

IMMISCIBILITY AND FLUID MIXING PROCESSES IN A GOLD-BEARING METACHERT OF THE SERRA DO ITABERABA GROUP, SÃO PAULO, SE BRAZIL

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Introduction

The Serra do Itaberaba Group (50 km NE of São Paulo city) is a Proterozoic meta-volcano-sedimentary sequence of the central Ribeira Belt (SE Brazil). It is composed of three units: the basal Morro da Pedra Preta (predominantly basic metavolcanic rocks of MOR affinity and \pm pelitic metasediments), the Nhanguçu (andaluzite-rich metapelites and Fe-Mg-rich schists) and the Pirucaia (quartz schists) formations (Juliani & Beljavskis, 1995).

Gold mineralization

In the 16th and 17th centuries, gold was mined from alluvial deposits along the Ribeirão das Lavras (0.2–0.36 g/m³), which runs through the Morro da Pedra Preta Formation (e.g. Garda et al., 2002). The mineralized zone is associated with basic and intermediate metatuffs and metandesitic-metadacitic bodies that intruded the metamafic rocks. Besides the metatuffs, volcanic metaconglomerates, metachert, tourmalinites, banded iron formation, and calc-silicate rocks characterize these seafloor exhalative centers, where hydrothermal alteration, brecciation and veining are also recognized (Fig. 1).

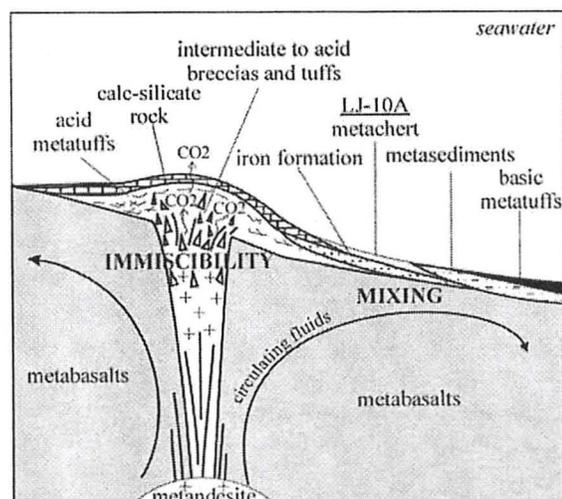


Figure 1. Representation of a seafloor exhalative center of the Morro da Pedra Preta Formation.

Fluid inclusions (FIs) in quartz and tourmaline

Sample LJ10-A (Fig. 1) comes from a gold-bearing, 15- to 60-cm thick metachert that overlies intermediate volcanoclastic rocks outcropping at the margin of the Ribeirão das Lavras. It comprises quartz, opaque minerals and chlorite. The metachert also contains thin, discontinuous, finely laminated tourmaline-rich layers constituted by 40–65% tourmaline and 35–60% quartz. The tourmaline also forms aggregates or occurs as isolated acicular grains in the metachert.

Table 1 presents some characteristics of the primary and pseudo-secondary FIs in the quartz constituting the tourmaline-rich layers of the metachert.

Table 1. Some characteristics of CO₂-rich^(*) and CO₂-bearing^(**) FIs in quartz.

FI types	Q1	Q2	Q3
V _{CO2(*)} or V _{gas(**)} /V _{total} (%)	55-85 ^(*)	30-90 ^(*)	< 45 ^(**)
Salinity (wt. % NaCl eq.)	5.7-6.9	0-5.0	2.5-9.0

Types Q1 and Q2 are aqueous-carbonic, whereas Q3 consists of CO₂-bearing aqueous FIs. Secondary FIs (Q4) also occur in quartz and are essentially aqueous, with V_{gas}/V_{total} varying from 5 to 14% and salinity from 7.8 to 16.5 wt. % NaCl eq.

The metachert brown tourmaline contains two types of primary FIs: a saline and predominantly aqueous and a less saline, CO₂-bearing, similar to the Q3-type in quartz.

Preliminary RAMAN analyses have shown that the gaseous phase of both quartz and tourmaline FIs can contain minor to negligible N₂ and CH₄ contents (D.C. Rodrigues and K. Fuzikawa, pers. comm.)

Discussion

When plotted against V_{CO2}/V_{total}, the total homogenization temperatures (Total Th) obtained for Q1 and Q2 of a same region of a quartz grain define a curve suggestive of the system *solvus*. H₂O-rich and CO₂-rich FIs homogenize at the same Total Th range

respectively to liquid and to gas (Fig. 2A). These criteria indicate phase immiscibility (Ramboz et al., 1982), which is also attested by a slight decrease in salinity with the increase in V_{CO_2}/V_{total} observed in Figure 3 for Q1 (Bowers & Helgeson, 1983).

