Map of deformation partitioning in the polydeformed and polymetamorphic Austroalpine basement of the Central Alps (Upper Valtellina And Val Camonica, Italy)

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ABSTRACT

Foliation trajectories, superposed to classical lithological information, have been used in this essay to represent the tectonometamorphic evolution of metamorphic rocks at the map scale. Each trajectory is characterized by a chronological connotation (dot pattern) and by a metamorphic connotation (colour); the relative timing of tectonic imprints has been reconstructed by means of the superposition of structures, while the metamorphic terms have been attributed on the basis of a meso- and microstructural-petrographic analysis of the metamorphic assemblages supporting all fabric elements (e.g. foliations, lineations). In addition, fabric gradients have been reported where pre-existing, quasi-isotropic rocks could be utilised (e.g. igneous rocks); these have been represented as colour gradients: from light colours (low strain domains = coronitic fabrics) to full colours (high strain domains = mylonitic fabrics). This new mapping approach, applied to a section of the Austroalpine domain of the Central Alps (Passo Mortirolo, Alta Val Camonica - Valtellina, Italy), which is characterized by polyphasic pre-Alpine and Alpine tectonometamorphic cycles, made the complete representation of lithostratigraphic and tectonometamorphic evolutions possible; therefore, this map is an example of a new method of representation of the full tectono-metamorphic history of a continental crust that underwent two superposed tectonic cycles (Variscan and Alpine) and successive structural stages related to a sequence of metamorphic re-equilibrations. Besides, this approach can be successfully applied in all tectonic and metamorphic settings generally recorded by metamorphic basements.

AIMS

The aim of this contribution is the construction of a foliation trajectory map that images the finite strain field by means of planar fabric configuration and systematic information on mineral re-equilibration steps in relation to microfabric changes. A consequence of the proposed representation technique is the individuation of units recording a coherent structural and metamorphic evolution, and the constraint of location, thickness and areal extent for each of them.

KEYWORDS

Foliation trajectory map, deformation partitioning, tectonometamorphic evolution, Austroalpine basement, central Alps.

RIASSUNTO

Le traiettorie delle foliazioni, sovrapposte alle informazioni litologiche sono qui utilizzate per rappresentare l'evoluzione tettonometamorfica delle rocce alla scala della carta. Ogni traiettoria è caratterizzata da una connotazione cronologica (numero di punti) e da una connotazione metamorfica (colore); la cronologia relativa delle impronte tettoniche è stata ricostruita sulla base della sovrapposizione geometrica delle strutture, mentre i termini metamorfici sono stati attribuiti a seguito dell'analisi meso e microstrutturale delle associazioni metamorfiche che supportano tutti gli elementi del fabric (es. foliazioni, lineazioni). Inoltre, i gradienti di fabric sono stati riportati solo dove è stato possibile riconoscere il carattere quasi iotropico del protolito (es. rocce ignee); il gradiente di fabric è stato rappresentato come gradiente di colore: da colore pallido (domini a bassa deformazione=coroniti) a colore pieno (domini ad alta deformazione=miloniti). Questo nuovo metodo di rappresentazione cartografica, applicato in una sezione del dominio Austroalpino delle Alpi centrali (Passo del Mortirolo, Alta Val Camonica - Valtellina, Italia) caratterizzata da due cicli polifasici pre-Alpino e Alpino, permette la completa rappresentazione dell'evoluzione litostratigafica e tettonometamorfica; perciò la carta è un esempio di un nuovo metodo di rappresensentazione dell'intera storia tettonometamorfica in una porzione di crosta continentale coinvolta in due cicli tettonometamorfici (Varisico e Alpino) e della successione di stadi strutturali collegati alla sequenza di riequilibrazioni metamorfiche; inoltre questo approccio può essere applicato con successo in tutti gli ambienti tettonici e metamorfici generalmente registrati dai basementi metamorfici.

STRUCTURAL MAP OF THE AUSTROALPINE BASEMENT (MORTIROLO AREA - CENTRAL ALPS)

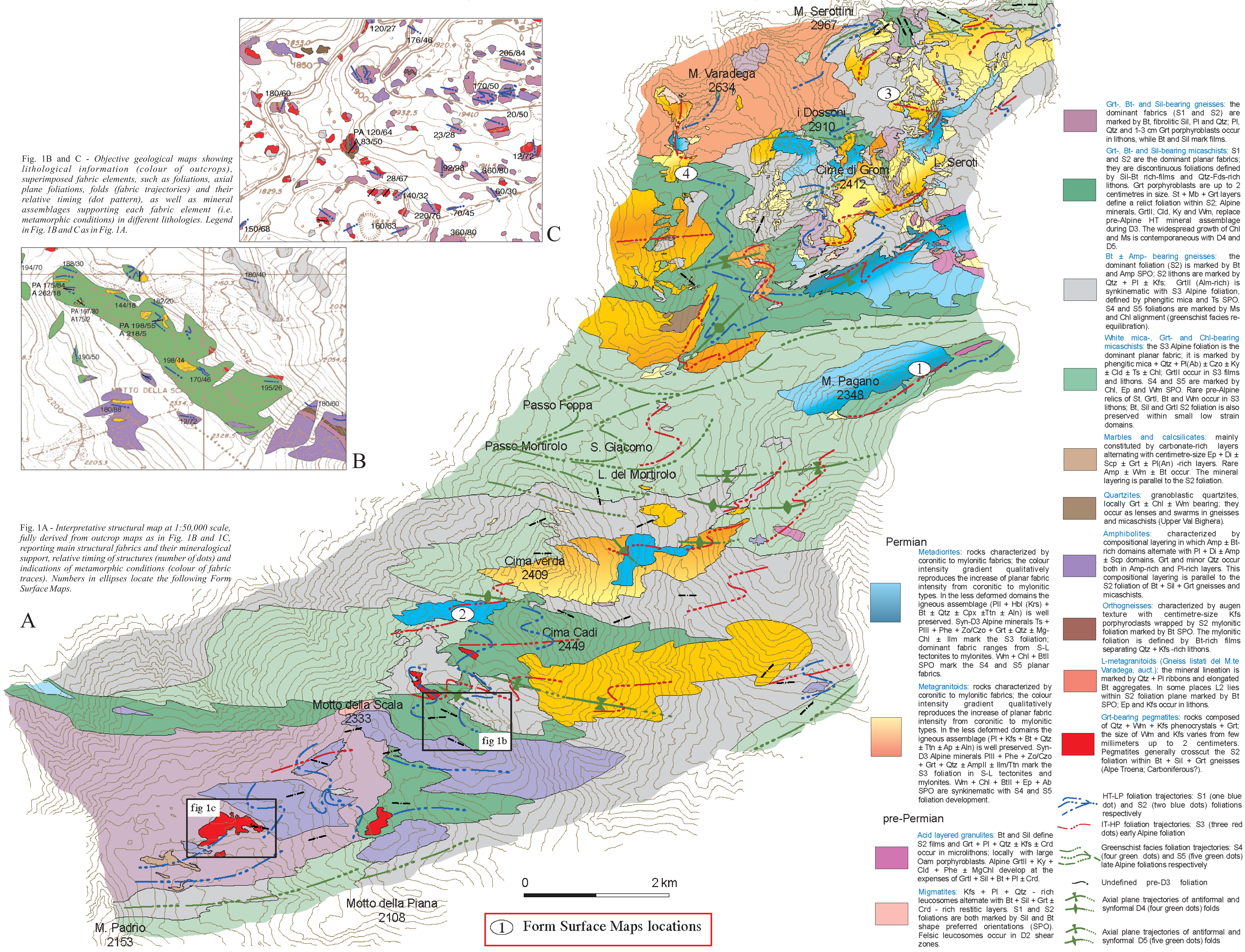


Fig. 1B and C - Objective geological maps showing lithological information (colour of outcrops), superimposed fabric elements, such as foliations, axial plane foliations, folds (fabric trajectories) and their relative timing (dot pattern), as well as mineral assemblages supporting each fabric element (i.e. metamorphic conditions) in different lithologies. Legend in Fig. 1B and C as in Fig. 1A.

Fig. 1A - Interpretative structural map at 1:50,000 scale, fully derived from outcrop maps as in Fig. 1B and 1C, reporting main structural fabrics and their mineralogical support, relative timing of structures (number of dots) and indications of metamorphic conditions (colour of fabric traces). Numbers in ellipses locate the following Form Surface Maps.

INTRODUCTION

When studying the crust of orogenic zones, attention is given to the development of tectonic events and the evolution of thermal history through time (Williams, 1985); grids representing superposed tectonic imprints (lineations and foliations; e.g. Gosso *et alii*, 1983; Johnson & Duncan, 1992; Connors & Lister, 1995), linked to indications of metamorphic conditions (Austrheim, 1990), which assist each deformation event, are graphic devices that may be conveniently adopted to display relevant steps of the geological history in a new type of geological map (Spalla *et alii*, 2000; Zucali *et alii*, 2002). A few metamorphic complexes from the internal Central Alps, defined decades ago in terms of litho-stratigraphic setting and presumably different metamorphic imprints (Bonsignore & Ragni, 1966, 1968), are analysed here by means of structural and lithologic mapping, microstructural analysis and thermobarometric estimates. An example representing the full tectonometamorphic history of a continental crust that underwent two superposed tectonic cycles (Variscan and Alpine) is developed here as a map which displays lithological and structural results, together with the metamorphic interpretations related objectively to space.

