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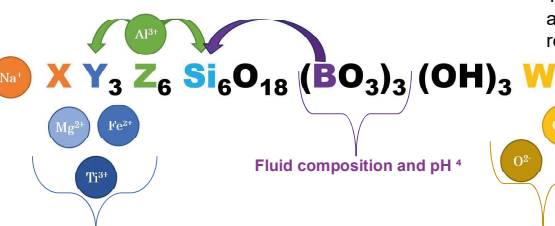
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Tourmaline : «A unique [and stable] recorder of its geological past»

Van Hinsberg et al., 2011

Quantitative estimation of fluid composition¹

Estimation of P and fO₂ conditions²



Petrogenetic indicator³

Fluid composition and pH⁴

Indicator of fluid salinity and fO₂ conditions⁵

Tourmalines are rhombohedral cyclosilicates and the most widespread borosilicates. They are occurring in most rock types (from magmatic to sedimentary), are stable over a large P-T field and their crystal structure accommodate an exceptional range of different elements (van Hinsberg et al., 2011).

Thus, many studies tried to use them :

- ▶ to constraint the chemistry of hydrothermal fluids (see on the left of this section)
- ▶ as geothermobarometer (Henry & Guidotti, 1985)

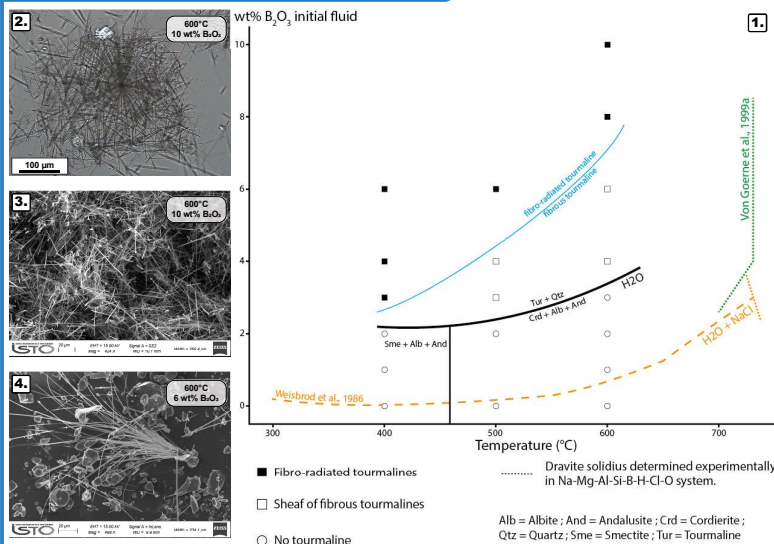
Those two uses imply a good knowledge of the thermodynamic properties of those minerals. But, due to their complexity and the lack of precise knowledge over their stability conditions, the geochemical simulations are generally working without those classical alteration

¹ Von Goerne et al., (2001, 2011) ; Dutrow & Henry, 2016
² Berryman et al., (2016)
³ Henry & Guidotti, 1985 ; Van Hinsberg & Schumacher, 2009 ; Van Hinsberg et al., (2011a, b) ; Dutrow & Henry, 2016
⁴ Morgan & London, 1989 ; Von Goerne et al., 1999a ; Lussier et al., 2009 ; Ertl et al., 2018
⁵ Von Goerne et al., (2001, 2011)

Experimental study of the stability field of the schorl-dravite solid solution, based on the metasomatic alteration of a (simplified) cordierite-bearing leucogranite by a boron-rich hydrothermal fluid.



