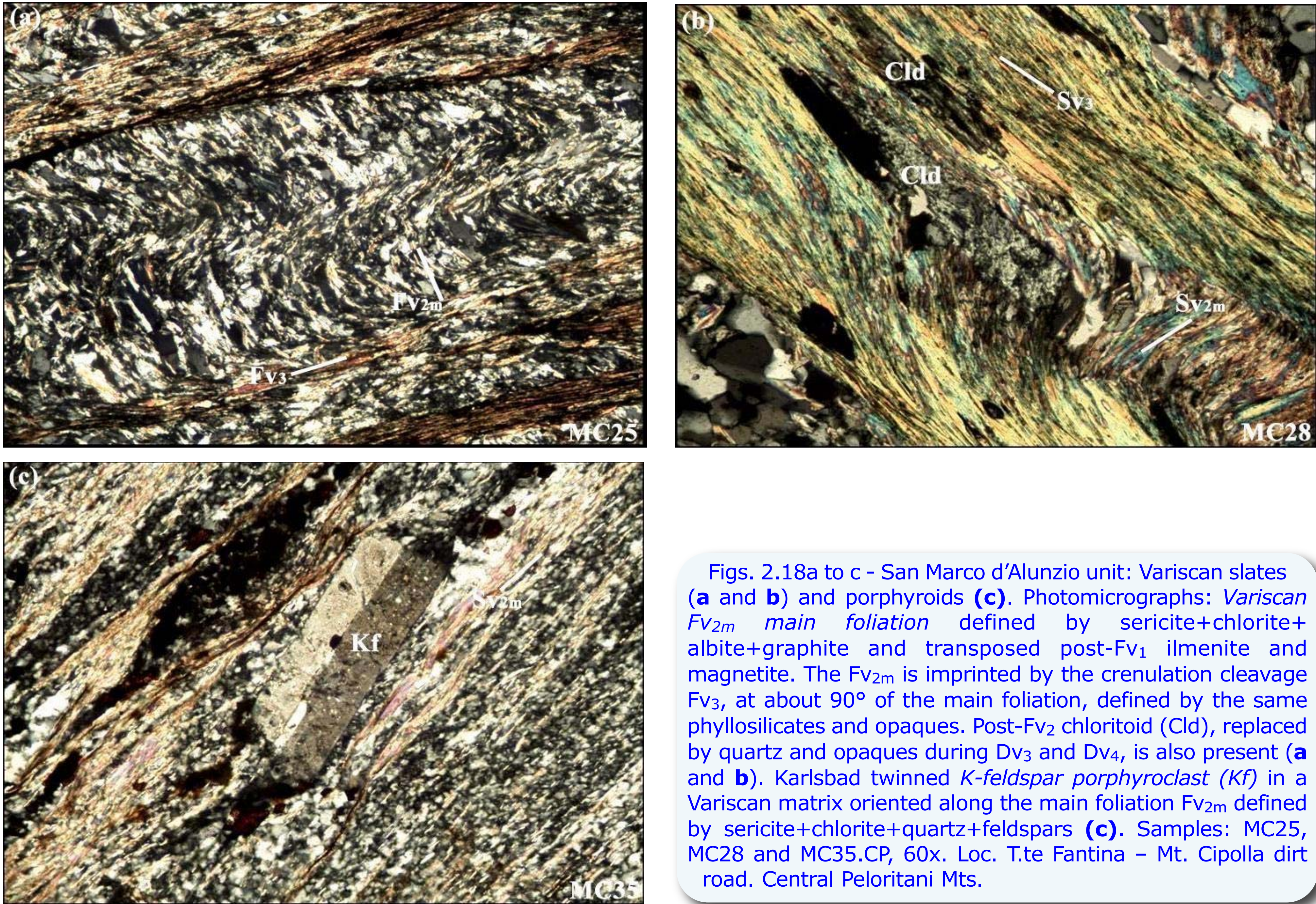

Figs. 2.18a to c - San Marco d'Alunzio unit: Variscan slates (**a** and **b**) and porphyroids **(c)**. Photomicrographs: *Variscan Fv_{2m} main foliation* defined by sericite+chlorite+ albite+graphite and transposed post-Fv_1 ilmenite and magnetite. The Fv_{2m} is imprinted by the crenulation cleavage Fv_3, at about 90° of the main foliation, defined by the same phyllosilicates and opaques. Post-Fv_2 chloritoid (Cld), replaced by quartz and opaques during Dv_3 and Dv_4, is also present (**a** and **b**). Karlsbad twinned *K-feldspar porphyroclast (Kf)* in a Variscan matrix oriented along the main foliation Fv_{2m} defined by sericite+chlorite+quartz+feldspars **(c)**. Samples: MC25, MC28 and MC35.CP, 60x. Loc. T.te Fantina – Mt. Cipolla dirt road. Central Peloritani Mts.

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The Dv_2 produced the Fv_{2m} main foliation defined by the same minerals of the Fv_1, often overprinting the previous foliation and transposing the ilmenite. Post-Fv_2 chlorite and/or chloritoid in small rosettes are also present (Figs. 2.18a and b).
The Dv_3 was responsible for the crenulation cleavage of the Fv_2 with the formation of the Fv_3 foliation defined by the same minerals characterizing the main foliation, with graphite and phyllosilicates prevail.
The Dv_4 determined the crenulation of the Fv_3 foliation (Figs. 2.18a and b).
According to the mineral associations, the thermal peak occurred at the beginning of the post-Dv_2 which took place under T between 350 and 400°C, indicated by the chlorite-chloritoid-albite paragenesis, typical of chlorite zone of greenschist facies. There are no elements that indicate conditions of pressure, which have been hypothesized as being low (between 0.3 and 0.2GPa), such as those reconstructed for the other Variscan lithotypes characterizing the Peloritani Paleozoic low grade basements (Carbone et al., 2011).

