

Carbon isotope diffusion in quartz & apatite and its relationship to biosignatures

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While organisms live, their enzymatic reactions tend to accumulate certain isotopes of particular elements more than others. The most abundant element in any organism – carbon – is no exception and its lighter isotope is preferentially accumulated and incorporated, leading to a general $\delta^{13}\text{C}$ of around -40.00‰ to -10.00‰. When an organism dies, its remains may be taken up by a growing host mineral, such as quartz or apatite. This inclusion would “freeze” the ratio, creating a biosignature that is thought to be stable over time. Most of the evidence for the earliest life forms on Earth is found in the form of isotopic biosignatures. Durable and inert minerals such as apatite and quartz are potential hosts for these isotopic anomalies, but their ability to accommodate carbon is uncertain, especially in the case of quartz. Recently, the origin and validity of biosignatures have been questioned, suggesting abiotic origins of lower $\delta^{13}\text{C}$ isotope ratios [1] rather than being strictly derived from enzymatic action.

To investigate the potential of apatite and quartz to record and retain biosignatures, the solubility and diffusion of different carbon species in these minerals were investigated. Carbon is detectable in both apatite and quartz treated at high temperature and pressure in the presence of graphite, CO, CO₂, and CO₃²⁻. Regardless of primary carbon species, however, the diffusion rates remained more or less constant. In addition, the values seemed to line up quite well with oxygen isotope diffusion data in quartz, when the diffusing species was CO₂ [2]. Based on these findings, it seems possible that the primary diffusion of carbon in these minerals depends greatly on the production of CO/CO₂ and thus the oxygen fugacity in the system.

Recent studies of isotope fractionation in the production of these gases from carbon indicate that CO production may lead to great distortion of the isotope ratio in the parent material. Evidence of such mechanisms would be suggesting a certain fallibility in interpreting isotopic ratios as biosignatures and recognizing proof of early life on earth.

[1] Horita, J (2005) *Chemical Geology* **218**(1-2), 171-186.

[2] Sharp, ZD, Giletti, BJ and Yoder, HS (1991) *Earth and Planetary Science Letters* **107**, 339-348.

The use of trace elements in Fe-oxides in deducing the fractionation history of a silicate magma: A LA-ICP-MS study

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Knowledge of the trace element compositions of Fe-oxides will help to develop indicator minerals for exploration in addition to improving our understanding of the petrogenesis of the deposit. This study has characterized Fe-oxides, using laser ablation ICP-MS, from the upper part of Sept-Îles layered intrusion (Québec, Canada), which hosts an Fe-Ti-P deposit, rich in magnetite, ilmenite and apatite. The Fe-oxides record a sequence of fractional crystallization that evolves from the bottom to the top of the deposit. Trace elements in both magnetite and ilmenite vary as a function of their stratigraphic position (Fig. 1). Aluminium, Co, Cr, Mg and V decrease in the Fe-oxides up sequence whereas Ga, Ge, Hf, Mn, Mo, Nb, W, Sc, Sn, Ta, Zr and Zn increase. These geochemical variations appear to be controlled by the partition coefficients of compatible (e.g., V) and incompatible (e.g., Mo) elements into the co-crystallizing phases (olivine, plagioclase, magnetite, ilmenite and apatite) and in the magma during fractional crystallization of the silicate magma. Although magnetite and ilmenite show similar variations (Fig. 1), elements partition differently between the two. For example, Hf, Mg, Nb, Sc, Ta, Ti, W, and Zr are more abundant in ilmenite whereas Al, Co, Cr, Ga, Ge, Mo, Ni, Pb, Sn and V are more abundant in magnetite.

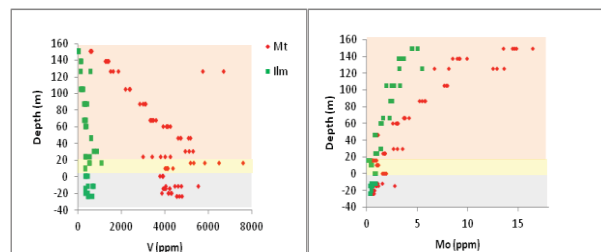


Figure 1: Variation of V and Mo in magnetite (Mt) and ilmenite (Ilm) as a function of depth in the Fe-Ti-P deposit of Sept-Îles. The layered sequence comprises, from bottom to top: magnetite (grey), nelsonite (yellow) and nelsonitic-gabbro (orange).

This study shows that the chemical composition of Fe-oxides varies over a wide range within a single Fe-Ti-P deposit as a result of fractional crystallization. Thus it is necessary to understand the processes that control the chemical variability of the Fe-oxides in any given deposit in order to develop an effective exploration tool for the mining industry.