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THE COMPOSITE SHEAR FRAME IN THE VARISCAN BELT OF SARDINIA (ITALY): IMPLICATIONS IN THE EMPLACEMENT OF HT ROCKS

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The Variscan Sardinian Belt (Italy) consits of four tectono-metamorphic zones, oriented in the NW-SE direction (Elter et al., 2004): the External Zone (Foreland Area), the Nappe Zone, the Posada Valley Zone and the High Grade Metamorphic Complex (HGMC, Axial Zone). The metamorphic grade increases rapidily northeastward from subgreenschist/greenschist facies in the External Zone/Nappe Zone to amphibolite facies (with lenses of retrogressed granulite and eclogite) in the HGMC (Elter et al., 1986, 1990, 2004). The Barrovian metamorphic isogrades (Ricci, 1992) are parallel to the Belt axis. The geochronological data of the Barrovian metamorphism is marked by a time span between 386 Ma and 340 Ma (Carosi & Palmeri, 2002, Cruciani, 2003). During the late stage of Sardinian Variscan and post orogenetic cycle, intrusive and extrusive magmatism took place. The widespread magmatism is due by the intrusive sequence, subdivided in three magmatic sequences (Bralia et al., 1981): the pre-tectonic intrusive sequence (made by strongly foliated Mg-K calc-alkaline granitoids, Rossi & Cocherie, 1991); the sin-tectonic intrusive sequence (made by foliated composite calc-alkaline granitoids, Rossi & Cocherie, 1991) and the post-tectonic intrusive sequence (made by alkaline granitoids, Rossi & Cocherie, 1991). The intrusive magmatism took place during a time span between 320 Ma and 280 Ma (Beccaluva et al., 1985, Di Vincenzo et al., 1996, Muzio 2003).

The final stage of the Sardinia Variscan belt is characterized by an extensional tectonism (destructive stage of the belt): it is the post-collisional Variscan evolution and it is characterized by Late Carboniferous – Permian extensional tectonics (Elter et al., 1999) that affected the whole belt and was due to gravitational collapse of the previously thicked crust (Elter et al., 1999, 2004).

During the extensional tectonism the emplacement of HGMC rocks took place (Ricci, 1992, Elter et al., 1999): at present time, infact, it is assumed that the migmatization process develops manly during the uplift of the Variscan belt.

A composite shear network took place during the extensional tectonism and it is recognizable mainly in the HGMC. The shear network could be subdivided in two events: Early Shear Event (ESE) and the Late Shear Event (LSE).

The ESE is characterized by HT normal (ESE) shear zones while the LSE by LT strike slip shear zones with often syn-tectonic emplacement of strongly foliated Mg-K calc-alkaline granitoids. The ESE is the widespread shear event with a sinkynematic HT-LP metamorphism (k-feldspar+sillimanite zone, T=600˚ C – 450˚ C, P= 6-4 Kbar, Ricci, 1992) and a penetrative schistosity. On the XZ plane many preserved kinematic indicators are recognizable as σ and/or δ porphiroclasts, domino like porphiroclasts, asymmetric boudins, shear folds, sheath folds and S-C planes. The kinematic indicators give a component of shear Top to NE/SE in a contest of extensional regime.

The LSE event is related with a composite network of strike slip shear zone (the main component is dextral while the secondary are sinistral shear zones): the metamorphic evolution is till complicated that the ESE and two types of LSE can be distinguished: the LSE1 with high-temperature texture ($T < 500$˚ C, Elter et al., 1999) and associated with synkinematic intrusions and the LSE2 with retrograde metamorphism (T= 400˚ C – 300˚ C, P=2- 3 kbar, Elter et al., 1999). The LSE2 can be subdivided in LSE2a, with a sinkinematic greenschist metamorphism and the LSE2b with higher retrograde metamorphism (muscovite+k-feldspar zone, Muzio, 2003, Elter et al., 1990, 1999, 2004, Elter & Ghezzo, 1995, Elter & Corsi, 1995).