GEOLOGICAL OUTLINE

This example deals with a polycyclic metamorphic rock association shown in the south-eastern corner of Sheet n. 040 - Tirano of the 1:50,000 scale geological map of Italy (Eastern Central Alps, between upper Valtellina and Val Camonica). Bonsignore & Ragni (1966; 1968) subdivided this basement into three lithostratigraphic units: i) the Scisti del Tonale series, composed of "catazone" gneisses and micaschists, along with marbles, amphibolites, orthogneisses and pegmatites; ii) the Cima Rovaia series, comprising "mesozone" micaschists with interlayered quartzites, biotitic amphibolites and orthogneisses; iii) and the Pietra Rossa series, containing "epizone" micaschists and phyllites, with amphibolites, quartzites and orthogneisses. Such subdivisions are mostly based on the metamorphic imprints that dominate in each "series". These lithostratigraphic units belong to the Upper Austroalpine nappes of the central part of the Alpine belt, including the Languard - Campo Nappe (LCN) and the Tonale Series (TS); LCN refers to the Pietra Rossa series while TS refers to the Cima Rovaia and Scisti del Tonale series. Structures in the LCN and TS immediately north of the Insubric line (Tectonic map inset, Fig. 1D) generally display steeply dipping attitudes (southern steep belt of Schmid *et alii*, 1996). In more detail, LCN is the uppermost tectonic element overlapping the Lower Austroalpine units (Margna, Sella and Bernina nappes) in which thin tectonic elements with ophiolitic affinity (e.g. Malenco - Platta) are interposed (inset in Fig. 1D). Previous interpretations underline differences between the LCN rocks and those of the TS in terms of lithologic ground and depth of crustal derivation. In the LCN, low to medium-grade, muscovite-biotite and minor staurolite-bearing gneisses and micaschists with interlayered amphibolites, marbles, quartzites and pegmatites occur, whereas higher-grade, sillimanite-bearing gneisses and micaschists, garnet and biotite-bearing amphibolites, marbles and pegmatites dominate in the TS. Post-Variscan intrusives (granitoids, diorites and minor gabbroids) commonly occur in both these units (Del Moro *et alii*, 1981; Bockemühl & Pfister, 1985; König, 1964; Tribuzio *et alii*, 1999). The mineral ages of igneous rocks fall within two time intervals: the first of these ranges from 298 to 224 Ma (igneous cooling ages), and the second from 125 to 78 Ma (mainly from biotite representing Cretaceous reactivation during Alpine tectonics) (Gazzola *et alii*, 2000). The occurrence of Permian intrusive has been used as a time reference to discriminate Alpine from pre-Alpine structural and metamorphic events.

MESOSTRUCTURAL ANALYSIS

The interpretative structural map of Fig. 1 summarises the analytical work (Figs. 2, 3 and 4) that supported the recent reconstructions of the complex polycyclic and poly-phase, tectono-metamorphic evolution recorded by these basement rocks (Spalla *et alii*, 1995; Gazzola *et alii*, 2000; Zucali, 2001) during pre-Alpine and Alpine times. Pre-Alpine imprints include two sets of pre-D2 fabrics, marked by contrasting mineral assemblages in the metapelites. The oldest of these consists of a continuous axial plane foliation, synchronous with the development of St + Grt + BtI + MsI + Qtz + Pl ± Ky; the younger pre-D2 foliation, dominant in the southern sector of the map, coincides with growth of Grt + Bt + Sil + Pl + Qtz. D2 structures include the most prominent pre-Alpine folds and related foliation. These developed during the emplacement of Permian diorites and granodiorites (260-280 Ma), contemporaneous with the crystallisation of BtII + Sil ± Grt ± Crd ± Kfs + Pl + Qtz in metapelites. Leucosomes fill syn-D2 tension-gashes and shear zones (Salvi, 2000). And + MsII overgrew S2.

The Alpine imprint is recorded in the rocks of the whole area. Three groups of superposed structures from the Alpine convergence overprint the pre-Alpine ones and the Permian intrusives. High pressure and intermediate temperature assemblages developed during D3 (the earliest Alpine structures), both in metapelites (GrtII + MsIII + Qtz + Ab ± Cld ± Ky ± Ts) and in metaintrusives (Grt + Ab + Qtz + Zo/Czo + Phe ± AmpII). Two groups of large-scale fold systems (D4 and D5) are associated with greenschist facies re-equilibration, accompanied by Alpine Bt growth (120-80 Ma in Table 1). Joint sets and two Chl and Kfs-bearing fracture systems overprint D5 structures. The quantitative Pressure-Temperature-deformation time path of Permian intrusives and their country rocks, corresponding to the described pre-Alpine and Alpine evolution, is summarised in Fig. 5.

