A Cretaceous-Tertiary Hydrothermal Event in the Atlantic-Tethys margin? Evidences from MVT Ores and Paleomagnetism

Dídac Navarro-Ciurana (1), Mireia Domènech (1), Esteve Cardellach (1), Mercè Corbella (1)

(1) Dpt. Geologia. Universitat Autònoma de Barcelona. Campus UAB, Edifici C, 08193, Bellaterra, (España)
* corresponding author: didac.navarro@uab.cat

Palabras Clave: MVT, Evento térmico, Mar Atlántico-Tetis | **Key Words:** MVT, Thermic event, Atlantic-Tethys Sea

INTRODUCTION

Different large and globally significant Zn-Pb Mississippi Valley-Type (MVT) ore provinces, hosted within Jurassic and Lower Cretaceous carbonates, are convincingly related to the formation of small Mesozoic basins, which opened and subducted between the N Atlantic and W Tethyan tectonic realms. These districts include the Basque-Cantabrian, Maestrat and Prebetic basins in N, E and SE Spain, respectively, as well as the Atlas Morocco-Algeria (Fig. 1). Moreover, these ores show surprising genetic similarities, like precipitation temperatures and formation ages. Consequently, we explore the idea of a regional-scale thermal event of fluid flow as generator of MVT deposits in the N Atlantic-W Tethys boundary. Are they all related to a simultaneous regional thermal event? It must have occurred during a quiescent period in this tectonic territory.

MVT ORE AS HYDROTHERMAL EVIDENCE

The Reocín Zn-Pb deposit, hosted within Aptian-Albian dolomitized carbonates in the Basque-Cantabrian Basin (Fig. 1) is the largest known MVT deposit in Spain (~60 Mt., 7% Zn, 1% Pb). The fluid inclusion (FI) homogenization temperatures (T_h) of the ore minerals are <110ºC (Grandia et al., 2003b). Velasco 2003 argued that the Reocín ore may have formed between Upper Cretaceous and Early Tertiary (Pb model age: 64±10 Ma) post-rift phase. However, paleomagnetic dating results indicate a Miocene age (15±10 Ma) for the ore, related to the orogenic uplift during the Alpine orogeny (Symons et al., 2009). However, it must be considered that the paleomagnetic method might fail due the oxidation of sulfide ores, and thus, the obtained age might correspond to the supergene oxidation stage.

The Maestrat Basin contains small Zn-Pb deposits (e.g., Resurrección, ~30,000 t., 6.7% Zn, 0.2% Pb), which are hosted in hydrothermally dolomitized Aptian and Albian carbonates in the Iberian System (Fig. 1). Subsidence and FI studies indicated that pre-ore dolomitization occurred between Cenomanian to Danian times (~100-63 Ma) at 100 to 150ºC (e.g. Martín-Martín et al., 2015), whereas ore minerals formed during the Early Paleocene (62.6±0.7 Ma, U/Pb dating) rift episode at maximum temperatures of 190ºC (Grandia et al., 2000, 2003a).

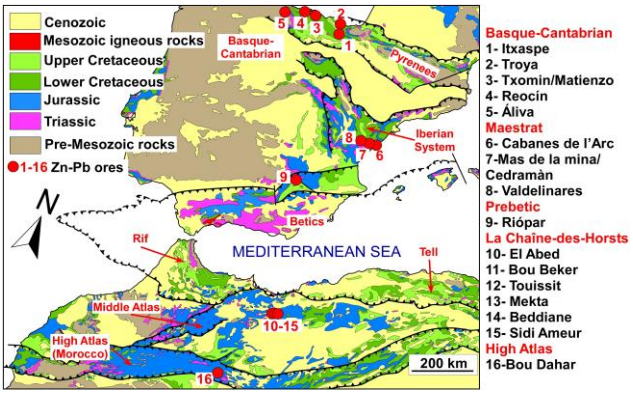

Fig 1*. Geologic map of the Mesozoic basins in the W Mediterranean area and location of the most important MVT ores (1-16).*

Although different Zn-Pb sulfides are recognized in the Betic Cordillera, the only known MVT deposit hosted in Lower Cretaceous (Berriasian-Valanginian) carbonates are located in the Prebetic Zone (Riópar, ~20,000 t. extracted Zn; Fig. 1). The Riópar ore is related to a dolomitization that affected Upper Jurassic-Lower Cretaceous carbonates. FI studies and $\Delta^{34}S$ geothermometry in sph-gn pairs show a formation temperature of 150-250ºC (Navarro-Ciurana et al., 2017). Moreover, a subsidence analysis suggests a relative timing range for the Riópar MVT ore formation from Upper Cretaceous to Tertiary (~95-20 Ma; Navarro-Ciurana et al., 2017) related to a post-rift event.

The MVT ores in the Bou Dahar (400,000 t., 17-47% Zn, 40-70% Pb) and Touissit-Bou Beker (>70 Mt., 4% Pb, 3.5% Zn) districts are hosted in Middle and Upper Jurassic carbonates of the oriental High Atlas (Morocco) and the "la Chaîne-des-Horsts" Atlasic belt (Morocco-Algeria), respectively (Fig. 1). FI data developed by Bouabdellah et al. (2012) and Rddad and Bouhlel (2016) indicate that the ore forming fluid temperatures are

<150ºC. Paleomagnetic dating indicate that the Bou Dahar sulfide oxidation started in the Eocene-Miocene (~50-10 Ma) compressive stage due the Europe-Africa convergence, leading to the orogenic belt uplift and Zn-Pb sulfide lens exhumations (Charles et al., 2016). Consequently, an ore formation period of ~168 to 50 Ma can be inferred, being possible a genetic relationship with the Jurassic-Cretaceous post-rift stage.

