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CHARACTERIZATION OF TOURMALINE FROM THE MAW ZONE, GRYPHON ZONE, AND SANDSTONES ABOVE THE PHOENIX URANIUM DEPOSITS, ATHABASCA BASIN, SASKATCHEWAN

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Introduction

A variety of tourmaline species has been reported in the Athabasca Basin. In this study, we characterized the occurrence and mineral chemistry of tourmaline from three different locations on the Wheeler River property, owned by Denision Mines Corp. (Fig. 1). The Maw zone is a breccia pipe enriched in rare earth elements (up to 8.1 wt % REE oxides; Agip Canada Ltd., 1985). The newly discovered Gryphon Zone is a high-grade basement-hosted uranium occurrence. The Phoenix deposits, with resources of 70. 2 Mlbs U_3O_8(Roscoe, 2014) lie along the unconformity between the Athabasca sandstones and the crystalline basement rocks at depths of ca. 400 m.

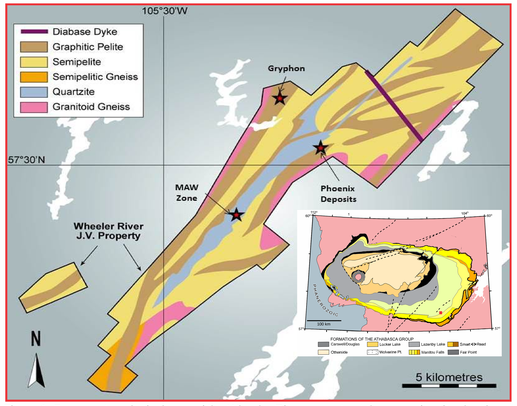

Figure 1: Basement geological map of the Wheeler River property at the unconformity showing locations of Maw Zone, Phoenix deposits, and Gryphon Zone (Denison Mines Corp., 2014). Inset: geological map of the Athabasca Basin with location of the property (after Jefferson et al., 2007).

Objectives

1) Document the occurrence of tourmaline associated with three different styles of mineralization;

2) Determine the composition of tourmaline and its spatial variation with respect to ore.

Methods

Field work;
- Detailed mapping of the Maw Zone outcrops in 0.2 m grids, collection of samples from outcrop and drill cores;
- Petrography;
- Scanning electron microscopy for semi-quantitative chemical analysis and backscatter electron imaging;
- Electron microprobe analysis of selected grains for quantitative determination of mineral compositions.

Table 1: List of sample locations, lithology of the host rocks, and distance to U mineralization

Collection Area	Drill hole	Lithological Unit	Depth from surface (m)	Proximity to U mineralization (m)
Maw Zone	ZQ-09	Sandstone, Manitou Falls Fm, Bird Member	210–220	N/A
Maw Zone	ZQ-09	Sandstone, Read Fm	220–230	N/A
Maw Zone	2-85	Sandstone, Manitou Falls Fm, Dunlop Member	2.1–20	N/A
Maw Zone	3-85	Sandstone, Manitou Falls Fm, Collins Member	66.85–73.25	N/A
Maw Zone	ZQ-09	Sandstone, Manitou Falls Fm, Dunlop Member	0.6–10	N/A
Maw Zone	3-85	Sandstone, Manitou Falls Fm, Bird Member	129.78–133.9	N/A
Maw Zone	3-85	Sandstone, Manitou Falls Fm, Collins Member	65–70	N/A
Gryphon	WR-556	Graphitic metapelite, Basement	717.8	17
Phoenix	WR-301	Sandstone, Manitou Falls Fm, Bird Member	300.9	115
Phoenix	WR-293	Sandstone, Uppermost Read Fm/ Lowermost Manitou Falls Fm, Bird Member	288.06	150
Phoenix	WR-299	Sandstone, Read Fm	N/A	In ore zone, Deposit A
Phoenix	WR-302	Sandstone, Read Fm	N/A	In ore zone, Deposit A
Phoenix	WR-345	Sandstone, Read Fm	N/A	In ore zone, Deposit A

Sampling Sites

Figure 2: Phoenix deposits with surface projections of ore bodies, and sampled drill hole collar locations. The drill holes in red (WR-293, and WR-301) denote location of sandstones (MFb) collected above the Phoenix deposits. Note that they were in the western margin of the surface projection of ore zones.