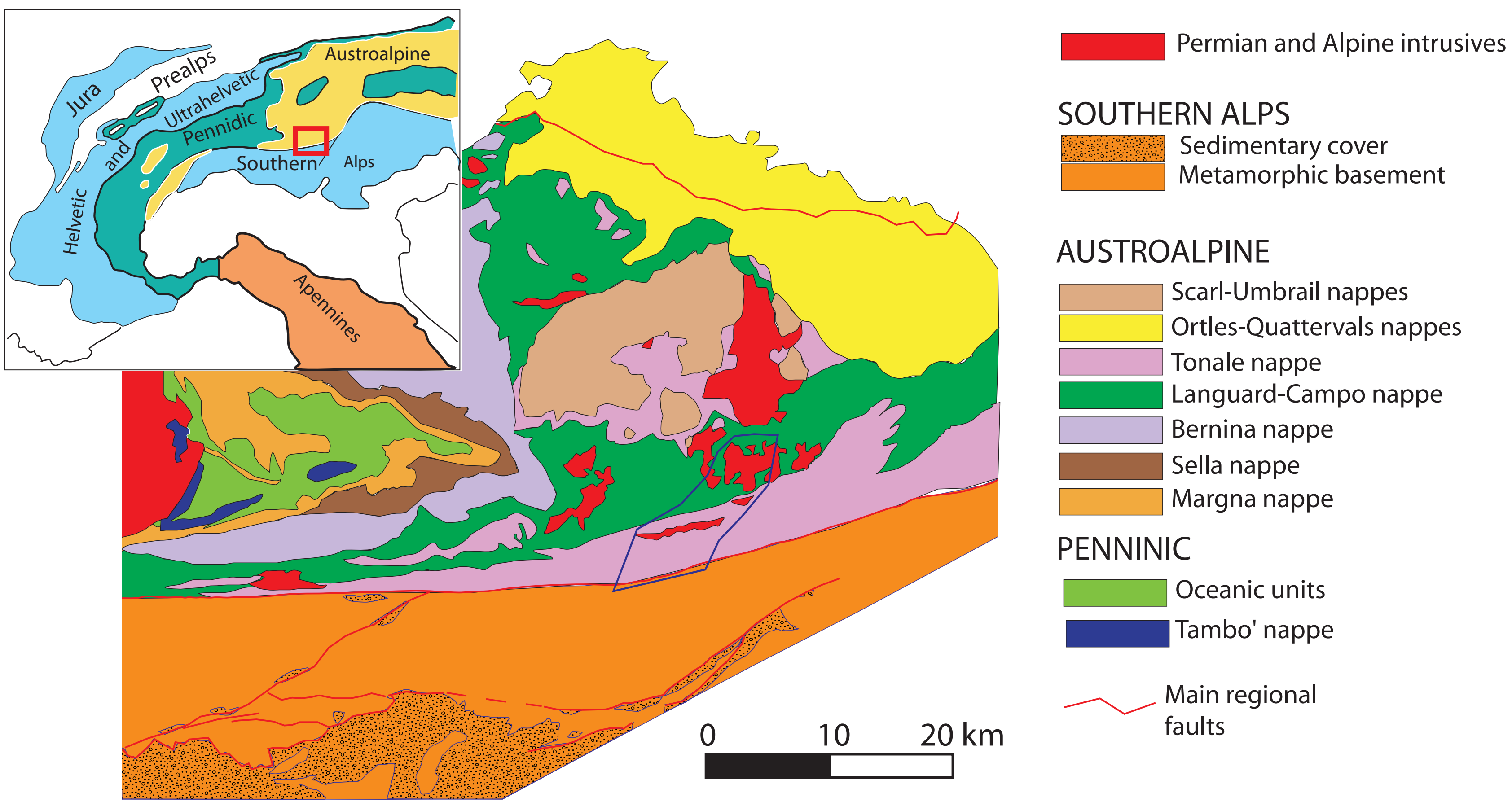
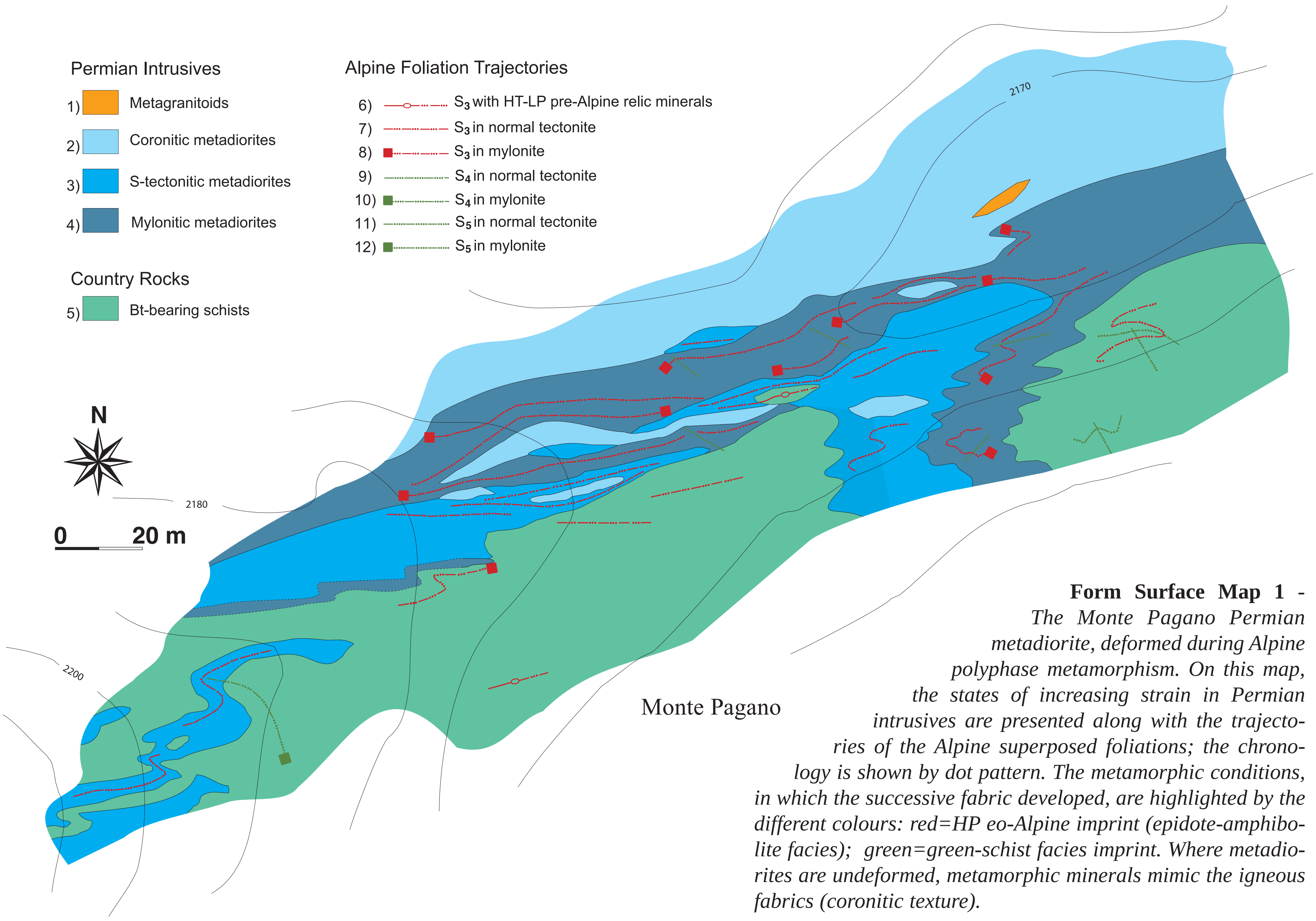
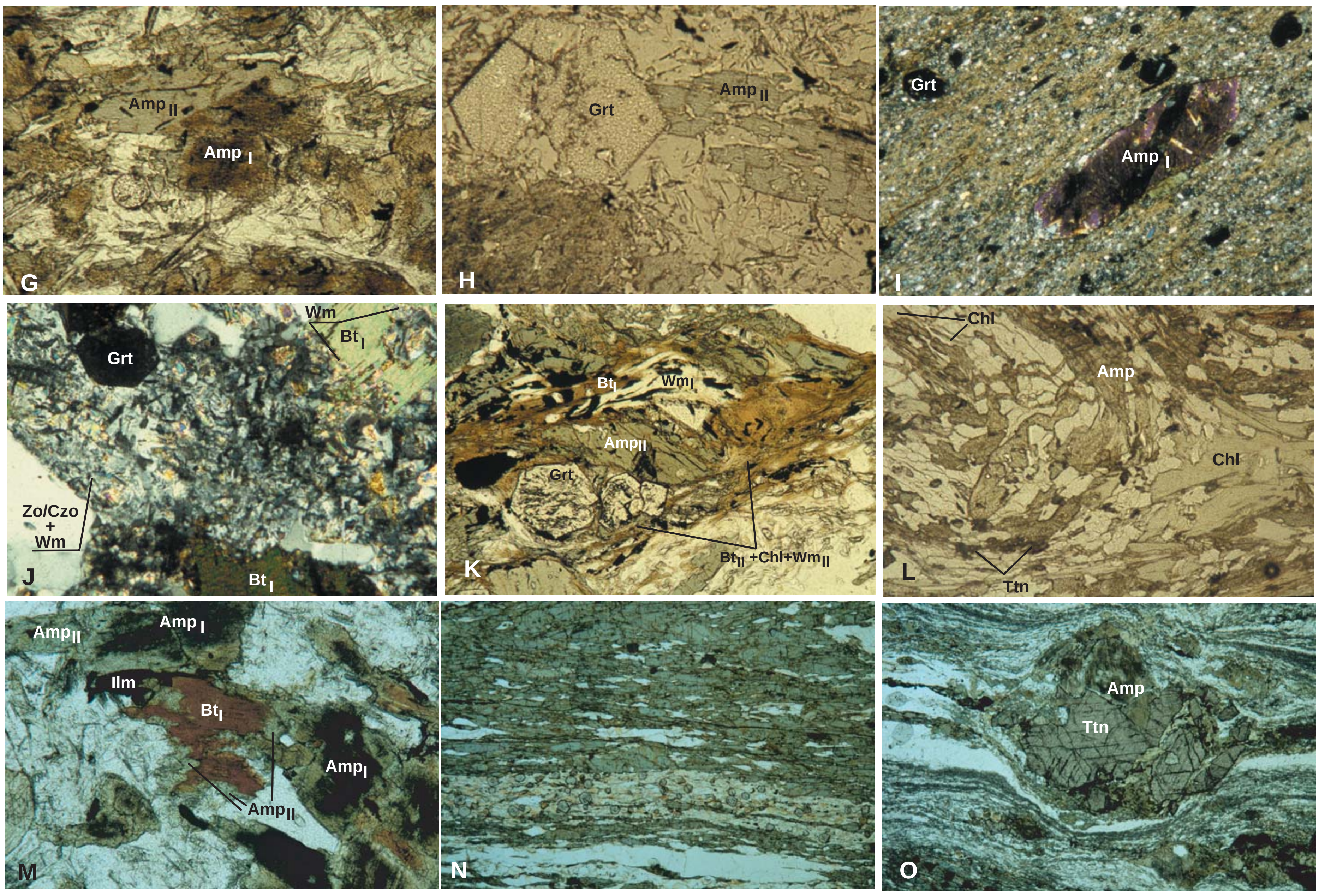


Fig. 1d - *Tectonic map of the Alpine chain and Southern Rhaetic Alps; the blue line locates the study area (Fig. 1A).*