On the other hand, significant variations in salinity observed in Q3 in quartz (Fig. 3) and in similar tourmaline FIs (Fig. 4) suggest fluid mixing, which is corroborated by the dispersion of data in Figure 2B.

Conclusions

Q1 and Q2 data indicate that quartz crystallization was favored by immiscibility of a CO₂-rich fluid taking place at the exhalative center (Fig. 1) at temperatures close to 300°C ($T_{trapping} \approx$ minimum Total Th – Fig. 2A).

CO₂ loss occurred during immiscibility, which is attested by CO₂-poor Q3-type FIs in quartz and similar FIs in tourmaline.

Quartz containing Q3-type FIs may have formed when the CO₂-depleted fluids, circulating close to the exhalative centers, started mixing with connate waters, which caused slight salinity changes (Fig. 3).

The circulation of these fluids further away from the exhalative center and mixing with connate and sea waters resulted in a considerable increase in salinity, as observed in more saline tourmaline FIs (Fig. 4). Tourmaline crystallization occurred at or near the sediment-water interface (Slack et al., 1993) under isothermal mixing (at ca. 300°C).

Both immiscibility and mixing promote gold deposition, in particular under low-salinity conditions, as attested by Q3-type FIs in quartz and similar tourmaline FIs.

A later mineralization event, not related to the seafloor hydrothermal system, is registered by the secondary, saline Q4-type FIs in quartz (Fig. 3). The low Total Th obtained for these FIs (80 °C to 180 °C) indicate mixing of saline fluids with meteoric waters, which favor the deposition of gold and other precious and base metals.

References

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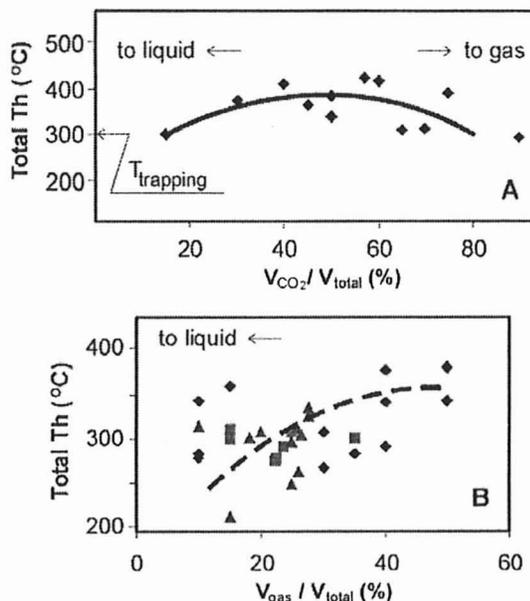


Figure 2. Total homogenization temperature versus (A) V_{CO_2}/V_{total} for Q1 and Q2 and (B) V_{gas}/V_{total} for tourmaline FIs. Obs.: Symbols identify different chips of LJ10A.

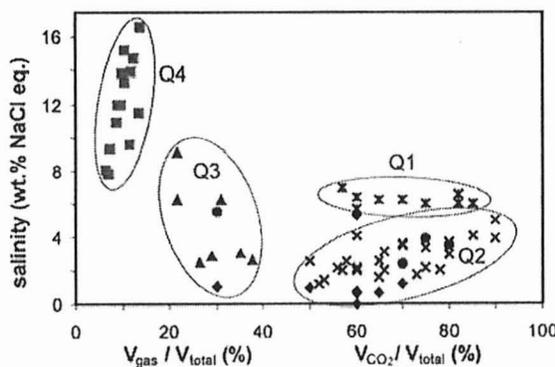


Figure 3. Salinity vs. V_{gas}/V_{total} , V_{CO_2}/V_{total} for quartz FIs.

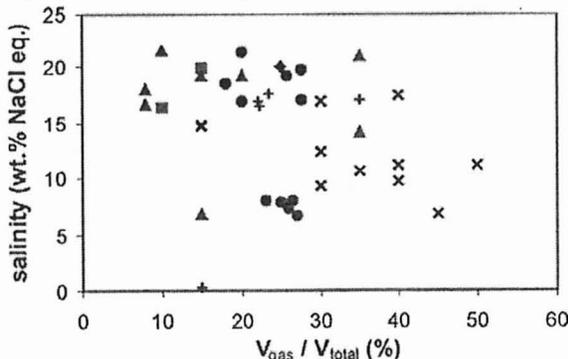


Figure 4. Salinity vs. V_{gas}/V_{total} for tourmaline FIs.