

# Tourmaline-group minerals from Norway, part II: Occurrences of luinaite-(OH) in Tvedalen, Larvik and Porsgrunn, and fluor-liddicoatite, fluor-elbaite and fluor-schorl at Ågskardet, Nordland

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## Introduction

As part of a wider study on the crystal chemistry of tourmaline-group members from Norway, occurrences of luinaite-(OH), fluor-schorl and other members have been reported (Kolitsch et al. 2011). The present contribution presents further results based on characterisations of different samples from various pegmatite localities in the Langesundsfjord area (Tvedalen, Larvik, Porsgrunn), in Østfold, Nordland, Oppland and Telemark. The Langesundsfjord samples also include material described by Brøgger (1890). The following species were detected: schorl, fluor-schorl, luinaite-(OH), "luinaite-(F)", dravite, fluor-elbaite, fluor-liddicoatite and rossmanite. Additionally, bastnäsite-(La) and cassiterite were detected as unexpected inclusions in a polished section of a Langesundsfjord schorl sample.

As in our previous study the chemical compositions of the samples have been derived from a combination of single-crystal structure refinements and semiquantitative SEM-EDS analyses (Kolitsch et al. 2011, see there for additional details). The refinements were again done using intensity data collected at ambient temperature on a Nonius KappaCCD single-crystal X-ray diffractometer equipped with a CCD detector. The SXRD data were collected from selected crystal fragments with high crystal quality (a common case for tourmaline-group species) and average diameters between about 0.1 and 0.2 mm. For all samples, intensity data were measured with high redundancy for a complete Ewald sphere up to  $2\theta = 75^\circ$ , ensuring high-resolution data sets and good statistics. The data were processed in a standard way, with absorption correction based on the multi-scan method. Final  $R(F)$  values usually ranged between around 1 and 2%. Since an accurate determination of the F:(OH,O) ratio at the  $W$  site can be achieved very easily from such high-quality datasets, it was consequently easy to distinguish between F- and OH-dominant members of the tourmaline group.

From the refined crystal-structure model, the chemical formula of a given sample was indirectly estimated by means of numerous well-established relations between unit-cell parameters, bond lengths, site occupancies and polyhedral geometries in the tourmaline group, as well as bond-valence constraints (e.g. Ertl et al. 2001 & 2002, Hawthorne 2002, Bosi & Lucchesi 2004, Ertl & Tillmanns 2010, Ertl et al. 2010, Henry & Dutrow 2011, Henry et al. 2011, Ertl & Tillmanns 2012). This correlation-based identification method only fails if a given tourmaline sample is very or fairly near the compositional boundary between two or more species. In such cases, quantitative EPMA data will be necessary, in part to be supplemented by SIMS or wet-chemical analyses for Li and determination of the accurate  $\text{Fe}^{3+}:\text{Fe}^{2+}$  ratio by Mössbauer spectroscopy.

For the SEM-EDS analyses at the Natural History Museum Vienna, a new, state-of-the-art JEOL JSM-6610LV equipped with a high-resolution and high-sensitivity detector (e-FlashHR+; detector area 30 mm<sup>2</sup>, resolution 127 eV) was employed. The data, obtained on carbon-coated samples (either polished sections or flat-lying fragments), were processed by Bruker Esprit 1.9.4 software, using an interactive PB-ZAF correction for the semi-quantitative analyses. This allowed surprisingly accurate determination of all non-oxygen and -hydrogen element constituents, including F (only F contents < 0.2-0.3 apfu are seemingly below the detection limit). Similarly to our previous study (Kolitsch et al. 2011), the largest variation within a given set of analysed fragments from the same sample was shown by the Al:Fe:Mg ratios.

Results from the SEM-EDS analyses all agree well with the results of the crystal-structure refinements and the derived structure models.

## Samples and localities

The following sample descriptions are arranged in a geographical order. First, the tourmalines from the Langesundsfjord area (Vestfold and Telemark) are described, followed by those from Østfold, Nordland, Oppland and Telemark.

Previously, only schorl was reported from the wider Langesundsfjord area (Brøgger 1890, Larsen et al. 1999, Larsen 2010). The blackish, prismatic crystals have crystallised in the hydrothermal stage of the nepheline syenite pegmatites, and are generally embedded in analcime. The prisms may reach a length of 5 cm and are often arranged in divergent groups (Larsen 2010).

## Midtfjellet quarry, Malerød, Larvik, Vestfold

Two samples from this operating larvikite quarry were studied. The first one (collected in 2007 by PA) shows a brown-black, radiating tourmaline (Fig. 1) embedded in an analcime/spreustein-type natrolite matrix, with minor pale blue sodalite and trace amounts of zircon and other minerals. Dark chlorite occurs in analcime voids.

The SXRD study clearly shows this sample to be luinaite-(OH) (IMA 2009-046). We remind that luinaite-(OH) is a monoclinic-pseudorhombic member of the tourmaline group, and has the simplified formula (Na,□)(Fe<sup>2+</sup>,Mg)<sub>3</sub>Al<sub>6</sub>Si<sub>6</sub>O<sub>18</sub>(BO<sub>3</sub>)<sub>3</sub>(OH)<sub>3</sub>(OH). The decrease in space-group symmetry from *R3m* (rhombohedral) to *Cm* (monoclinic) is caused by an ordering of Fe<sup>3+</sup> and Al<sup>3+</sup> cations which appears to be governed by the conditions of crystallisation (Mills et al., to be submitted).

The ordering is strongly pronounced at the Y site, less so at the Z site. The Y1O<sub>6</sub> polyhedron is unusual because it shows a very strong bond-length distortion (range: 1.925(2) - 2.1632(18) Å), unlike the Y2O<sub>6</sub> polyhedron (range: 2.0269(11)- 2.1877(12) Å). The refined occupancies of the Y1 and Y2 sites are Fe<sub>0.593(4)</sub>Al<sub>0.407(4)</sub> and Fe<sub>0.803(3)</sub>Al<sub>0.197(3)</sub>, respectively. Further details will be reported in the original description of luinaite-(OH) (Mills et al., to be submitted).

The only impurity element detected by SEM-EDS is Ti in trace amounts.

Refined unit-cell parameters:  $a = 10.453(2)$ ,  $b = 16.013(3)$ ,  $c = 7.232(1)$  Å,  $\beta = 117.64(3)^\circ$ .  
Refined chemical formula (bulk formula, occupancies of individual split Y and Z sites not indicated):  $\sim(\text{Na}_{0.98}\text{Ca}_{0.02})(\text{Fe}_{0.70}\text{Al}_{0.30})_3(\text{Al}_{0.89}\text{Fe}_{0.11})_6\text{Si}_6\text{O}_{18}(\text{BO}_3)_3(\text{OH})_3(\text{OH}_{0.8}\text{F}_{0.2})$ .