GEMex Project Report

Oxygen isotopic results on skarn minerals from the Las Minas Exhumed system (Addendum to the final report on understanding from exhumed systems – Deliverable D4.2)

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Executive summary

Oxygen isotope data of skarn minerals pairs (quartz-magnetite, garnet-magnetite) provided a temperature estimate range of 600-650°C in agreement with maximum fluid inclusion trapping temperature derived from fluid inclusion studies of skarn minerals of the Las Minas system reported in the “Final report on understanding from exhumed systems – Deliverable D4.2”.

The computed temperatures and isotopic compositions of the fluid in equilibrium with the skarn minerals are coherent with a magmatic derivation of the fluid.

1.Introduction

This report represents an addendum to the Chapter 6 “Fluid inclusion studies and radiogenic and stable isotope analyses” by Morelli et al. (2018) of the “Final report on understanding from exhumed systems – Deliverable D4.2”. This addendum provides additional information on the isotopic composition and temperature of the fluid which flowed in the exhumed geothermal system of Las Minas, on the basis of the results of stable isotope ($\delta^{18}O$) on skarn hydrothermal minerals (quartz, magnetite, and garnet) in selected samples.

2. Stable isotope analyses

Oxygen isotope analyses of hydrothermal minerals provide significant information to potentially discriminate among different source of the fluid(s) responsible for mineral precipitation and therefore they can contribute to the reconstruction of the paleo-hydrology of hydrothermal systems. Stable isotopes show specific signature of their ratios for different type of rocks, minerals and fluids linked to their origins. Moreover, oxygen isotopic fractionations between minerals precipitated contemporaneously provide information of both fluid temperature and $\delta^{18}O$ compositions.

Stable isotopes analyses (O) were performed to apply a multi isotope approach for the study of skarn minerals of the exhumed hydrothermal system of Las Minas. Results integrate radiogenic isotope ratios of Sr, Nd, and Pb analysed in the same samples in Las Minas area (see Morelli et al. 2018, chapter 6.3). The obtained results provide information on the i) fluid temperature and origin, ii) fluid/rock interaction processes.

3. Method

Oxygen isotope compositions of single mineral grains were measured at the CNR-IGG, Pisa, by conventional laser fluorination (Sharp, 1995), reacting the samples under an BrF5gas atmosphere. Purified oxygen gas was directly transferred into a Thermo Finnigan Delta XP Isotope Ratio Mass Spectrometer via a 13A zeolite molecular sieve. All the data are given following the standard δ-notation relative to SMOW (Standard Mean Oceanic Water). Duplicate measurements were performed when sufficient material was available and the average $\delta^{18}O$ values were considered ± the standard error of the mean. In the course of analysis, an in-house laboratory QMS quartz standard ($\delta^{18}O$ SMOW=14.05‰) was used and calibrated vs. the international quartz standard NBS28 ($\delta^{18}O$=+9.58‰).

4. Selected samples

The samples processed for $\delta^{18}O$ isotope determination were selected among the collected rocks from Las Minas exhumed complex. Selected samples consist of five skarn hydrothermal minerals: LM-1, LM-10, LM-14, LM-15, LM-18 (Fig.1). Samples description was made by optical microscope observation and by electron microprobe analyses for samples LM-10, LM-15 and LM-14 (see Morelli et al., 2018 for details, in particular section 6.2.2 and figure 6.1).

Sample LM-1 was collected form a large quartz vein associated to a skarn assemblage (quartz + garnet + magnetite ± albite ± calcite ± pyrite ± chalcopyrite) and is mainly formed by anhedral quartz crystals with fractures filled by late stage microcrystalline quartz.

The main minerals found in sample LM-10 represent a typical skarn assemblage formed by actinolite + epidote + quartz + magnetite. In all the section the actinolite is mixed with epidote minerals. Magnetite is sparse around the section with variable size. When in contact, mangnetite and quartz are apparently in textural equilibrium. Minor opaque minerals-sulphides are also present.

Samples LM-14 are similar LM-15 and they are mostly formed by garnet and magnetite in textural equilibrium. Microprobe analyses have shown that garnet is mainly formed by andradite, with a lower component of almandine. Amphibole with actinolite composition is present included in the garnet. Veins are present in the sample and are filled with quartz, calcite and pyrite. Sample LM-14 has very similar composition of LM-15.

Sample LM18 mineral assemblage is mainly formed by garnet + minor amount of quartz + sulphides + calcite. Microprobe analyses reveal that garnet is compositionally andradite. Andradite has compositional variation, with areas richer in Al. Fractures are filled with sulphide minerals formed by sphalerite, chalcopyrite and pyrite. Calcite is also present in the fractures.

Fig. 1. Samples selected for $d^{18}O$ determination from Las Minas area.