Stop 2.10. Novara di Sicilia Hamlet.

Geo-cultural visit of the Medieval Hamlet of Novara di Sicilia, one of “The most beautiful Italian hamlets”.
“In the Central Peloritani Mts., running along the SS 185 by the hydrographic right slope of the Torrente Mazzarrà-Novara-Paratore, after a series of curves that carve the steep slopes of the valley allowing to admire the articulated course of the river dotted with beautiful scenery… at km 13, the glance of a pilgrim, tourist, poet and geologist is attracted by the Mt. Rocca Salvatesta (or Rocca Novara). The Rock is high (1,340 m), hard and stands in the background and all around seems conjugate in a unique and beautiful mosaic that in every moment of the day and in any season can communicate strength and harmony.
Continuing the path, shortly after, we get to see, set in this particular geological landscape, the Medieval Hamlet of Novara di Sicilia: a labyrinth of alleys, streets and stairways between churches and houses, almost unchanged over time, still tell their beautiful history, rich of culture and traditions....” (Messina, 2007 - Introduction to the “Territorial Museum of Novara di Sicilia”), (Figs. 2.19a to f).

The Novara di Sicilia Municipality covers an area of about 48 sq km and has a population of 1,414 in habitants (November 2011). Until 1950, the Municipality included the adjacent Fondachelli and Fantina villages (currently about 41 sq km and population of 1,117). The hamlet is 650 m above sea level, in a central position relative to the entire territorial Peloritani system.

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Fig. 2.19a - *"In the Central Peloritani Mts., running along the SS 185 by the hydrographic right slope of the Torrente Mazzarrà-Novara-Paratore, after a series of curves that carve the steep slopes of the valley allowing to admire the articulated course of the river dotted with beautiful scenery..."* Loc.: along SS 185. Central Peloritani Mts.

The territory occupies a strategic position. It is bounded by the Peloritani Main Ridge, including the Montagna Grande (1,374 m) and the Rocca Salvatesta to the South. This area (Portella Pertusa) is also the origin of main water courses including the T.te Patrì-Fantina-Fondachelli to the East and the T.te Mazzarrà-Novara-Paratore to the West, water courses that going north flow into the Tyrrhenian Sea. Additionally, the T.te Zavianni, which flowing south forming the main left tributary of the Alcantara River, which flows into the Ionian Sea has its origins in this region.
Over the centuries, this important territory with its complex network of fiumare and torrents and the two passes of Portella Pertusa (974 m a.s.l.) and Portella Mandrazzi (1,125 m a.s.l.), was the official transit point linking the Ionian and Tyrrhenian sides of the North-Eastern corner of the Sicilian Island.
The ancient village is sited at the base of the Rocca Salvatesta limestone massif, which shows the image of "crouching lion", on which are preserved the remains of a Byzantine settlement with evidence from the Arab period. This beautiful natural setting over looks on the Mazzarrà-Novara Valley all the way extends to the Tyndari promontory (ancient Greek $A\beta$-$\kappa\alpha\iota\nu o\nu$), up to the distant Aeolian Islands in the large Tyrrhenian Sea. The territory has been inhabited since the dawn of time. Near the San Basilio village, South-West of Novara di Sicilia, is located one of the two Sicilian Mesolithic stations, the "Sperlinga Shelter" (geosite, Figs. 2.20a to e), used by humans fora very long period. The artifacts found, of the Neolithic and Bronze Age, are preserved in the Museum

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Fig. 2.19b -*"…. at km 13, the glance of a pilgrim, tourist, poet and geologist, is attracted by the Rocca Salvatesta Mt. The Rock is high (1340 m), hard and stands in the background and all around seems conjugate in a unique and beautiful mosaic that in every moment of the day and in any season can communicate strength and harmony…"*. Loc.: km 13 of the SS 185. Central Peloritani Mts.

