Tourmalinisation in peraluminous granitic context : from experiment to thermodynamic modelling

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Tourmalinisation in peraluminous granitic context : from experiment to thermodynamic modelling

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Solving geoscience problems using mineralogy

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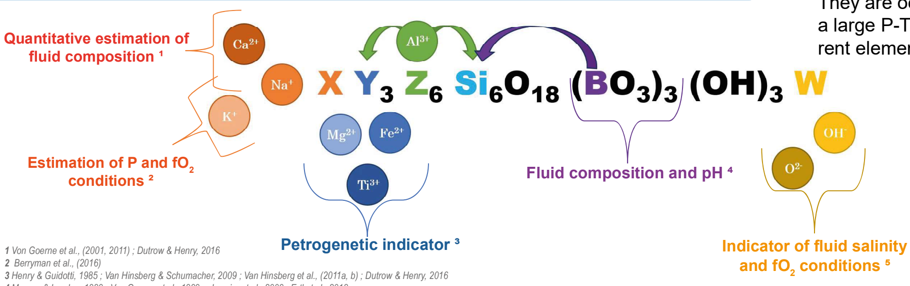
Tourmaline : «A unique [and stable] recorder of its geological past»

Van Hinsberg et al., 2011



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)

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 used them :

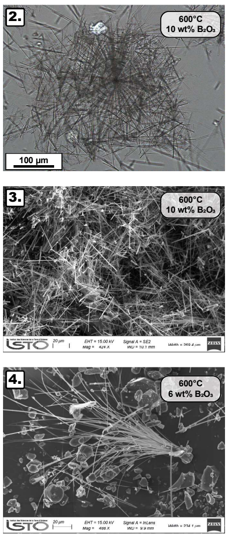
- ▶ to **constraint the chemistry of hydrothermal fluids** (see on the left of this section)
- ▶ as **geothermobarometer** (Henry & Guidotti, 1985)

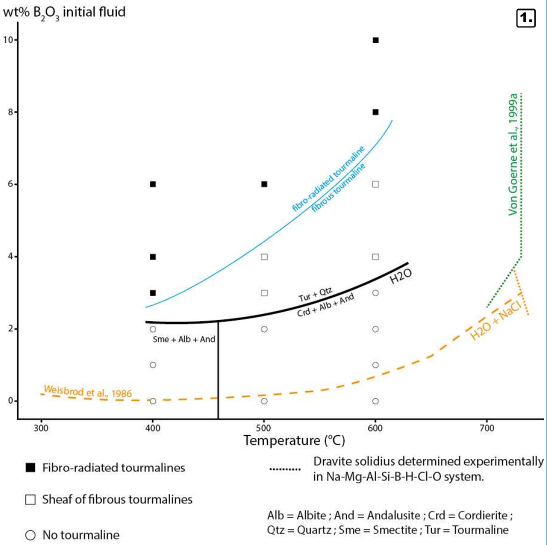
Those two uses imply a **good knowledge of the thermodynamic properties** of those minerals. But, due to their **complexity and the lack of precise knowledge over their stability conditions**, the geochemical simulations are generally working without those classical alteration

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

$$3\ \text{Cordierite} + 2\ \text{Albite} + 6\ H_3BO_{3\,(aq)} \longrightarrow 2\ \text{Dravite} + 8\ \text{Quartz} + \text{Andalusite} + 5\ H_2O$$

Stability field and tourmaline textures





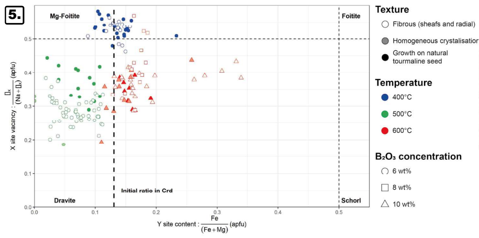
- ▶ **The boundaries of the stability field slightly change with temperature** (1.) : decreasing from 4 wt% at 600°C to 3 wt% at 400°C.
- ▶ First occurence of tourmaline : **sheaf of fibrous crystal** (4.), growing from cordierite and/or albite nucleus.
  At higher boron concentration : **fibro-radiated 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.).

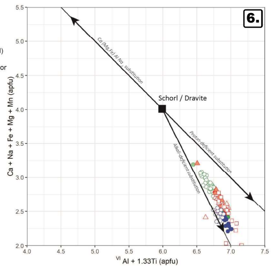
Experimental conditions

Metasomatic experiment using an **internally heated gas apparatus.**

- **Temperature :** 600°C (2 weeks), 500°C (1 month) and 400°C (2 months).
- **[B_2O_3]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

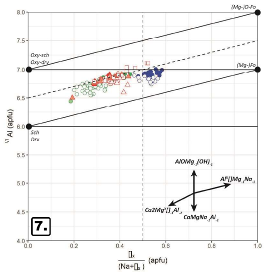




- ▶ Dravite - Mg-Foitite solid solution.
- ▶ **Higher Na-content with increasing temperature and increasing boron concentration.**
- ▶ **No modification on the proportion of Mg-Fe** from 400 to 600°C. *Variation at 500°C may be due to an experimental bias.*
- ▶ No chemical variation between the different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

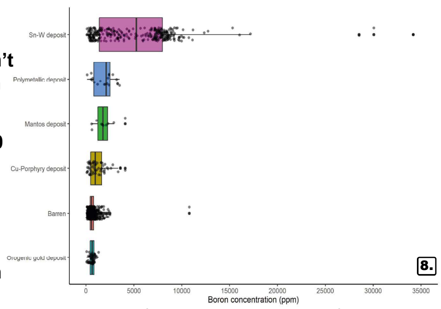
Two main substitutions :

$$Mg\ Na \longleftrightarrow Al^{VI}\ []_X$$
$$Mg\ (OH) \longleftrightarrow Al\ O$$



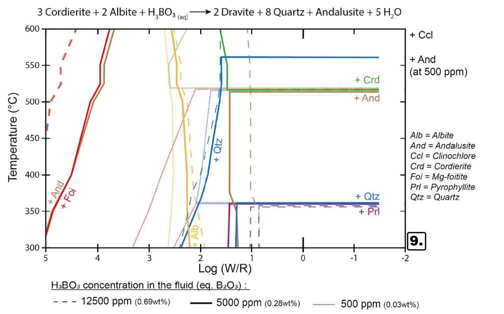
Comparison to natural and thermochemical data

- ▶ **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 crystalise even with just 500 ppm of H_3BO_3** in the fluid and always as a Mg-foitite (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.



Distribution of boron concentrations in natural fluid inclusions, according to the type of mineralization.

Th = [100 ; 450]°C
Salinity = [1 ; 40] wt% eq. NaCl



Alteration mineral phase diagram showing the condition of temperature and reaction ratio of a H_3BO_3+H_2O fluid with an assemblage Crd + Alb. Created using CHIM (Reed et al., 2016) and reproducing Weisbrod et al. (1986) experiment.

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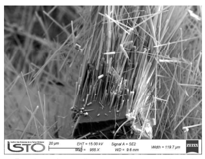

Experimental tourmaline overgrowth on natural schorl seed crystal