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Geological map of the Fontane Talc Mineralization (Germanasca Valley, Italian Western Alps)

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Abstract

The 1:5,000 scale Geological Map of the Fontane Talc Mineralization 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 Fontane Talc Mineralization 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 a input for further researches onto geodynamic context wherein talc formed and for new mineral exploration outside the mapped area.

Keywords: 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 a geological body with a significant content in 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 et al., 1955; Peretti, 1966; Zucchetti, 1969, 1972; Sandrone et al., 1987, 1990; Sandrone & Zucchetti, 1989). 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 (Sandrone et al., 1993) (Fig. 1).

Despite its industrial significance, both origin and geological structure of the FTM has been never defined in detail, and published map exists only at small scale (i.e., the Pinerolo sheet of the Geological Map of Italy at 1:100,000 scale; Mattirolo et al., 1913). In this paper, we present a new 1:5,000 scale geological map that spans an area of about 8 km^2 above the main infrastructures (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 map with geological cross sections that allow identifying their location at depth, as well as defining their geometry and lithostratigraphic association with embedding rocks.

2. Methods

The geological map presented in this study is the result of fieldwork carried out at 1:5,000 scale. Lithological observations and collection of structural data were performed both in the field and in underground locations. Data were stored in a GIS database (Coordinate System WGS 1984 UTM Zone 32N) and represented on a raster topographic map derived from “Carta Tecnica Provinciale” 1:5,000 ("Dai tipi di proprietà della Città Metropolitana di Torino - Servizio Cartografico", authorization n.105625/2015 on July 21, 2015).

The geological map includes (*i*) three cross sections localized 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), 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 (Fig. 1) (see e.g. Bigi et al., 1990; Dal Piaz et al., 2003). The Dora-Maira (Vialon, 1966; Sandrone et al., 1993; Cadoppi et al., 2002) was involved in Alpine-related E-dipping subduction, W-verging continental collision and deep crust/mantle indentation (see e.g. Wheeler, 1991; Chopin et al., 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., Tricart and Schwartz, 2006; Balestro et al., 2014).

In its northern sector, the Dora-Maira comprises two main superposed units that, during Alpine orogeny, were metamorphosed under different P–T peak conditions (Fig. 1). The upper one corresponds to an eclogite-facies polymetamorphic complex, which consists of metasediments and Upper Ordovician meta-intrusives (Bussy and 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; Vialon, 1966; Borghi et al., 1984; Sandrone et al., 1993). 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 (Sandrone et al., 1987, 1990; Borghi and Sandrone, 1990; Cadoppi, 1990; Cadoppi and Tallone, 1992; Damiano, 1997; Camanni, 2010).

4. Lithostratigraphy

In the map area, 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 (Fig. 2a). This micaschist locally preserves Variscan-related medium grade mineral relics, corresponding to garnet porphyroblasts (Fig. 2a) 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 (Fig. 2b). 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 ten of meters-thick) and small boudins (decimetre in size), and occurs within the micaschist (Fig. 2c) and marble (Fig. 2b and Fig. 2d). The metabasite, despite of 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 (Fig. 2e) and coarse-grained K-feldspar-bearing ones (Fig. 2f and 2g). The former is characterized by a compositional banding defined by alternating centimetres-thick light grey and dark green layers (Fig. 2e), which mainly consist of albite + quartz + garnet + phengite, and epidote + phengite + albite + quartz + Ca-amphibole, respectively. The coarse-grained K-feldspar-bearing (Fig. 2f and 2g) gneiss also consists of quartz, albite, phengite, epidote and biotite, and is characterized by occurrences of centimetres to decimetres-thick levels of silvery micaschist (Fig. 2h), 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 occurrence of few 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 et al., 2013, 2015).

5. Structures

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

The D_1 developed during the eclogite-facies metamorphism and is responsible for the development of a mylonitic foliation (i.e. the S_1; Fig. 3a). 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_2 developed under the early blueschist-facies metamorphic re-equilibration and is defined by isoclinal folds, with thickened hinges and thinned limbs (Fig. 3a and 3b), characterized by N-S sub-horizontal axes and W-dipping axial planes (Fig. 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 (Fig. 4). At the map scale, an example of these structures is the folding of the impure marble body in the central part of the map area (see also cross section E-F).

