

Exploratory Data Analysis (EDA) of Trace Element Variations in Apatite from Skarn Deposits

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Apatite is an important accessory mineral capable of recording the physicochemical conditions of magmatic–hydrothermal fluids, making its trace element composition an effective proxy for interpreting skarn-forming processes. Skarn deposits form through metasomatic reactions between magmatic–hydrothermal fluids and carbonate host rocks in the vicinity of magmatic intrusions and are associated with a wide range of metallic commodities. This study aims to characterize the geochemistry of apatite and to evaluate its variations across four types of skarn deposits, namely Fe skarn, Cu skarn, Zn skarn, and W–Sn skarn, using an exploratory data analysis (EDA) approach applied to standardized trace element datasets. (Meinert, 1992) The results indicate that variations in trace element signatures and apatite types are primarily controlled by tectonic setting, intrusion type, fluid characteristics, and host rock composition. Apatite from Fe skarns is characterized by enrichment in LREEs, V, and Th, reflecting oxidizing conditions associated with mafic to intermediate intrusions in subduction-related settings, and typically occurs as fluorapatite to fluor–chlorapatite. Apatite from Cu skarns shows relatively high Sr and Ba contents, along with enrichment in Mn and U, recording the dominance of magmatic–hydrothermal fluids derived from evolved intermediate to felsic intrusions, with fluorapatite being the predominant apatite type. In contrast, apatite from Zn skarns is characterized by enrichment in Mn, Sr, Ba, and Pb and low U contents, reflecting the influence of high-salinity, Cl-rich, and relatively reducing basinal brines in extensional tectonic settings; the apatite is dominated by chlorapatite. Apatite from W–Sn skarns exhibits enrichment in Mn and fluorine-compatible elements and is associated with evolved S-type granitic intrusions in post-collisional to extensional intracontinental environments, where fluorapatite is the dominant apatite phase. Overall, apatite is demonstrated to be a robust geochemical indicator for distinguishing skarn commodity types and for interpreting the geological conditions that control skarn mineralization.