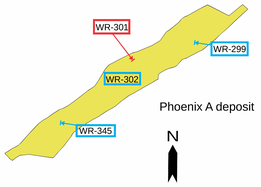

Figure 3: Photograph from Maw Zone showing hematitized and silicifed sandstone breccia blocks.

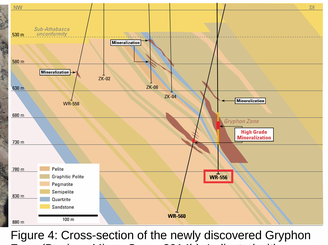

Figure 4: Cross-section of the newly discovered Gryphon Zone (Denison Mines Corp., 2014b). Indicated with red box is the discovery hole, WR-556 from which the Gryphon sample was collected (see Fig. 5).

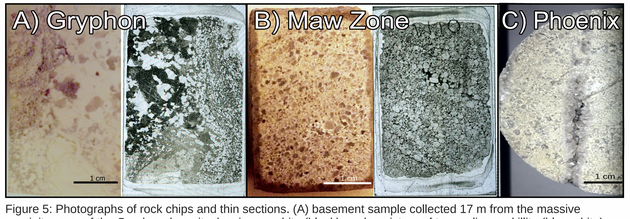

Figure 5: Photographs of rock chips and thin sections. (A) basement sample collected 17 m from the massive uraninite zone of the Gryphon deposit, showing graphite (black), and a mixture of tourmaline and illite (blue-white). (B) MFc quartz arenite from the Maw Zone with silica cement. Clays and tourmaline fill along grain boundaries of detrital quartz (DDH 3-85, depth 67.5 m). (C) quartz arenite with silica cement, interstitial clays and drusy quartz vein from 288.6 m of depth at the Phoenix deposit (DDH WR-293, depth).

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Petrography

Figure 6: Core sample from the Gryphon Zone DDH WR-556, depth of 717.8 m. The black is graphite and the bluish-white colore is a mixture of fine-grained tourmaline and illite. Photomicrograph of the tourmaline is shown below.

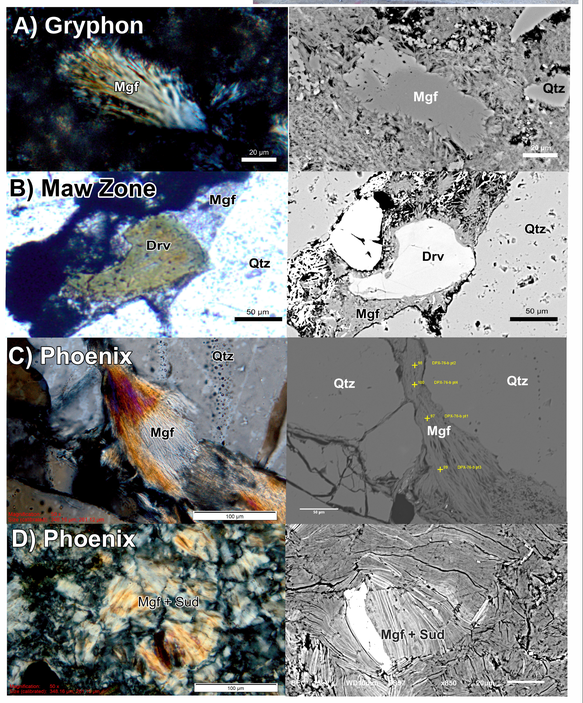

Figure 7: Photomicrographs and back-scattered electron (BSE) images. (A) Magnesio-foitite (Mgf) and quartz (Qtz) in an illite groundmass from the Gryphone Zone. (B) Maw zone Mgf encasing detrital dravite (Drv) surrounded by detrital Qtz grains. (C) A fan-shaped aggregate of Mgf grains between detrital Qtz grains from the Phoenix zone. In the BSE-image, the yellow "+" symbols represents areas analyzed with the electron microprobe. (D) Mixture of very fine-grained Mgf and sudoite (Sud) in the ore zone of the Phoenix deposits. Low Na and high Mg suggests that Mgf likely has high vacancy at the X-site and high Mg at the Y-site. Due to the very small size, quantitative analysis was not possible.

