The Roses Giant Quartz Vein (Cap de Creus, Eastern Pyrenees): Geology and Fluid Inclusion Data

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INTRODUCTION

The Pyrenean Axial Zone is characterized by thick series of metasedimentary and orthogneissic materials derived from pre-Variscan rocks. These sequences were intruded by large bodies of Variscan granitoids, some exposed after the Alpine orogeny. In the Eastern Pyrenees, a number of quartz veins of kilometric length and metric to decametric width, are present. Although these veins are mostly hosted by Variscan and pre-Variscan rocks, in the southeastern limit of the Roc de Frausa Massif, large fault-related quartz bodies crosscutting Mesozoic sedimentary rocks, have also been recognized (Liesa, 1988). The Roses giant quartz vein constitutes a remarkable example of these regional-scale quartz veins. It is located at the southern portion of the Cap de Creus Massif, extending for 2700 m and reaching widths up to 25 m. Apparently, the vein continues towards the NW depicting a much longer structure (Fig. 1).

The aim of this work is to provide new insights for a better understanding of the hydrothermal system/s that generated the giant veins of the Eastern Pyrenees. For this, fluid inclusion (f.i.) and petrographic studies together with a detailed geological mapping and structural analysis of the area hosting the Roses Vein have been performed. Finally the results are compared with data from quartz veins crosscutting Upper Cretaceous sedimentary rocks in the Empordà area, and with existing data of giant veins from the Canigó massif (Ayora & Casas, 1983).

ROSES QUARTZ VEIN GEOLOGY

The Roses Vein depicts a NW-SE discontinuous (pinch and swell) trending structure hosted by different rock types. In the NW section (NWS) the vein is hosted by a granodiorite of Variscan age affected by a network of shear zones (Carreras et al., 2004). In this section, the vein dips approximately 65° to the SE, pinching and becoming sub-vertical in the central part of the NWS. In the SE section (SES) the vein is hosted by pre-Variscan fine-grained metasedimentary rocks dipping from sub-vertical to the NW.

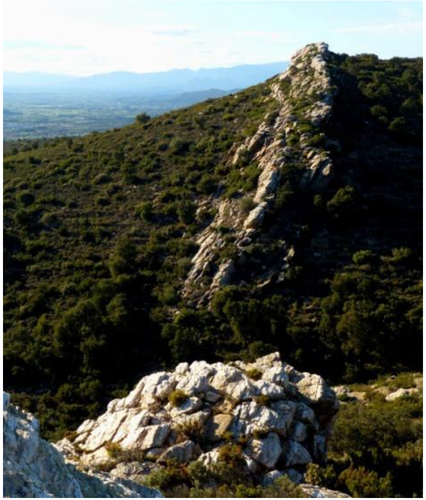

fig 1. *Outcrop of the Roses Quartz Vein. View towards the NW. The depressed area on top left belongs to the Neogene Empordà basin.*

The vein shows distinct types of deformation depending on the section. Whereas in the NWS the quartz bodies present cataclastic to mylonitic /ultramylonitic foliation, in the SES the vein shows protomylonitic to protocataclastic foliation.

Three successive planar deformational structures were identified in the area hosting the veins. S1 is parallel to bedding and has only been observed in two outcrops in the SES, intensively affected by late folding. S2 and S3 affect both the large quartz bodies and the wall rocks. Whereas S2 is more penetrative and strikes parallel to sub-parallel to the giant vein, S3 is transversal and tends to be concentrated on high-strain zones (Fig. 2A). Regarding the kinematic analyses, while S2-related shear zones, indicate a predominantly sinistral movement, S3-related shear zones show a dominantly normal movement. Similar fabrics in the Roses Vein and in the quartz veins crosscutting Mesozoic rocks, seem to suggest that at least part of the deformation history recorded in the Roses Vein could be Alpine in age.

FLUID INCLUSION STUDY

We have carried out f.i. microthermometry in quartz from the Roses Vein. F.i. microthermometry yields reliable values of fluid salinity and density if the inclusions follow the "Roedder's Rule" (Bodnar, 2003). In this study six quartz types were recognized along the vein. Unfortunately, the volumetrically most abundant quartz type shows grain sizes from 30 to 300 µm, serrated contacts and sweeping extinction, characteristics that make them unsuitable for microthermometrical measurements.

