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SCIENCE

Geology of the Fontane talc mineralization (Germanasca valley, Italian Western Alps)

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ABSTRACT
The 1:5000 scale Geological Map of the Fontane talc mineralization (FTM) aims to give new information about the origin and geological structure of an important talc mineralization occurring in the axial sector of the Italian Western Alps. The FTM is hosted within a pre-Carboniferous polymetamorphic complex which was deformed and metamorphosed during both Variscan and Alpine orogenesis, and is part of the Dora-Maira continental crust. Field mapping and underground investigations highlight that the talc bodies (i) never crop out but occur at depth along a well-defined lithostratigraphic association between micaschist, marble and gneiss and (ii) were deformed during different Alpine-related deformation phases (i.e. D_1, D_2 and D_3 syn-metamorphic phases and post-metamorphic extensional faulting). The here defined lithostratigraphic and structural characterization of talc bodies, is an input for further research into the geodynamic context of where talc forms and for new mineral exploration outside the mapped area.

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Western Alps; Talc mineralization; Alpine tectonics; extensional faulting

1. Introduction

One of the industry-related geological features of the Italian Western Alps is a discontinuous, several kilometre-wide belt of talc mineralizations (throughout the paper we define talc mineralization as a geological body with a significant content of talc). The most important of these mineralizations (and one of the most important in Europe), due to both quantity and quality of the extracted talc, is located in the Germanasca Valley (Italian Western Alps) and is known as the Fontane talc mineralization (FTM hereafter) (Grill, Pagliani, & Sacchi, 1955; Peretti, 1966; Sandrone et al., 1990; Sandrone & Zucchetti, 1989; Sandrone, Trogolo Got, Respino, & Zucchetti, 1987; Zucchetti, 1969, 1972). The FTM is hosted within a pre-Carboniferous polymetamorphic complex that was deformed and metamorphosed during both Variscan and Alpine orogenesis, and is part of the Dora-Maira continental crust (Sandrone, Cadoppi, Sacchi, & Vialon, 1993) (Figure 1).

Talc exploitation started in the mid-1800s in the Germanasca Valley and gradually extended into adjacent valleys, until talc production reached over 40,000 tons per year (Ridoni, 1938). After the Second World War, talc production progressively decreased and the FTM is now the only site where talc is currently being extracted.

Despite its industrial significance, both the origin and geological structure of the FTM has never been defined in detail, and a published map exists only at small scale (i.e. the Pinerolo sheet of the Geological Map of Italy at 1:100,000 scale; Mattirolo, Novarese, Franchi, & Stella, 1913). In this paper, we present a new 1:5000 scale geological map that spans an area of about 8 km^2 above the main infrastructure (i.e. tunnels) of both past and current extraction sites, with the aim of further advancing knowledge about geology of the FTM. Since the talc bodies never crop out, we have integrated the main map with geological cross sections that allow identification of their location at depth, as well as defining their geometry and lithostratigraphic association with embedding rocks.

2. Methods

The main map presented in this study is the result of fieldwork carried out at 1:5000 scale. Lithological observations and the collection of structural data were performed both in the field and at underground locations. Data were stored in a geographical information system (GIS) database (Coordinate System WGS 1984 UTM Zone 32N) and represented on a raster topographic map derived from ‘Carta Tecnica Provinciale’ 1:5000 (‘Dai tipi di proprietà della Città Metropolitana di Torino – Servizio Cartografico’, authorization n.105625/2015 on 21 July 2015).

