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Evolution of fluid sources during the neogene exhumation of the Sierra Almagrera (Betics, Spain)

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INTRODUCTION

The orographic evolution of the orogenic wedge of the Betics is quite specific since marine depositions occurred in the internal zone, coevally with the existence of continental and detrital deposits revealing the uplift of metamorphic ranges (Sierras). Their evolution reveals early Metamorphic Core Complexes (MCC) stages intersected by more recent major transcurrent faults related to local transpressional and transtensional contexts. Volcanism, belonging to different magmatic series (tholeitic, calc-alkaline, shoshonitic, and ultrapotassic) also occurred in a extensional tectonic setting (López-Ruiz and Rodríguez-Badiola, 1980).
In the Sierra Almagrera, the N-S striking Palomares fault separated an uplifted block to the East (Booth-Rea et al., 2004) where Fe-Ba-Pb-Cu-Zn-(Ag) mineralizations led to the development of a mining district. To the West, the basement is buried below Neogene sediments locally presenting silicification and stratabound ore deposits Fe-Ba-Pb-(Ag) (Morales-Ruano, 1994).

The question related to the orographic evolution of the wedge is addressed in this work: Did basinal and meteoric fluids from the sierras have circulated within the crust and interacted with deeper crustal fluids related to the metamorphism, volcanism and hydrothermal events?

Answers are given by the study of fluid inclusions (FI) trapped within several vein generations of different minerals such as quartz, siderite barite and calcite, related to different stages of exhumation. Fluids are identified by microthermometry, Raman spectroscopy and halogens characterization.

Vein type and chronology	Location	Vein / rock foliation relationships	Vein mineralogy
V-Qtz1	Subsiding area	Parallel to the rock foliation	Quartz (Qtz1)
	Mining district	Parallel	Quartz (Qtz1)
V-Qtz2	Subsiding area Mining district	Parallel to oblique Parallel to oblique	Quartz (Qtz2) Quartz (Qtz2)
V-Qtz3	Mining district	Oblique	Quartz (Qtz3), Hematite
V-ore	Mining district	Oblique	Siderite, Barite, (Quartz) Pyrite, Marcasite, Galena, Chalcopyirite, Sphalerite, tetrahedrite-tennantite…
V-Cal	Subsiding area	Oblique	Calcite

Table 1. *Nomenclature, location and description of sampled veins*

VEIN CHRONOLOGY (Table 1)

Quartz veins (V-Qtz1) parallel to the foliation and partly parallel (V-Qtz2) have been recorded FI from ductile to ductile/brittle transition conditions during exhumation.

Two types of veins oblique to the foliation are distinguished in the mining district, (i) V-Qtz3 veins (oriented N000E and N140E) are hematite-rich and may display euhedral quartz (Qtz3) growth on previous quartz nucleus (fig.1). They frequently crosscut V-Qtz2 quartz (ii) V-ore veins (oriented N000E and N130E) crosscut V-Qtz3 (fig.1) and contain the following paragenesis: micro-euhedral quartz - siderite - pyrite - galena -barite.
On the western side of the Palomares Fault, late discordant V-Cal (calcite) veins (oriented N000E) cross-cut V-Qtz2 veins.

FLUID INCLUSION STUDY

V-Qtz1 veins display various types of microstructure diagnostic for plastic dynamic and static deformation where primary FI have been rejected to grain boundaries. Early metamorphic fluids were lost during recrystallization of the original quartz grains during the transposition of the vein into the foliation.

Fluid inclusions of V-Qtz2 veins are H_2O-NaCl (12-20 mass% eq.NaCl) brines (Qtz2-ig in fig.2) trapped at the ductile brittle transition at minimum trapping temperatures (Th) of 340 °C.

Some V-Qtz2 veins contain FI planes (FIP) (fig.1) with low salinity inclusions (0.1-2.4 mass% eq.NaCl) (Qtz2-tg in fig.2). These FIP are lacking in N000E striking V-Qtz3 and V-Cal veins.

In the mining district, some V-Qtz1 veins are affected by NW-SE transgranular FIP with FI showing a large range of salinities (10 to 23 mass% eq.NaCl with Th of 320-350 °C) (Qtz1-tg1 in fig.2). These FIP are crosscut by N000-030E striking FIP showing salinities of 23 mass% NaCl with Th of 300-340 °C (Qtz1-tg2 in fig.2).

Euhedral quartz Qtz3 recorded Qtz3-p (in fig.1 and 2) FI with salinities varying from 12 to 20 mass% eq.NaCl and Th of 200-300 °C.

The latest fluid events in the mining

Palabras clave: Inclusiones Fluidas, Cordillera bética, Falla de Transalboran, fluidos metamórficos, mineralizaciones	***key words:*** Fluid inclusions, Betic Cordillera, Trans-alboran fault, Metamorphic brines, evaporites, mineralisations.

