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Tourmaline as an evidence of exhalative origin for Besham base metal deposits in northern Pakistan

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ABSTRACT: *Tourmaline occurs as an accessory phase in the metaquartzite/meta-arkose unit of the Pazang group in Besham area. The chemistry of different tourmaline grains varies within the same sample but there is no change in composition within a single grain. These tourmalines have an intermediate composition between schorl and dravite. This composition along with FeO/FeO+MgO ratio for the studied tourmaline grains is unlike those of granitic terrain and can be comparable to that of the tourmalinites found in association with submarine exhalative massive sulfide deposits.*

INTRODUCTION

Base metal deposits in Besham area are confined to the Sulfide Formation of the Pazang group (Fletcher et al., 1986; Shah, 1991; Shah et al., 1992). The Sulfide Formation is overlain by the Metaquartzite/Meta-arkose Formation. The later has blue-green tourmaline which occur as subhedral to anhedral accessory phase (up to 10%).

Tourmaline, a common boron mineral in the crust, has a variety of occurrences, i.e. (1) metasomatic, (2) late stage accessory phase in granites, (3) commonly associated with Sn-W deposits in altered granites and metasediments, (4) hydrothermal breccias, and (5) associated with submarine hydrothermal ore deposits (especially sediment-hosted Proterozoic deposits). The tourmaline can, therefore, be used to get information about the petrogenesis of the associated ores and host rocks (Henry & Guidotti, 1985; Plimer, 1986).

TOURMALINE CHEMISTRY

The natural tourmaline has general formula of $WX_3Y_6(BO_3)Si_6O_{18}(OH,F,Cl)$ where W= Na, Ca and K; X= Al, Fe, Li, Mg, Mn; and Y= Al, Fe, Cr, V. The principal end members are elbaite (W= Na; X= Al, Li and Y= Al), schorl (W= Na; X= Fe^{2+}, Fe^{3+} and Y= Al), dravite (W= Na; X= Mg, and Y= Al) and uvite (W= Ca, X= Mg and Y= Al, Mg). These end members include the schorl-dravite and elbaite-schorl solid solution series (Deer et al., 1962). The solid solution between dravite and uvite has also been recognized by Dunn et al. (1977). An apparent miscibility gap exists between elbaite-dravite (Donnay & Barton, 1972) and elbaite-uvite (Dunn et al., 1977).

Few grains of tourmaline in two specimens (B58 and B52) from metaquartzite/meta-arkose unit were analyzed by electron microprobe and the results are shown in Table 1. These analyses are not as accurate as for other silicate minerals because of assuming the presence of B_2O_3 contents, of both ferric and ferrous iron, the abundance of light elements (boron and fluorine) and the high and variable H_2O contents.

The tourmalines of sample B58 are Fe-rich, having composition between schorl and dravite (schorl > dravite) with Fe > Mg. The tourmalines of sample B52 are also having composition between schorl and dravite (dravite > schorl) with Fe < Mg and Na > Ca. The FeO/FeO+MgO ratio varies from 0.57 to 0.82 (average 0.68) and Na_2O/Na_2O+CaO ratio varies from 0.51 to 0.88 (average 0.70) in the studied tourmalines (Table 1).

A significant variation in the chemical composition is noticed among the different grains of tourmaline in sample B58 as compared to B52 (Table 1). However, core to rim compositional variations in individual crystals are generally similar in both the samples. The tourmaline grains of sample