The main map includes (i) three cross sections located in the area where talc is currently being extracted and defined through an integration of field data with borehole data (i.e. data available from companies holding the mining concession over the years)

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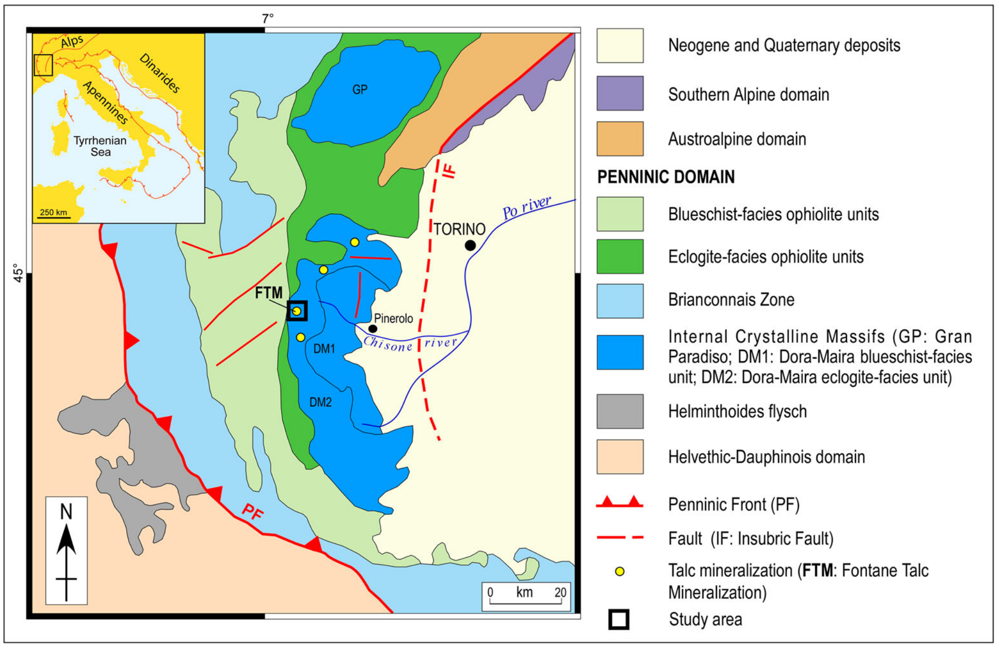

Figure 1 . Localization of the FTM in the tectonic map of the Western Alps.

and (ii) a 1:20,000 scale tectonic map wherein geological interpolation, interpretation and generalization of outcrops and structures are given.

3. Regional setting

The FTM is located along the western edge of the Dora-Maira, a slab of paleo-European continental crust which belongs to the Penninic Domain of the Western Alps (Figure 1) (see e.g. Bigi et al., 1990; Dal Piaz, Bistacchi, & Massironi, 2003). The Dora-Maira (Cadoppi et al., 2002; Sandrone et al., 1993; Vialon, 1966) was involved in Alpine-related E-dipping subduction, W-verging continental collision and deep crust/mantle indentation (see e.g. Chopin, Henry, & Michard, 1991; Wheeler, 1991), and is now stacked in the axial sector of the Western Alps and tectonically overlain by blueschist-facies and eclogite-facies meta-ophiolite units (i.e. the Queyras Schistes Lustrès Complex and the Monviso Meta-ophiolite Complex, respectively; see e.g. Balestro et al., 2014; Festa, Balestro, Dilek, & Tartarotti, 2015; Tricart & Schwartz, 2006).

In its northern sector, the Dora-Maira comprises two main superposed units that, during Alpine orogeny, were metamorphosed under different P–T peak conditions (Figure 1). The upper one corresponds to an eclogite-facies polymetamorphic complex, which consists of metasediments and Upper Ordovician meta-intrusives (Bussy & Cadoppi, 1996) covered by thin Mesozoic carbonate metasediments; the lower one consists of a blueschist-facies Permo-Carboniferous monometamorphic complex (i.e. the Pinerolo Graphitic Complex; Borghi, Cadoppi, Porro, Sacchi, & Sandrone, 1984; Sandrone et al., 1993; Vialon, 1966). Both complexes contain meta-intrusives of granitic to dioritic composition, which can be related to a late Variscan magmatic event (Bussy & Cadoppi, 1996).