From a set of forty-two samples taken along the vein, seven were selected to be measured. Special care was taken on the selection of the studied f.i. choosing those with regular shapes together with sets of inclusions having fairly constant phase ratios. Most measured inclusions, range in sizes from 5 to 30 µm and have two phases at room temperature. Only a few inclusions present an isometric trapped solid that did not experience visible changes throughout microthermometrical measurements.

Eutectic temperatures (Te) below -30°C indicate the presence of a polysaline fluid (H_2O–NaCl–$CaCl_2$) with melting ice temperature (Tmi) variation from -22 to -

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6°C, corresponding to a salinity from 24 to 10 wt% NaCl +$CaCl_2$ (Steele-MacInnis et al., 2011). Homogenization temperature (Th) shows also a wide range from 140 to 280°C and a bimodal distribution with peaks at 190°C and 240°C (Fig. 2B). However, excluding the Th data from the milky quartz showing the largest dispersion, the Th standard deviation is notably lowered, defining a different fluid inclusion assemblage (FIA) for each quartz type. Moreover, a negative correlation trend between Th and Tmi is observed (Fig. 2C). Inclusions from a quartz pod in a S3 shear zone transversal to the giant vein located in the northwestern part of the NWS shows a homogenous population of fluid inclusions that lie out of the trend (squares in Fig. 2C).

Near the southern end of the vein, data from euhedral, centimetric to decimetric milky quartz crystals, with a millimetric transparent rim (Fig. 2D) allowed to establish a local fluid chronology. F.i. in milky quartz have a Th mode at 182°C (n=21), whereas f.i. from the rim present a higher Th mode (220°C, n=22). F.i. from milky quartz from other parts of the vein show a high standard deviation suggesting post-entrapment changes. This f.i. reequilibration is consistent with the late high-temperature event recorded in the f.i. present in the rim.

FLUID INCLUSION DATA FROM OTHER EASTERN PYRENEES QUARTZ VEINS

Fluid inclusion data from a quartz vein crosscutting the upper Cretaceous sedimentary rocks were obtained from subcentimetric size euhedral quartz crystals showing a milky core and a transparent rim. Microthermometrical data yield homogeneous values with no differences between core and rim, and Tmi and Th averaging -3.8°C (n=14) and Th 230°C (n=28) respectively (Fig. 2B, C).

Th of f.i. from kilometric-sized quartz veins of the Canigó Massif range from 165 to 190°C in massive microcrystalline quartz and slightly lower (140 to 160°C) for vug filling quartz crystals. Fluids trapped in both types of quartz are polysaline with total salinity up to 20 eq. wt% NaCl (Ayora & Casas, 1983).

Fluid inclusions not trapped at atmospheric pressure, require an additional pressure correction to calculate the entrapment temperature. Therefore, for temperature comparison between different FIAs and different veins, the depth of formation must be known. Whereas at the Canigó quartz veins Ayora & Casas (1983) were able to evaluate the entrapment pressure from geological constrains, in the case of the Roses Vein further geological information is required. Nonetheless, it is interesting to point out the presence of a similar high salinity brine in both giant veins (Canigo and Roses). The low salinity fluid (<6 eq. wt% NaCl) found in the post Cretaceous quartz veins is similar to that reported in other giant quartz veins (Lemarchand et al., 2012; Wanningen et al., 2000).

