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Different Zoning Pattern in Tourmalines from North Victoria Land Pegmatites, Antarctica

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Summary: Tourmaline is an important indicator for the petrogenesis of the pegmatites from North Victoria Land, Antarctica. Depending upon the lithology of the pegmatitic wall rocks the tourmaline crystals show different zoning patterns. Tourmalines from pegmatites intruded in granitoid rocks of the Granite Harbour Intrusives (Frontier Mountain) are normally zoned with schorl rich, but dravite and uvite poor cores. The rim composition behaves antagonisticly. Tourmalines from pegmatites injected in medium-grade biotite — sillimanite bearing metapelites (Priestley schist from Tourmaline Plateau) are inversely zoned with dravite and uvite rich, but schorl poor cores. The inversion of the normal zoning is caused by metasomatic influence of the metapelitic wall rocks. The zoning pattern of tourmalines from antarctica has not only regional importance, but may serve generally as an indicator for metasomatic alteration of pegmatites.

Zusammenfassung: Die antarktische Pegmatite von Nordviktoria-Land sind gekennzeichnet durch ihre Turmaline. Sie zeigen in Abhängigkeit von der Nebengesteinsausbildung unterschiedliche Zonierungsmuster. Turmaline aus Pegmatiten, die granitoide Gesteine der „Granite Harbour Intrusives" intrudierten (Untersuchungsgebiet Frontier Mountain), weisen eine normale Zonierung mit schörlreichen aber dravit- und uvit-armen Kernen auf, während die Zusammensetzung der Randpartien sich umgekehrt verhält. Turmaline aus Pegmatiten, die in mittelgradig metamorphe Biotit-Sillimanit-Schiefer injiziert wurden (Untersuchungsgebiet Tourmaline Plateau), besitzen eine inverse Zonierung mit dravit- und uvit-reichen aber schörl-armen Kernen. Die Inversion des normalen Zonierungsmusters wird durch metasomatische Beeinflussung verursacht, die vom pelitischen Nebengestein ausgeht. Das Zonierungsmuster der Turmaline aus der Antarktis hat nicht nur regionale Bedeutung, sondern kann ganz allgemein als Indikator für metasomatische Veränderungen bei Pegmatiten angewendet werden.

1. INTRODUCTION AND GEOLOGICAL SETTING

Tourmaline occurs frequently in the rocks of the metamorphic basement and of the Granite Harbour Intrusives from North Victoria Land. The modal fraction varies from an accessory mineral to a main rock-forming constituent. 34 vol.-% was observed as maximum modal value of tourmaline. The rock series are regionally so enriched in tourmalines that this mineralogical term became part of geographical names, e. g. Tourmaline Plateau (74° 10 'S, 163° 30 'E. Antarctica 1:250,000 Reconnaissance series, sheet SS 58-60/9).

Whereas first results of the tourmaline bearing rocks of the metamorphic basement were reported by ULITZKA (1987), the tourmalines of pegmatites associated with the Granite Harbour Intrusives were not studied intensively up to now. The general mineralogy and petrography of the aplites and pegmatites are reported by OLESCH & SCHUBERT (1987). The aim of this paper is to summarize the mineralogy of the tourmaline bearing pegmatites and the mineral chemistry of tourmalines from the Granite Harbour Intrusives as well as their petrogenetic implications concerning the formation conditions of the pegmatites.

The crystalline basement of the Wilson Terrane, the south-western part of North Victoria Land, is formed by medium-grade to high-grade metamorphic rocks of the Ross Orogen. During late Cambrian to early Ordovician calc-alkaline S-type granitoids intrude syn- and posttectonically the schists and gneisses. The intrusives are interpreted by VETTER & TESSENSOHN (1987) as products of a Cordilleran-type continental margin with a subduction zone active during the Cambro-Ordovician and dipping below the Eastantarctic continental plate.

The postkinematic plutonism is connected with a subsequent emplacement of numerous pegmatites in the Granite Harbour batholith as well as in the enclosing Wilson Terrane metapelites. To study the influence of the different wall rock lithology on the pegmatite mineralogy two different sample localities were cho-

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Fig. 1: Coarse-grained quartz-albite-microcline pegmatite with nests of black tourmalines (Frontier Mountain).

