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## Structural control of ore deposits: the Baccu Locci shear zone (SE Sardinia)

ANTONIO FUNEDDA \*, STEFANO NAITZA \*\*, PAOLO CONTI \*\*\*, ANDREA DINI \*\*\*\*, CRISTINA BUTTAU \*, SANDRO TOCCO \*\* & LUIGI CARMIGNANI \*\*

### RIASSUNTO

#### Controllo strutturale di giacimenti minerali: il caso della Zona di taglio di Baccu Locci (Sardegna SE)

Molte delle mineralizzazioni a metalli (Pb,Zn, As,Ag, Au) ospitate nel basamento paleozoico sardo sono strettamente correlate alla strutturazione varisca, nonostante in passato spesso venissero interpretate come sinsedimentarie. L'area mineraria di Baccu Locci, ubicata nella parte orientale di un sistema di mineralizzazioni che insiste lungo l'omonima zona di taglio duttile, presenta diversi tipi di giacimenti legati a differenti geometrie derivate dal diverso controllo esercitato dalle strutture varisiche e tardo varisiche.

KEY WORDS: *Variscan chain, structural geology, ore bodies.*

### INTRODUCTION

Many of the most important mining zones hosted in the Paleozoic basement of Sardinia are clearly related to Variscan structures, although that relationships are not even easily recognizable. In the past these relationships were be often misinterpreted, generally because the lack of a careful geological mapping, and also because the power of theoretical models that in the past favored a depositional origin of ore bodies.

Recently, the connection between structural geologists, mineralogists and economic geologists allows to change the old interpretation and to provide a new model to consider many of important mine zone hosted in the Variscan Basement of SE Sardinia (fig. 1). This is the case of the Baccu Locci mine area, assumed to be the eastern part of a mineralized corridor linked with an important ductile shear zone and characterized both by a complex structural framework achieved during the Variscan orogenesis and by different type of mineralization (FUNEDDA *et alii*, 2011, with a Geological and metallogenic map of the Baccu Locci mine area at 1:10,000 scale).

The Baccu Locci (BL) mine area was active from 1866 to 1961 for the extraction of Arsenopyrite, PbS and ZnS. Recent studies found also a noteworthy occurrence of Au (GARBARINO *et alii*, 2003). Here we would underline the overprinting of different paragenetic sequences of mineralizations and their relationships with pre-existing Variscan structures.

### GEOLOGICAL OUTLINE

The study area belongs to the Nappe zone of the Variscan metamorphic basement of Sardinia (fig. 1), which is a part of the Southern Variscan realm (ROSSI *et alii*, 2009). The Nappe zone consists of several tectonic units (among them three crop out in the Baccu Locci area) emplaced with an earliest top-to-the-south and later top-to-the-east transport direction; metamorphism and internal deformation of rocks increase northward: from an anchizone in the south, up to medium grade in the northern part of the Island. The Variscan basement that crops out in the study area is metamorphosed in lower-greenschist facies conditions and is intruded by a Late Palaeozoic (Upper Carboniferous to Lower Permian) Intrusive complex.

The BL area is characterized by three tectonic unit, from the bottom to the top: Riu Gruppa, Gerrei and Meana Sardo units, and recorded all the main tectonic evolution typical of the nappe zone. The oldest structures that affected the primary bedding are