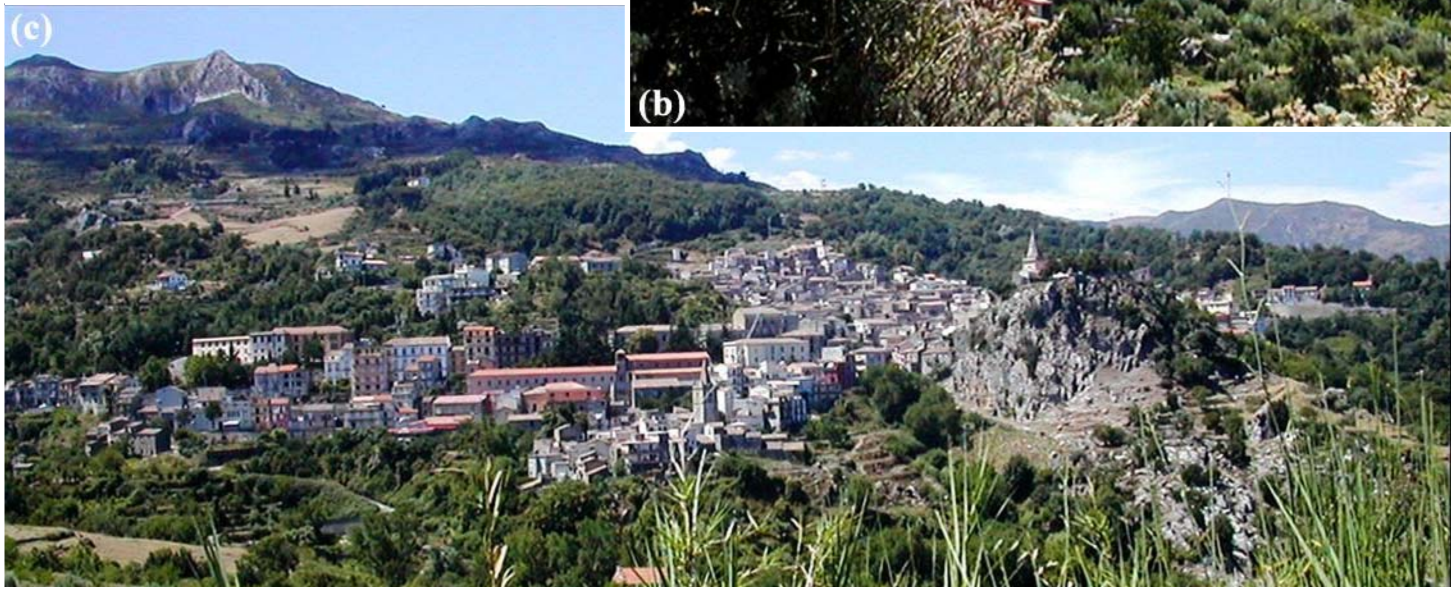

Fig. 2.19c - *"… Continuing the path, shortly after, we get to see, set in this particular geological landscape, the Medieval Hamlet of Novara di Sicilia…"*. Loc.: SS 185. Central Peloritani Mts.

of Lipari (Aeolian Island). The urban centre dates back historically to the Roman period, before Christ. The settlement was known by many names, including Noa (*fallow*), Noara, Noae and others. The Normans repopulated Novara with a colony of Lombardian dextend real control over the entire territory (1195). The expansion of the castle, perhaps on an existing fortification of the Arabs, dates back to the thirteenth century. Of this original old manor house, built on a cliff overlook in the valley below the San Giorgio, only the remains of walls are preserved today.

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Figs. 2.19d to f - *"… a labyrinth of alleys, streets and stairways between churches and houses, almost unchanged over time, still tell their beautiful history, rich of culture and traditions" (A. Messina, 2007 - Introduction to the "Territorial Museum of Novara di Sicilia")*.
Loc.: Novara di Sicilia Hamlet. Central Peloritani Mts.

The current village contains many important monuments, including: the Abbey of Santa Maria La Noara (1137-1167), the Churches of San Francesco (XIII century), Sant'Antonio Abate (XVI c.), Annunziata (XVI c.); the Cathedral (built in the XVII c., has been continually decorated up to XVIII c.), the Church of Sant'Ugo Abate (XVII c.), the Churches of San Giorgio (XVII c.), San Nicola (XVII c.), the Stancanelli and the Salvo Risicato Palaces (XVIII c.) (the latter is the home of the "Territorial Museum", 2007), and the Sister Teresa Fontana House (XVIII c.).

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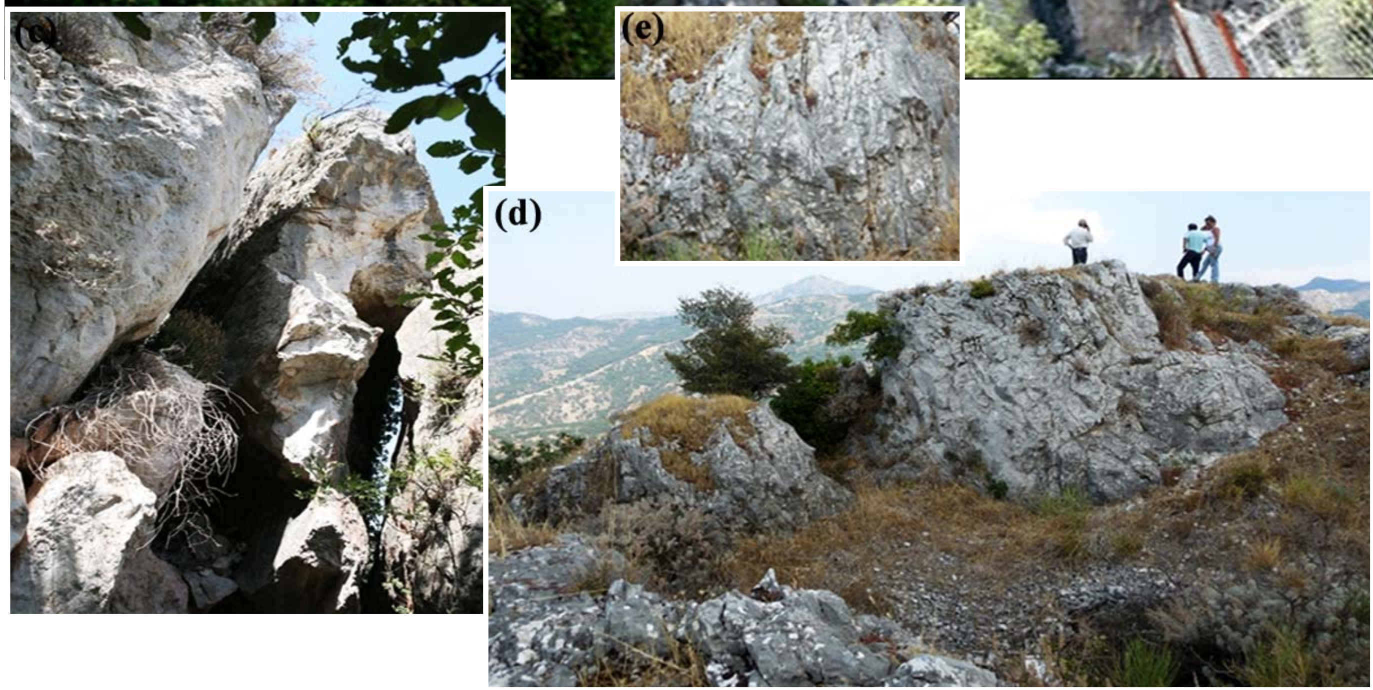

Figs. 2.20a to e – The Novara di Sicilia Medieval Hamlet. *The prehistoric Sperlinga Caves* testifying one of the two Sicilian Mesolithic stations (**b** and **c**), sited in an outcrop, up to 10 m in thickness, of grey-whitish massive limestones grading to Scaglia facies red marls (Upper Jurassic-Eocene sedimentary cover of the Fondachelli unit) with karst karren (**a**, **e**) and doline (**d**). Loc.: San Basilio, South-West of Novara di Sicilia village. Central Peloritani Mts. (from Messina et al., 2010).

