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GEOLOGICAL MAP OF MONTE GRIGHINI VARISCAN BASEMENT
(SARDINIA, ITALY)

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Abstract

The study area belongs to the Nappe zone of the Sardinian Variscan basement in the NW part of the Flumendosa Antiform. The area shows a section of the Variscan orogen in Sardinia with three tectonic units stacked and folded during the Middle Carboniferous Variscan tectonics under lower greenschist and upper amphibolites facies conditions, successively juxtaposed during late Variscan tectonics. The presented 1:25,000 scale geological map, the cross sections and the shear zone deformation map illustrate the tectonic and metamorphic setting of the area, resulting from the polyphasic Variscan collisional evolution including early nappe stacking and following strike slip and extensional tectonics coeval with a late Carboniferous magmatism.

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1. Introduction

The Monte Grighini complex is located in the Nappe zone of the Variscan metamorphic basement of Sardinia (Fig. 1), which is a part of the Southern Variscan realm (Carmignani et al., 1994). In the Nappe zone all of the tectonic units are emplaced with a top-to-the-south transport direction (Conti et al., 2001); metamorphism and internal deformation of rocks increase northward from subgreenschist in the south, up to amphibolite facies in the internal Nappe zone (Franceschelli et al. 1990; Elter et al. 1986). The inner zone of the chain, north of Posada-Asinara line, is characterized by widespread occurrence of migmatite (Cruciani et al. 2008a,b) with subordinate eclogite and granulite (Franceschelli et al. 2002, 2007).

The Monte Grighini complex (Fig. 2) was firstly considered a basement of pre-Variscan age (Carmignani et al., 1982) on the basis of occurrence of metamorphic rocks of amphibolites facies. Successively detailed field survey coupled with structural and petrological studies allow to reinterpret the Monte Grighini complex as a Variscan basement marked by the occurrence of (i) the deepest unit of the Nappe zone and (ii) a major late Variscan strike-slip shear zone (Elter et al. 1990) exploited by metaluminous (diorite to monzogranite) and peraluminous (leucogranite) synkinematic intrusions (Cherchi and Musumeci 1986; Musumeci 1992).

The aim of this map is to give new and updated information about the lithological, structural and metamorphic setting of the Variscan basement in the Nappe zone of central Sardinia.

2. Methods

The map at 1:25,000 scale covers an area of nearly 60 km² that was originally mapped at the 1:10,000 scale. Both the original data and map are represented on a vector topographic map (Carta Tecnica Regionale – Regione Autonoma della Sardegna) and stored in a GIS database

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(Coordinate System Monte Mario Gauss Boaga ovest). The overall dataset includes i) lithological, structural and petrographic data collected in two master theses (Cherchi 1985, Musumeci 1985) and PhD thesis (Musumeci 1991a), together with ii) new geo-petrographic data (M.E. Spano PhD thesis, in progress). During the first field survey a wide ductile shear zone (Monte Grighini Shear Zone) and synkinematic intrusions were recognized for the first time in the Variscan basement of Sardinia and described in Cherchi and Musumeci (1986), Carmignani et al. (1987) and Elter et al. (1990). Structural data interpretation is based on geometrical analysis (equal-area lower-hemisphere stereographic projections) of the main foliation (S_1 and S_2) in the tectonic units and mylonitic and cataclastic foliation in the shear zone that allow to calculate the shear strain variation and the amount of ductile displacement (Musumeci 1991b; 1992)

62

63 **Lithostratigraphy**

64 The Variscan basement in the study area consists of three tectonic units with lower greenschist to upper amphibolites facies metamorphism and late Carboniferous intrusive rocks. From bottom to top they are: Monte Grighini Unit, Castello Medusa Unit and Gerrei Unit.