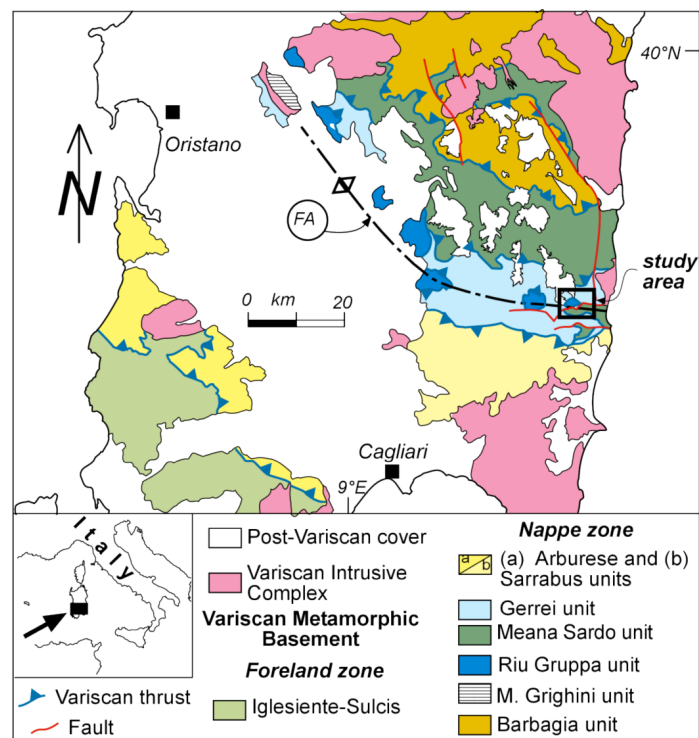


Fig. 1 – Tectonic sketch map of the Variscan nappe zone of Central-southern Sardinia

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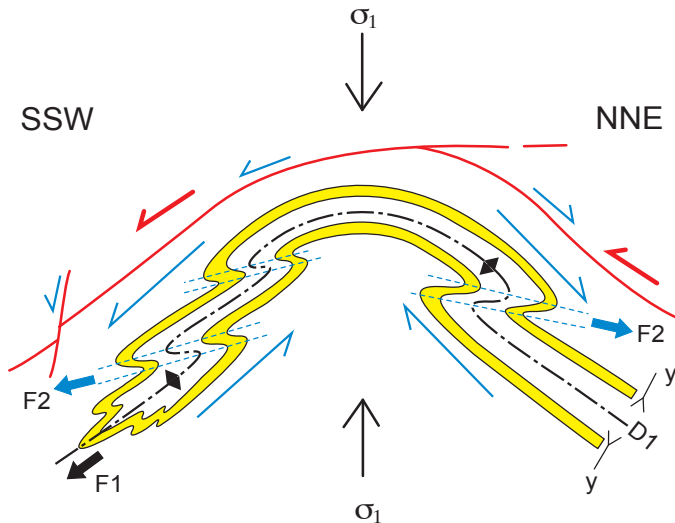


Fig. 2 – Synoptic sketch of Variscan deformation stages in the Bacchu Locci area. D1: axial plane of folds related to D1 shortening phase; F1: facing direction of D1 folds; F2: facing direction of asymmetrical folds related to D2 extensional phase (after CARMIGNANI *et alii*, 2001, modified).

kilometric recumbent isoclinal folds facing to SSW, with a well developed axial plane foliation (S1) in low-grade metamorphic condition, and overthrusts between the tectonic units with top-to-south transport direction.

The overthrusting produced mylonitic shear zones, the larger one is the Bacchu Locci shear zone (CONTI *et alii*, 1998; CASINI *et alii*, 2010) that occurs between the Gerrei and Riu Gruppa Unit and it is thick up 700 m), locally the main foliation in the mylonite zone (Sm) overprints and transposes the S1 foliation. Thrusts and foliations S1 and Sm are affected by a late shortening event (Late D1) that produced the upright km-scale Bacchu Locci antiform (BLA) that is a minor order structure of the larger Flumendosa Antiform, recognized from the eastern coast of Sardinia and extending for 50 km in a WNW direction.

Later than the antiformal structures were enhanced by low-angle ductile normal shear zones and they become structural high zones, because the uplift of the nappe stack during post-collisional extension (CONTI *et alii*, 1999). Inside the normal shear zone, asymmetric folds at different scale developed, and they overturned away from the hinge zone of the antiforms (fig. 2).

The latest structures affecting the area are a set of right strike-slip reverse faults, striking about N150E. They generally dip towards the west, cut all the previous structures and are sealed by Eocene sediments.

#### METALLOGENIC OUTLINE AND STRUCTURAL CONTROL

Two type of ores have been exploited in the BL area: a) Zn-Pb-Cu mixed sulfide lenses of the Su Spillongargiu sector (NW part of the area); b) Qtz-As-Pb sulfide veins that are located throughout most of the study area. These two type of ores are both strongly influenced by the geometry of the previous variscan structures.