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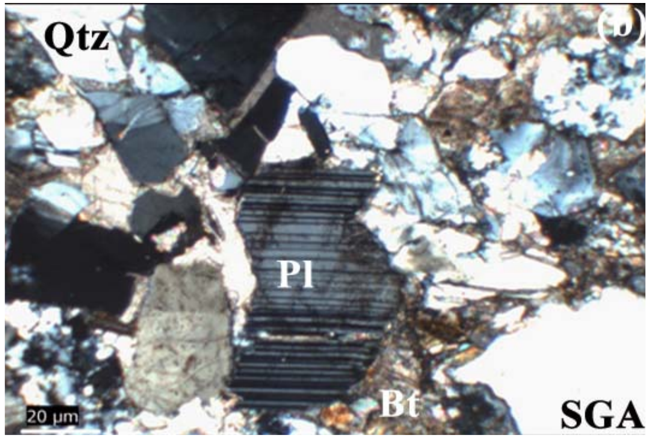
The local dialect is spoken "Gallo-Italic". The village was famous for the art of the "stonecutters". The image of the country is given mainly by stones treets paved with slabs of sandstones of the Capo d'Orlando flysch which decorate the beautiful portals of the Cathedral and the Churches of San Nicola, Sant'Antonio, San Giorgio (Figs. 2.21a and b) and Annunziata, and from the frames of the shelves, balconies and supports below called "Cagnò" of ancient buildings; all major works carried out from 500 to 700.



Figs. 2.21a and b - The Novara di Sicilia Medieval Hamlet. *The San Giorgio Church façade* (XVII c.) with decorative elements of the eighteenth century, made up of sandstones of the Oligo-Miocene Capo d'Orlando flysch **(a)**; photomicrograph of decorative arkosic sandstones showing medium-coarse grained angular to sub-angular grains of quartz (Qtz), twinned plagioclase (Pl), subordinate muscovite, calcite and rare biotite (Bt), in a fine matrix of clay minerals, micas and Fe-oxides **(b)**. Sample SGA. CP, 60x. Loc.: Novara di Sicilia village. Central Peloritani Mts.

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Third Day

Itinerary 3: Novara di Sicilia - Rocca Novara - Portella Pertusa - Portella Mandrazzi.

Themes: Fondachelli unit low-grade basement. Stratigraphic-structural features of the Fondachelli unit Meso-Cenozoic cover (Rocca Novara fm. and red conglomerate) and geometrical relationships between this cover and the Fondachelli and San Marco d'Alunzio units basements.

Stop 3.1. SS 185 Novara di Sicilia - SP 95 San Marco junction.

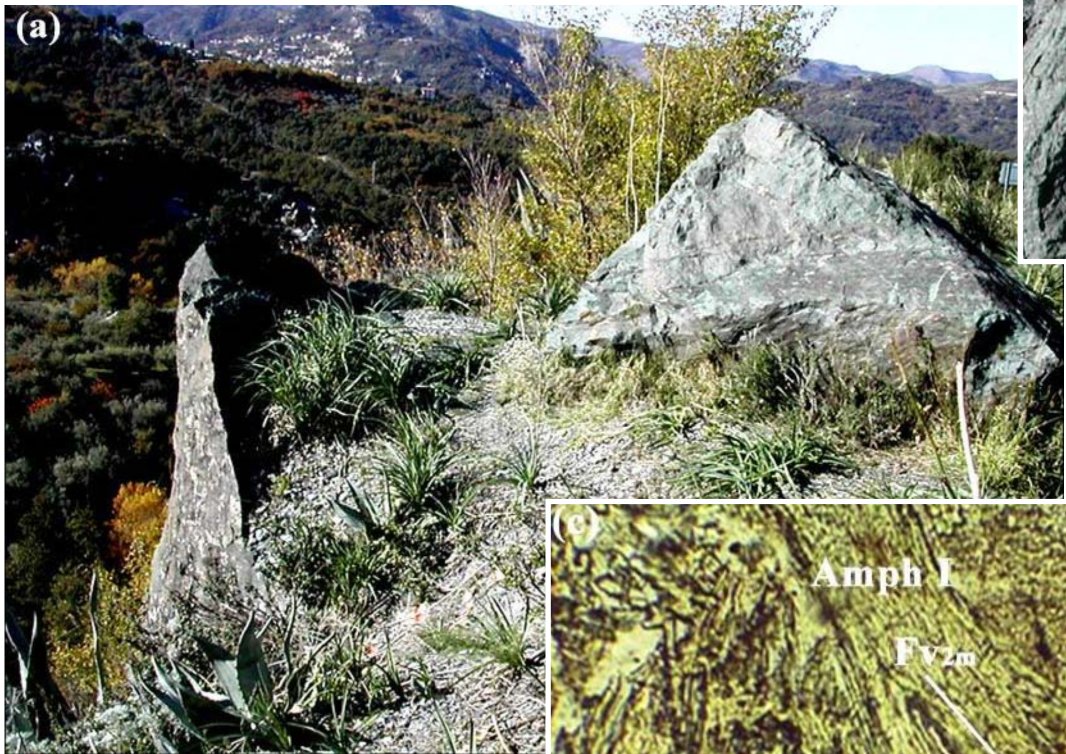
Fondachelli unit Paleozoic low-grade basement: Variscan azure-green metadiabases.
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

The Fondachelli unit extensively crops out on the northern side of Rocca Novara between Fondachelli-Fantina and Novara di Sicilia-Tripi villages (APAT, 2011, Carbone et al., 2011).