The FTM is included within the upper, polymetamorphic complex, which was affected by Variscan-related medium-grade metamorphism and, after the Alpine-related eclogite-facies metamorphism, was pervasively re-equilibrated under blueschist- and greenschist-facies metamorphic conditions (Borghi & Sandrone, 1990; Cadoppi, 1990; Cadoppi & Tallone, 1992; Camanni, 2010; Damiano, 1997; Sandrone et al., 1987, 1990).

4. Lithostratigraphy

In the main map, the Dora-Maira consists of a Paleozoic basement and a thin Mesozoic cover.

The Paleozoic basement corresponds to a pre-Carboniferous polymetamorphic complex that mainly consists of medium-grained garnet-chloritoid micaschist (Figure 2(a)). This micaschist locally preserves Variscan-related medium-grade mineral relics, corresponding to garnet porphyroblasts (Figure 2(a)) and muscovite lepidoblasts. The garnet-chloritoid micaschist embeds layers and bodies of impure marble, metabasite and gneisses. The impure marble is several metres-thick and is characterized by a mylonitic fabric defined by alternating centimetres-thick grey (calcite-rich) and yellow-whitish (dolomite-rich) layers (Figure 2(b)). It also consists of subordinate chlorite, white mica, tremolite and clinopyroxene (diopside), which likely represents a relic of the Variscan mineral assemblage. The metabasite crops out both as boudinage layers (up to tens of meters-thick) and small boudins (decimetre in size), and occurs within the micaschist (Figure 2(c)) and marble (Figure 2(b) and 2(d)). The