68 **Gerrei Unit:** Middle Ordovician to Siluro–Devonian very low metamorphic grade lithostratigraphic succession that starts with the Middle Ordovician metavolcanics (Carmignani et al 1994) that consists of metavolcanite of intermediate composition (Monte Santa Vittoria Fm.) upward followed by metasandstone and metarkoses (Su Muzzioni Fm.) and rhyolitic-rhyodacitic metavolcanics (Porfiroidi Fm.). The Upper Ordovician-Silurian succession starts with metarkoses and quartzites (Genna Mesa Fm.) followed by metapelites with fossiliferous metasiltites (crynoids articles and inarticulated brachiopods) with thick

75 fossiliferous (encrinite) metalimestone (Rio Canoni Fm.). Black shales with decametre thick
 76 lenticular bodies of nodular limestone correspond to the Siluro-Devonian succession (Scisti
 77 Neri Fm.).

78 **Castello Medusa Unit:** low metamorphic grade (biotite zone, upper greenschist facies)
 79 metarkoses related to the Upper Ordovician volcanoclastic succession of Genna Mesa Fm.,
 80 upward followed by metapelites with intercalated decameter thick marble and calc-schist
 81 belonging to the Sa Lilla Fm. of Upper Silurian-Devonian age.

82 **Monte Grighini Unit:** metavolcanic-volcanoclastic (Truzzulla Fm.) and metasedimentary
 83 (Toccori Fm.) rocks of medium metamorphic grade (Figs 3a, b, c) intruded by late
 84 Carboniferous granitoids (Figs 3d, e, f). The metamorphic grade increases from the biotite-
 85 garnet zone at east-southeast to the sillimanite zone at west-northwest. Common mineral
 86 assemblages are (i) muscovite + biotite + garnet, (ii) muscovite + biotite + garnet + staurolite
 87 + oligoclase, (iii) biotite + andalusite + plagioclase + K-feldspar, (iv) biotite + staurolite +
 88 andalusite + plagioclase + K-feldspar + fibrolite (Musumeci 1992).

89 The Truzzulla Fm. consists of Upper Ordovician (447 ± 4.3 Ma) acidic metavolcanics,
 90 metarkose and arkosic metasandstones of calc-alkaline affinity (Cruciani et al. 2013).
 91 Metavolcanics are upward followed by metarkoses and arkosic metasandstones with augen
 92 textures partitioned in intensely foliated domains (Fig. 3b).

93 The Toccori Fm. consists of metapelite with intercalated centimeter to decimeter-thick
 94 metasilite layers. White quartzite levels (Fig. 3c) marks the base of the Toccori Fm., while
 95 black graphitic metapelite and meter-thick marble lenses occur in the uppermost portion of
 96 the formation. The garnet + staurolite + biotite + K-white mica + plagioclase mineral
 97 assemblage of the Toccori Fm. (Fig. 3a) is interpreted as the result of medium metamorphic

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98 grade conditions developed in the deepest portion of external nappes during the main phase of
99 folding and south verging nappe stacking (Musumeci 1992).

100

101 **Monte Grighini Intrusive complex**

102 Late Variscan intrusive rocks and dyke system (305-295 Ma) constitute the Monte Grighini
103 intrusive complex emplaced in the Monte Grighini Unit. On the basis of mineral assemblages
104 and geochemical signature (Del Moro et al. 1991), a diorite, tonalite, monzogranite suite (I-
105 type calc-alkaline metaluminuos suite) and a leucogranite (S-type peraluminous suite) have
106 been distinguished.

107 Monte Grighini Diorite: fine-grained biotite-bearing diorite occur as metre to decametre thick
108 bodies and as centimetre to decimetre thick enclaves within tonalites and monzogranites (Fig.
109 3d, e). The largest bodies of diorites crop out at north and northwest of Monte Grighini top.

110 Monte Grighini Tonalite: biotite-bearing medium to fine grained tonalites are two NW-SE
111 elongated sheet bodies. Fabric marked by alignment of igneous plagioclase and biotite
112 characterizes the tonalite body emplaced within the Toccori Fm. at east of Cuccuru Mannu.

113 Monte Grighini Monzogranite: medium-grained biotite monzogranite (Fig. 3d, e), forms a
114 wide NW-SE elongated sheet intrusion exposed in the central and northern portion of the
115 massif, that extends eastward at shallow depth within the Monte Grighini Unit.