Around km 17.8 of the SS 185, ***Variscan azure-green metadiabases of Fondachelli unit crop out in bodies up to 100 m in thickness,*** *which dip in the right slope of the Torrente Novara (Fig. 3.1a). They are less-foliated and at the mesoscale show a* Fv_{2m} *main foliation cut by a thin and spaced* Fv_3 *foliation* (Fig. 3.1b).

At the microscale they exhibit large pseudomorphoses of *chlorite* or *calcite±epidote±opaques* after amphibole and pyroxene(?), respectively, wrapped by a fine matrix made up of *acicular tremolite-actinolite amphibole* and *chlorite* intergrowth along a crenulated Fv_{2m} main foliation (Fig. 3.1c), in addition to rare *quartz*. *Amphibole porphyroclasts* are also present. A spaced not penetrative and irregular Fv_3 is defined by very fine grained *chlorite*.

Figs. 3.1a and b - Fondachelli unit: Variscan metadiabases. Mesostructures: hectometer in thickness Variscan *azure-green metadiabases* dipping in the right slope of the T.te Novara **(a)**. They show a Fv_2 main foliation cut by a thin and spaced Fv_3 foliation **(b)**. Loc.: near km 17,8 of the SS 185. Central Peloritani Mts.



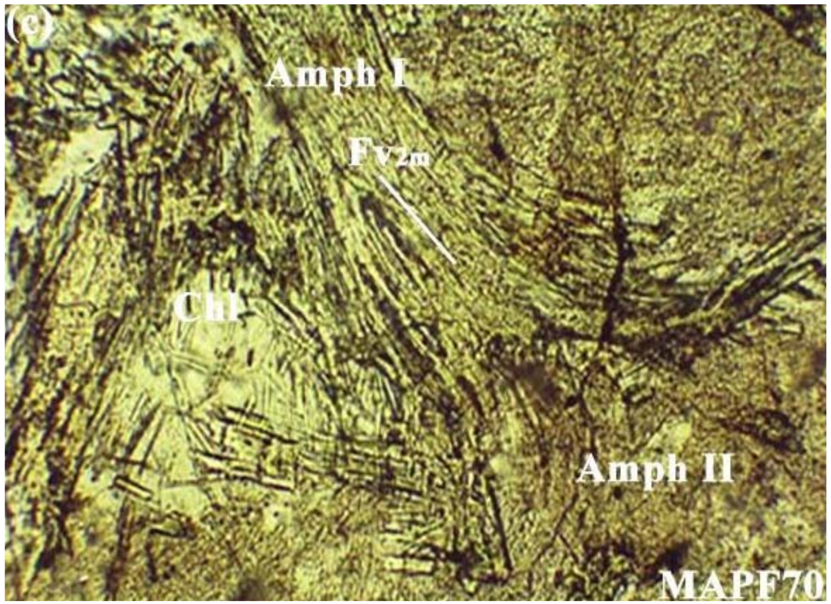


Fig. 3.1c - Fondachelli unit: *Variscan metadiabases*. Photomicrograph: large post-Fv_1 chlorite (Chl) growing after hornblende porphyroclasts (not evident in the picture) rimmed by acicular tremolite-actinolite amphibole (Amph I) intergrown with chlorite along a crenulated Fv_{2m} main foliation. Small sized post-Fv_2 (tremolite?)-actinolite (Amph II) cut previous structures. Sample MAPF70. PPL, 60x. Loc: km 17,8 of the SS 185. Central Peloritani Mts.

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Stop 3.2. Novara di Sicilia – Fantina old road – trail to northern side of Rocca Novara (1,340 m a.s.l.).

Stratigraphic-structural setting of the area around Rocca Novara (38°00’33.0’’ N; 015°09’04.0’’ E).
Geological Map: Milazzo (Sheet 587) – Barcellona P.G. (Sheet 600), 1:50.000 scale - CARG Project.

In the area around Novara di Sicilia an important NNW-SSE oriented fault system, belonging to the Tindari fault system, separates the Rocca Novara (1,340 m a.s.l.) from Monti Ritagli di Lecca (1,206 m a.s.l.), downfaulted respect to the former one.

The *Rocca Novara formation*, composed of ***Upper Jurassic*** **grey carbonate platform facies**, often crystallized, crops out at the top (Fig. 3.2a) *of the Mt. Santa Croce and with minor blocks in the Novara village, and as well as in Poggio Campi (West of San Basilio).*
The restored original succession of the Novara Unit is composed of the Jurassic limestones of the Rocca Novara formation, of thin levels of Lower Cretaceous *Aptychus* marls, of Late Cretaceous-Early Eocene Scaglia upgrading to sandstones, followed by the red conglomerate, Upper Eocene-Lower Oligocene in age. This succession is overturned and thrusts over the metamorphics of the San Marco d’Alunzio unit, cropping out South of Rocca Novara. Consequently, the Fondachelli unit, that widely outcrops in the northern side, represents the original basement of the Novara succession (ex Novara tectonic unit).