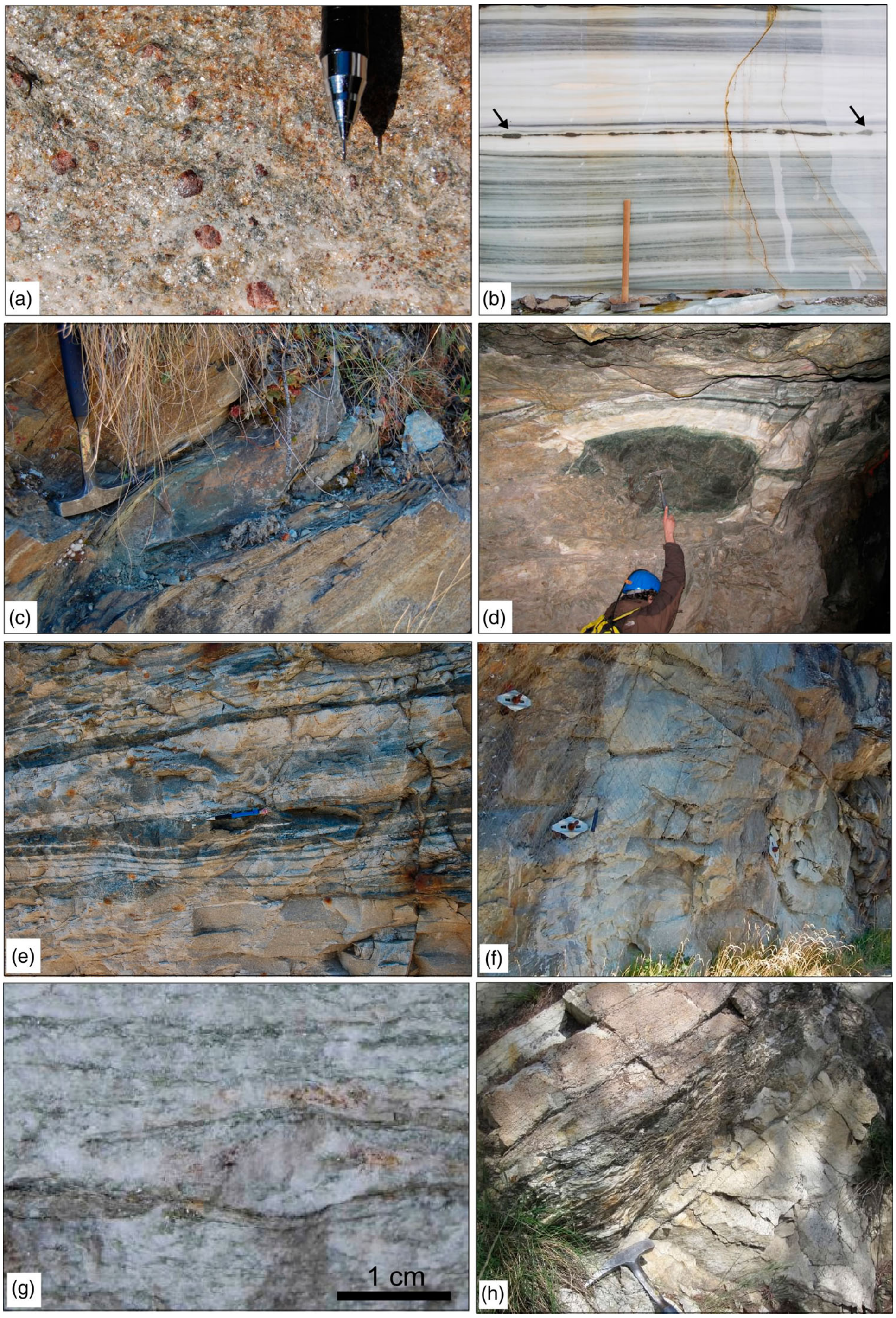

Figure 2. (a) Medium-grained garnet-chloritoid micaschist with porphyroblasts of centimetric pre-Alpine garnet (road to Rodoretto Village); (b) impure marble with mylonitic fabric defined by a compositional banding of grey (calcite-rich) and yellow-whitish (dolomite-rich) alternating layers. Black arrows indicate a boudinated centimetres-thick layer of metabasite occurring within the marble (Rocca Bianca quarry, just outside the study area); (c) and (d) boudins of metabasite embedded into the micaschist and marble, respectively (road to Rodoretto Village and Gianna mine tunnel); (e) layered gneiss with its characteristic compositional banding (near the bridge on the mouth of the Rodoretto Stream in the Germanasca Stream); (f) outcrop view and (g) detail of the K-feldspar-bearing gneiss (road to Rodoretto Village); (h) decimetres-thick level of silvery micaschist embedded in the K-feldspar-bearing gneiss (Serrevecchio locality).

metabasite, despite its widespread re-equilibration under greenschist-facies conditions, preserves relics of the eclogitic assemblage consisting of garnet, omphacite, white mica (phengite) and rutile. The up to tens of meters-thick gneisses can be distinguished in fine-grained layered gneiss (Figure 2(e)) and coarse-grained K-feldspar-bearing ones (Figure 2(f) and 2(g)). The former is characterized by a compositional banding defined by alternating centimetres-thick light grey and dark green layers (Figure 2(e)), which primarily consist of albite + quartz + garnet + phengite, and epidote + phengite + albite + quartz + Ca-amphibole, respectively. The coarse-grained K-feldspar-bearing (Figure 2(f) and 2(g)) gneiss also consists of quartz, albite, phengite, epidote and biotite, and is characterized by occurrences of centimetres to decimetres-thick levels of silvery micaschist (Figure 2(h)), which is made up of quartz and white mica (phengite).

The Mesozoic cover consists of massive white marbles and overlying calcschists. The former is made up of calcite, with minor dolomite and white mica (phengite), and is locally characterized by occurrences of several centimetres-thick metapelitic layers. The calcschists are fine- to medium-grained and consist of calcite, quartz, white mica (phengite), with minor chlorite and albite. Similar cover successions occur in other sectors along the western edge of the Dora-Maira and have been interpreted as Middle Triassic to Early Jurassic in age (Balestro, Festa, & Tartarotti, 2015; Balestro, Fioraso, & Lombardo, 2011, 2013).