D_2 isoclinal folds and their axial plane foliation appear to be gently refolded by D_3 folds (Fig. 3c and 3d), especially in the western part of the map area. D_3 folds developed under greenschist-facies metamorphic condition and are characterized both by tight profiles in the form of crenulation folds (Fig. 3c) 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 (Fig. 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 et al., 2009, 2011). Extensional faults are nearly NE-SW striking and NW steeply dipping (Fig. 5a), and their displacements range from a minimum of a few centimetres to a maximum of several metres (Fig. 5b, 5c, 5d and 5e). Fault rocks are mostly represented by tectonic breccia that are well exposed close to Fontane locality and in the northern part of the map area (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 spaced 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 talc and for any industrial operations related with 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.

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 1:5,000 scale Geological Map of the Fontane Talc Mineralization 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. Extensional tectonics model is described for other important talc mineralization, such as the Trimouns Talc Deposit in the Pyrenees (Schärer et al., 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 the software ArcMap of the suite ArcGis Desktop (v. 9.3) by ESRI®.

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Figure captions

Figure 1: Localization of the Fontane Talc Mineralization in the tectonic map of the Western Alps.

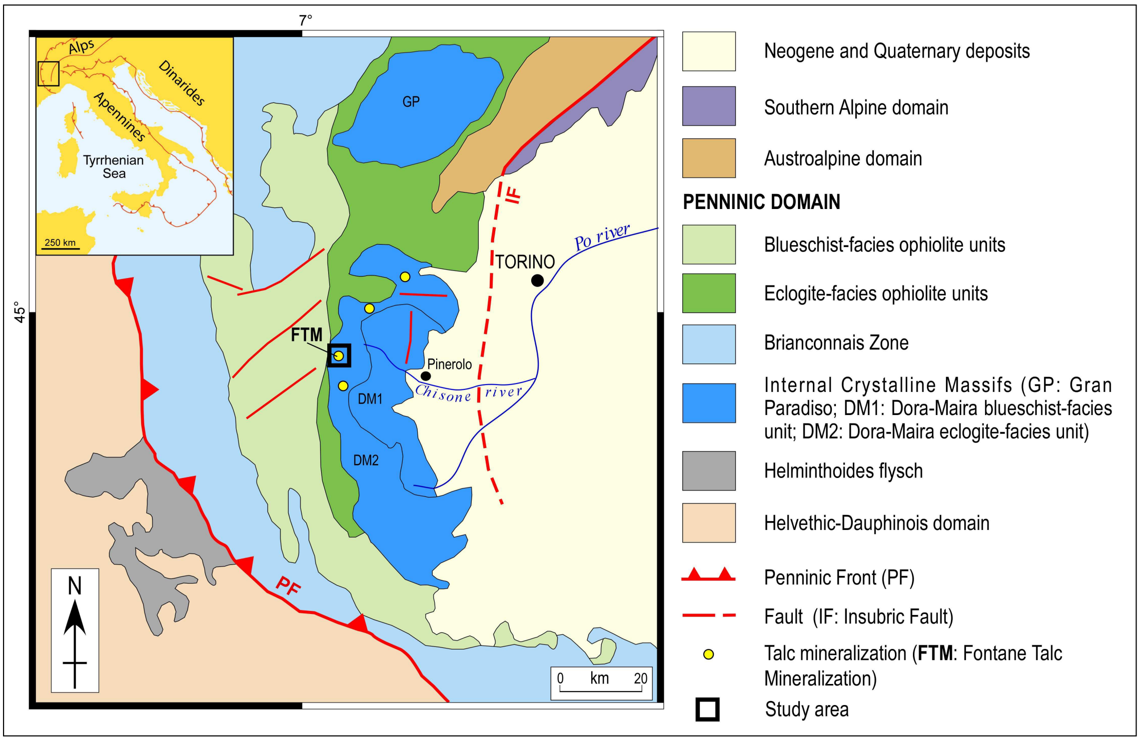
Figure 2: a) medium-grained garnet-chloritoid micaschist with porphyroblasts of centimetric pre-Alpine garnet (road to Rodoretto Village); b) impure marble with mylonitic fabric defined by a compositional banding of grey (calcite-rich) and yellow-whitish (dolomite-rich) alternating layers. Black arrows 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).