116 Monte Grighini Leucogranite: fine-grained muscovite-bearing leucogranite (Fig. 3e, f) forms
117 a NW-SE elongated sheet intrusion. Mineral assemblages are (i) quartz + K-feldspar +
118 plagioclase + K-white mica + biotite ± garnet and (ii) quartz + K-feldspar + plagioclase + K-
119 white mica +garnet ± biotite. K-white mica -bearing assemblage dominates in the southern

120 portion (Su Cruccuri-Monte Corongiarbu) while K-white mica - and biotite-bearing
121 assemblages occur in the northern portion (Cuccuru Mannu).

122 Dyke system consists of aplitic dykes related to intrusive complex and quartz dykes that are
123 very abundant and cross-cutting lithological contacts and tectonic structures including the
124 shear zone. Dykes strike mainly along ENE-WSW and NW-SE directions, orthogonal and
125 parallel to the shear zone, respectively.

126

127 **Tectonic and metamorphic evolution**

128 The tectonic units experienced a polyphase Variscan tectonic and metamorphic evolution
129 characterized by an early shortening deformation related to the syn-collisional southward
130 nappe stacking (D_1 phase Gerrei Unit and D_1 - D_2 phases Castello Medusa and Monte Grighini
131 Unit) with isoclinal folds overturned towards southwest and axial plane foliation (F_1 - S_1
132 Gerrei Unit and F_2 - S_2 Castello Medusa and Monte Grighini Unit; Fig. 4a). Deformation
133 developed under lower greenschist facies (chlorite zone) in the Gerrei Unit while Castello
134 Medusa and Monte Grighini units experienced syn- D_2 upper greenschist facies (biotite zone)
135 and amphibolite (garnet – staurolite zone) facies metamorphism, respectively (Fig. 5a). In the
136 Monte Grighini Unit upper amphibolite facies P-T conditions are testified by syn-post D_2
137 growth of andalusite and sillimanite/fibrolite and cordierite assemblage (Fig. 5b). Recent
138 geothermobarometric data (Spano et al. 2012), indicate P-T condition of 7,5 kbar - 500°C for
139 syn- D_2 and 4 kbar –for post- D_2 amphibolite facies metamorphism. Nappe-stacking structures
140 were deformed by successive deformation phase (D_2 Gerrei Unit and D_3 Castello Medusa and
141 Monte Grighini Unit; Fig. 5c) with development of large scale NW-SE trending upright
142 antiform and synform (F_2 Gerrei Unit and F_3 Castello Medusa Unit and Monte Grighini Unit).

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Late Variscan shear zone: NW-SE trending kilometer-wide dextral strike-slip shear zone marked by the synkinematic emplacement of the intrusive complex represents the main tectonic lineament of the Monte Grighini complex (Musumeci 1992). Shear deformation increases toward west from protomylonite zone to ultramylonite zone forming a narrow belt along the western side of shear zone (Figs, 4b, c). At mesoscopic scale, mylonite fabrics are NW-SE trending C-type shear bands and mylonitic-ultramylonite foliation that steeply dip toward southwest and bear subhorizontal to gently plunging mineral lineations (Figs 4e, f and Figs 5d,e,f). The C-type shear bands are homogeneously distributed throughout shear zone, while consistently with the westward increase of shear strain , the ultramylonite foliation are partitioned in the ultramylonite zone where the highest value of shear strain are attained (Musumeci 1991b). The westernmost and southernmost portions of the shear zone correspond to a west dipping zone of cataclastic rocks of variable thickness (decametre to hectometre), marked by brittle deformation. Southwest dipping cataclastic foliation and shear planes show a top to the southwest sense of shear (Fig. 4d).

Conclusions

A detailed field survey, including geological mapping, petrographic/petrologic investigations and systematic structural analyses allowed the depiction of a 1:25,000 scale geological map of the Monte Grighini complex that gives new insights about the Ordovician magmatism and the composite stack of Variscan units in the north-western sector of Sardinia Nappe zone. Specifically, detailed geological mapping has allowed us to pursue the following main topics:

- compilation of a synthesis of both existing and new data about the lithological, structural and petrological features that characterize the metamorphic and igneous units of the mapped area;
- detailed mapping of late Variscan shear zone and synkinematic intrusions;

167 - the role of late Variscan strike-slip and extensional tectonics in the final architecture of the
168 chain.

