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Diversity of trace elements in kyanite and its petrogenetic and economic implications

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Kyanite (Al_2SiO_5) is a common mineral in Al-rich, medium- to high-pressure metamorphic rocks, an important resource for the refractories industry, and occasionally used as gemstone. In metamorphic petrology, kyanite is an essential indicator mineral constraining p-T conditions of rock formation, most notably by transformation into/from its polymorphs andalusite and sillimanite. Despite the relatively high abundance of kyanite in medium- to high-grade metamorphic rocks, the industrial demand and gemmological interest, only a handful and mostly older studies deal with trace element contents [1]. Therefore, a better understanding of the trace element variation in kyanites and its link to the genetic history is generally needed.

Kyanite crystals from fourteen localities worldwide representing different geological settings and genetic histories were studied in terms of abundances of the trace elements Na, Mg, K, Ca, Ti, V, Cr, Mn, and Fe and cathodoluminescence (CL) properties. Based on protolith type, metamorphic setting and distinctive trace element fingerprints a genetic classification of kyanites is suggested: A) coarse-grained quartz–kyanite segregations in metasediments, (B) metamorphosed granitic rocks, specifically granulites, (C) metamorphosed argillic alteration zones hosted originally in felsic igneous rocks, (D) metamorphosed argillic alteration zones hosted in originally mafic igneous rocks, and (E) metamorphosed mafic to ultramafic rocks, specifically eclogites. Vanadium and Cr concentrations reflect protolith compositions and, thus, they can be utilized as geochemical protolith fingerprints. The incorporation of Fe into kyanite is largely controlled by the oxidation fugacity during kyanite formation and, thus, Fe in kyanite is in most cases unrelated to the Fe content of the protolith. The Ti content is mainly controlled by the metamorphic grade and increases with increasing formation temperature. Our results suggest that there is a promising future potential for a Ti-in-kyanite geothermometer.

Correlation of trace element abundances with CL spectra confirms that the common red CL is related to Cr^{3+} defects. Kyanites with $>3200 \mu\text{g g}^{-1}$ Fe show generally no detectable CL due to the CL quenching effect of Fe^{2+} . CL spectra of most kyanites show in addition a low-intensity blue emission (485 nm) suggestively related to or sensitized by Ti^{4+} or Ti^{3+} defects.

Our findings lead to a better prognosis of the chemical quality of potential kyanite deposits. The Ti content, one of the critical contaminants of kyanite products beside Fe, Ca, and Mg, appears predictable on the basis of the observed correlation of Ti with formation temperature. Iron will be hard to predict because its incorporation is mainly controlled by the oxidizing conditions during kyanite formation and the estimation of these conditions requires advanced analytical methods. Magnesium and Ca are consistently low in all investigated samples. Group C and D kyanites have lowest Ti and relative low Fe

and, therefore, provide the best refractoriness quality. Due to the attractive bluish color the kyanite-bearing rocks of group C have a certain potential as ornamental or dimension stone.

References:

[1] Albee AL, Chodos AA (1969) Am J Sci 267: 310-316.