Figure 3: D2 and D3 structures. a) S_1 mylonitic layering of impure marble fabric deformed by D_2 folds (Maiera quarry, near the study area); b) isoclinal D_2 folds with thickened hinges occurring within the garnet-chloritoid micaschist (road to Rodoretto Village); c) D_3 structures folding of S_2 foliation within the garnet-chloritoid micaschists (road to Rodoretto Village); d) Type-3 interference pattern (Ramsay, 1967) between D_2 and D_3 folds and related axial plane foliation (S_2 and S_3), occurring within the impure marble (ma) and garnet-chloritoid micaschist (ms) (S_M corresponds to the S_1 foliation; sample from the Gianna mine tunnel).

Figure 4: contoured stereographic projections (equal-area, lower hemisphere) of the D_2 and D_3 structures. The great circles show the mean orientation. N is the number of data.

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 S_2 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).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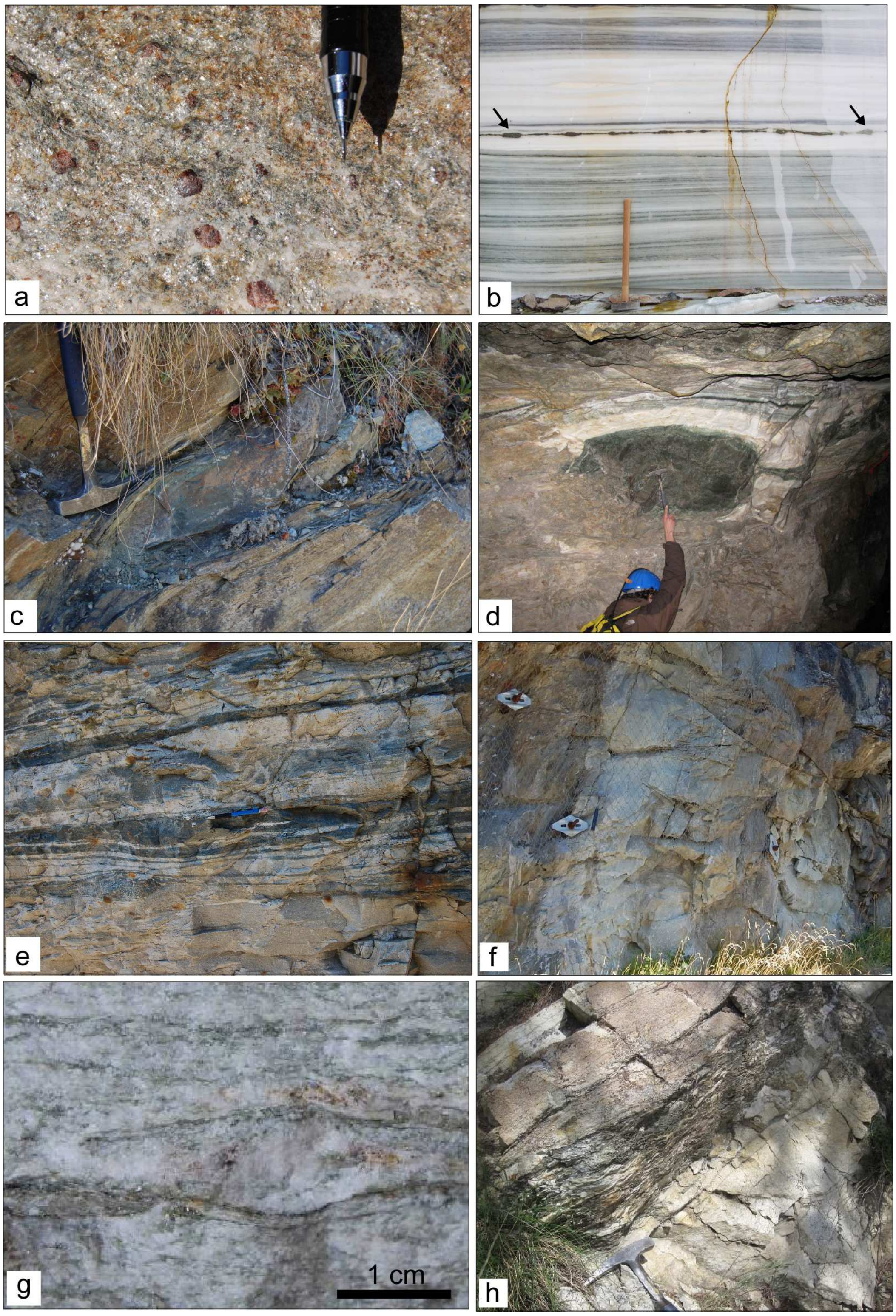
Dinarides
Apennines
Tyrrhenian Sea
250 km
GP
TORINO
Po river
FTM
Pinerolo
Chisone river
DM1
DM2
IF
PF
N
0 km 20
Neogene and Quaternary deposits
Southern Alpine domain
Austroalpine domain
PENNINIC DOMAIN
Blueschist-facies ophiolite units
Eclogite-facies ophiolite units
Brianconnais Zone
Internal Crystalline Massifs (GP: Gran Paradiso; DM1: Dora-Maira blueschist-facies unit; DM2: Dora-Maira eclogite-facies unit)
Helminthoides flysch
Helvethic-Dauphinois domain
Penninic Front (PF)
Fault (IF: Insubric Fault)
Talc mineralization (FTM: Fontane Talc Mineralization)
Study area