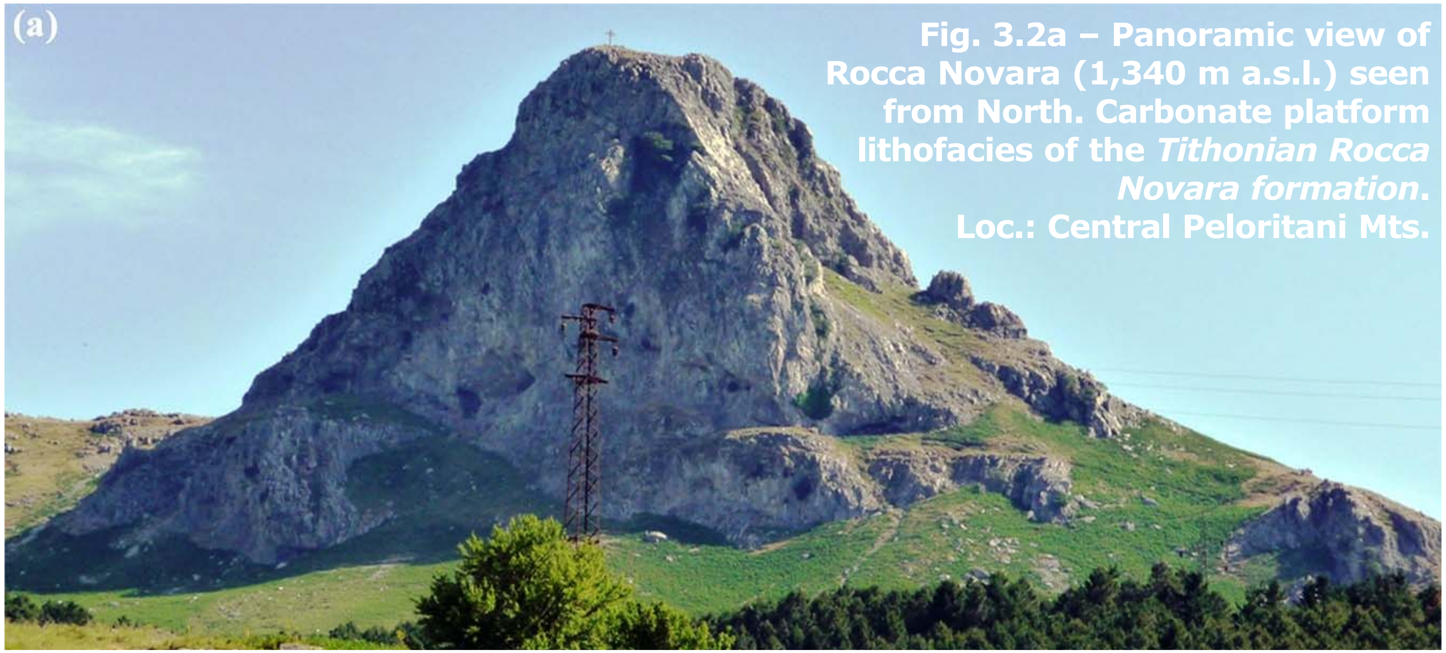

Fig. 3.2a – Panoramic view of Rocca Novara (1,340 m a.s.l.) seen from North. Carbonate platform lithofacies of the *Tithonian Rocca Novara formation*. Loc.: Central Peloritani Mts.

Toward East on the downfaulted side is exposed the succession: Capo d’Orlando flysch, Antisicilide unit and Floresta calcarenites (which form Monti Ritagli di Lecca) (Fig. 3.2b).

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Fig. 3.2b - Panoramic view of the *downfaulted area* eastwards. The profile shows (from left to right) the Capo d'Orlando flysch (Upper Oligocene-Lower Burdigalian) dipping beneath the Cretaceous varicoloured clays (Antisicilide unit), underlying the Floresta calcarenites (Upper Burdigalian-Lower Langhian), which form Monti Ritagli di Lecca (1.206 m a.s.l.). Loc.: Central Peloritani Mts.

Stop 3.3. South-Western slope of Rocca Novara, SS 185 Novara di Sicilia - Portella Mandrazzi (1,125 m a.s.l.).

Stratigraphic-structural setting of the Rocca Novara area. The red conglomerate (37°59'26.9'' N; 015°08'27.7'' E; 1,005 m a.s.l.).
Geological Map: Carta Geologica della Provincia di Messina, 1:50.000.

The panoramic view of the South-Western side of the Rocca Novara (Fig. 3.3a) shows the Tithonian limestones thrusted over the red conglomerate, which in turn tectonically overlies the low-grade metamorphics of the San Marco d'Alunzio unit. This can be interpreted as the frontal wedge of the Fondachelli-Novara Units overthrusting the San Marco d'Alunzio unit. This front belongs to an alignment that extends from Sant'Alessio Cape (Ionian coast) to San Piero Patti, passing through Novara di Sicilia.

The ***red conglomerate formation*** is exposed in small outcrops along the road toward Portella Mandrazzi (Figs. 3.3b and c). Regionally it is mainly associated to the above described Mesozoic limestones of the Rocca Novara fm.

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Fig. 3.3a – Panoramic view of Rocca Novara seen from SW: the Tithonian limestones thrust over the red conglomerate, that in turn tectonically overlie the low-grade metamorphics of the San Marco d'Alunzio unit. This represents the *frontal wedge* of the Fondachelli-Novara Units tectonically overlying the San Marco d'Alunzio unit. Loc.: SS 185 Novara di Sicilia - Portella Mandrazzi. Central Peloritani Mts.

Fig. 3.3b - Rocca Novara formation. *Graded reddish sandstones* (the strata are overturned) represent the original transition to the red conglomerate. This transition has been observed on the Southern flank of Rocca Novara, as well as in other localities (i.g. Forza d'Agrò ridge). Loc.: near San Basilio village, South-West of Novara di Sicilia. Central Peloritani Mts.

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The red conglomerate is polygenic, from matrix- to grain-supported, with heterometric elements, generally rounded and composed of various grade metamorphics and of Mesozoic limestones. The matrix, made up of reddish and subordinately green shales and dark siltites, shows a marked fissility produced by thin boudinage lamination and by a pervasive cleavage (Figs. 3.3b and c).

Near San Basilio village, West of Novara, an overturned alternation of graded arkosic sandstones and greyish shales can be observed. It represents a further example of transition from the Scaglia Fm. to the red conglomerate (Fig. 3.3b). That confirms what described by Atzori et al. (1977) for the outcrops exposed in the Southern side of the Rocca Novara, where the overturned succession is represented by the Scaglia Fm., that progressively grades to sandstones and to conglomerate. The thickness is about 100-150 m. The formation is fossil barren; however on the basis of its stratigraphic position, it has been ascribed to Upper Eocene or Lower Oligocene (?).