Stability field and tourmaline textures



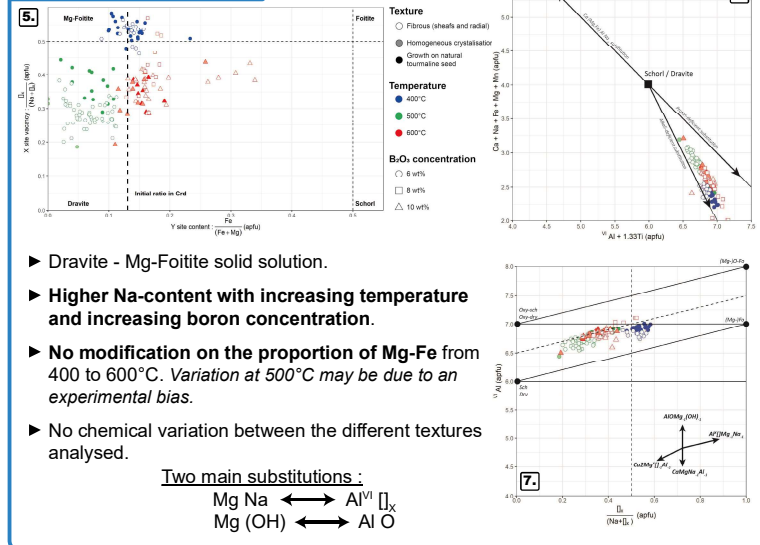
- ▶ The boundaries of the stability field slightly change with temperature (1.) : decreasing from 4 wt% at 600°C to 3 wt% at 400°C.
- ▶ First occurrence of tourmaline : sheaf of fibrous crystal (4.), growing from cordierite and/or albite nucleus. At higher boron concentration : fibro-radiated aggregates (2.) and homogeneous crystallisation (3.)
- ▶ Presence of NaCl in the fluid (Weisbrod et al., 1986) seems to lower the boron concentration needed to precipitate tourmaline (1.).

Experimental conditions

Metasomatic experiment using an internally heated gas apparatus.

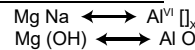
- Temperature : 600°C (2 weeks), 500°C (1 month) and 400°C (2 months).
- [B₂O₃]_{init} : from 0 to 10 wt%, with changes in the order of 1 wt%.
- Pressure : constant, at 200 MPa.
- Oxygen fugacity : included in the range ΔNNO +[1;2].

Tourmaline chemistry



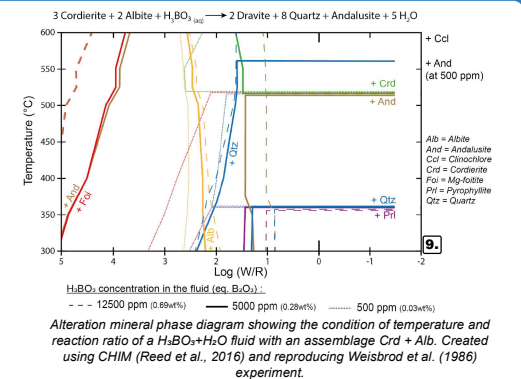
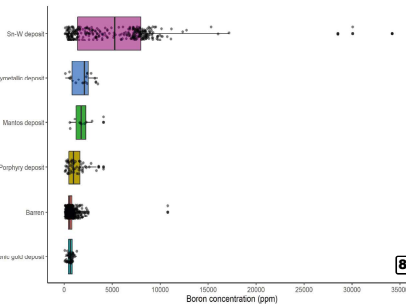
- ▶ Dravite - Mg-Foiteite solid solution.
- ▶ Higher Na-content with increasing temperature and increasing boron concentration.
- ▶ No modification on the proportion of Mg-Fe from 400 to 600°C. Variation at 500°C may be due to an experimental bias.
- ▶ No chemical variation between the different textures analysed.

Two main substitutions :



Comparison to natural and thermochemical data

- ▶ Boron concentration in natural fluid inclusion generally doesn't exceed 1wt%, even in systems known to present tourmaline as an hydrothermal alteration product (8.).
- ▶ In geochemical models, tourmaline crystallise even with just 500 ppm of H₃BO₃ in the fluid and always as a Mg-foiteite (9.).
- ▶ However, our experiments show a stability field requiring higher boron concentration to make tourmaline crystallise (1.).
- This difference with the fluid inclusion can be explained by the high salinities presented in those contexts.
- The actual thermodynamic properties seem to overestimate tourmaline stability field.



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