The Su Spillongargiu mineralization crops out just below the Eocene cover and is characterized by extensive supergene alteration. It consists of several Zn-Pb-Cu mixed sulfide lenses, parallel

to the main (mylonitic) foliation and dipping to west, it attains a maximum thickness of 6-7 m and a maximum extension in strike of 80-100 m.

According to previous authors the Spillongargiu lenses were interpreted as lateral expansions of discordant quartz-arsenopyrite veins or remobilized old sedimentary mixed sulfide ore (protore) (ZUCCHETTI, 1958). These two models propose only partial explanations of the relationships between the two ores. Indeed, as observed by CONTI *et alii* (1998) and FUNEDDA *et alii* (2005), the Spillongargiu-type ore shows distinct textural and mineralogical differences when compared to quartz-arsenopyrite veins. New observations of the upper mine-works of that sector and on the paragenesis of the primary ore allow us to assess that the quartz-sphalerite mineralized lenses are hosted in folded mylonitic rocks close to the hinge zone of minor order antiform of the BLA. Thus, the hinge zone of smaller antiforms acted as classical trap for hydrothermal fluids bearing mixed sulfides (fig. 3). Recent underground survey in the Spillongargiu area mine-works highlight that Qtz-AsPy vein clearly crosscut the mixed sulfides body, thus different paragenesis are related to different geometries (fig. 4).

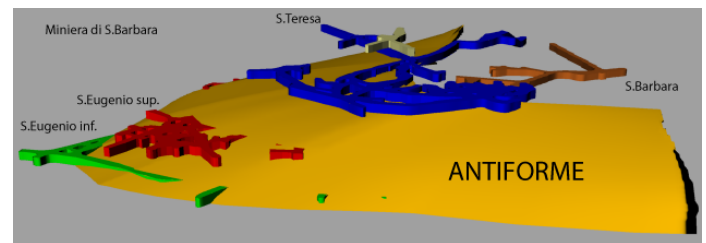


Fig. 3 – 3D model of the mixed sulfides ore body at Spillongargiu and the mine-works.

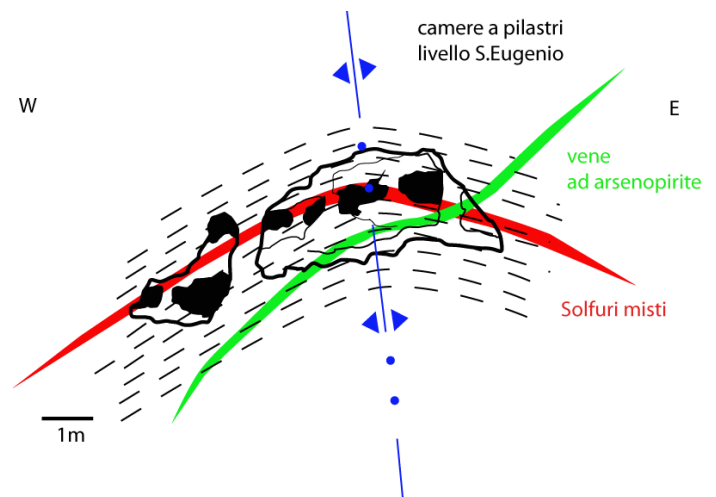


Fig. 4 – Relationships between two types of mineralizations (lenses and veins) of the Spillongargiu ore; room and pillars exploitation of Sant'Eugenio mine-work (after FUNEDDA *et alii*, 2011).

The second type of ore bodies are As-Pb-(Cu, Zn, Ag, Au) quartz-sulfide veins that are widespread in the whole BL mine area and surrounding areas. Sulfide-bearing quartz and sheeted veins or disseminations crosscut the Gerrei Unit mylonitized rocks of the BL Shear Zone, and the underlying Riu Gruppa Unit inlier, with very similar paragenetic and structural features.