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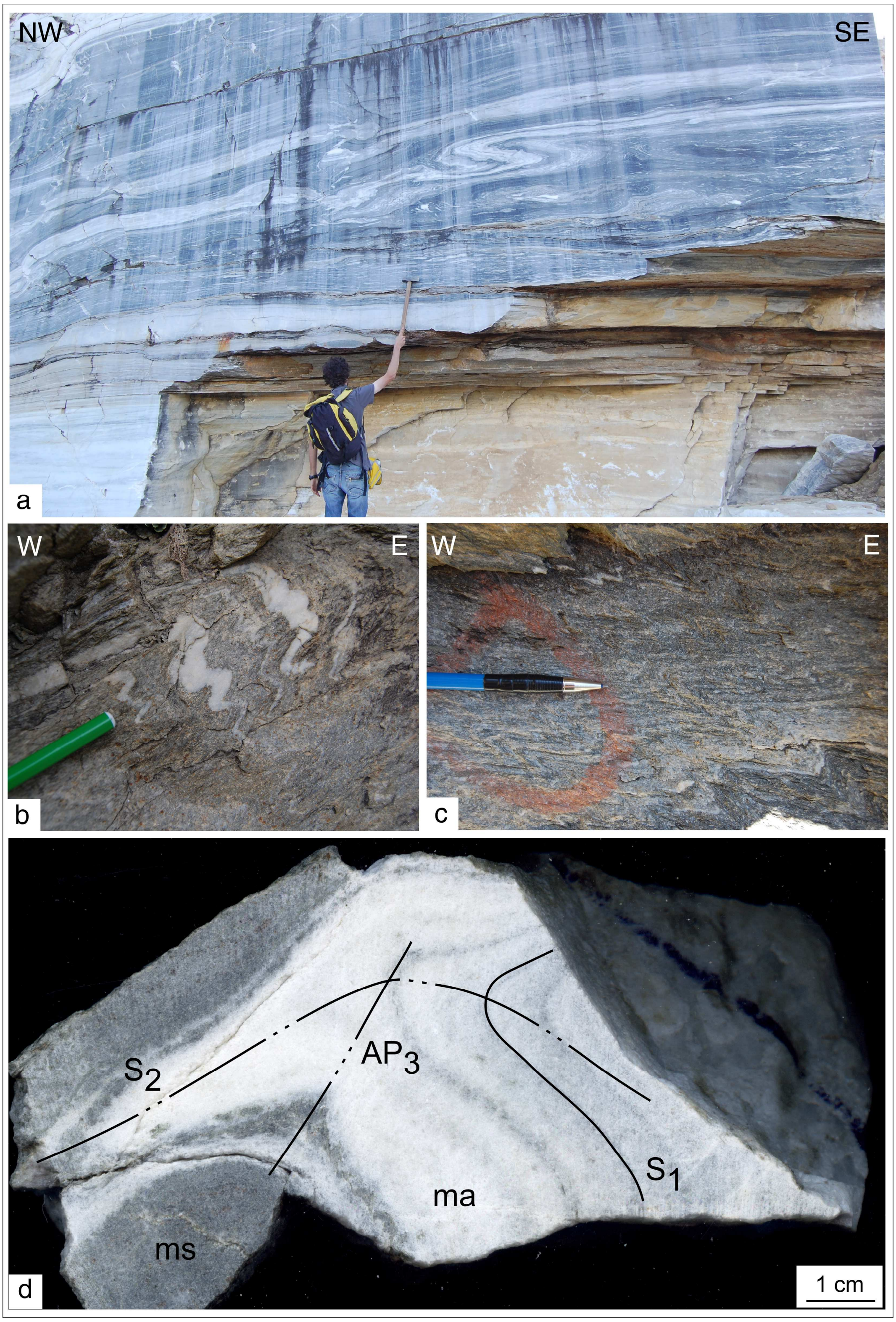
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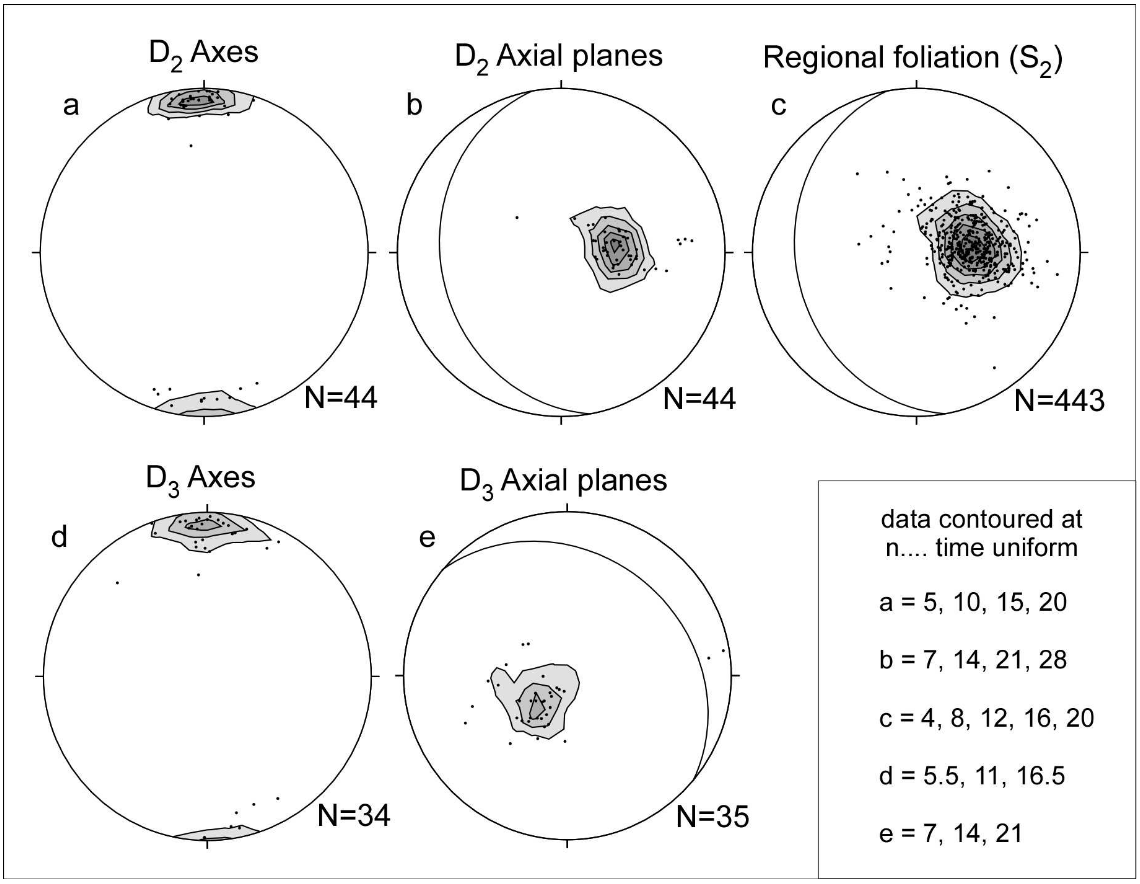
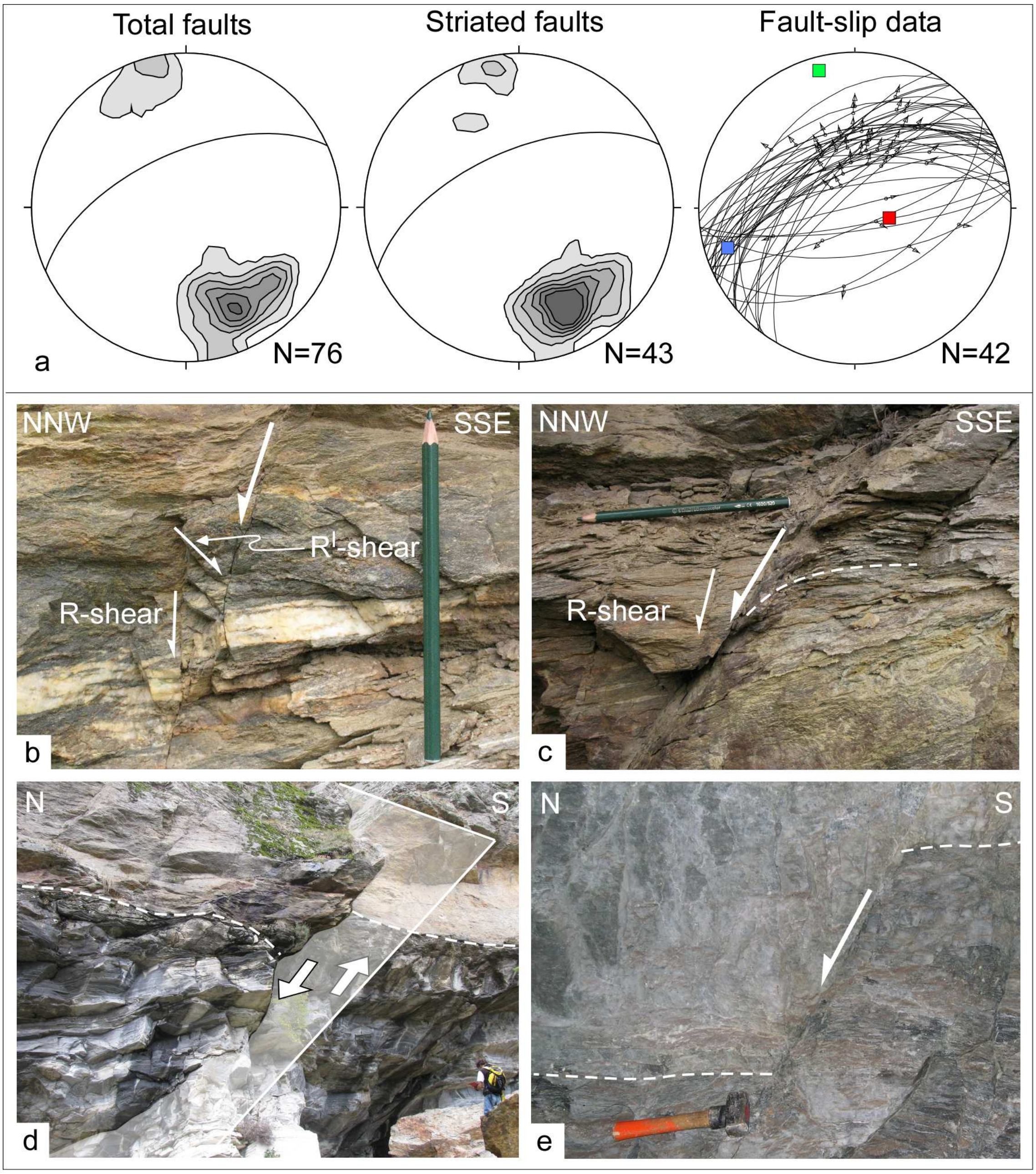

D2 Axes
a
N=44
D2 Axial planes
b
N=44
Regional foliation (S2)
c
N=443
D3 Axes
d
N=34
D3 Axial planes
e
N=35
data contoured at
n.... time uniform
a = 5, 10, 15, 20
b = 7, 14, 21, 28
c = 4, 8, 12, 16, 20
d = 5.5, 11, 16.5
e = 7, 14, 21

414 
Total faults
Striated faults
Fault-slip data
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N=76
N=43
N=42
NNW
SSE
R'-shear
R-shear
b
NNW
SSE
R-shear
c
N
S
d
N
S
e

415