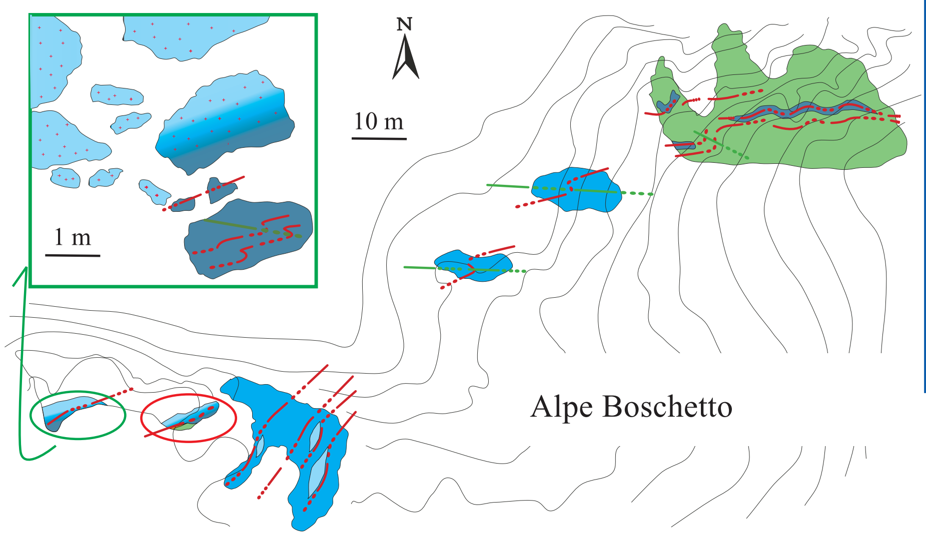
Fig. 2 - *Mesostructural features of CORONITIC-TECTONITIC-MYLONITIC domains within metadiorites at Monte Pagano (A-D) and Alpe Boschetto (E-F). (A) Poorly deformed metadiorite with a well preserved igneous texture overgrown by metamorphic minerals (coronitic texture), such as millimetric garnets (reddish round-shaped grains), that formed at the boundary between igneous plagioclase, amphibole and biotite; (B) Detail of an undeformed igneous contact between diorite and a granitoid dyke; the fuzzy and irregular contact suggests that the permeation of the granitoid occurred in an incompletely solidified dioritic magma (mingling); (C) Tectonitic fabric in metadiorite; the S1 penetrative foliation is underlined by shape preferred orientation of tschermakitic amphibole; (D) Mylonitic S1 foliation in a metadiorite is well marked by the orientation of quartz- and feldspar-rich ribbons, alternated with amphibole-rich layers, and by a stronger grain size reduction with respect to the normal tectonitic fabric; (E) Strain gradient in a garnet-bearing metadiorite shown by the fabric variation from coronitic to mylonitic; (F) Mylonitic metadiorite with quartz ribbons. The mylonitic fabric is marked by thin, amphibole-rich layers alternating with garnet-rich layers.*
Features of CORONITIC-TECTONITIC-MYLONITIC domains within metadiorites at Monte Pagano (G-N) and Alpe Boschetto (O-Q). (G) Undeformed metadiorite with tschermakitic amphibole (AmpII) at the rims of dark brown igneous hornblende (AmpI); igneous plagioclase (colourless domains) replaced by zoisite/clinozoisite, albite-rich plagioclase and a fine-grained white mica intergrowth; plane polarised light (PPL), long side of photomicrograph (LSP)= 2.4 mm. (H) Metadiorite with tectonitic texture in which tschermakitic amphibole (AmpII), in mutual contact with garnet (Grt), defines S1; fine-grained epidote and white mica overgrow plagioclase; PPL, LSP = 2 mm. (I)

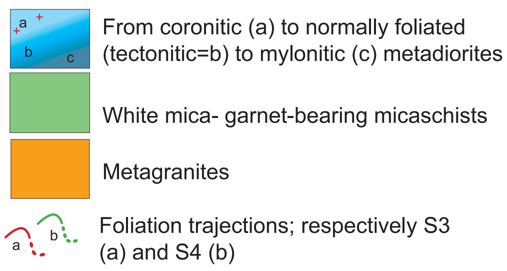


Form Surface Map 1 - *The Monte Pagano Permian metadiorite, deformed during Alpine polyphase metamorphism. On this map, the states of increasing strain in Permian intrusives are presented along with the trajectories of the Alpine superposed foliations; the chronology is shown by dot pattern. The metamorphic conditions, in which the successive fabric developed, are highlighted by the different colours: red=HP eo-Alpine imprint (epidote-amphibolite facies); green=green-schist facies imprint. Where metadiorites are undeformed, metamorphic minerals mimic the igneous fabrics (coronitic texture).*

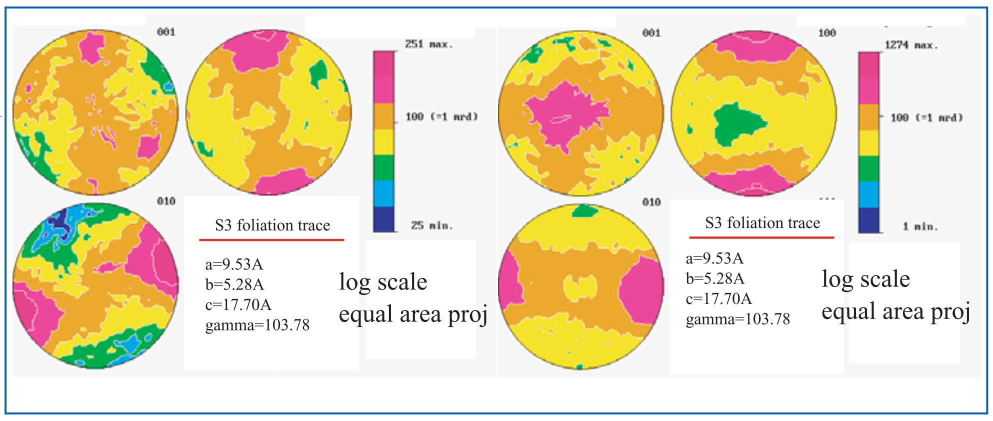


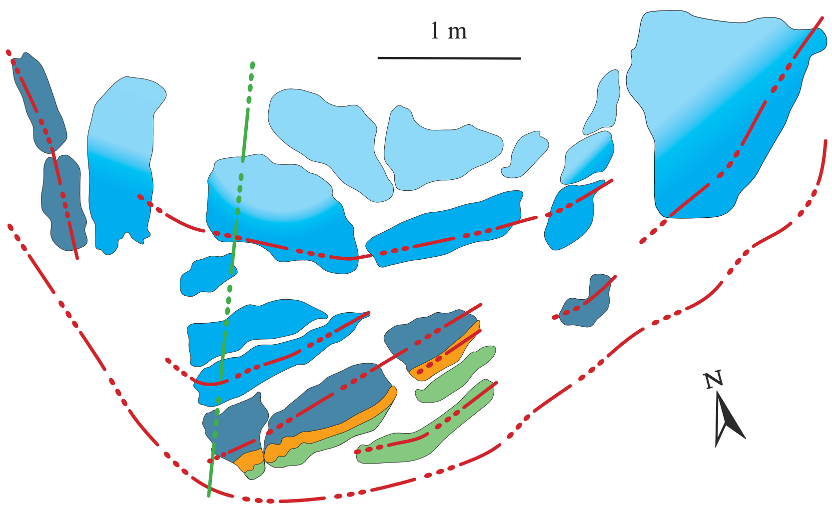
Mylonitic foliation in metadiorite, wrapping garnet porphyroblasts (Grt) and igneous amphibole porphyroclasts (AmpI), defined by fine-grained aggregate of AmpII, white mica and clinozoisite. AmpI shows subgrains and new grains of AmpII at the margins; crossed polars (CP), LSP = 3 mm. (J) Undeformed metagranitoid with plagioclase completely replaced by microaggregate of zoisite/clinozoisite (Zo/Czo) and white mica (Wm). Euhedral garnet (Grt) and white mica (Wm) grow at the biotite (BtI)/plagioclase interface; white mica replaces biotite. CP, LSP = 1.9 mm. (K) BiotiteII (Bt II), chlorite (Chl) and white micaII (WmII) define the spaced microshear planes (S4) crosscutting S3 which contains amphiboleII (AmpII), garnet (Grt) and white micaI (WmI); the latter mineral replaces relict igneous biotiteI (BtI); PPL, LSP = 2.2 mm. (L) Tectonitic metadiorite in which the foliation, marked by amphibole (Amp), chlorite (Chl) and titanite (Ttn) is folded; chlorite (Chl) recrystallises in the microfold hinge; PPL, LSP = 1.2 mm. (M) Coronitic tschermakitic amphibole (AmpII) developed at the boundary of dark igneous hornblende (AmpI) and biotite (BtI) in an undeformed metadiorite; PPL, LSP = 2 mm. (N) S3 foliation is marked by the SPO of light green alpine amphiboles, quartz ribbons and white mica + garnet-rich layers; PPL, LSP = 8 mm. (O) Igneous titanite (Ttn) and ampibole (Amp) porphyroclasts wrapped by the S3 mylonitic foliation; PPL, LSP = 4 mm.



