CO$_2$-RICH FLUIDS IN THE MANTLE: A COMPARATIVE FLUID INCLUSION STUDY

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Introduction

- Transport of fluids through the convecting mantle are the least understood and state-of-the-art problems.

- The composition and behavior at upper mantle depths of the supercritical aqueous fluids have been intensively studied (Keppler, 1996; Newton and Manning, 2000; Scambellurri and Philpot, 2001; Kessel et al., 2005; Hermann et al., 2006; Spandler et al., 2007).

- However, less information is available on CO$_2$-rich supercritical mantle fluids and their interactions with peridotitic mantle wall rocks.

- As study on fluid inclusion is the most suitable method to obtain information and evidences on upper mantle fluid systems (Roedder, 1984; Szabó and Bodnar, 1996; Andersen and Neumann, 2001), we aimed to carry out a complex study of a representative series of such fluid inclusions.
Sampling – 5 continent’s rocks

Rio Grande Rift, New-Mexico, USA

Pannonian Basin, Hungary

Cameroon Volcanic Line

Cameroon, Africa

Mt. Quincan, Victoria, Australia

Jeju- island, S-Korea
**Sampling – Balaton-highland (Hungary)**

The most significant outcrops of the mantle xenoliths in the Bakony–Balaton–Highland Volcanic Field

- Basaltic lava rocks
- Basaltic pyroclasts
The fluid inclusions—photomicrographs

- Hosted mainly by silicates (e.g. Opx—orthopyroxene: \( \text{Mg}_2\text{Si}_2\text{O}_6 \))
- At room temperature, commonly one visible liquid ± solid phase(s) within the inclusions
- Occurs along healed fractures or in clusters
- Their size ranges between 2–90 microns
Detection of $\text{N}_2$ within the fluid inclusions became easy by using the LabRAM HR!
**SOLID PHASES—Raman spectroscopy**

**Enstatite—hosted fluid inclusion:**
- Magnesite
- $\alpha$-Quartz

\[
\text{MgSiO}_3 \text{ (enstatite)} + \text{CO}_2 = \text{MgCO}_3 \text{ (magnesite)} + \text{SiO}_2 \text{ (quartz)}
\]

**Diopside—hosted fluid inclusion:**
- Dolomite

\[
\text{CaMgSi}_2\text{O}_6 \text{ (diopside)} + 2\text{CO}_2 = \text{CaMg(CO}_3)_2 \text{ (dolomite)} + 2\text{SiO}_2 \text{ (quartz)}
\]

*Berkesi et al. 2012*
**SOLID PHASES—Raman spectroscopy**

Sample from Mt. Quincan, Australia

- **H₂O in CO₂**
- **OH-bearing silicate**

Intensity vs. Raman shift (cm⁻¹)

3 440 3 480 3 520 3 560 3 600 3 640 3 680 3 720
**Why FIB–SEM?**

- Calculation of the volume proportions
- Morphology
- Identification at submicron scale

**Arbitrary size can be cut from the surface exposed by the ion beam and then see the exposed part of the inclusion by SEM and analyze with EDX.**

**The actual progress of the inclusion exposing process is monitored acquiring secondary electron (SE) images of the sample.**

Berkesi et al. 2012
Magnesite

Quartz

Glass film

Opx-orthopiroxene (Mg$_2$Si$_2$O$_6$)

Berkesi et al. 2012
Silicate components dissolved in a supercritical, CO₂-rich fluid is the most likely explanation of the ability of mantle fluids to transport trace elements and produce cryptic metasomatism.

Berkesi et al. 2012
S-bearing solids

- Sulfides as well as sulfates were identified pointing out the significance of sulphur in mantle volatiles!
The complexity of mantle fluid inclusions shown by an exposed inclusion

Sample from the Cameroon Volcanic Line, Cameroon

Opx-orthopyroxene (Mg$_2$Si$_2$O$_6$)
Concluding remarks

1) The fluid inclusions from mantle peridotites represent CO$_2$-rich, S-, N$_2$- and H$_2$O-bearing fluid system as proved by Raman microspectrography at elevated temperatures.

2) Daughter phases including their volume proportions can be efficiently studied by FIB-SEM technique on mantle fluid inclusions. The S-bearing solids and the glass could not been detected by using any other routinely used analytical technique for fluid inclusion studies.

3) We can conclude that similarly to the rocks, building up the subcontinental lithospheric mantle, the co-existing fluid can also be heterogeneous in the mantle although the dominant component in each case is the common CO$_2$.

4) The combination of heating freezing experiments and high resolution Raman microspectrography together with FIB-SEM technique allow us to determine or at least approximate the bulk composition of the fluid, which is in turn one of the main aims of the fluid inclusion studies.
Thank You for your attention!

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