169 The new and updated geological information about the Monte Grighini complex may be the
170 base for further studies on the tectono-metamorphic evolution and geodynamic setting of
171 Paleozoic basement in Sardinia.

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174 **Software**

175 The map database was built using ArcGIS software with the final map layout assembled using
176 CorelDRAW X5 graphics suite. Topographic maps of Carta Tecnica Regionale of the
177 Regione Autonoma della Sardegna were downloaded from www.sardegna.territorio.it. Photos
178 were managed and compiled with CorelDRAW X5 graphics suite.

179

180 **Acknowledgements**

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187 field work.

188

Map Design

The topographic map has been done through the following steps: i) cartographic base was imported in ArcGIS software, ii) then it was edited: contour lines directives (every 50 m) has been stained by black color whereas the contour lines every 10 meters are grey, iii) few listed spots are reported at the top of the hills, iv) roads are brown and rivers are blue, v) few toponyms are reported. Coordinate grid is related to UTM (Universal Transversal Mercator - Zone 32S – European Datum 1950) coordinate system and Gauss Boaga (West– Rome 1940) and latitude /longitude system are also reported.

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262 Figure captions

263 **Figure 1.** Tectonic map of the Variscan basement of Sardinia (after Carmignani et al., 2001,
264 modified).

265 **Figure 2.** Tectonic sketch map of Monte Grighini complex.

266 **Figure 3.** (a) staurolite-garnet-bearing micaschist of Toccori Fm.; (b) metavolcanic
267 sandstone of Truzzulla Fm with augen fabric; (c) white quartzite at the base of Toccori Fm;
268 (d) intrusive contact between diorite (MGd) and monzogranite (MGm). Scale bar: 30 cm; (e)
269 monzogranite (MGm) with diorite enclaves (MGd), cross cut by muscovite –bearing
270 leucogranite (MGI); (f) muscovite-bearing leucogranite. Red dots are Fe-oxides.

272 **Figure 4.** (a) F_2 isoclinal folds in micaschist. Scale bar: 12 cm; (b) ultramylonite-phyllonite
273 rocks at the western boundary of the shear zone; (c) outcrop scale view of mylonite-
274 ultramylonite transition. Scale bar: 20 cm; (d) cataclastic zone, detail of southwest dipping
275 cataclastic foliation enveloping leucogranite dykes; (e) muscovite-bearing mylonitic
276 leucogranite with C/S fabric. Scale bar: 3 cm; (f) ultramylonite fabric in sheared
277 monzogranite marked by quartz ribbons and K-feldspar porphyroclasts. Scale bar: 1 cm.

