

## Crystallization conditions of micas in oxidized igneous systems

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### ABSTRACT

The Catalão II and Catalão I carbonatite complexes are Cretaceous intrusions in the northwestern part of the Alto Paranaíba Igneous Province, central Brazil, and contain various trioctahedral micas. Drill-hole sampling and mineralogical and geochemical data suggest the existence of different types of cumulate rocks as carbonatites (calcio- and ferrocarnatites in Catalão II; magnesiocarbonatites in Catalão I), magnetitites, apatitites, and phlogopitites. In Catalão II complex the presence of ultramafic lamprophyres (phlogopite-picrites) and fenites (syenites and clinopyroxenites) are identified. Phlogopite, Fe<sup>3+</sup>-rich phlogopite, and tetraferriphlogopite are ubiquitous, with marked and variable pleochroism. In the Catalão II, micas from magnetitites, apatitites, and calciocarbonatites are close in composition to the tetraferriphlogopite end-member. The Mg/(Mg+<sup>[IV]</sup>Fe<sub>tot</sub>) average value is 0.959 for micas from magnetitites, 0.878 for micas from apatitites, and 0.875 for micas from calciocarbonatites, suggesting an enrichment of octahedral iron in crystals from calciocarbonatites. The trioctahedral micas from the fenites are intermediate in composition between phlogopite and tetraferriphlogopite, with  $0.227 \leq [^{IV}Fe] \leq 0.291$  apfu. Micas of phlogopitites, ferrocarnatites, and phlogopite-picrites show a significant variation in <sup>[IV]</sup>Fe, <sup>[IV]</sup>Al, <sup>[IV]</sup>Mg, and <sup>[IV]</sup>Fe contents, suggesting the existence of different mica populations. In the Catalão I magnetitites micas show a quite constant Mg content but marked differences in <sup>[IV]</sup>Fe<sup>3+</sup> and <sup>[IV]</sup>Al content, so there are <sup>[IV]</sup>Fe<sup>3+</sup>-bearing phlogopite and tetraferriphlogopite. The micas from Catalão I apatitites have variable <sup>[IV]</sup>Fe<sup>3+</sup>, <sup>[IV]</sup>Al, and Mg contents and are mainly tetraferriphlogopite with a minor phlogopite population. Trioctahedral micas from Catalão I magnesiocarbonatites contain crystals close to tetraferriphlogopite with <sup>[IV]</sup>Fe<sup>3+</sup> and a limited variation in Mg content. In these complexes, heterovalent octahedral substitutions are mainly related to Ti<sup>4+</sup> and, only in a few samples, to Fe<sup>3+</sup>. The primary mechanism regulating Ti uptake into the mica structure is the Ti-oxy  $[^{[IV]}Ti^{4+}[^{IV]}(Mg,Fe)_2(OH)_2O_2^-]$  substitution. Crystal structural analysis shows that all mica crystals are 1M polytypes with the expected space group *C2/m*. The nearly equal size and mean electron count between M1 and M2 octahedral sites suggest a disorder of octahedral cations between these two sites. The low Al and the high Fe<sup>3+</sup> content in the tetrahedral site of these micas, as well as the high (OH)<sup>-</sup> content, reflects the general enrichment in FeO and H<sub>2</sub>O and the peralkaline nature of magma from which Catalão I and Catalão II micas crystallized. Micas strongly enriched in Fe<sup>3+</sup> and poor in Ti and Al, are used, for the first time, as indicators of crystallization temperature using published geothermometers. Temperatures range between ~800 and 558 °C for the Catalão II cumulate rocks, in high oxygen fugacity conditions, mainly over the HM condition. In contrast, the variability in temperature (703–631 and 1050–952 °C) for Catalão II phlogopite-picrites is consistent with mica crystallization in an HM-NiNiO environment. The calculated temperatures for Catalão I cumulate rocks (742–542 °C for magnesiocarbonatites, 923–540 °C for magnetitites, and 679–550 °C for apatitites) are quite similar with those of Catalão II rocks, but they generally show higher oxygen fugacity conditions (over HM condition).

**Keywords:** Phlogopite, tetraferriphlogopite, carbonatites, Catalão, Alto Paranaíba Igneous Province, Brazil