The extensional shear frame ESE took place in a time span between 350 - 344 Ma (Ferrara et al. 1978, Beccaluva et al., 1985, Del Moro et al. 1991, Elter & Corsi, 1995, Elter et al., 1990, 1999, 2004), while the LSE develops beteween 325 Ma – 290 Ma, (LSE1 at 325-306 Ma, Muzio, 2003, Elter et al., 2004 while the LSE2 at 300 – 290 Ma, Elter et al., 1990, 1999, 2004).

Nevertheless, the new geochronological time span of the kyanite + biotite$\pm$ amphibole migmatite bearing (385 – 370 Ma, T=650˚ C - 700˚ C, P= 9-10 kbar, Cruciani et al., 2002) allow to assume an older migmatisation stage related with the assumption that migmatization process could took place in different tectonism.

The structural studies about the tectonic frame of the kyanite + biotite± amphibole migmatite bearing allow to point out a new scattered noncoaxial deformation with preserved kinematic indicators (σ porphiroclasts, shear band boudins) on XZ plane that gives a Top to NW component of shear.

The Top to NW component of shear isn't in agree with the common Top to SE component of shear recognizable for the ESE (extensional event), in all the HGMC (Elter et al., 1999).

Locally it's recognizable the superposition of the Top to SE on Top to NW: it's clear the presence at least of two different tectonism during the formation and the emplacement of the Sardinian Variscan migmatites.

These structural considerations are also in agreement with the different time of formation of the kyanite + biotite± amphibole migmatite bearing (older) and the other k-feldspar+sillimanite bearing migmatite (younger).

From these chronological data, in attempt with the metamorphic-structural evolution of the shear events, could point out the following considerations:

- the emplacement of the HT rocks develops in a time span between 385 Ma and 290 Ma;
- the emplacement metamorphic of LT rocks develops in a time span between 325 Ma and 290 Ma coeval with the emplacement of the late intrusive complex;
- the emplacement of the HT metamorphic rocks can be subdivided in two different periods of time: the older (at 385- 370 Ma) took place with a Top to NW component of shear and it could be developped during the late stage of the constructive stage of the Variscan belt (beginning of migmatisation of the thickened crust at depht of 30-27 km, before its uplift); the migmatization might develop before the beginnig of the uplift of the Variscan thycked crust as in the Massif Central (Faure, 1995); the younger (at 350 - 344 Ma) develops with a Top to SE component of shear (ESE), in an extensional regime with a new migmatization process sintectonic to uplift of the thycked crust at depht of 18 – 12 km;
- when the ESE stage stopped, the directions of shortening and of extension change and the geodinamic frame develops through the strike slip events with a NW-SE sense of shortening (LSE, 325 Ma – 290 Ma); the uplift of the Variscan Sardinia belt allows the emplacement of the granitoids;

- the NW-SE sense of shortening stays constant till 290 Ma, the age of emplacement of the sin - tectonic granitoids (Bralia et al, 1981); nevertheless, during this time the belt, is not undergone by deformational events;
- the Variscan belt is closed by the emplacement of the post tectonic granitoids.

From this frame we colud be conclude:

the Variscan belt in Sardinia shows at least two migmatization events in two different contest of geodynamic significance: the first develops during the constructive end-stage of the belt and the second during the destructive stage;

the emplacement of granitoids begin during the change of directions of shortening after the emplacement of the second phase of migmatisation.

385 – 350 Ma	**350 – 340 Ma**	**325 – 300 Ma**	**300 – 290 Ma**
Ky+bt±amp bearing migmatites	K-feld+sill bearing migmatites	Emplacement of Pre-tectonic granitoids	Emplacement of Syntectonic g
Top to NW sense of shear	Top SE sense of shear ESE	Strike slip shear zones LSE	End of the LSE shear zones
End of constructive stage of belt	Uplift of the belt Destructive stage of belt	End of Uplift of the belt change of shortening	Same direction of shortening