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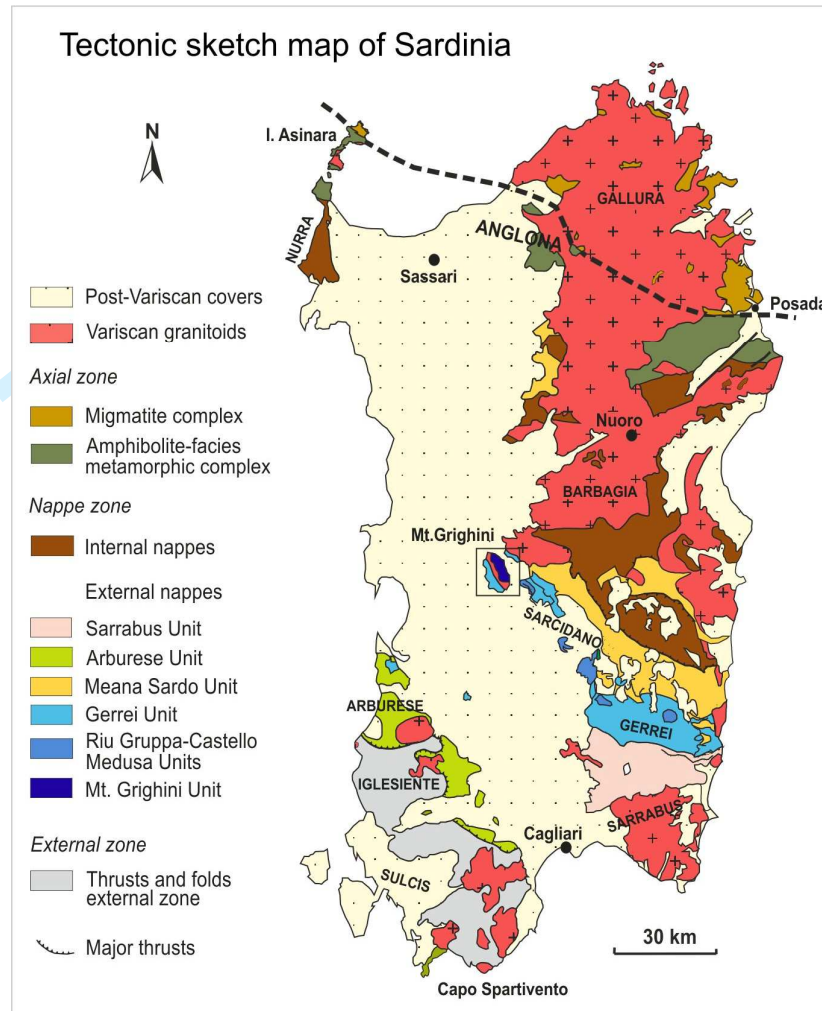
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Figure. 5 (a) Toccoi micaschist, syntectonic garnet porphyroblast in a fine- to medium-grained quartz and phyllosilicate-rich layered matrix; (b) millimetric mica fish of potassic white mica with growth of fibrolitic sillimanite in a fine -grained quartz and fibrolite matrix; (c) F_3 microfold deforming S_2 foliation; (d) C/S fabric in mylonitic K-white mica bearing leucogranite. Scale bar: 1 mm; (e) ultramylonite fabric in strongly sheared monzogranite marked by quartz ribbons with K-feldspar porphyroclasts; (f) phyllonite fabric in the most deformed domain of the ultramylonite zone.