5. Structures

Variscan-related structures have been recognized exclusively as microscale relics, whereas Alpine structures are widely exposed at the mesoscale and result from three main syn-metamorphic deformation phases (named D_1, D_2 and D_3).

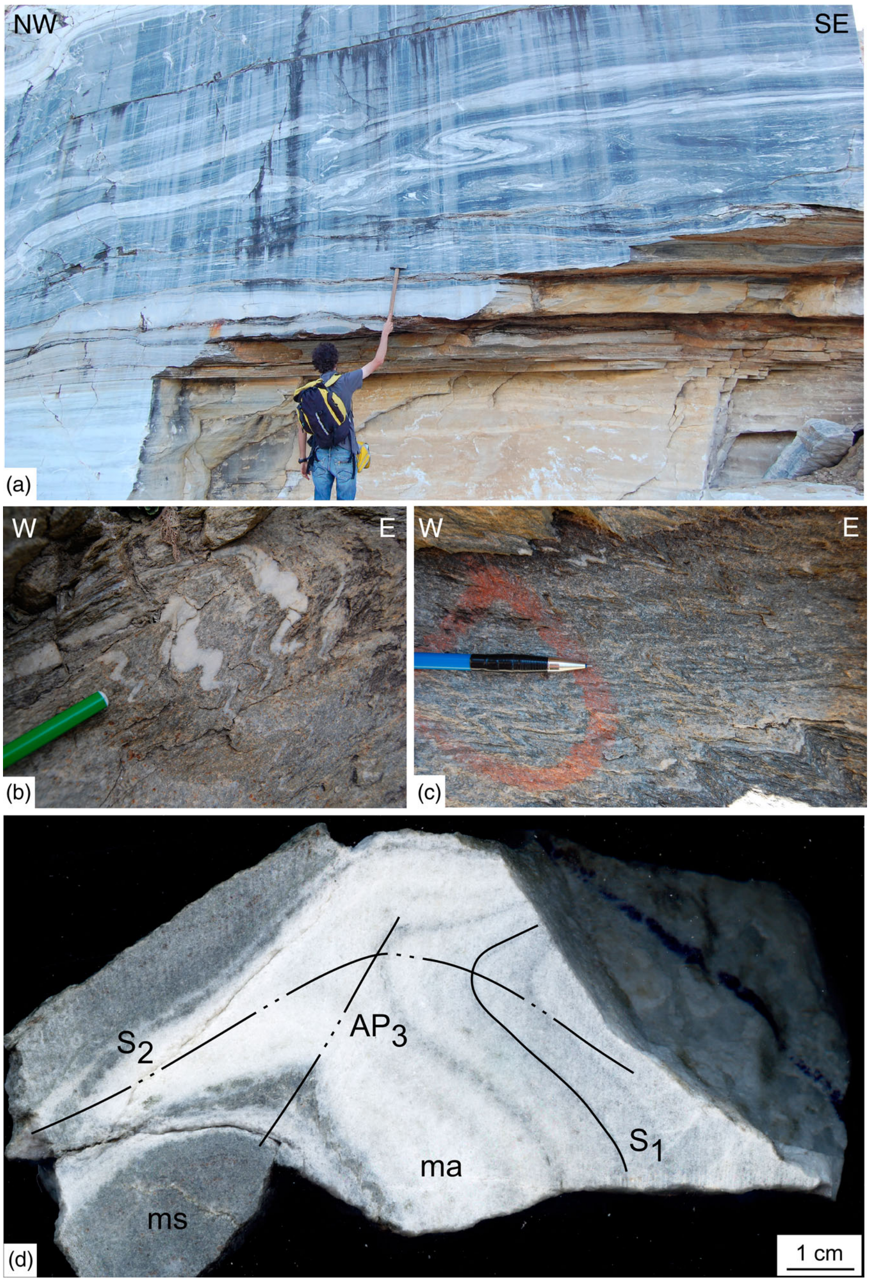

Figure 3 . D2 and D3 structures. (a) S1 mylonitic layering of impure marble fabric deformed by D2 folds (Maiera quarry, near the study area); (b) isoclinal D2 folds with thickened hinges occurring within the garnet-chloritoid micaschist (road to Rodoretto Village); (c) D3 structures folding of S2 foliation within the garnet-chloritoid micaschists (road to Rodoretto Village); (d) Type-3 interference pattern (Ramsay, 1967) between D2 and D3 folds and related axial plane foliation (S2) and axial plane (AP3), occurring within the impure marble (ma) and garnet-chloritoid micaschist (ms) (sample from the Gianna mine tunnel).

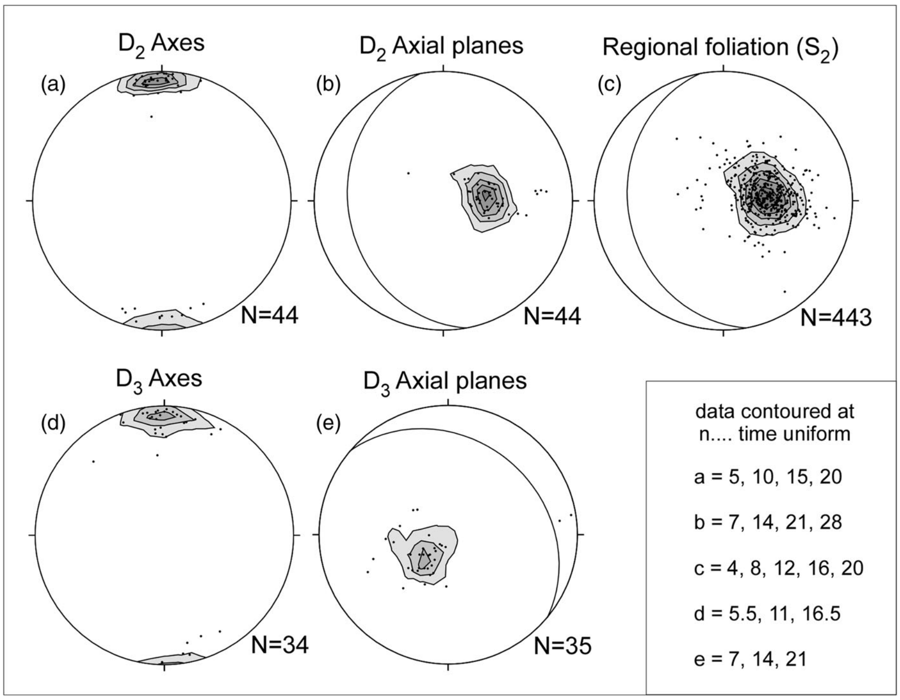

Figure 4 . Contoured stereographic projections (equal-area, lower hemisphere) of the D2 and D3 structures. The great circles show the mean orientation. *n* is the number of data.

The D_1 developed during the eclogite-facies metamorphism and is responsible for the development of a mylonitic foliation (i.e. the S_1; Figure 3(a)). Symmetric and asymmetric boudins of metabasite occurring within the impure marble, garnet-chloritoid micaschist and layered gneisses, are interpreted to be related to the S_1-parallel stretching during D_1 simple shear. The D_1-related stretching lineation dips at a low angle to the W (Borghi & Sandrone, 1990).

The D_2 developed under the early blueschist-facies metamorphic re-equilibration and is defined by isoclinal folds, with thickened hinges and thinned limbs (Figure 3(a) and 3(b)), characterized by N–S sub-horizontal axes and W-dipping axial planes (Figure 4). The pre-existing S_1 mylonitic fabric is clearly deformed by D_2 folds that developed an axial plane foliation (i.e. the S_2), which corresponds to the W-dipping main regional foliation (Figure 4). At the map scale, an example of these structures is the folding of the impure marble body in the central part of the main map (see also cross section (e)–(f)).