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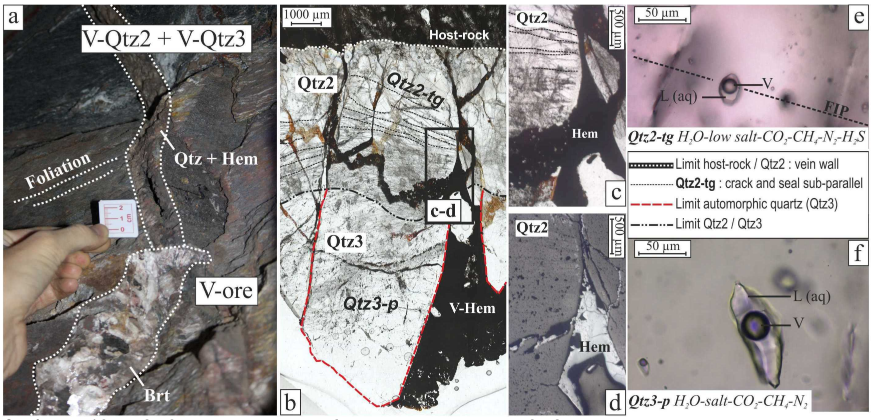

fig 1. a) N10E V-Qtz2 discordant to the foliation reopened as V-Qtz3, intersected by V-ore discordant vein. Optical microphotographs under natural light: b) Contact between Qtz2 and Qtz3. Qtz2 grains still show undulose extinction and are affected by Qtz2-tg transgranular FIP. Qtz3 euhedral quartz contains only Qtz3-p primary fluid inclusions. Hematite microfissures affect Qtz2. Hematite also fills open spaces between Qtz3 crystals. c) Zoom of zone localized in b). d) Hematite in reflected light. e) Qtz2-tg transgranular FIP e) Qtz3-p primary FI.

district correspond to V-ore veins related to the Messinian transcurrent faulting. FI in siderite display fluids with 15-25 mass% eq.NaCl and Th of 190 °C (Sd-p in fig.2). This fluid is also present in µ-quartz as FIP parallel to the siderite wall vein. FI in barite revealed salinities around 20-25 mass% eq.NaCl and Th 230-330 °C (Brt-p in fig.2). This temperature rise between siderite and barite may be due either to a thermal pulse or by the important cleavage of barite which ease fluid inclusion leakage.

The coolest fluids (Cal-p in fig.2) are trapped in V-Cal where FI indicate salinities of 11-18 mass% eq.NaCl and Th of 80 °C.

All the described fluids contain a volatile phase made of CO_2, CH_4 and N_2 in various proportions, with the exception of Qtz2-tg which shows an addition H_2S and Sd-p which contain CH_4 only.

Halogen signatures of Qzt1-tg1 and Qtz1-tg2 display a Br/Cl ratio of 1000. Fluid inclusions (Sd-p and Brt-p) in siderite and barite from V-ore display a Br/Cl ratio more typical of secondary brines, indicating distinct fluid movements and the dissolution of evaporites. Others generations of fluids did not yield signal in halogens.

CONCLUSION

During the emersion of the Sierra, the strong decrease in salinity from Qtz2-ig to Qzt2-tg may indicate the involvement of surficial fluid in interaction with previous metamorphic brines (Qtz2-ig, Qzt1-tg1 and Qzt1-tg2) issued from the

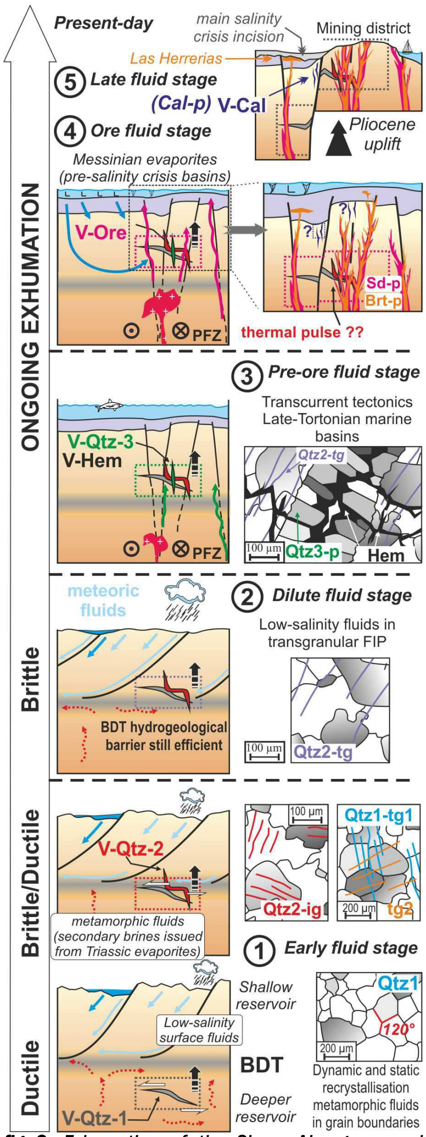

fig 2. Exhumation of the Sierra Almagrera and associated tectonics, paleo-orographic evolution and paleofluid sequence. Abbreviations: BDT: Brittle-Ductile Transition, PFZ: Palomares Fault Zone.

dissolution of Triassic evaporites. During the following events, the salinity increased (Qzt3-p). The origin of these fluids can be discussed between the first metamorphic fluids and hydrothermal fluids induced by the beginning of the volcanism mixing with surficial fluids. In the mining district, the salinity remained constant and the temperature gradually decreased, during the mineralized phase (V-ore). V-Cal recorded more superficial low temperature circulations. This can be related to more recent fluid flows, but also to the superficial expression of one of the previous deeper fluid flows since both tectonic zones are now close, together due to the more recent uplift of the eastern side of the Palomares fault.

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REFERENCES

*Booth-Rea, G., Azañón, J.-M., Azor, A., and García-Dueñas, V., (2004): Influence of strike-slip fault segmentation on drainage evolution and topography. A case study: the Palomares Fault Zone (southeastern Betics, Spain. J. Struc. Geol., **26**, 1615-1632.*

*López Ruiz, J. Rodriguez Badiola, E. (1980): La región volcánica del sureste de España. Estudios Geológicos, **36**, 5-63.*

Morales Ruano, S. (1994): Mineralogía, geoquímica y metalogenia de los yacimientos hidrothermales del SE de España. Unpublished PhD Thesis, University of Granada, Granada, Spain, 254 p.