**Figure 1**

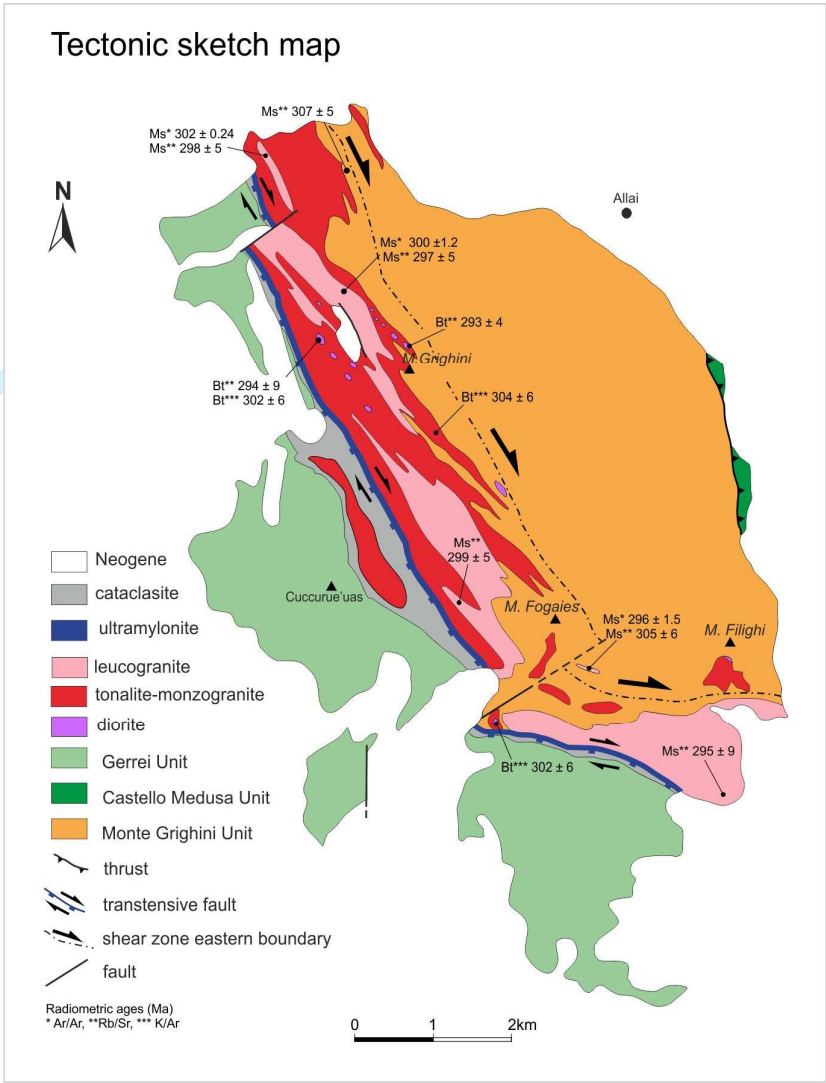


Figure 2

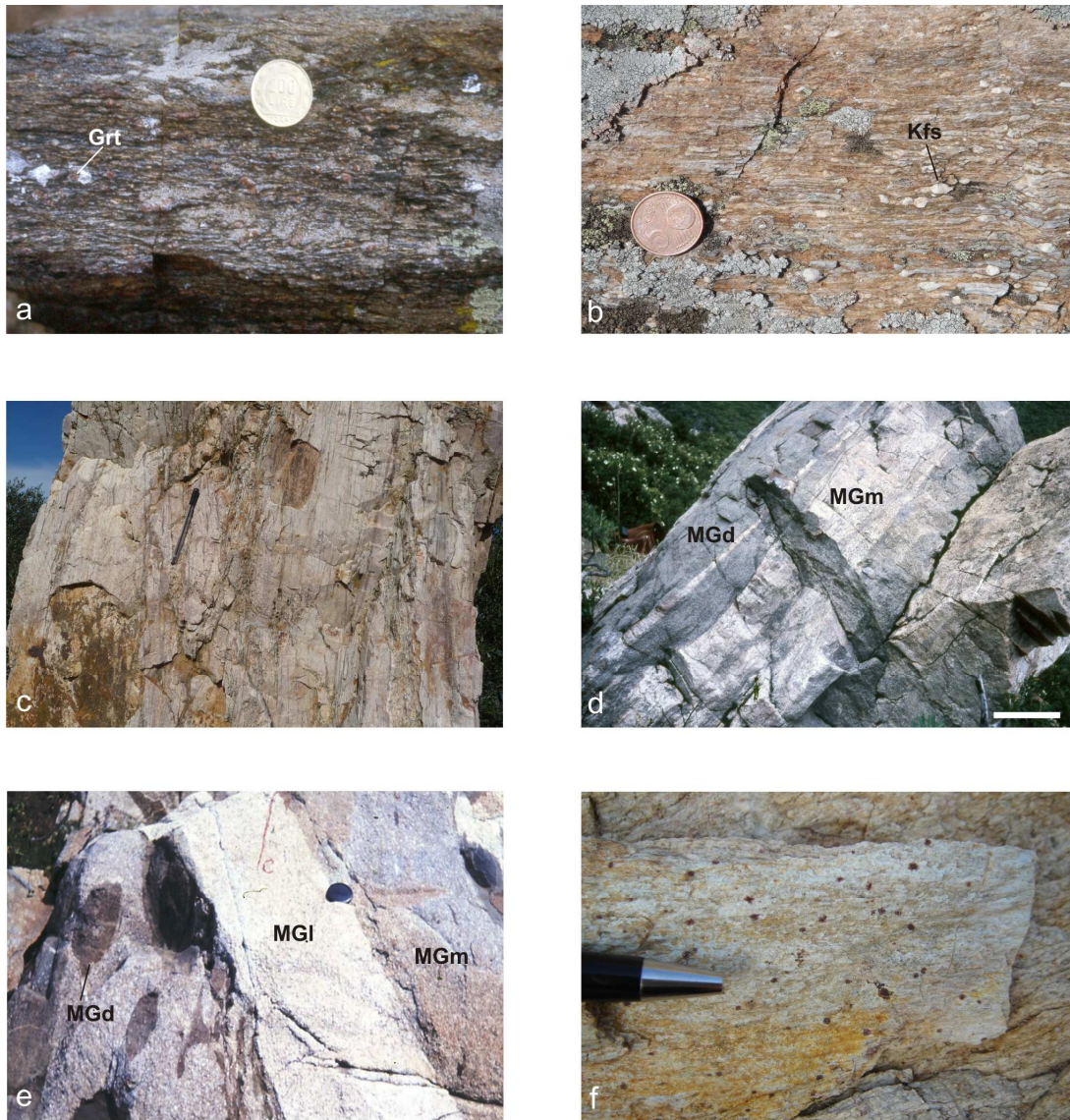


