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

Paola Cadoppi, Giovanni Camanni, Gianni Balestro and Gianluigi Perrone

Department of Earth Sciences, University of Torino, Torino, Italy; Fault Analysis Group, School of Geological Sciences, University College Dublin, Belfield Dublin 4, Ireland

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. D1, D2 and D3 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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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, 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 (Sandro, 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 km² 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)
and (ii) a 1:20,000 scale tectonic map wherein geologi-

cal 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, Bis-

tacchi, & 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 oro-

geny, 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 carbonatic metasediments; the lower

one consists of a blueschist-facies Permo-Carbonifer-
ous monometamorphic complex (i.e. the Pinerolo Gra-

phitic Complex; Borghi, Cadoppi, Porro, Sacchi, &

Sandro, 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, polymeta-
morphic complex, which was affected by Variscan-
related medium-grade metamorphism and, after the
Alpine-related eclogite-facies metamorphism, was per-
vassively re-equilibrated under blueschist- and greens-
chist-facies metamorphic conditions (Borghi &
Sandro, 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 Paleo-
zoic basement and a thin Mesozoic cover.

The Paleozoic basement corresponds to a pre-Car-

boniferous polymetamorphic complex that mainly

consists of medium-grained garnet-chloritoid micas-

chist (Figure 2(a)). This micaschist locally preserves
Variscan-related medium-grade mineral relics, corre-

gerating to garnet porphyroblasts (Figure 2(a)) and

muscovite lepidoblasts. The garnet-chloritoid micas-

chist 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 clinoxyroxene (diopsdie), which
likely represents a relic of the Variscan mineral assem-
blage. 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
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, & Tar tarotti, 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 D1, D2 and D3).

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).
The D1 developed during the eclogite-facies metamorphism and is responsible for the development of a mylonitic foliation (i.e. the S1; 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 S1-parallel stretching during D1 simple shear. The D1-related stretching lineation dips at a low angle to the W (Borghi & Sandrone, 1990).

The D2 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 S1 mylonitic fabric is clearly deformed by D2 folds that developed an axial plane foliation (i.e. the S2), 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)).

D2 isoclinal folds and their axial plane foliation appear to be gently refolded by D3 folds (Figure 3(c) and 3(d)), especially in the western part of the main map. D3 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. D3 axial planes weakly dip towards the NE and D3 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 D1 deformation. These lenses were later deformed during the D2 phase and now outcrop in the form of thickened hinges of rootless folds, and were slightly affected by the D3 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 1:5000 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 D1, D2 and D3 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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