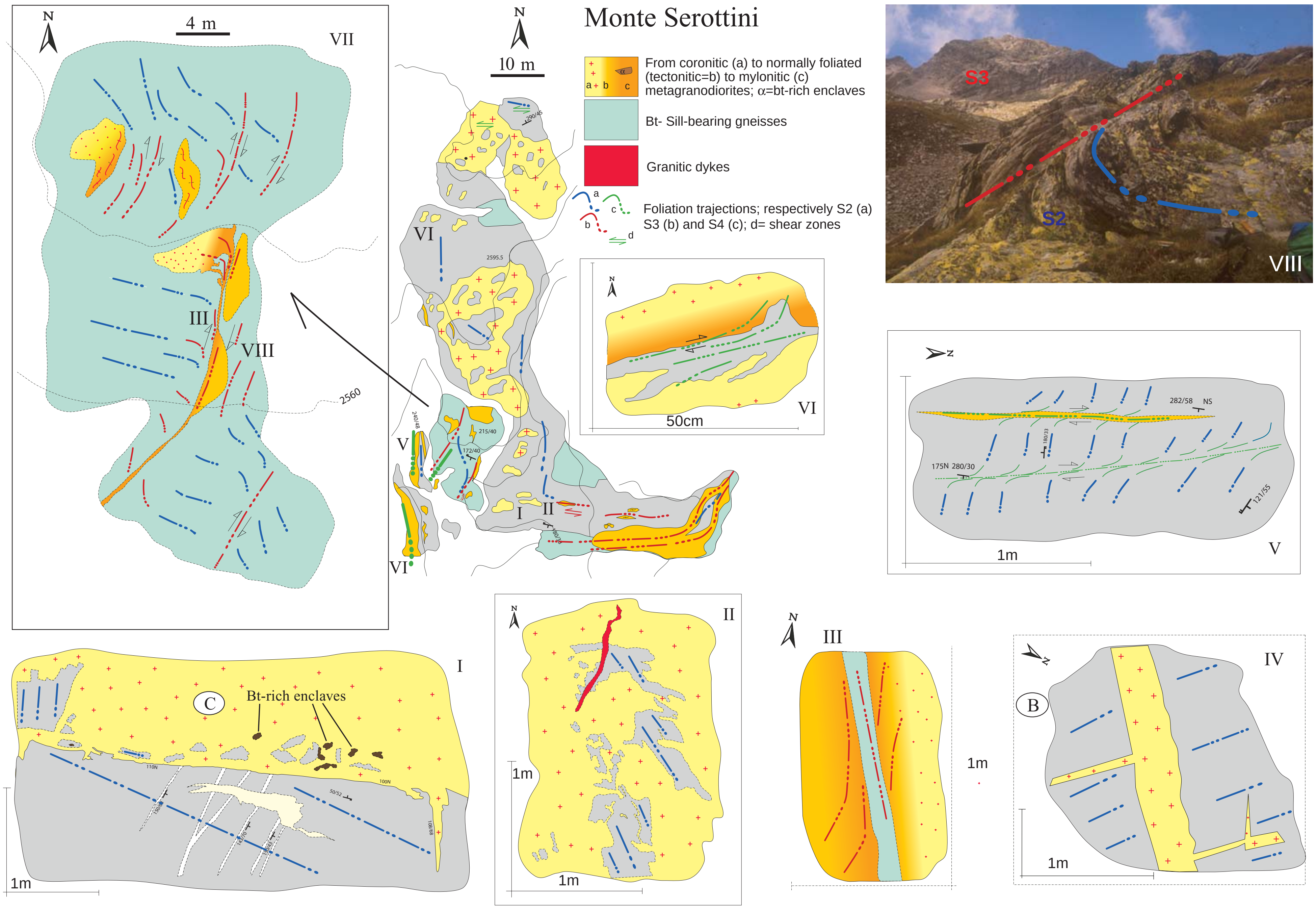


Form Surface Map 2 - *The Boschetto Permian diorite and country rocks, deformed during Alpine polyphase metamorphism. During D3, S3 foliation developed within both micaschists and tectonitic to mylonitic volumes of metadiorites (Figs. 2E and 2F). The S3 foliation is marked by SPO of Wm+Ctd in micaschists and Wm+Ep+Amp in garnet-bearing metadiorites (Figs. 2N and 2O). The transition between tectonitic to mylonitic foliation is marked by an increase in shape orientation of Alpine amphiboles, which also corresponds to an increase in texture intensity (lattice preferred orientation) of amphiboles. During D4, large-scale structures folded lithological boundaries and pre-existing fabrics (S3); locally, S4 crenulation cleavage developed within micaschists and foliated metadiorites. S4 foliation planes are marked by Chl + Wm ± green-biotite ± Amp (Fig. 2 L).*





Quantitative Textures Analyses (QTA) of amphiboles involved syn-D3 metre-size shear zones (photograph E); from tectonitic to mylonitic domains [010] [100]* reciprocal directions tend to be parallel to the S3 foliation plane. The symmetry among lattice orientations and S3 foliation is monoclinic in tectonitic domains, while it is closer to orthorombic in mylonitic domains (see* Zucali *et alii, 2002 for references on QTA using neutron diffraction).*



Form Surface Map 3 - *Permian metagranitoids and their relationships with biotite-gneisses (grey) and amphibole-biotite-gneisses (pale green) at Serottini cirque. The angle between lithologic contact and foliation within gneisses is generally high (I, II and IV); metre-scale shear zones developed during Alpine D3 (III, VII), characterised by a mylonitic foliation (S3) marked by white mica, epidote and plagioclase, while garnet aggregates are elongated parallel to S3 foliation. During D4, metre scale shear zones re-activated D3 shear planes (VI and VII) marked by films of chlorite and white mica. Where the Alpine D3 and D4 structural and metamorphic re-equilibration is less penetrative, igneous character is well preserved: gneisses within metagranitoids may display different shapes (I, II). B, C and D locate photographs of Fig. 3; I-VII are enlargements.*

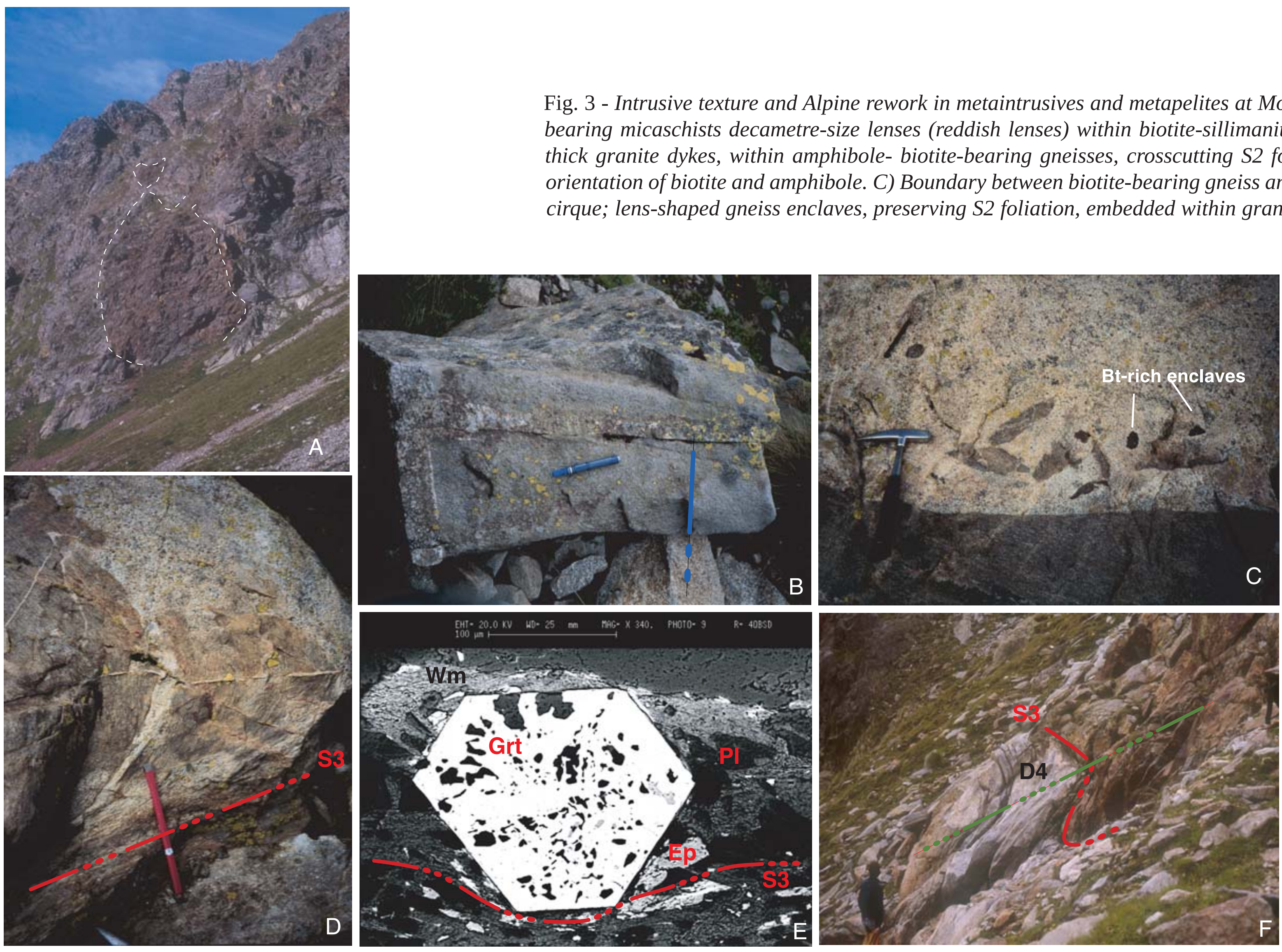
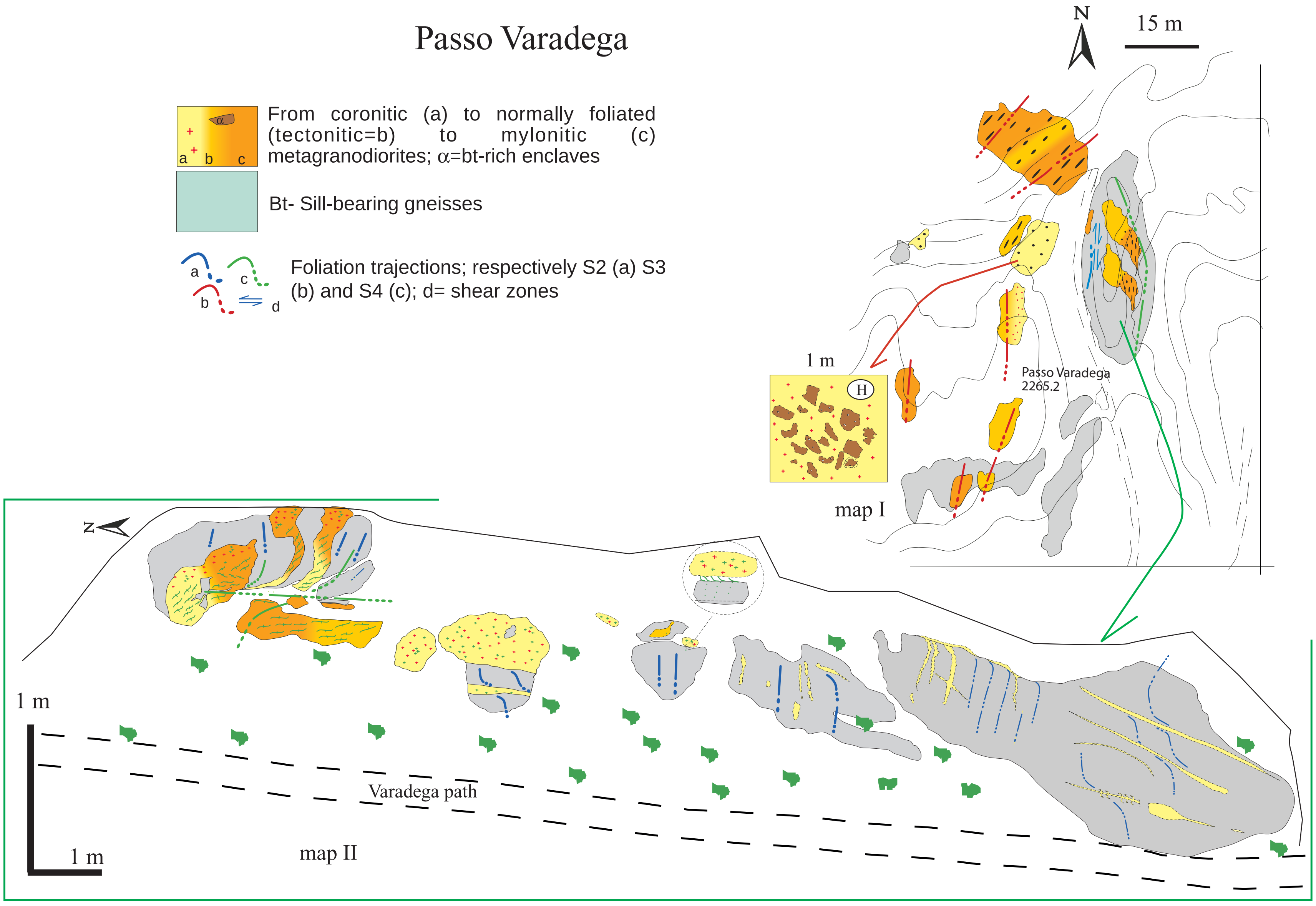


