Fluid inclusion compositions as a geo-thermobarometer: example of the Umwindsi shear zone, NE Zimbabwe

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Introduction

Compositions of graphite buffered C-O-H fluids can be used to fix pressure and temperature at a given f_{O_2} (French, 1966; Ohmoto & Kerrick, 1977). Fig. 1 shows the results of composition calculations for a QFM buffered system, using the reactions of Ohmoto & Kerrick (1977). On a PT diagram, $X_{CO_2}/(X_{CO_2}+X_{CH_4})$ is relatively pressure independent and can thus be used as a thermometer.

Applications to fluid inclusions show that if f_{O_2} cannot be estimated, the molar volume can be used as an extra parameter to estimate the fluid P-V-T-f_{O_2} conditions during trapping. An example of this method is given by a fluid inclusion study of the Archean Umwindsi Shear Zone (USZ), NE Zimbabwe.

Geological setting

The USZ is located in the late Archean (2.7–2.6 Ga) Harare-Shamva-Bindura greenstone belt. It forms a highly strained zone of greenstones in between two granitoid batholiths. Regional metamorphism resulted in PT conditions of 3–4 kbar, 600–650C respectively along the contact zone of the greenstones and granitoid gneisses (Jelsma *et al.*, 1993).

Shear related quartz veins have been sampled for fluid inclusion study. Fluid inclusions have been studied by optical microscopy, microthermometry and Raman spectroscopy to identify the chronology of the different inclusion types, the fluid composition and molar volume.

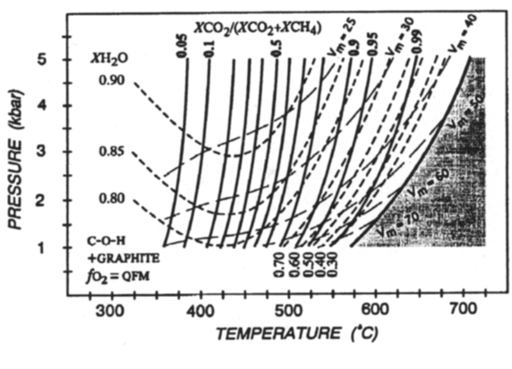

FIG. 1. Results of fluid composition calculations for the graphite buffered C-O-H system. f_{O_2} is buffered by QFM. The solid line indicates $X_{CO_2}/(X_{CO_2}+X_{CH_4})$, the dashed line X_{H_2O}, and the thin dashed line the molar volume (cm^3 mole^{-1}). Dashed area: graphite is unstable.

Fluid inclusion results

Two types of fluid inclusions are identified:

(1) Highly saline H_2O-CO_2-CH_4 graphite-bearing inclusions, occurring in trails parallel to the vein walls. The gas composition shows a relative constant $X_{CO_2}/(X_{CO_2}+X_{CH_4})$ of 0.66, whereas X_{H_2O} as well as the amount of graphite is highly variable. Some H_2O-rich inclusions contain a solid salt phase. The molar volume of the gas phase shows a positive correlation with $V_{H_2O}/(V_{H_2O}+V_{GAS})$ (degree of fill). The gaseous rich inclusions (degree of fill $\leqslant 0.1$) show a large variation in molar volume.

(2) Low salinity (9–11 wt.% NaCl) aqueous inclusions with a density of 0.9 gcm^{-3}, developed in trails normal to the vein walls.

Interpretation of (type 1) fluid inclusion results

The random presence of salt crystals in the H_2O-CO_2-CH_4 graphite-bearing inclusions indicates an oversaturation of NaCl in the H_2O-rich fraction of the fluid (> 26.3 wt.% NaCl). This means that the fluid was immiscible at high temperatures and that at the time of trapping the fluid was fractionated in a H_2O-rich and a CO_2-CH_4 gaseous rich phase.

The intersection of isochores for both fluid types should give the PT conditions of trapping. More information, however, is needed because the isochores are parallel for a large PT range. This information can be given by the fluid composition, especially the composition of the gas phase, which appears to be a sensitive thermometer. To adapt this thermometer, some constraints on f_{O_2} are necessary.

Although no mineralogical data are available to estimate f_{O_2}, the assumption of taking f_{O_2} around QFM is justified by two arguments:

(1) Greenstone belt rocks equilibrate around QFM (e.g. Cameron and Hattori, 1987).

(2) The presence of graphite under metamorphic conditions of 3 kbar and $\geqslant$600°C indicates that f_{O_2} was at most QFM + 0.4.

With this constraint, the molar volume and $X_{CO_2}/(X_{CO_2}+X_{CH_4})$ indicate a trapping temperature and pressure of 440–500°C, 2.5–3.5 kbar respectively.

Conclusions

Combination of the fluid composition and molar volume leads to the following conclusions:

(1) The original fluid before fractionating was a graphite-bearing, highly saline H_2O-CO_2-CH_4 fluid ($X_{H_2O} \geqslant 0.85$).

(2) PT conditions of trapping are estimated at 2.5–3.5 kbars and 440–500°C for f_{O_2} between QFM and QFM + 0.4 and $X_{CO_2}/(X_{CO_2}+X_{CH_4})$ = 0.66.

(3) The variation in molar volume of nearly pure gaseous inclusions is the result of selective water leakage of originally more H_2O rich inclusions.

References

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