Abb. 1: Grobkörniger Quarz-Albit-Mikroklin-Pegmatit mit schwarzen Turmalinnestern (Frontier Mountains).

Fig. 2: Contact range of very coarse-grained pegmatite with biotite-sillimanite schist. The black tourmalines are enriched at the contact (Tourmaline Plateau).

Abb. 2: Kontaktbereich des sehr grobkörnigen Pegmatits und Biotit-Sillimanit-Schiefers. Schwarzer Turmalin ist am Kontakt angereichert (Tourmaline Plateau).

sen. Tourmaline bearing pegmatites intruded in granitoids are represented by occurrencies of the Frontier Mountain located at the margin of the Polare Plateau (72° 58 'S, 160° 21 'E. Antarctica 1:250,000 Reconnaissance series, sheet SS 55-57/4). Tourmaline bearing pegmatites injected into Priestley Schists were studied from ocurrencies of the south-western spur of the Tourmaline Plateau (74° 13 'S, 163° 17 'E). The rock samples were collected during the German Antarctic North Victoria Land Expedition 1984/85 (GANOVEX IV).

2. MINERALOGY OF PEGMATITES

2.1 *Pegmatite of Frontier Mountain*

The tourmaline bearing pegmatites of Frontier Mountain vary strongly in thickness over short distances from some centimetres to about one metre and intrude the granitoid rocks without preferred orientation. The irregular to bulbous shape of the pegmatite veins and dikes indicates ductile hydrostatic conditions at lower levels in the crust (BRISBIN 1986). A source of the magmatic melt and/or fluid supply for the pegmatitic emplacements was not observed in the field.

The pegmatitic veins usually show an irregular and indistinct differentiation of the crystal sizes with very coarse-grained outer parts and coarse- to medium-grained inner parts. Colourless quartz, white albite with up to 8.2 mole per cent orthoclase and 2.8 mole per cent anorthite component, and white microperthitic microcline with 9.2 to 12.9 mole per cent albite and less than 1 mole per cent anorthite component form the matrix of the pegmatites. Tourmalines, uniformly black in hand specimen, are embedded in this matrix often enriched in nests (Fig. 1). Tourmaline shows in thin section a strong pleochroism from an almost colourless to a greenish brown core and an olive green rim. Muscovite books with leaves up to 2 cm in diameter occur as an additional rock-forming mineral. Biotite does not coexist with tourmaline, but could be found separately. Short prismatic, bluishgreen apatite and light red garnet with a mean composition in mole per cent of the end member components of almandine 62, spessartine 32, pyrope 4, and grossular 2 were observed as accessory minerals in coarse-grained quartz-feldspar-muscovite-tourmaline pegmatites.

2.2 *Pegmatite of Tourmaline Plateau*

The tourmaline bearing pegmatites occur in veins from some centimetres to decimetres in thickness that varies strongly within a few metres. The magmatic melt injected medium-grade metapelites following generally their weakly marked schistosity. The Priestley Schists contain the mineral assemblage muscovite, biotite, quartz, plagioclase, +/— sillimanite, +/— garnet, and +/— green hornblende (SCHUBERT & OLESCH 1987). Very coarse-grained colourless quartz dominates the modal composition of the pegmatites. Medium-grained K feldspar, albite, and tiny flakes of muscovite are associated. Tourmalines occur preferentially in the contact range of the pegmatite with the schist. The size of the crystals increases from the schists to the pegmatites from less than 1 mm to more than 1 cm in diameter (Fig. 2). The uniformly black hand specimens of tourmaline show in thin sections strong pleochroism with a patchy irregular zoning. The cores are dominantly olive green, the maximum absorption colours of the rims vary from brown to yellow.