Mineral separates of quartz, magnetite, and garnet were isolated by hand-picking for stable isotope determination. $\delta^{18}O$ were determined in garnets (LM-18, LM-15-grt, LM-14-grt), magnetite (LM-15-mgt, LM-14-mgt, LM-10-mgt) and in quartz (LM-1 and LM-10-qtz). All the separates are nearly pure minerals except the LM-1 sample in which quartz is accompanied by small amount of other phases.

5. Results

Oxygen isotopic compositions of the analysed minerals ($\delta^{18}O_{mineral}$) are shown in Table1. $\delta^{18}O$ values represent the average measurements on different fractions of the same sample. The highest $\delta^{18}O$ (10.61‰) was found in sample LM-1 which is mainly formed by quartz minerals and in sample LM-10 quartz fraction. In all the other samples the magnetite fraction shows the lowest $\delta^{18}O$ ranging from 2.16‰ in sample LM-15 to 3.34‰ in sample LM-10. Garnet minerals show higher $\delta^{18}O$ with the highest values of 6.91‰ in sample LM-18.

Sample name	Location	Rock type	Mineral	$\delta^{18}O_{mineral}$ (‰)	$\delta^{18}O_{H2O}$ (‰)	Temperature (°C)
MEX-LM-1	Las Minas, Perote	skarn	quartz	10.61	8.54**	570**
MEX-LM-10 - qz	Las Minas, Perote	skarn	quartz	10.10	8.83*	635*
MEX-LM-10 - mgt	Las Minas, Perote	skarn	magnetite	3.34	8.83*	635*
MEX-LM-14 - mgt	Las Minas, Perote	skarn	magnetite	2.95	8.59*	600*
MEX-LM-14 - grt	Las Minas, Perote	skarn	garnet	6.49	8.59*	600*
MEX-LM-15 - mgt	Las Minas, Perote	skarn	magnetite	2.21	7.63*	650*
MEX-LM-15 - grt	Las Minas, Perote	skarn	garnet	5.36	7.63*	650*
MEX-LM-18	Las Minas, Perote	skarn	garnet	6.91	9.01**	600**

Table 1. $\delta^{18}O$ results in the studied samples of Las Minas. Standard deviations of the analyses are comprised within the 0.08-058‰. * Temperature and $\delta^{18}O$ of H_2O were computed on the basis of $\delta^{18}O$ fractionations between two minerals (quartz-magnetite in LM-10, garnet-magnetite in LM-14 and LM-15) from the equations of Bottinga and Javoy (1973), **temperature for LM-1 sample is the maximum trapping temperature computed from fluid inclusion studies in quartz (Morelli et al., 2018), whereas for LM-18 sample estimated temperature correspond to the maximum trapping temperature of fluid inclusions in garnet of D-23 sample (see Morelli et al., 2018). ** $\delta^{18}O$ compositions of H_2O for LM-1 and LM-18 samples were computed from the isotopic composition of the minerals and the presumed temperature suggested by fluid inclusions by using the equation of Bottinga and Javoy (1973).

6. Discussion

The occurrence in three samples (LM-10, LM-14 and LM-15) of two oxygen-bearing minerals (quartz-magnetite or garnet-magnetite), which are believed to be contemporaneously precipitated during skarn formation, allows the computation of the isotopic temperature of formation of such phases from the $\delta^{18}O$ fractionation between the two minerals. The computed temperatures are between 600 and 650°C (Table 1). Such temperatures are in good agreement with the maximum trapping temperature of hypersaline (LH1) fluid inclusions (650°C) found in quartz from skarn of the Las Minas area (Morelli et al., 2018). The very high-temperature together with the hypersaline feature of the fluid suggested an origin from magmatic exsolution of the fluid. The magmatic nature of the fluid is also supported by computed $\delta^{18}O$ composition of the H2O in equilibrium with the mineral pairs. In fact, the $\delta^{18}O$ of values H_2O values are comprised between 7.63 and 8.89‰ which are within the range of "magmatic water" composition (Sheppard, 1984).

For LM-1 and LM-18 samples the $\delta^{18}O$ of values of H_2O were computed considering the maximum trapping temperature of LH1 fluid inclusions (LM1 sample) or extrapolated from the maximum trapping temperature of L1 inclusions in garnet if D23. Also in these cases the computed $\delta^{18}O$ values are in agreement with a magmatic origin of the fluid which precipitated the skarn minerals.

The precipitation of garnet and magnetite from a fluid exsolved from a magma is also in agreement with the radiogenic isotopic (Pb and Nd) data of these minerals which are similar to those of qz-diorite dikes associated to the skarn mineralization (Morelli et al., 2018).

7. Conclusion

Temperatures computed from oxygen isotopic data on skarn mineral pairs are comprised in the 600-650°C, which are in agreement with maximum fluid inclusion trapping temperature derived from fluid inclusion studies of skarn minerals of the Las Minas system.

The computed temperatures and isotopic compositions of the fluid in equilibrium with the skarn minerals are coherent with a magmatic derivation of the fluid.

References

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