

## Fluid inclusion study of the Reppia VMS deposit in the northern Apennine ophiolites, Italy

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The Reppia Fe-Cu-Zn sulphide deposit is one of the numerous volcanogenic massive sulphide (VMS) deposits associated with the northern Apennine ophiolites in the eastern Liguria and Emilia Romagna regions (Italy). The deposit is located close to the village of Reppia, about 50 km far from Genova. The geology of this area is connected to the evolution of the Ligurian Ocean which formed in the western limb of the Neotethys and its present-day tectonic setting is the result of the early Cretaceous-late Eocene Alpine Orogeny. The Ligurian Ocean was a slow spreading system in which from the Triassic until the middle Jurassic the intrusion of gabbroitic bodies into Proterozoic and Permian formations was continuous. In the late Jurassic MORB-type pillow basalt was formed at the bottom of the ocean (Garuti *et al.*, 2009). The stratigraphic successions of the Ligurian ophiolites differ from the classical reconstruction of oceanic crust deduced from other ophiolites of the world, because of the lack of a sheeted dyke complex and the scarcity of layered gabbro cumulates (Garuti *et al.*, 2009). Most of the known sulphide deposits in the North-Apennines are Cyprus-type Fe-Cu-Zn volcanogenic massive sulphide deposits connected to those mafic and ultramafic rocks, which represent the former oceanic crust. These deposits bear valuable information regarding the VMS ore-formation at the bottom of the sea because almost no effect of later metamorphic events can be traced (Garuti *et al.*, 2009). The aim of this study was to carry out the first detailed analysis of fluid inclusions in the sulphide ore to provide more valuable information about the origin and evolution of hydrothermal activity in the Ligurian ophiolites. For this purpose, the VMS deposit of Reppia was selected, since it contains sulphide mineralization in three different settings, within one single stratigraphic section comprising the serpentinite-basalt-sediment transition. They are: i) stratiform deposit in the ultramafic breccia at the top of the serpentinite unit (type 1), ii) stratiform deposit at the top of the pillow basalts (type 2), and iii) stockwork-vein ore mineralization (type 3) crosscutting the pillow basalt, below type-2 stratiform mineralization (Zaccarini & Garuti, 2008).

By petrography pyrite, chalcopyrite, pyrrhotite, sphalerite and detrital chromite as ore minerals and quartz, chlorite and calcite as gangue minerals were identified in the type-1 mineralization. In type-2, pyrite, pyrrhotite and minor chalcopyrite were observed as ore minerals, along with quartz, chlorite and clay minerals as gangue. In the type-3 deposit, we have identified chalcopyrite, pyrite, sphalerite, hematite and ilmenite as ore minerals, and quartz and chlorite as gangue.

Three generations of quartz were distinguished in the stockwork veins, possibly corresponding to a sequence of crystallization events. The first (earliest) generation consists of euhedral-subhedral, prismatic crystals, commonly characterized by growth zoning with a spongy core. The size of the first generation varies between 0,5 and 2 cm. The grains in the second generation are subhedral, rounded, the crystals are clear and slightly smaller (around 0.3 cm) with the absence of zoning in most of the cases. In the second generation, the grains are rounded and have a size below

20 µm. Every generation contains primary fluid inclusions, which are round-shaped and exhibit a constant phase ratio (5-10% vapour phase and 85-90% liquid phase). The primary inclusions may be connected to the growth zones of the quartz or may occur independently in the limpid crystals. The occurrence of secondary inclusions is very common. Their shape, size and phase ratio are variable. Fluid inclusion micro-thermometry measurements were done on both quartz generations and chlorite thermometry calculations based on the EPMA analyses of the chlorite were done on chlorite crystals which are syngenetic with the first quartz generation, based on petrographical evidences. Since the measured homogenization temperature values give the minimum formation temperature of the quartz, the chlorite thermometry calculations were also taken into consideration to obtain the real formation temperature (Zang & Fyfe, 1995). The formation pressure can be determined with the combination of the two methods, if the chlorite and the quartz are syngenetic. The average minimum formation temperatures were 150±15°C in the case of the first generation and 145±13°C in the case of the second generation. The observation of the final melting temperatures was often hindered by the metastability of the inclusion fluid upon cooling. Where metastability did not occur, an average salinity of 3 NaCl equiv. wt% was calculated. In the case of the chlorite cogenetic with the first quartz generation, the thermometry calculations (Zang & Fyfe, 1995) gave an average of 198°C as the formation temperature. The combination of these data results in a formation pressure of about 0.9 kbar, if the effects of the observed (with Raman spectroscopy) methane gas phase is also taken into consideration. This could be caused partly by the water depth, or by the thickness of the overlying rock series. To decide this, more research is needed.

Comparison of these results with the formation temperature values of several different VMS deposits (250-400°C, Pirajno, 2009; Inverno *et al.*, 2008; Zengqian *et al.*, 2008) shows that the research area formed at lower temperatures. This can be explained either by the difference in the tectonic setting or by the possibly distal formation of the studied veins, in relation to the centre of the hydrothermal fluid flow.

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