

Al- and ¹⁴B-rich tourmaline from the Sahatany Pegmatite Field, Madagascar, and its relevance on a new barometer

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An Al-rich tourmaline from the Sahatany Pegmatite Field in Manjaka, Sahatany Valley, Madagascar, was structurally and chemically characterised. The combination of chemical (EMPA, ICP-AES, TGA) and structural data, yields an optimized formula of $X(\text{Na}_{0.5}\text{Ca}_{0.1}\square_{0.4})^Y(\text{Al}_{1.8}\text{Li}_{1.1}\text{Mn}^{2+}_{0.1})^Z\text{Al}_6(\text{BO}_3)_3^T[\text{Si}_{5.5}\text{B}_{0.5}]\text{O}_{18}(\text{OH})_4$, with $a = 15.7768(2)$, $c = 7.0858(1)$ Å ($R1 = 0.017$ for 3241 reflections). The $\langle T-O \rangle$ distance of ~ 1.611 Å is one of the smallest distances observed in natural tourmalines to date. The very short $\langle Y-O \rangle$ distance of ~ 1.976 Å reflects the relatively high amount of Al at the Y site. The F content was below detection limit. This reddish tourmaline sample consists of several \sim parallel arranged idiomorphic tourmaline crystals with ~ 1 mm in diameter and ~ 5 cm in length, embedded in quartz.

Together with other natural and synthetic Al-rich tourmalines, a very good inverse correlation between ¹⁴B and the unit cell volume with $r^2 \approx 1.00$ was found. Marler *et al.* [1] published the crystal structure (by Rietveld refinement) of two Al-rich tourmalines which were synthesized at 600°C/2500 MPa and 650°C/2000 MPa [2].

By correlating the two well characterised synthetic tourmaline samples, which were grown under known *HP* conditions, the natural Al-rich tourmaline from Momeik, Myanmar [3], and the natural Al-rich tourmaline from this study, which crystallized at minimum *PT* conditions of ~ 200 MPa/ $\sim 350^\circ\text{C}$ [4, 5], we observed a very good positive relationship ($r^2 \approx 0.99$) between pressure conditions and the amount of tetrahedrally coordinated boron in Na- and Al-rich tourmaline. By correlating the pressure conditions of natural and synthetic Na-, Al- and ¹⁴B-rich tourmalines with the unit cell volume we found a very good inverse correlation with $r^2 \approx 0.99$. Hence, we believe that the pressure conditions of Al- and B-rich tourmaline can be estimated by using either the ¹⁴B content or the unit cell volume.

- [1] Marler *et al.* (2002) *Eur. J. Mineral.* **14**, 763–771.
[2] Schreyer *et al.* (2000) *Eur. J. Mineral.* **12**, 529–541.
[3] Ertl *et al.* (2007) *Can. Mineral.* **45**, 891–899.
[4] Ranoroa (1986) Thesis, Université Paul Sabatier, 240 pp.
[5] London & Burt (1982) In: Černý (ed.) *Min. Assoc. Can., Short Course Handbook* **8**, 99–133, Winnipeg.

Arsenic mobilization associated with applied recharge of low-TDS water in Central Valley, California

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A dissolved gas tracer study, tritium/helium-3 groundwater age dating, and stable isotope and dissolved trace metal data were used in conjunction with geochemical modeling using PHREEQC to identify and characterize the recharge of low-TDS recharge water into a shallow aerobic aquifer affected by a groundwater banking project in California's San Joaquin Valley. The integrated dataset consistently points to a substantial degree of mixing of recharge water from surface ponds with ambient groundwater in nearby monitoring wells screened within 60 m of ground surface. Specific geochemical interactions associated with recharge of the low-TDS water include ion exchange (comparative enrichment of affected groundwater with Na and K at the expense of Ca and Mg) and the desorption of oxyanion-forming trace elements (As, V, and Mo) in response to the elevated pH of the recharge water. The SF₆ tracer arrival times for the recharge-influenced wells range from weeks to months, indicating these interactions occur over a relatively short time scale.

Recharge water is characterized by a somewhat elevated pH in comparison to site groundwater, so displacement of oxyanions by OH⁻ on the HFO binding sites is a plausible explanation for the observed behavior of As, V, and Mo. Modeled solid-phase exchangeable arsenic concentrations compare well to reported leachable concentrations in the literature. Taken together, the results of this study indicate that mixing of recharge water with ambient groundwater creates a geochemical footprint that includes a shift in the relative abundances of major cations and the mobilization of certain trace elements. In a broader sense – beyond considerations of trace element geochemistry – this study illustrates that a set of independent and measurable indicators of the age and mixing of artificial recharge water with ambient groundwater can be self-consistent and can be modeled to constrain the local flow regime and specific geochemical processes affecting water quality. This study expands on work our laboratory has done with noble gas tracers and tritium/helium-3 in southern California (e.g. [1]).

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- [1] Clark *et al.* (2004) *Ground Water* **42**(2), 167–174.