Enhancing understanding of VHMS-like deposits in the Carajás Province: the role of Principal Component Analysis in interpreting magnetite chemical data

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Discriminant diagrams generally used to classify deposit types based on the chemical composition of magnetite should be used with caution due particularly to the significant overlap in the conditions of magnetite formation among different deposit types. This has raised the need to investigate the chemistry of magnetite considering the approach of Principal Component Analysis by reducing the complexity of multi-dimensional geochemical data. This has been done by investigating the chemical signature of magnetite derived from three different geological contexts in the Serra Sul and Serra Norte regions in the Carajás Province, Brazil: (i) magnetite from BIF (Mag I and Mag II - S11D deposit) and jaspilite (Mag III - N4WS deposit primary banding; (ii) magnetite from brecciated quartz-magnetite BIF (Mag IV - S11D deposit); and (iii) magnetite from VHMS-type base metal mineralization hosted in volcanic breccias (Mag IV - GT57 and N4WS deposits). Dimension reduction was applied to the magnetite dataset considering a database (n = 92) above detection limit of six elements: Al, Si, Ti, Mg, Ca, Mn. PC1, PC2, and PC3 were selected for further data interpretation. PC1 explains 30.38% of the variability being dominated by the behavior of Al, Ti, Ca, and Mn. PC2 explains 27.39% of the variability that is represented by the behavior of Mg and Si. PC3, in turn, represents 19.08% of the variability and is dominated by Ti and Mg. Along PC1, Ti, and Al are positively correlated, whereas Ca and Mn display a negative correlation with those elements. Along PC2 and PC3, Si and Mg and Mg and Ti are negatively correlated, respectively. The elements Al, Ti, Ca, and Mn in Mag V are likely indicative of the precipitation of magnetite, coeval with ore precipitation, from higher temperatures under relatively higher oxygen conditions. This is further evidenced by the increased incorporation of Ti and Al. This suggests variable oxygen fugacity during the precipitation of coexisting pyrrhotite and magnetite in VHMS-bearing breccias. Consequently, Mag V may have formed after pyrrhotite given the inclusions of the latter within Mag V crystals. The inverse relationship between Ca and Mn with Al and Ti demonstrates the depletion of these elements in Mag V, given that Mn and Ca are incompatible with hydrothermal magnetite. Owing to their mobility during hydrothermal alteration, both elements were likely incorporated into calcite-ankerite of the carbonate alteration. Mg and Si in Mag I and Mag II might indicate the progressive precipitation of BIF-related

magnetite from higher temperatures (Mag I) to lower temperatures (Mag II, Mag III, and Mag IV). Mag III and Mag IV indicate the influx of Si-rich fluids given BIF brecciation. Ti and Mg exhibit a negative correlation along PC3. Although PC3 accounts for less than 20% of the data variance, it may suggest that Mg serves as a more effective temperature indicator for magnetite from the BIF environment, whereas Ti is more indicative of magnetite from VHMS-like mineralization.