Figure 3

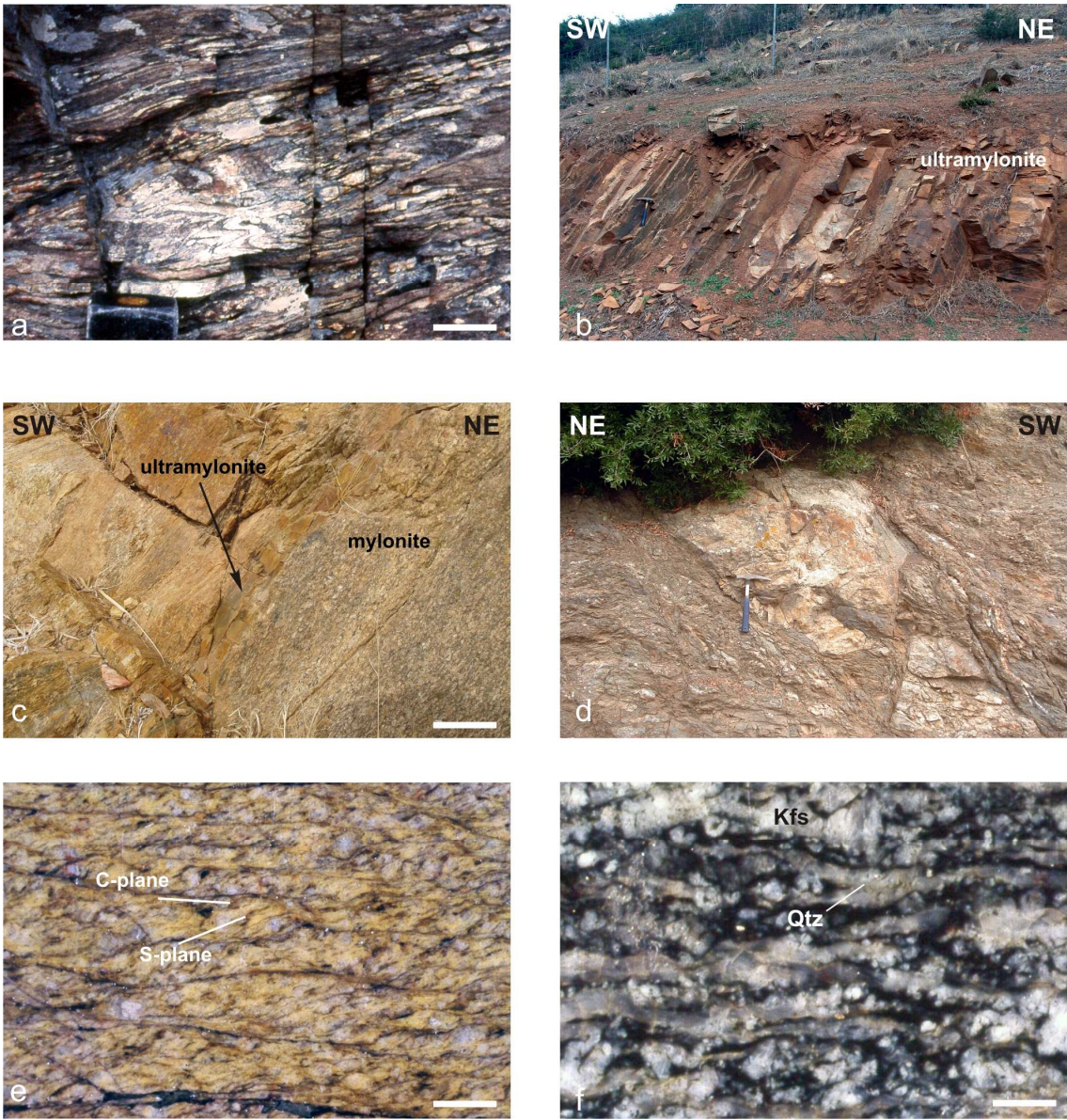
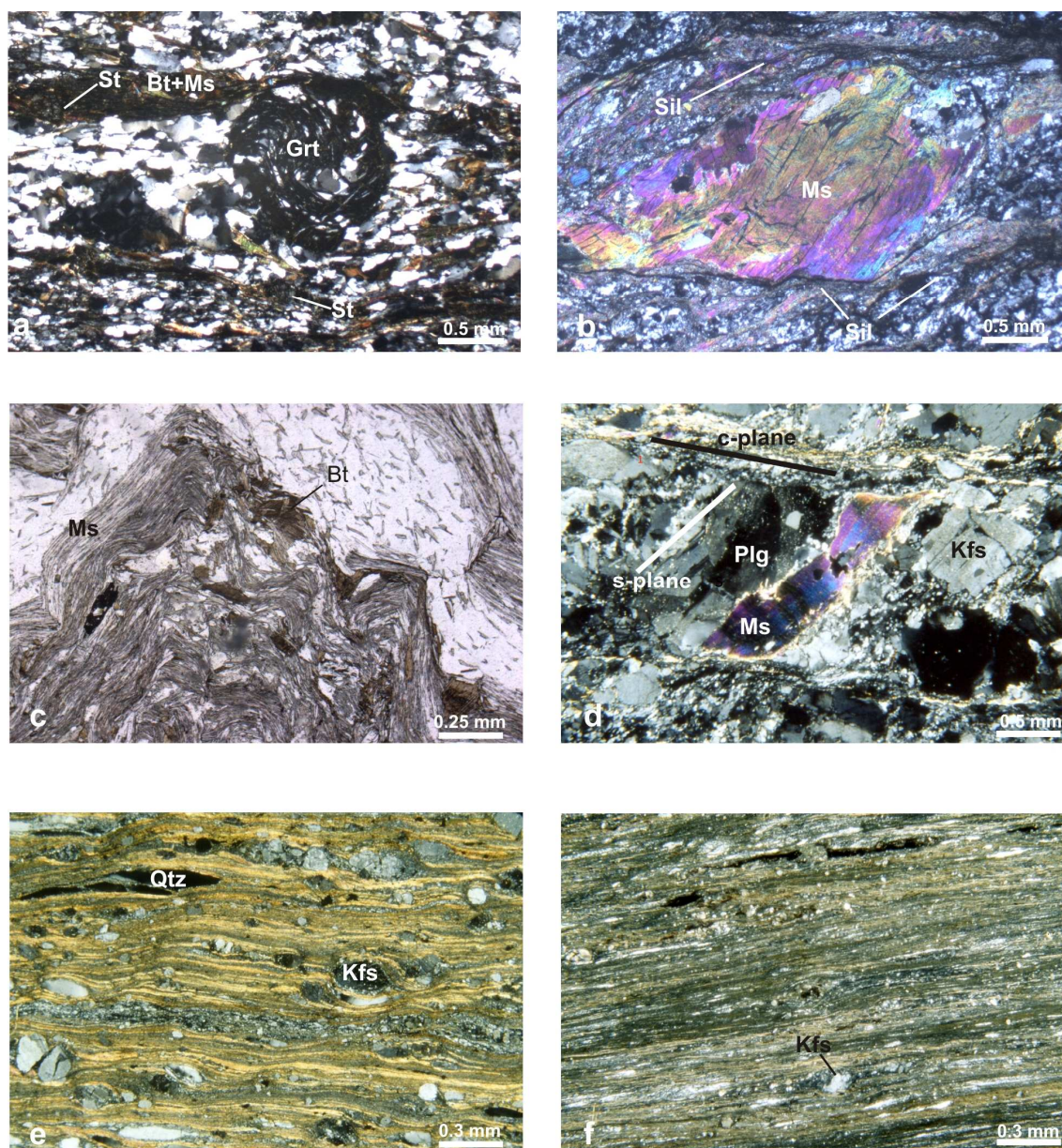


Figure 4

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Figure 5

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