Fig. 3 - *Intrusive texture and Alpine rework in metaintrusives and metapelites at Monte Serottini A) Biotite, sillimanite-bearing micaschists decametre-size lenses (reddish lenses) within biotite-sillimanite-bearing gneisses. B) Centimetre-thick granite dykes, within amphibole- biotite-bearing gneisses, crosscutting S2 foliation marked by shape preferred orientation of biotite and amphibole. C) Boundary between biotite-bearing gneiss and Permian granodiorite at Serottini cirque; lens-shaped gneiss enclaves, preserving S2 foliation, embedded within granodiorite. D) D3 shear zone deforming gneiss enclaves and granodiorite (Serottini cirque); mylonitic foliation (S3) marked by white mica; garnet aggregates are elongated parallel to S3 foliation. E) Back-scattered scanning electron microscope image showing a garnet porphyroblast within S3 foliation in metagranodiorite. Foliation S3 marked by shape preferred orientation of white mica. F) D4 metre-scale folds within micaschists and a metre-thick granitic layer.*



Form Surface Map 4 - *Permian metagranitoids and surrounding gneisses at Passo Varadega (map I). Permian granodiorites still preserve igneous textures (Fig. 3N) within metre-size volumes, which partially escaped Alpine deformation and metamorphism. Metre-scale shear zones, filled by granites and granodiorites (Fig. 3K and in map II), developed within gneisses; granodiorite coronitic volumes are characterised by centimetre to metre-size enclaves, constituted by fine-grained biotite-rich matrix and feldspar phenocrysts (Fig. 3H). S3 foliation developed within Alpine centimetre to ten-metre-size shear zones (map II); S3 is marked by thin aggregates of white mica and plagioclase within gneisses, and by shape preferred orientations of white mica, plagioclase, epidote and biotite-rich enclaves within metagranodiorites. During D4, centimetre to metre-size shear zones developed; these mainly reactivated S3 shear zones that are marked by chlorite and white mica aggregates. Coronas of Alpine minerals formed at the expense of igneous mineral (Fig. 3J) or of pre-Alpine metamorphic assemblages, within less deformed domains in gneisses. H locates the photograph of Fig. 3H.*