Fig. 3.3c - Rocca Novara formation. *The red conglomerate* is polygenic and formed mainly by various grade metamorphic rocks, granitoids and Jurassic limestones. Loc.: SS 185 (37°59’26.9” N; 015°08’27.7” E). Central Peloritani Mts.

Stop 3.4. About 400 m South of Stop 3.3, SS 185 Novara di Sicilia - Portella Mandrazzi (1,125 m a.s.l.).

Relationships between the Rocca Novara succession and the Variscan low-grade basement of the San Marco d’Alunzio unit.
Geological Map: Carta Geologica della Provincia di Messina, 1:50.000.

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Going to Portella Mandrazzi along the SS 185, a large overthrusting contact band at the base of Rocca Novara formation crops out on the left side of the road. It is made up of cataclastic levels of both polychrome slates, phyllites and porphyroids of San Marco d'Alunzio unit basement (Fig. 3.4) and Rocca Novara meso-paleogenic deposits. The San Marco d'Alunzio basement extensively crops out along the T.te San Basilio and near San Basilio village.

Fig. 3.4 - San Marco d'Alunzio unit: Variscan phyllites. *Cataclastic grey-violet phyllite* in the overthrusting contact band at the base of Rocca Novara succession, cropping out along the SS 185 Novara di Sicilia–Portella Mandrazzi. Loc.: SS 185 Novara di Sicilia–Portella Mandrazzi (400 m South of the Stop of Fig. 3.3c). Central Peloritani Mts.

Stop 3.5. SS 185 Novara di Sicilia-Portella Pertusa – SP 97 Novara di Sicilia-Fondachelli junction.

Relationships among the Rocca Novara Mesozoic-Palaeogene succession and the Fondachelli and San Marco d'Alunzio units.
The panoramic view of the South-Eastern side of Rocca Novara (Fig. 3.5): the structural setting of the whole area depends on a general inversion of the original tectono-stratigraphic succession.
The Mesozoic-Paleogene succession (Rocca Novara fm. and red conglomerate) is overturned and the relationships with the Fondachelli unit indicate that this latter is the basement of the Rocca Novara succession. Furthermore relations among the Capo d'Orlando flysch, the Antisicilide unit and the Floresta calcarenites are explained. These are downfaulted by a regional NW-SE oriented structure that extends from Tindari promontory and passing between Ritagli di Lecca Mts. and Rocca Novara.

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Fig. 3.5 - Panoramic view of the South-Eastern side of Rocca Novara. Loc.: SS 185 Novara di Sicilia-Portella Pertusa – SP 97 Novara di Sicilia-Fondachelli junction. Central Peloritani Mts.

Concluding remarks

In the Alpine Peri-Mediterranean Orogen, the Calabria-Peloritani Chain represents the innermost tectonic element of the Apenninic-Maghrebian Orogen showing compositional, structural and tectono-metamorphic correlations with the internal tectonic units of the Western Mediterranean Chains, exposed both in North Africa (Kabylias and Rif) and in the Betic Cordillera. The internal continental crust units, which would derive from palaeogeographic domains located on a Mesomediterranean Microplate (Guerrera et al., 1993; Martin-Algarra et al., 2000; Bonardi et al., 2002, 2003, 2008; Perrone et al., 2006, 2008; Careri et al., 2004), involve Pre-Paleozoic, Paleozoic and Meso-Cenozoic crustal elements.
The geological evolution recognized in each units of the Southern sector of the Calabria-Peloritani Chain (CPCSS), including that of the units which are the object of this feld trip guide, when compared with the geological history of the remained CPC units and Betic Chain internal units, allows the indication of hypotheses of ***evolutional models,*** on the basis of their recognized Alpine and pre-Alpine features, that deserve to be further in-depth and refined.

The ***first model*** is characterized by the presence of a Proterozoic to Miocene evolution. It is indicated by the polymetamorphic ***Aspromonte unit*** (AsU).

The AsU, devoid of a Meso-Cenozoic cover, consists of a Paleo-Proterozoic plutonic (and metamorphic ?) lower crust segment affected by a Pan-African HT granulite facies metamorphism and intruded by a Late Pan-African orogenic peraluminous plutonic series. This basement was further affected by a Variscan LT granulite to LT amphibolite facies metamorphic re-equilibration, intruded by a Late-Variscan orogenic plutonic series and interested by a localized Alpine MHP greenschist to MP amphibolite facies metamorphic overprint.

In the Northern sector of the Calabria-Peloritani Chain (CPCNS), an analogous evolution is shown by the *Gariglione-Polia-Copanello subunit* of the *Sila unit*, where the Alpine overprint is localized in the Polia-Copanello area, as far as by the *Castagna unit,* where the widespread Alpine overprint locally masked the pre-Alpine features (Bonardi et al., 1996, 2004).

In the Alpujarride Complex (Upper Alpujarride) of the Betic Cordillera, similar Neo-Proterozoic to Miocene evolution has been reconstructed in the *Sayalonga-Torrox unit* (Macaione et al., 2008, 2010).

The ***second model*** involves the oldest evolution characterizing the Paleozoic sequences. It is represented by the polymetamorphic ***Mela unit*** (MeU).

The MeU, devoid of both Meso-Cenozoic cover and Alpine re-equilibration, consists of a Variscan mid-crustal segment composed of a Paleozoic pelitic-arenaceous-carbonatic and volcanic sequence affected by an Eo-Variscan eclogite facies metamorphism and by a Variscan Barrovian-type retrograde LT amphibolite to HT greenschist facies re-equilibration.

This model adapts to many crustal segments of European Variscan Chains (e.g. Iberic Massif) not shows agreement with the other units of the CPC, and it is also not supported by features of the Betic Alpujarride and Malaguide units.

The ***third model*** includes a Paleozoic to Paleogene evolution, without the Alpine metamorphic overprint. It is represented by the polymetamorphic ***Stilo unit*** (StU).