3. MINERAL CHEMISTRY OF TOURMALINES

3.1 *General aspects*

The cyclosilicate tourmaline is a borosilicate mineral with the general formula

$$X\,Y_3\,Z_6\,(BO_3)_3\,Si_6O_{18}\,(OH)_4 \text{ (DONNAY \& BARTON 1972).}$$

	X	Y_3	Z_6	$(BO_3)_3\ Si_6\ O_{18}\ (OH)_4$*
Schorl	Na	$Fe^{2+}{}_3$	Al_6	$(BO_3)_3\ Si_6\ 0_{18}\ (OH)_4$
Dravite	Na	Mg_3	Al_6	,,
Ferridravite	Na	Mg_3	$Fe^{3+}{}_6$	,,
Tsiliasite	Na	Mn_3	Al^6	,,
Elbaite	Na	$(Li, Al)_3$	Al_6	,,
Liddicoatite	Ca	$(Li, Al)_3$	Al_6	,,
Uvite	Ca	Mg_3	$MgAl_5$	,,

Tab. 1: Important tourmaline end members. * General formula after DONNAY & BARTON (1972).

Tab. 1: Wichtige Turmalin-Endglieder. * Allgemeine Formel nach DONNAY & BARTON (1972).

The X position generally contains sodium or/and calcium but can be partly or even completely vacant. The Y position shows the greatest variety of elements incorporating monovalent, divalent, trivalent, and tetravalent cations (cf. Table 1). The Z site is usually occupied by aluminum but it can be substituted by ferric iron, or in smaller amounts by titanium, magnesium, chromium, or vanadium. Due to the numerous possible substitution mechanisms, tourmaline solid solution is commonly described in terms of end member components (Table 1). Neglecting the monovalent cations of sodium and lithium, the chemical variation can be well expressed in the model system Ca0 — Mg0(Mn0) — $(Fe0 + Fe_20_3)$ — Al_20_3, because the borosilicate complex $([B0_3]_3Si_60_{18}[0H]_4)^{25-}$ is not affected by the potential substitutions (Fig. 3). For clarity the compositional trends of tourmaline reported in this study are not plotted within the 3-dimensional system, but projected onto the calcium-free plane of the system. This projection results in a Fe(total)-Mg-Al diagram introduced by HENRY & GUIDOTTI (1985).

The mineral analyses were carried out with a Cameca microprobe with wavelength dispersive spectrometers. Details of the analytical procedure are given by OLESCH & SCHUBERT (1987). It must be mentioned that only the concentration of elements with atomic numbers >8 can be determined by the procedure used. Therefore, the important tourmaline constituents boron, lithium, and hydrogen could not be measured. Instead some assumptions had to be made: (1) Boron fully occupies all regularly three-coordinated sites in the tourmaline structure (TSANG & GHOSE 1973). (2) Lithium can be neglected. The lack of Li bearing minerals in the pegmatites suggests no remarkable Li contents in the tourmaline. Furthermore, the projection points of the chemical compositions of tourmalines within the Fe(total)-Mg-Al diagram do not fall into the region of lithium rich granitoids (HENRY & GUIDOTTI 1985), thus justifying the neglection of lithium. (3) The four hydroxyl sites are fully occupied by hydroxyl groups.

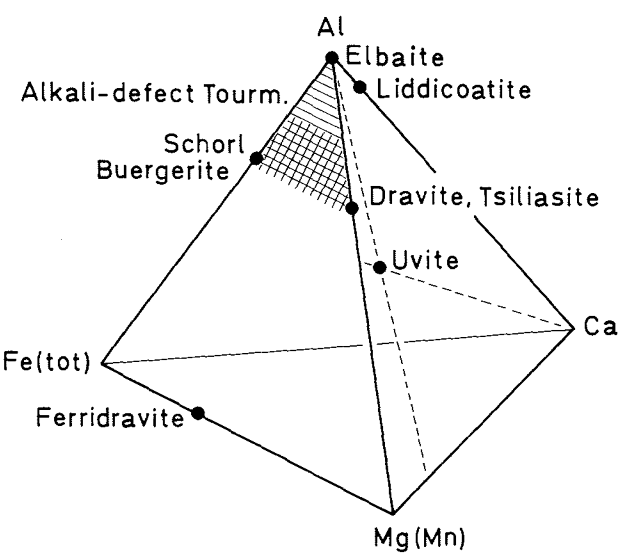

Fig. 3: End member components of tourmaline solid solution plotted in mole per cent into the system Ca0 — Mg0(Mn0) — $(Fe0 + Fe_20_3)$ — Al_20_3. The cross hatched area refers to Fig. 5.