D_2 isoclinal folds and their axial plane foliation appear to be gently refolded by D_3 folds (Figure 3(c) and 3(d)), especially in the western part of the main map. D_3 folds developed under greenschist-facies metamorphic conditions and are characterized both by tight profiles in the form of crenulation folds (Figure 3(c)) and open to gentle geometries. D_3 axial planes weakly dip towards the NE and D_3 axes are on average sub-horizontal with a roughly N–S trend (Figure 4).

A last significant phase of deformation is a stage of extensional faulting that post-dates the syn-metamorphic structures and has been also described outside the study area (Perrone, Cadoppi, Tallone, & Balestro, 2011; Perrone, Morelli, Cadoppi, Tallone, & Giardino, 2009). Extensional faults are nearly NE–SW striking and NW steeply dipping (Figure 5(a)), and their displacements range from a minimum of a few centimetres to a maximum of several metres (Figure 5(b)–(e)). Fault rocks are mostly represented by tectonic breccia that are well exposed close to the Fontane locality and in the northern part of the main map (i.e. the 'Meison breccias' of Novarese, 1895, Borghi et al., 1984). At map scale, extensional faults are expressed as NE–SW hectometre- to kilometre-scale fault segments arranged in en-echelon, left-stepping geometrical pattern, and with spacings of several hundreds of metres.

6. Geometry of the FTM

Defining the structure and extent of the FTM is of critical importance both for understanding the origin of the talc and for any industrial operations related to its extraction. Talc is not distributed in continuous horizons but forms isolated bodies embedded within the garnet-chloritoid micaschist and the K-feldspar-bearing gneiss closely associated with the impure marble.

Talc bodies appear to define lenses with a shape similar to that of the boudins of metabasite (see cross section (c)–(d)), suggesting that their early geometry resulted from D_1 deformation. These lenses were later deformed during the D_2 phase and now outcrop in the form of thickened hinges of rootless folds, and were slightly affected by the D_3 that seems to cause minor changes in the dip of the isolated lenses.

