American Mineralogist, Volume 100, pages 2468–2483, 2015

Temperature micro-mapping in oscillatory-zoned chlorite: Application to study of a green-schist facies fault zone in the Pyrenean Axial Zone (Spain)

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Abstract

Oscillatory compositional zoning in minerals has been observed in hydrothermal, magmatic, and metamorphic environments and is commonly attributed to chemical or physical cyclical changes during crystal growth. Chemical zoning is a common feature of solid solutions, which has been rarely reported in phyllosilicates. In this study, oscillatory zoning in chlorite is described in samples from the Pic-de-Port-Vieux thrust, a minor thrust fault associated to the major Gavarnie thrust fault zone (Central Pyrenees, Spain). The Pic-de-Port-Vieux thrust sheet comprises a 1–20 m thick layer of Triassic red pelite and sandstone thrust over mylonitized Cretaceous dolomitic limestone. The thrust fault zone deformation comprises secondary faults and cleavage affecting the Triassic pelite and sandstone. An important feature responsible to this deformation is a set of veins filled by quartz and chlorite. Chlorite is present in crack-seal extension veins and in shear veins; both structures opened under the same stress conditions. In some shear veins, chlorite occurs as pseudo-uniaxial plates arranged in rosette-shaped aggregates. These aggregates appear to have developed as a result of radial growth of the chlorite platelets. Oscillatory zoning has been imaged by backscattered scanning electron microscopy and by X-ray quantitative micro-mapping. These oscillations correspond to chemical zoning with alternating iron-rich and magnesium-rich bands. The chlorite composition ranges from a Fe-rich pole to a Mg-rich pole. $Fe^{3+}/\Sigma Fe$ values were measured in chlorite using μ-XANES spot analyses and vary from 0.23 to 0.44. The highest values are in the Fe-rich area. Temperature maps, built from standardized microprobe X-ray images and redox state using the program XMapTools, indicate oscillatory variations from about 310 to 400 ± 50 °C during chlorite crystallization. These temperature variations are correlated with a $Fe^{3+}/\Sigma Fe$ variation by $Al^{3+}Fe^{3+}_{-1}$ and di-trioctahedral substitutions highlighted by Mg and Fe_{Tot} contents (Fe-Mg zoning). Chemical variations could be then explained by alternation of cooling times and cyclical pulses of a fluid hotter than the host rock. It is however not excluded that kinetic effects influence the incorporation of Mg or Fe during chlorite crystallization.

Keywords: Oscillatory zoning, chlorite, $X_{Fe^{3+}}$, geothermometer, μ-XANES, X-ray mapping, XMapTools