

## Pre-eruptive conditions of ore-forming magma that produced the Henderson molybdenite deposit, CO: Insights from melt inclusions and mineral thermobarometry

CELESTINE N. MERCER<sup>1\*</sup>, ALBERT H. HOFSTRA<sup>1</sup>, TODOR I. TODOROV<sup>1</sup>, AND ERIN E. MARSH<sup>1</sup>

<sup>1</sup>USGS, Denver, USA, cmercer@usgs.gov (\* presenting author)

The Henderson ore body is a Climax-type porphyry molybdenum deposit related to Oligocene high-silica rhyolite intrusions of the Red Mountain Complex near Empire, Colorado [1, 2]. The Hideaway Park rhyolite ashflow tuff outcrops 17 km NE of the Henderson deposit, and is thought to be a co-genetic extrusive expression of the intrusive complex that formed the Henderson deposit [3, 4]. We use quartz-hosted melt inclusions and phenocryst mineral chemistry to place constraints on the pre-eruptive magmatic conditions (P, T,  $f_{O_2}$ ,  $f_{S_2}$ ), volatile contents (H<sub>2</sub>O, CO<sub>2</sub>, F, Cl, S), and metal concentrations to better understand the process of metal segregation within Climax-type ore-forming stocks.

Melt inclusions in the Hideaway Park rhyolite are comprised of glass, devitrified glass, crystals, and vapor. Crystals typically include quartz, alkali feldspar, magnetite, fluorite, zircon, and monazite. No molybdenite crystals have yet been identified within the crystallized inclusions, however some inclusions likely contain them because preliminary trace element analysis by LA-ICP-MS reveals several inclusions with anomalously high Mo concentrations (15-115 ppm) compared to the modal Mo concentration (10 ppm).

Accessory minerals in the Hideaway Park rhyolite include magnetite, ilmenite, biotite, zircon, and monazite. Preliminary magnetite-ilmenite pairs indicate crystallization at an  $f_{O_2}$  of NNO+1.7 and an  $a_{TiO_2}$  of 0.4 [6].

SEM-CL images of quartz phenocrysts show alternating bright-to-dark euhedral growth rims and resorbed zones. Ti concentrations in quartz measured by electron microprobe range from 39 to 66 ppm corresponding to crystallization temperatures [7] between 720-790°C (assuming  $a_{TiO_2} = 0.4$  and a preliminary pressure estimate of 2 kbar, equivalent to a shallow crustal magma reservoir at ~6 km depth). Quartz phenocrysts contain zircon inclusions, but pyrrhotite and molybdenite inclusions have not yet been found in any phenocrysts. Given that the Henderson deposit was formed in an extensional tectonic regime, carries a deep crustal/upper mantle signature (Mo/Rb = 0.013-0.040), and is only moderately oxidized, the magma is likely to be saturated with both molybdenite and pyrrhotite [5]. Assuming pyrrhotite and magnetite saturation at 750°C and an  $f_{O_2}$  of NNO+1.7, the Hideaway Park rhyolite should saturate with molybdenite with 8 ppm Mo in the melt [5]. The modal Mo value of 10 ppm may be indicative of a slightly higher average crystallization temperature (+10-20°C) or a slightly higher prevailing  $f_{O_2}$  of NNO+2.

[1] Wallace (1978) *B Soc Econ Geol* **73**, 325-368. [2] Seedorff (2004) *Econ Geol* **99**, 3-37. [3] Adams (2009) *GSA Annual Meeting* **93-7**. [4] Geissman (1992) *GSA B* **104**, 1031-1047. [5] Audéat (2011) *J Petrol* **52**, 891-904. [6] Ghiorso (2008) *Am J Sci* **308**, 957-1039. [7] Huang (in press) *Geochim Cosmochim Acta*.

## Experimental solubility of silica in nano-pores

LIONEL MERCURY<sup>1,\*</sup>, MAJDA BOUZID<sup>2,3</sup>, JEAN-MICHEL MATRAY<sup>3</sup>

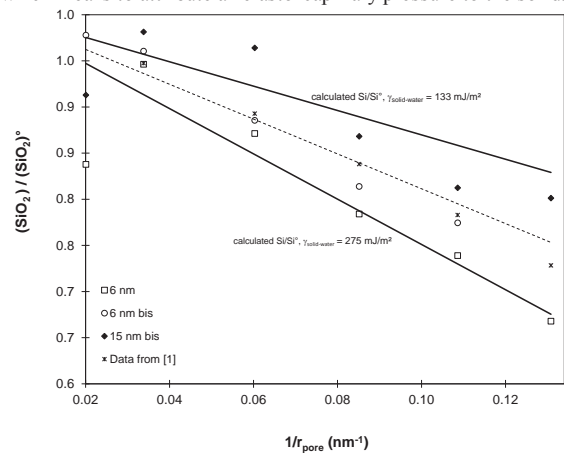
<sup>1</sup> Institut des Sciences de la Terre d'Orléans, UMR 7327 Université d'Orléans/CNRS/BRGM, 1A rue de la Férollerie, 45071 Orléans Cedex, France. (\* presenting author)

<sup>2</sup> IDES, UMR 8148 CNRS/Université Paris-Sud, bâtiment 504, 91405 Orsay cedex, France

<sup>3</sup> IRSN, DEI/SARG/LETS, BP 17, 92262 Fontenay-aux-Roses cedex, France

We used a pressure membrane extractor (Model 1020, Soil Moisture Equipment Corp.) to study the silica content at equilibrium with the decreasing pore sizes of amorphous silica. The principle is to extract the aqueous solution through a sequential process from the larger (micrometric) pores to the thinner (some nm) pores. Each extraction step is followed by an equilibration period.

The measurements confirmed earlier observations [1,2] that the concentration in dissolved silica decreases when the extraction pressure increases. The direct conclusion is that the silica solubility is pore-size dependent. These results are interpreted with the Young-Laplace relationship, at constant silica-solution surface tension, which means to attribute an elasto-capillary pressure to the solid.



**Figure 1:** Decreasing silica solubility extracted from pores having decreasing radii.

The geological implication can be illustrated using a simple scheme (e.g. [3]), wherein aquifer compartments with changing pore sizes are successively put along a flowing line (in series). Depending on the modeling assumption (pore sizes, succession type, equilibrium state of the solution), this process can result in a preferential cementation of the thin or the large pores.

Our experiments demonstrate that the negative curvature of the solids has a geochemical feed-back on the solid-solution interactions, with a threshold size at around 0.1  $\mu\text{m}$ .

[1] Dandurand J.-L., Mizele J., Schott J., Bourgeat F., Valles V., and Tardy Y. (1982) *Sci. Géol. Bull.* **35**, 71-79. [2] Emmanuel S. and Berkowitz B. (2007) *Geophys. Research Letters* **34**, L06404. [3] Mizele J., Dandurand J.-L., and Schott J. (1985) *Surf. Sci.* **162**, 830-837.