Abb. 3: Komponenten der Turmalin-Endglieder (in Mol%) im System Ca0-Mg0(Mn0) — $(Fe0 + Fe_20_3)$ — Al_20_3. Kariert = Darstellungsbereich von Abb. 5

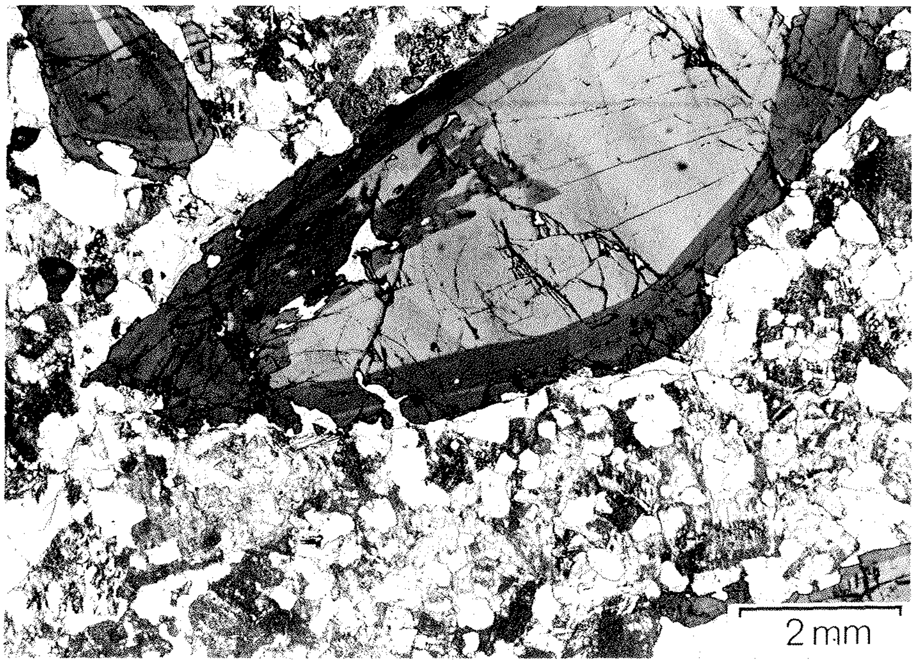

Fig. 4: Microphotograph of a discontinuously zoned tourmaline in a fine- to medium-grained quartz-albite-microcline matrix (Frontier Mountain, plane polarized light, maximum absorption colours).

Abb. 4: Dünnschliffaufnahme eines unregelmäßig zonierten Turmalins in fein- bis mittelkörniger Quarz-Albit-Mikroklinmatrix (Frontier Mountains).

3.2 *Results*

The tourmalines from Frontier Mountain pegmatites are characterized by a strong discontinuous chemical zoning that corresponds to the microscopically observed zoning of the crystals (Fig. 4). The mean composition of the cores in end member components is schorl (sch) 42, dravite (dr) 32, elbaite (elb) 16, and uvite (uv) 10 mole per cent. This composition is very similar to that of the first generation of the tourmalines from aplites of the same region (OLESCH & SCHUBERT 1987). The mean composition of the rims (sch 36, dr 35, elb 11, and uv 18) shows lower content of the schorl and elbaite but higher content of the dravite and uvite components.

The tourmalines from Tourmaline Plateau pegmatites exhibit a more continuous zoning. It is less regular than that of the tourmalines from the Frontier Mountain. The cores are richer in dravite and uvite components than the rims, schorl and elbaite components behave antagonisticly. Mean values of core and rim compositions are: sch 34, dr 28, elb 2, uv 36, and sch 38, dr 24, elb 14, uv 24 mole per cent, respectively.