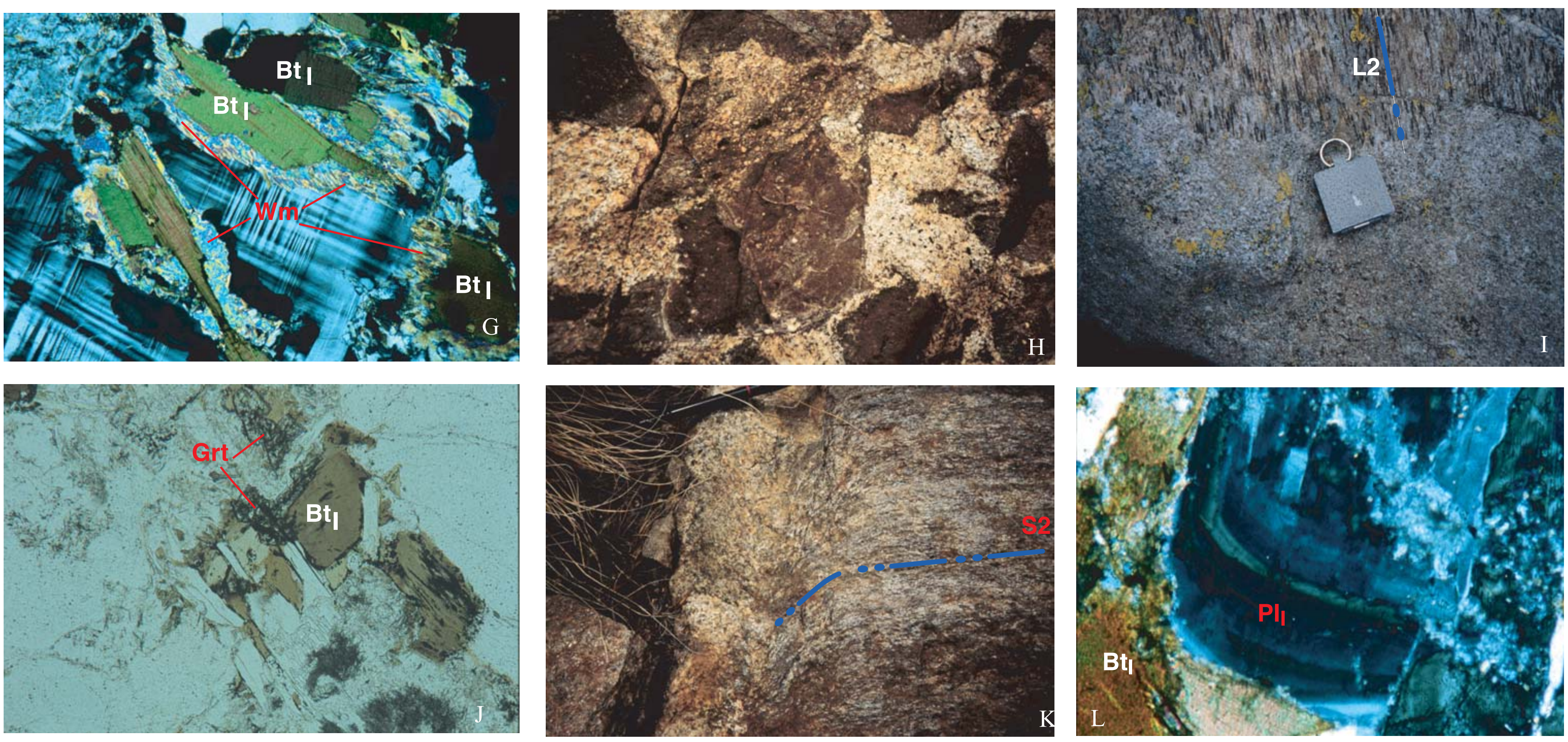


Fig. 3 - (continued). *G) Decametre-scale syn-D3 shear zone within gneisses at Serottini cirque. Figure 3 (continued). G) Undeformed metagranitoid with coronas of Alpine white mica (Wm) around igneous biotite (BtI) enclosed in K-feldspar; CP, LSP = 3 mm. H) Biotite-rich enclaves within undeformed granodiorites (Passo Varadega). I) Pre-Alpine L2 mineral lineation, marked by biotite and plagioclase SPO, within Gneiss Listati of Monte Varadega crosscut by undeformed granodiorite. J) Alpine garnet (Grt) coronas at the boundary between igneous biotite (BtI) and plagioclase (dusty colourless field); white mica develop along biotite (001) cleavages. PPL, LSP = 1.9 mm. K) S2 foliation, marked by biotite, sillimanite and plagioclase deflected within metre-size shear-zone, filled by granite. L) Zoned igneous plagioclase (PlI) and igneous biotite (BtI) within undeformed granodiorite (Monte Varadega); a thin rim of white mica develops around biotite; CP, LSP = 0.5 mm.*

MAPPING TECHNIQUE AND CONCLUDING REMARKS

In order to carry out a full analysis of the structural history of a polydeformed and polymetamorphosed region, our approach was to integrate lithostratigraphy with different superposed fabric elements, mineralogical support of successive planar fabrics and three estimated states of finite strain (localising the isotropic igneous rocks, the normally foliated L-S-tectonites and the mylonites on maps; Figure 1, 6 and Form Surface Maps 1, 2, 3, 4 in figs. 2 and 3). Rocks that are foliated, or that display planar mylonitic fabrics, often alternate with poorly-deformed igneous rocks, and their relationships and abundances may be estimated. Foliations are distinguished geometrically (dot pattern within trajectory lines), and metamorphic environments in which successive structure developed are indicated (different colours). The relationship between foliation trajectories manifesting the sequence of structural events and the metamorphic conditions that dominate during the development of each foliation is supported by petrologic investigations following a micro-structural study. This representation technique, which is based on a mapping method requiring rapid iterations between field and laboratory analyses, facilitates the immediate correlation of petrologic data with structural history. For example, all this information is included in Form Surface Map 1 (Fig. 2), which illustrates the spatial arrangement of: 1) coronite texture, a diorite or granodiorite-looking protolith with mesoscopically random fabric, in which the granular scale strain is very poor, and with metamorphic mineral growth localised at the rims of igneous grains (Form Surface Map 1 in Fig. 2 and Fig. 2 A-G-J-M), 2) normally foliated, syn-metamorphic tectonite texture (Figs. 2C, 2H, 2K, 2L and 3), mylonitic texture (Fig. 2D, 2E, 2F, 2I, 2N, 2O). Although time-consuming, this type of map supports a more objective correlation of the time sequence of mineral re-equilibrations with fabric evolution. Two distinctive features arise using this representation technique: the first is

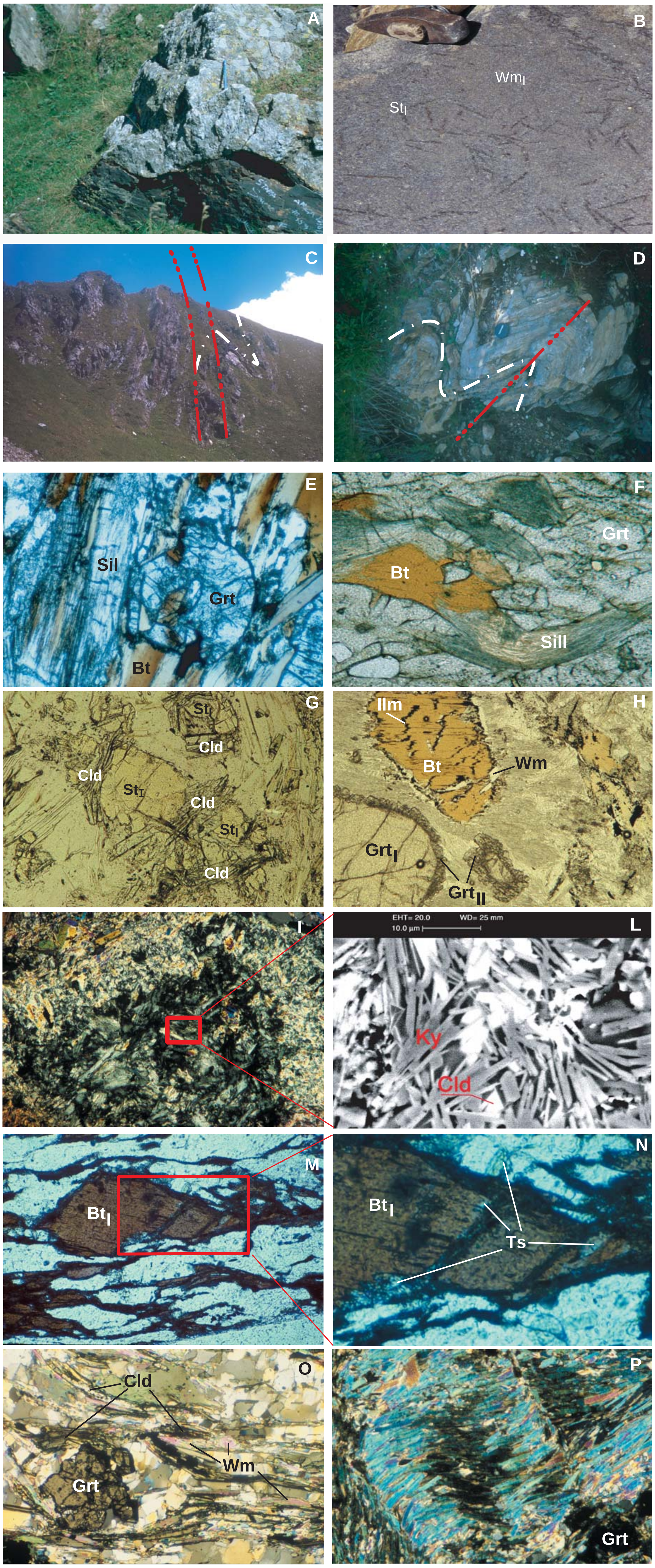


Fig. 4 - *Pre-Alpine and Alpine meso- and microstructures and related metamorphic assemblages within the whole area. A) Pre-Alpine age garnet-bearing pegmatite crosscutting S1 foliation within biotite, sillimanite and garnet-bearing gneisses at Lagazzuolo. B) Pre-Alpine white mica (WmI) + staurolite (StI) aggregates within micaschists at Dossoni-Serottini (G). C) Large-scale D3 shear zone, involving S2 in biotite, sillimanite-bearing gneisses at Val Andrina. D) D3 folds at Alpe Troena; S1 folation marked by carbonate, diopside and garnet-rich layers alternating with plagioclase and scapolite-rich layers. E) S1 foliation marked by shape preferred orientation of biotite, fibrolitic sillimanite, quartz and plagioclase. PPL; LSP = 2mm. F) Relict biotite and sillimanite within syn-D2 garnet porphyroblast. PPL, LSP = 0.2 mm. G) Alpine chlorithoid (Cld) overgrew pre-Alpine staurolite (StI) porphyroblasts (B). PPL; LSP = 5 mm. H) Alpine coronas of garnet (GrtII) around garnet porphyroblasts (GrtI); white mica (Wm) and ilmenite (Ilm) partially replace pre-Alpine biotite grains (Bt). PPL; LSP = 5 mm. I) Fine-grained aggregates of Alpine chloritoid and kyanite, rimmed by aggregate of white mica. CP; LSP = 2 mm. L) Back-Scattered Electron image of aggregate of Alpine chloritoid and kyanite (red rectangle in I). M) Fractured pre-Alpine biotite porphyroclast (BtI) wrapped by S3 foliation. PPL; LSP = 4mm. N) Alpine tschermakitic amphibole (Ts) filling fractures in biotite porphyroclast (BtI). PPL, LSP = 1mm, magnification of M. O) S3 foliation within micaschists at Alpe Boschetto; S3 marked by white mica (Wm) and chloritoid (Cld) shape preferred orientation, while Grt porphyroblast occurs in microlithons. CP; LSP = 4 mm. P) D4 microfolds within garnet-bearing micaschists; S3 foliation marked by shape preferred orientation of white mica. CP; LSP = 1mm.*

the multi-scale (fractal?) character of strain partitioning from a mm to a km scale, and the second the direct relation between strain gradient and rate of metamorphic transformation. The contemporaneous representation of strain gradients (in metaintrusives) and of foliation trajectory ages highlights the partitioning of strain during each deformation stage. In addition, by paying attention to maps at different scales and to meso- and micro-structure images, the direct dependence of reaction rates on fabric evolution (coronite to tectonite to mylonite) is overwhelming. In particular, is very easy to qualitatively evaluate the decreasing volume of igneous minerals in Permian intrusives, which are progressively replaced by Alpine metamorphic minerals during the transition from undeformed to mylonitic types. During poly-phase Alpine evolution (Figs. 4 and 6), strain partitioning is clearly responsible for the preservation of pre-Alpine igneous or metamorphic fabrics over large areas within the northern and southern sectors of the map area. In the central portion of the map, Alpine fabric evolution is complete locally and very little of the fabric and mineral relics are preserved in metaintrusives and in their