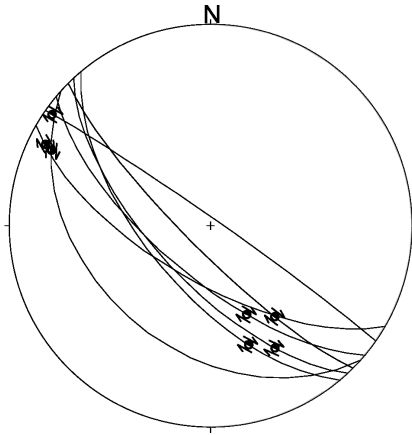


Fig. 5 – Stereographic projection of some transpressive faults in the Baccu Trebini valley, dextral tributary of the Baccu Locci river (equal area, lower hemisphere).

In the Baccu Locci mine area, vein swarms attain thickness less than 10 m in thickness; single veins are 2-3 cm to 1 m thick. The veins strike N140-160E, dipping 50° -80° WSW and are strongly related to a NW-SE system of dextral-reverse faults (fig. 5).

At some places, the veins suddenly enlarge reaching more than 30 m in thickness, there are the main quartz lodes. The fieldwork carried both at the surface and underground inside the old mine-works, points out that these larger lodes are hosted in dilatational jogs developed in the hangingwall of transpressive dextral faults.

They occur on releasing zone related to the bending of the faults that locally became more flat, decreasing their dip when the fault cross cut the reverse limb of the overturned asymmetric folds related to post-collisional extension (D2 in fig. 2) previous described. The fault planes generally dip about 70° or more to the SW, crosscutting the Variscan foliations (S1 and S<sub>m</sub>) generally dipping in the opposite direction. When they crosscut the reverse limb, the S1/S<sub>m</sub> are sub-horizontal or gently dipping to the SW, and the fault plane partially follow this surface until the foliation is again turned in the normal limb (fig. 6).

The influence of the fold geometry on the subsequent structures involves also the permian-carboniferous mafic dykes, whose relationships with mineralization are not still defined, that change suddenly their attitude when crosscut that reverse limbs of asymmetric D2 folds.

As a whole, the continuity of similarly directed mineralized structures in two different tectonic units (Gerrei Unit and Riu Grappa Unit) indicates a wide framework, with a km-scale system that must be related to the development of the stress field in the area, with strong and repeated cataclasis of the older variscan mylonites and fracture filling by quartz-sulfide veins.

### CONCLUSION

In the BL mine area ore bodies dissimilar in paragenesis and geometry are related to different structural control by pre-existing Variscan structures. According to this study we can assess that in the BL mine area both upright antiforms and overturned folds influence, in different way, the developments of ore bodies and the mineral paragenesis.

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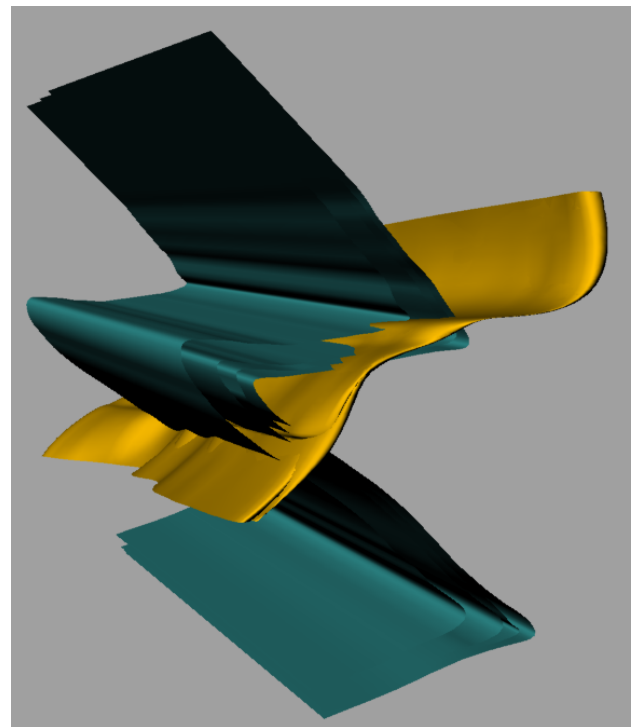


Fig. 6 – 3D model of the relationship between asymmetric overturned folds (dark green) and ores along transpressive faults (yellow).