The StU corresponds to a Variscan mid-upper crustal segment composed of a Paleozoic pelitic-arenaceous-carbonate and basic and acidic volcanic sequence affected by a polyphase metamorphic prograde zoning (Dv_1-Dv_4, the first two, and locally in the most pelitic types, also the Dv_3, syn-metamorphic. The Fv_2 is the main foliation), from chlorite-zone of greenschist facies to oligoclase-staurolite zone of amphibolite facies, and intruded by a Late-Variscan mesaluminous to peraluminous orogenic tonalite to leucomonzogranite plutonic series and affected by a Late-Variscan contact metamorphism up to hornblende *hornfels* facies. The unit

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preserves a Meso-Cenozoic (Upper Triassic-Aquitanian) sedimentary cover (Crisci et al., 1983; Bonardi et al., 1984, 1996, 2004; Messina et al., 1996a; Graessner & Schenk, 1999).
Similar history is reconstructed in the *Mandatoriccio and Bocchigliero subunits* of the *Sila unit* (CPCNS) (Borghi et al., 1992), which can represent parts of the same Variscan crustal segment.

The ***fourth model*** considers the Paleozoic to Mesozoic evolution, devoid of Late-Variscan intrusions and Alpine metamorphic overprint. It is exhibited by the monometamorphic ***Piraino*** (PU) and ***Mandanici*** (MaU) ***Units.***
They consist of two different Variscan (mid)-upper crustal segments made up of Paleozoic pelitic-arenaceous-carbonate (carbonates are rare in the PU) and basic and acidic (although acidic volcanics are absent in the PU) volcanic sequences affected by a polyphase metamorphic prograde zoning (Dv_1-Dv_4 in the PU, the first three syn-metamorphic; Dv_1-Dv_3 in the MaU, the first two syn-metamorphic in the MaU), from chlorite-zone of greenschist facies to the beginning of amphibolite facies, marked by oligoclase-almandine-staurolite zone in the Piraino unit and oligoclase-almandine zone (without staurolite) in the Mandanici unit.
Both units preserve remains of original Mesozoic cover, dating at Upper Triassic?-Aalenian in the Piraino unit and Upper Triassic - lower Lias in the Mandanici unit.
All geological data indicate for these CPCSS units a genesis from two different Variscan paleogeographic domains.

The ***fifth model*** is based on the Paleozoic to Paleogene evolution, devoid of Late-Variscan intrusions and Alpine metamorphic overprint, and is documented by the monometamorphic ***Fondachelli*** (FU), ***San Marco d'Alunzio*** (SMU), ***Longi-Taormina*** (LTU) ***and Capo Sant'Andrea units*** (SAU).
They represent Variscan upper-crustal segments constituted by sedimentary-volcanic sequences affected by a Variscan polyphase metamorphism (Dv_1-Dv_4 and three syn-metamorphic) which developed under conditions of chlorite zone of greenschist facies in the FU and SMU, up to subgreenschist facies in the LTU, and under subgreenschist facies in the SAU.
These units preserve remains of a more or less thick Meso-Cenozoic cover, dated at Lower Kimmeridgian – Lower Oligocene? in the FU, Upper Triassic – Eocene in the SMU, Upper Triassic – Lower Oligocene? in the LTU and Upper Triassic – Lower Eocene in the SAU.
Characteristics of the Paleozoic sequence (dated from Cambrian to Early Carboniferous in the Longi-Taormina unit), Variscan tectono-metamorphic evolution and Meso-Cenozoic deposits indicate that the three dipping Peloritani units are part of a same Variscan upper-crustal segment, whereas the Fondachelli unit has a different Variscan paleogeographic domain.

The LTU has been compared with the Malaguide units of Betic Cordillera (Somma et al., 2005b).

The ***sixth model,*** which includes the youngest part of the evolution that characterizes the Paleozoic sequences correlated to the Alpine tectonics, is indicated by the polymetamorphic ***Alì unit*** (AU).
The AU consists of a Variscan upper-crustal segment originated from a Paleozoic (Devonian-Lower Carboniferous) sedimentary sequence covered by a Middle? Upper Triassic – Lower Cretaceous deposit. The sequence was affected by a Variscan low-grade metamorphism masked by an Alpine polyphase overprint, with also interested the Mesozoic cover, and which realized under MLP subgreenschist facies conditions (Somma et al., 2005a; Messina & Macaione 2010).
Low-grade Variscan metamorphism and Alpine overprint also affected the Bagni (CPCNS) (Bonardi et al., 1996; Cirrincione et al., 2002), Africo (Heymes et al., 2008, 2010) and Cardeto (CPCSS) (Messina et al, 1996a) Units, where the Alpine re-equilibration developed at higher thermobaric conditions with respect to the Alpine overprint recognized in the Alì unit. The Meso-Cenozoic cover is absent in the Cardeto and Africo Units. At the present time there are no elements which indicate the origin of these units from different levels of the same Variscan upper crustal segment.
The model of the *Alì unit* is perfectly adaptable to the Betic *Felix unit* (Sierra de Gádor) ascribed to the intermediate units located between the Alpujarride and Malaguide Complexes (Martín-Rojas, 2004; Perrone et al., 2006).
Whereas the evolution of the Betic *Benamocarra Unit* (Upper Alpujarride), where recently a Paleozoic sequence, a Variscan metamorphism and an Alpine overprint have been recognized (Macaione et al., submitted), does not fall within the sixth model, because it consists of a Variscan mid-crustal segment devoid of Meso-Cenozoic cover. Consequently, this unit defines a ***seventh model.***

In the framework of the above indicated evolutional models, concerning all the CPC tectonic units and some Betic ones, the strongly supported hypothesis is that the internal Units of both orogens derive from the same palaeogeographic domain deformed since the Late Cretaceous(?)-Late Oligocene, during the Alpine tectonics of the Central-Western Mediterranean.

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