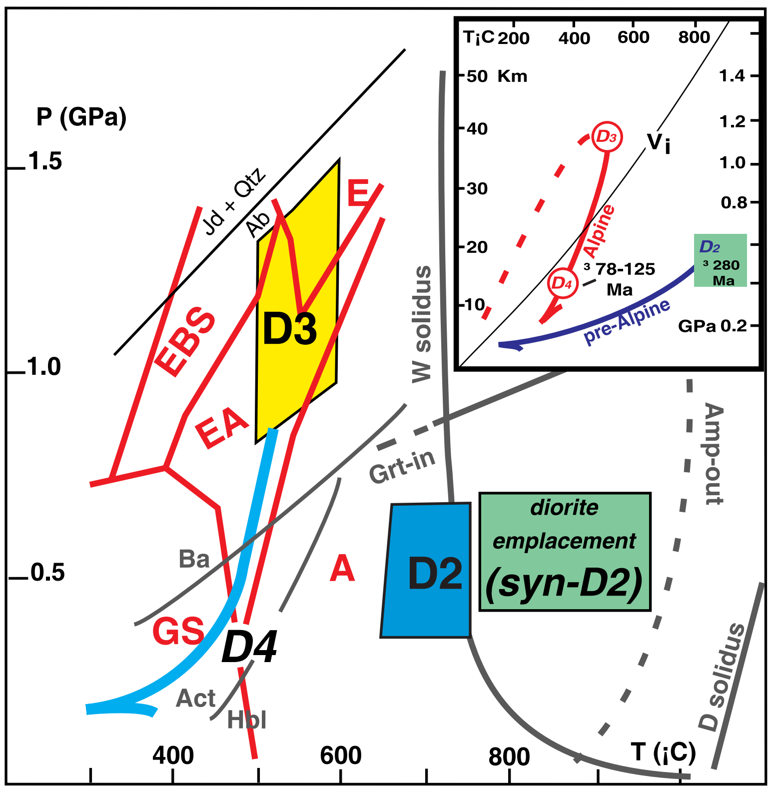


Fig. 5 - *P-T-d-t paths of the Languard Campo Nappe - Tonale Series (after* GAZZOLA et alii *2000;* ZUCALI*, 2001); inset: pre-Alpine and Alpine P-T paths compared with stable geotherm (Vi).*

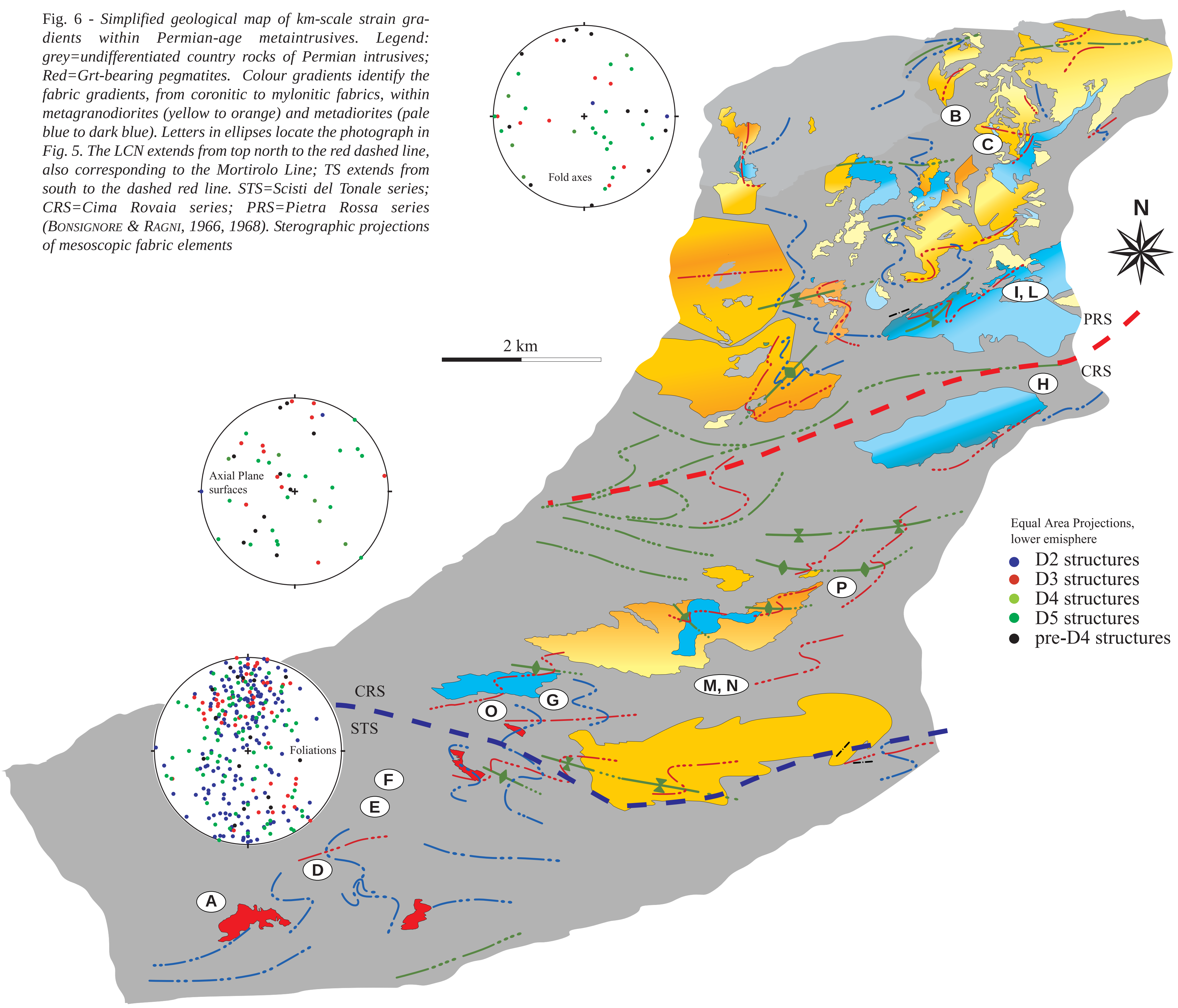


Fig. 6 - *Simplified geological map of km-scale strain gradients within Permian-age metaintrusives. Legend: grey=undifferentiated country rocks of Permian intrusives; Red=Grt-bearing pegmatites. Colour gradients identify the fabric gradients, from coronitic to mylonitic fabrics, within metagranodiorites (yellow to orange) and metadiorites (pale blue to dark blue). Letters in ellipses locate the photograph in Fig. 5. The LCN extends from top north to the red dashed line, also corresponding to the Mortirolo Line; TS extends from south to the dashed red line. STS=Scisti del Tonale series; CRS=Cima Rovaia series; PRS=Pietra Rossa series (*BONSIGNORE *&* RAGNI*, 1966, 1968). Sterographic projections of mesoscopic fabric elements*

country rocks (Fig. 4), despite the whole area underwent equivalent tectonic and thermal history (Fig. 5). The superposition on this map of the boundaries between the three lithostratigraphic zones, individuated by BONSIGNORE & RAGNI (1966; 1968), shows that they reflect the Alpine strain gradient and related reaction rates in a single Alpine tectono-metamorphic unit. As a general conclusion, we underline that even in this portion of the Austroalpine basement, which records the effects of two superposed tectono-metamorphic orogenic cycles, the regional distribution of dominant metamorphic imprints does not necessarily correspond to the "metamorphic field gradient" (ENGLAND & RICHARDSON, 1977; SPEAR *et alii*, 1984). This is due to the dependence of the dominant metamorphic imprint by the most pervasive fabric on a regional scale, provided the degree of granular scale reorganisation be greater than a critical stage (tectonite > mylonite); therefore, the "metamorphic field gradient" is not useful for distinguishing tectono-metamorphic units, if no attention is paid to the areal distribution of superposed syn-metamorphic fabrics, as was already seen in the Southalpine basement which, with respect to this example, only records the pre-Alpine tectono-metamorphic evolution (SPALLA *et alii*, 1998, 2000; DI PAOLA & SPALLA, this vol.; ZUCALI *et alii*, 2002).

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