4. CONCLUSIONS

The zoning of the tourmalines from pegmatites with granitoid wall rocks differs in principle from that with schists as wall rocks (Fig. 5). The core to rim relations of tourmaline solid solution from pegmatites in a granitoid environment exhibit a trend from schorl-rich, uvite-poor core compositions to rim compositons richer in dravite and uvite components. A minor tsilaite component remains nearly constant, an elbaite component decreases slightly. This trend can be simplified as an increase of the $Mg/(Mg + Fe^{2+})$ mole ratio from core to rim. It is commonly observed in zoned tourmalines from aplitic and granitic intrusives (e. g. BLACK 1971) and also described from high-grade metamorphic rocks (e. g. SCHREYER

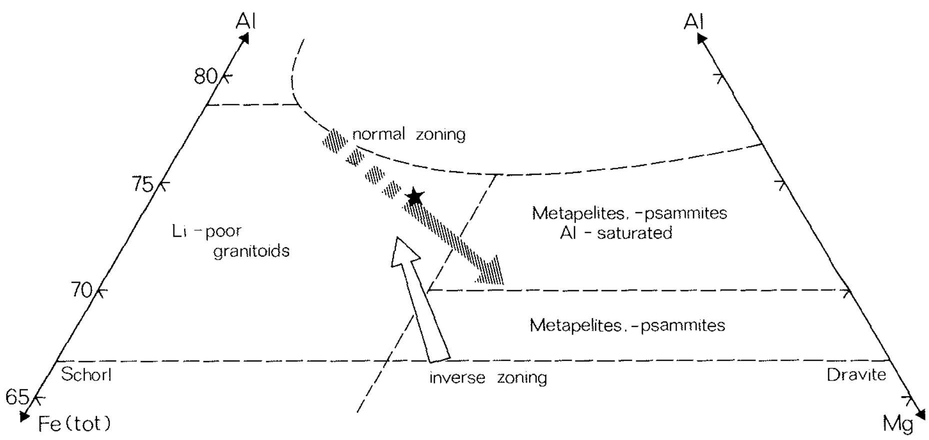

Fig. 5: Fe(total)-Mg-Al diagram with compositional trends of normal zoning (hachured arrow) and inverse zoning (lined arrow) in tourmalines from pegmatites. The broken part of the hachured arrow represents a range of core compositions that seldom occurs. The star marks the mean composition of homogeneous tourmalines from associated aplites. The limitations of the different tourmaline bearing rock groups are taken from HENRY & GUIDOTTI (1985).

Abb. 5: Fe(ges.)-Mg-Al-Diagramm mit Verlauf der normalen Zonierung (schraffierter Pfeil) und inverser Zonierung (offener Pfeil) in Turmalinen aus Pegmatiten. Der unterbrochene Teil des schraffierten Pfeils bezeichnet selten auftretende Zusammensetzungen. Der Stern bezeichnet die mittlere Zusammensetzung homogener Turmaline aus umgebenden Apliten.

et al. 1976). This compositional trend is defined as *normal* zoning. It is probably caused by decreasing crystallization temperature and/or by differentiation of the liquid and fluid phase composition.

The core to rim relations of tourmaline solid solution from pegmatites intruded in schists show an opposite trend with cores richer in dravite and uvite components than the rims, which is defined as *inverse* zoning. It indicates a formation of tourmalines influenced metasomatically by a fluid phase that was altered in composition by reaction with the surrounding schists. The alteration had its peak at the beginning of the crystallization of the tourmaline and faded with progressive crystallization. In the last stage the fluid may reach a composition similar to its initial composition, i. e. a composition representing the fluid before the crystallization of tourmaline started and before the metapelites affected the fluid. The last stage of the change in fluid composition might be caused by the end of the leaching process of the metapelitic wall rock and/or by diluting with fresh magmatic fluid.

The zoning pattern observed in tourmalines from antarctic pegmatites are not only important for the rocks studied but can also be used in other regions. The zoning may serve as an indicator for metasomatic alteration of a fluid coexisting with tourmaline during its formation.

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