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Mineral Chemistry

General Formula of Tourmaline $X\ Y_3\ Z_6\ (T_6\ O_{18})\ (BO_3)_3\ V_3\ W$

X = Ca, Na, K, □ (vacancy) **Y** = Li, Mg, Fe^{2+}, Mn^{2+}, Al, Cr^{3+},V^{3+}, Fe^{3+} **Z** = Mg, Al, Fe^{3+}, Cr^{3+}, V^{3+} **B** = B **V** = OH, O **W** = OH, F, O

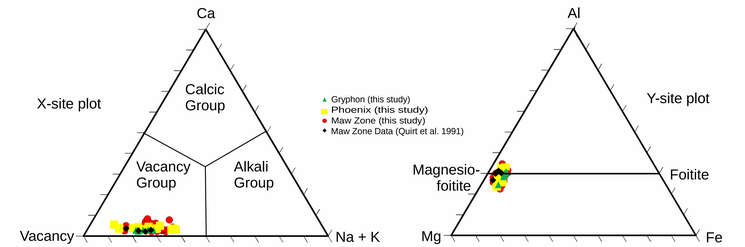

Figure 8: Ternary diagram showing Ca, Na+K, and vacancy at the X-site following the classification of tourmaline by Hawthorne et al. (1997) based on EMPA data. Data plotted include tourmaline from sandstones (MFb, RD/MFb) above the Phoenix deposits, the Gryphon Zone, and the Maw zone. Tourmaline compositions reported from the Maw Zone by Quirt et al. (1991) are plotted for comparison.

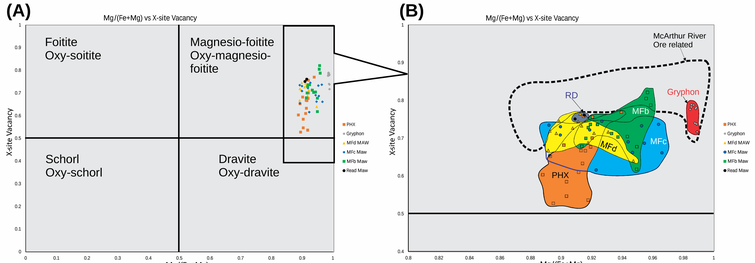

Figure 9. (A): Biplot of X-site vacancy versus Mg/(Mg+total Fe) from this study, in tourmaline classification plot after Henry et al. (2011). (B) Biplot of X-site vacancy versus total Mg/(Fe+Mg) fields of Maw zone [Read Formation (RD) = grey, Mantiou Falls Formations: Bird Member (MFb)=green, Collins Member (MFc)=blue and Dunlop Member (MFd)=yellow, Phoenix zone (PHX)=orange, Gryphon zone=red]. Note that the Phoenix samples are more than 100 m from the mineralization. McArthur River ore related field from Adlakha et al. (2015).

Summary

1) Tourmaline in all three locations crystallized after corrosion of detrital quartz in sandstone.
2) All tourmaline grains studied show high vacancies (> 53%) in the X-site and are classified as magnesio-foitite following Hawthorne and Henry (1999).
3) Similar chemistry and mineral parageneses suggest that tourmaline of all studied areas precipitated from similar fluid compositions and may have been contemporaneous.
4) Tourmaline grains within and near uranium mineralization show high Mg/(Mg+total Fe) values ranging from 0.98 to 0.99, and high X-site vacancies. Tourmaline grains not proximal to uranium mineralization show varied Mg contents and relatively low X-site vacancies (< 72%).
5) Magnesio-foitite in the ore zone of the Phoenix deposits is intricately mixed with sudoite. Its very low Na and high Mg suggest high X-site vacancy and high Mg/(Mg+Fe), close to the end member composition of magnesio-foitite.

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