



Compositional variations of accessory chlorite from sulfide ore deposits and their mafic-ultramafic country rocks in the Northern Apennine ophiolites (eastern Liguria and Emilia Romagna, Italy)

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A total of 872 electron microprobe analyses of accessory chlorite were performed in 80 samples of Cu-sulfide ore, country-rock basalt, gabbro and serpentinite from Jurassic ophiolites of the Northern Apennine (eastern Liguria and Emilia Romagna, Italy). According to the recommended nomenclature for trioctahedral chlorites, the analyzed samples contain chlorite varying from clinochlore, ferroan clinochlore to magnesian chamosite, with a predominance of clinochlore types on chamosite. The accessory chlorite in ophitic basalts and gabbros varies from magnesian chamosite to ferroan clinochlore (with relatively low Mg/Fe). Clinochlore with relatively high Mg/Fe appears in basalts showing increasing spilitization, possibly as a result of interaction with hydrothermal fluids. The highest Mg/Fe ratios occur in clinochlore from serpentinite. The Cu-sulfide deposits represent: 1) disseminated sulfide in quartz-carbonate stockwork veins cutting across basalts, gabbros and serpentinite, 2) stratiform sulfide ore in breccia laying over pillow basalt or serpentinite, and 3) stratabound sulfide ore within pillow basalt. Chlorite from stockwork veins is clinochlore with considerably high AlIV content, and variable Mg/Fe ratio depending on the type of country rocks (basalt-gabbro versus serpentinite). Stratiform ores contain clinochlore, ferroan clinochlore and magnesian chamosite. Several analyses display an increase in AlVI and Si at the expenses of Mg and AlIV, respectively, the substitution trend suggesting the development of clay-mineral interlayering inside chlorite. Stratabound ore within pillow basalt is dominated by magnesian chamosite with minor ferroan clinochlore.

Detected alkali elements were generally less than 0.20 at % Ca+K+Na in all types of chlorite. Chromium concentrations up to 0.60 at% Cr were found in chlorites from veins and stratiform ores in contact with serpentinite. Manganese may reach up to 0.20 and 0.15 at % Mn in chlorites from vein ores and basalts, whereas it is generally lower than 0.05 at % Mn in the stratiform ores. Results of the chlorite geothermometry suggest that chlorite from stratiform ores crystallized at relatively low temperatures, between 50°C and 298°C, with 85% of the values clustering in the range of 100-200°C. In contrast, the highest temperatures were obtained from chlorites in stratabound and the stockwork ores, varying in the range 85-360°C, with more than 90% of data plotting between 200°C and 310°C. These data are in agreement with the formation of chlorite as a result of low-grade oceanic metamorphism and the establishment of a hydrothermal convective cell in a sub-oceanic crust. A first generation of clinocllore and magnesian chamosite formed by alteration of primary mafic silicates (i.e. chlorite in basalt, gabbro and serpentinite), or direct precipitation from hydrothermal fluids (i.e. chlorite in quartz-carbonate veins). Primary chlorites in basalts may change to Mg-rich composition by reaction with fluids emanating from stockwork veins. Chlorites in stratiform ore formed by a complex mechanism probably involving deposition from hydrothermal solution venting at the sea floor, accumulation of detrital chlorite from adjacent mafic and ultramafic rocks, and partial alteration during post-depositional diagenesis.