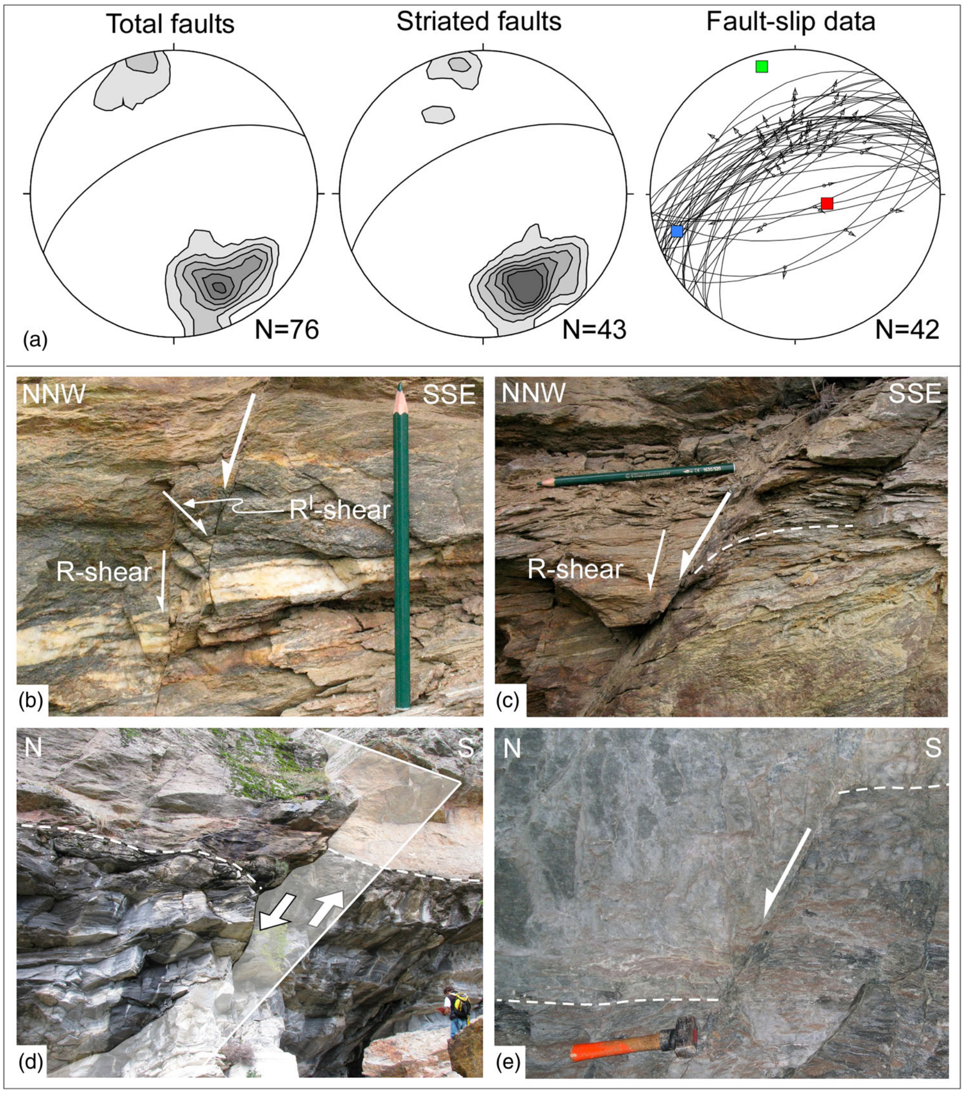

Figure 5 . (a) Contoured stereographic projections (equal-area, lower hemisphere projections) of the extensional faults. The great circles show the mean fault plane orientations. Data contoured at $n = 2, 4, 6, 8, 10, 12$ times uniform, n is the number of data. The red, blue and green squares represent the maximum (P), intermediate and minimum (T) shortening axes for the average incremental strain solution, respectively; (b) and (c) Riedel shear-sense indicators (R and R′) and inflection of the S2 foliation (dashed white line) along normal fault planes occurring within the garnet-chloritoid micaschist (entrance of the Gianna mine tunnel); (d) Plurimetric displacement of the contact (dashed white line) between the garnet-chloritoid micaschist (above) and impure marbles (below) (E of Fontane Village); (e) pluridecimetric displacement of the contact (dashed white line) between the K-feldspar-bearing gneiss (above) and garnet-chloritoid micaschist (below) (Gianna mine tunnel).

Finally, extensional faults that intersect talc bodies at depth appear to be responsible for their dislocations towards the NW with displacements of up to several tens of metres (see cross section (a)–(b)).

7. Conclusions

The 1:5000 scale geological map of the FTM gives new information for interpreting the origin and distribution of talc bodies.

Detailed geological mapping and underground observations highlight that the talc bodies (i) are embedded within a pre-Carboniferous polymetamorphic complex, (ii) occur along a well-defined lithostratigraphic association between micaschist, marble and gneiss and (iii) never occur within the Mesozoic cover.

Structural analysis highlights that the talc bodies were clearly deformed during Alpine-related deformation phases (i.e. the D_1, D_2 and D_3 phases) and, therefore, their genesis predate Alpine tectonics.

These considerations may be useful for future research regarding the origin of the FTM as well as other talc mineralizations occurring along the western edge of the Dora-Maira. Pre-rift tectonics (and associated metasomatic processes?) which affected the paleo-European continental margin likely appear as a geodynamic context wherein talc could be formed. An extensional tectonics model is described for other important talc mineralization, such as the Trimouns Talc Deposit in the Pyrenees (Schärer, de Parseval, Polvé, & de Saint Blanquat, 1999).

Moreover, the here defined lithostratigraphic and structural characterization of the FTM may represent a useful geological model for new mineral explorations outside the map area.

Software

The geological map was digitized using Esri ArcGIS v 9.3.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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