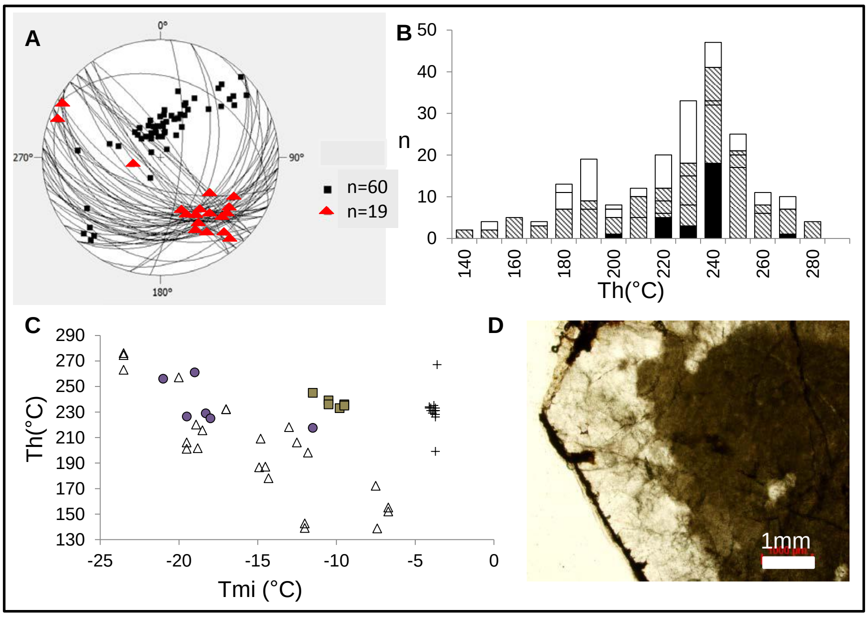

fig 2. *A) Lower hemisphere stereoplot of structures in the Roses Vein. Black squares correspond to mylonitic foliation (S2 and S3), triangles stand for the stretching lineation on S1 and S2 (Fonseca, 2014). B) F.i. Th histogram of distinct quartz types. White pattern: milky quartz; stippled: different transparent quartz types; black: post-Cretaceous quartz veins. C) Th - Tmi diagram of inclusions from different quartz types. Squares: quartz pod mentioned in the text; triangles: transparent quartz; circles: milky quartz; crosses: post-Cretaceous quartz veins. D) Photomicrograph of euhedral milky quartz with transparent patches and transparent rim.*

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REFERENCES

Ayora, C. & Casas, J.M. (1983): Estudi microtermometric dels filons de quars de les Esquerdes de Roja, Massis del Canigo, Pirineu Oriental. Acta Geol. Hisp., ***18****, 35-46.*

Bodnar, R. (2003) Reequilibration of fluid inclusions in: "Fluid Inclusions: Analysis and Interpretation".Samson, I., Anderson, A., Marshall, D. (Eds.), Mineral. Assoc. Canada, Short Course, ***32,*** *213-231.*

Carreras, J., Druguet, E., Griera, A., Soldevila, J. (2004): Strain and deformation history in a syntectonic pluton. The case of the Roses granodiorite (Cap de Creus, Eastern Pyrenees). In "Flow Processes in Faults and Shear Zones", Alsop, G.I., Holdsworth, R.E., McCaffrey, K.J.W., Hand, W. (Eds.). Special Publications. Geological Society, London, ***224****, 307-319*

Fonseca, H.A.M. (2014): Structural framework and microthermometry analysis of the giant quartz vein of Roses – Cap de Creus, Eastern Pyrenees. Masters Degree. Universitat de Barcelona. 25 p.

Lemarchard, J., Boulvais, P., Gaboriau, M., Boiron, M., Tartese, R., Cokkinos, M., Bonnet, S., Jegouzo, P. (2012): Giant quartz vein formation and high-elevation meteoric fluid infiltration into the South Armorican shear zone; geological, fluid inclusion and stable isotope evidence. J. Geol. Soc. London, ***169****, 17-27*

Liesa, M. (1988): El metamorfisme del vessant sud del Massís del Roc de Frausa (Pirineu Oriental). Tesi Doctoral, Universitat de Barcelona. 233 p.

Steele-MacInnis, M., Bodnar, R. J., Naden, J. (2011): Numerical model to determine the composition of H_2O-NaCl-$CaCl_2$ fluid inclusions based on microthermometric and microanalytical data. Geochim. Cosmochim. Acta, ***75****, 21-41.*

Wanningen, S.N., Canals, A., Grandia, F., Cardellach, E., Martínez, F., Soler, A., Garreta, M. (2000): How many fluids are related to O Barquero? (NW Galicia, Spain). Quartz vein formation: Fluid inclusion data. Cad. Lab. Xeol. Laxe, ***25****, 277-279.*