The conceptual genetic model for most MVT deposits hosted in the Mesozoic basins of the SW Europe and N Africa point to a mixing between fluids of low salinity and temperature, probably derived from the Cretaceous Sea, and hydrothermal metal-rich brines that circulated through the Paleozoic basement (e.g., Navarro-Ciurana et al., 2017). The similarity of the probable formation ages for all of them during Late Cretaceous-Early Tertiary, suggests they formed as a consequence of a reginal-scale thermal event.

ATLANTIC-TEHTYS MARGIN TECTONISM

A Late Cretaceous remagnetization event that affected Mesozoic rocks of the W Mediterranean Mesozoic basins was reported by Torres-López et al. (2014) and references therein. The remagnetization origin was explained as chemical and linked to the circulation of hydrothermal fluids in the basins.

The age coincidence of the remagnetization and MVTs formation prompted the crustal and mantellic reconstruction of the W Mediterranean, with data from many authors. The lithospheric section points to an important crustal thinning and hyper-extension episode during Cretaceous. The hyper-extension must have triggered a rise of the mantle and also the isotherms, and, consequently, these may have facilitated deep fluids circulation. The maximum hyper-rift in Iberian basins corresponds to Early Cretaceous times that was followed by a strongly subsiding event until beginning the Late Cretaceous. However, in the High Atlas the maximum hyper-extensional tectonics occurred during Early to Middle Jurassic times.

Consequently, the formation of MVT ore seems to be related posteriorly to rift stages in the Atlantic-Tethyan margin and with a crustal thinning in response to a previous hyper-extension -and mantle rise- within the basins. Clearly, more work is needed to confirm the proposed model.

REFERENCES

Bouabdellah, M., Sangster, D.F., Leach, D.L., Rown, A.C., Johnson, C.A., Emsbo, P. (2012): Genesis of the Touissit-Bou Beker Mississippi Valley-Type District (Morocco-Algeria) and its relationship to the Africa Europe collision. Econ. Geol., **107**, 117-146.

Charles, N., Choulet, F., Sizaret, S., Chen, Y., Barbanson, L., Ennaciri, A., Badra, L., Branquet, Y. (2016): Internal structures and dating of non-sulphide Zn deposits using rock magnetism: insights from the Moroccan High Atlas. Miner. Deposita, **51**, 151-175.

Grandia, F., Cardellach, E., Canals, À., Banks, D.A. (2003a): Geochemistry of the fluids related to epigenetic carbonate-hosted Zn-Pb deposits in the Maestrat basin, Eastern Spain: fluid inclusion and isotope (Cl, C, O, S, Sr) evidence. Econ. Geol., **98**, 933-954.

—, Canals, À., Cardellach, E., Banks, D.A., Perona, J. (2003b): Origin of ore-forming brines in sediment-hosted Zn-Pb deposits of the Basque-Cantabrian basin, Northern Spain. Econ. Geol., **98**, 1397-1411.

—, Asmeromb, Y., Gettyc, S., Cardellach, E., Canals, À. (2000): U-Pb dating of MVT ore-stage calcite: implications for fluid flow in a Mesozoic extensional basin from Iberian Peninsula. J. Geochem. Explor., **69**, 377-380.

Martín-Martín, J.D., Travé, A., Gomez-Rivas, E., Sizun, J.P., Vergés, J., Corbella, M., Stafford, S.L., Alfonso, P. (2015): Fault-controlled and stratabound dolostones in the Late Aptian-earliest Albian Benassal Formation (Maestrat Basin, E Spain): Petrology and geochemistry constrains. Mar. Pet. Geol., **65**, 83-102.

Navarro-Ciurana, D., Cardellach, E., Vindel, E., Griera, A., Gómez-Gras, D., Corbella, M. (2017): Implications for the genesis of the Riópar Zn-(Fe-Pb) carbonate-hosted deposit (Prebetic Zone, SE Spain): Sulfur and lead isotope systematics. Ore Geol. Rev., **91**, 928-944.

Rddad, L., Bouhlel, S. (2016): The Bou Dahar Jurassic carbonate-hosted Pb–Zn–Ba deposits (Oriental High Atlas, Morocco): Fluid-inclusion and C-O-S-Pb isotope studies. Ore Geol. Rev., **72**, 1072-1087.

Symons, D.T.A., Lewchuk, M.T., Kawasaki, K., Velasco, F., Leach, D. (2009): The Reocín zinc-lead deposit, Spain: paleomagnetic dating of a Late Tertiary ore body. Miner. Deposita, **44**, 867-880.

Torres-López, S., Villalaín, J.J., Casas, A.M., EL Ouardi, H., Moussaid, B., Ruiz-Martínez, V.C. (2014): Widespread Cretaceous secondary magnetization in the High Atlas (Morocco). A common origin for the Cretaceous remagnetizations in the western Tethys? J. Geol. Soc., London, **171**, 673-687.

Velasco, F., Herrero, J.M., Iñaki, Y., Alonso, J.A., Seeblod, I., Leach, D. (2003): Geology and geochemistry of the Reocín Zn-Pb deposit, Basque-Cantabrian Basin, Northern Spain. Econ. Geol., **98**, 1371-1396.