TABLE 1. CHEMICAL ANALYSES OF TOURMALINE FROM METAQUARTZITE/META-ARKOSE UNIT, PAZANG GROUP, BESHAM AREA

	B58					B52			
	GR1	GR2		GR3		GR1		GR2	GR3
		rim	core	rim	core	rim	core		
SiO_2	33.75	34.69	34.67	35.22	34.72	35.77	35.88	33.52	33.56
TiO_2	0.02	0.00	0.00	0.00	0.00	1.22	1.05	0.91	0.68
Al_2O_3	22.13	24.66	23.89	25.58	24.00	31.76	31.55	29.89	30.34
FeO	21.36	17.02	17.62	16.51	19.04	8.55	8.69	8.72	8.29
MnO	0.23	0.37	0.32	0.17	0.17	0.05	0.02	0.15	0.05
MgO	4.74	6.00	6.20	5.48	4.96	6.39	6.47	5.90	6.00
CaO	0.84	1.59	1.51	1.18	1.00	0.46	0.54	0.37	0.31
Na_2O	1.47	1.65	1.61	1.93	1.63	2.18	2.13	2.28	2.34
K_2O	0.08	0.08	0.07	0.09	0.10	0.07	0.07	0.06	0.03
Total	84.64	86.10	85.91	86.17	85.64	86.46	86.44	81.84	81.68
Numbers of cations on the basis of 31 oxygens									
Si	7.80	7.65	7.70	7.75	7.75	7.44	7.44	7.39	7.39
Al	5.99	6.41	6.25	6.61	6.30	7.75	7.70	7.80	7.85
Ti	0.00	0.00	0.00	0.00	0.00	0.21	0.16	0.16	0.10
Fe	4.13	3.15	3.26	3.05	3.57	1.50	1.50	1.60	1.50
Mn	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Mg	1.65	1.96	2.07	1.81	1.65	1.96	1.96	1.91	1.96
Ca	0.21	0.36	0.36	0.26	0.21	0.10	0.10	0.10	0.05
Na	0.67	0.72	0.67	0.83	0.67	0.88	0.88	0.98	0.98
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO/FeO+MgO	0.82	0.74	0.74	0.75	0.79	0.57	0.57	0.60	0.58
Na_2O/Na_2O+CaO	0.64	0.51	0.52	0.62	0.62	0.83	0.80	0.86	0.88

B58 has higher FeO, MnO, CaO and lower Al_2O_3, TiO_2 and Na_2O contents as compared to sample B52. SiO_2, MgO and K_2O have similar composition in the tourmaline grains of both the samples (Table 1). The bulk iron content (TFe_2O_3) is higher in the sample B58 (12.16wt%) as compared to that of sample B52 (4.31wt%), which suggest that the bulk rock composition has strongly influenced the Fe contents of tourmaline in these rocks as also reported by Henry and Guidotti (1985).

DISCUSSION

The composition of studied tourmaline, falling within the schorl-dravite solid solution series, is the characteristic of the tourmaline from metasedimentary rocks (i.e. metapelites and metapsammite) associated with metamorphosed massive sulfide deposits (Taylor and Slack 1984). Igneous tourmaline, however, has typical schorl composition (Taylor & Slack, 1984; Plimer & Lees, 1988). Tourmaline of granite has high (~0.88) FeO/FeO+MgO ratio while that of massive sulfide deposits has low (~0.25) FeO/FeO+MgO ratio (see Etheir & Campbell, 1977; Taylor & Slack, 1984). An intermediate FeO/FeO+MgO ratio (~0.41 to 0.67) has been reported for the tourmalines of various metasedimentary rocks associated with exhaltive massive sulfide deposits elsewhere (see Abraham et al., 1972; Ethier & Campbell 1977; Taylor & Slack, 1984). The average FeO/FeO+MgO ratio (0.68) of the tourmaline from the metaquartzites of the study area is comparable to that of the metasedimentary rocks associated with exhalative massive sulfide deposits.

The studied tourmaline compositions plot in the schorl-dravite series in the Ca-Fe-Mg diagram (Fig. 1a). The tourmaline of sample B58 is schorl-rich and plot in the field of Li poor granitoids and their associated pegmatites and aplites while that of sample B52 is dravite-rich and plot within the field of Ca-poor metapelites, metapsammites and quartz-tourmaline rocks. The plotting of sample B58 in the field 2 of Figure 1b is not unusual as other iron-rich tourmaline from massive sulfide deposits of exhalative origin (e.g. Broken Hill, Australia; Penobscot Bay, USA; Sullivan, Canada; Taylor & Slack, 1984; Golden dyke Dome, Australia; Plimer, 1986) also plot in this field. Analyzed tourmaline of sample B58 plot in the field of Fe^{3+}-rich quartz-tourmaline rocks, calc-silicate rocks and metapelites while that of sample B52 plot in the field of Metapelites and metapsammite not coexisting with an Al-saturating phase on the Al-Fe-Mg diagram (Fig. 1b). The composition of studied tourmaline also plot within or close to the field of tourmaline associated with other strata-bound ore bodies on the Na_2O-FeO-MgO diagram (Fig. 2).

It is clear from the chemistry of the studied tourmalines that their composition is completely different from those of granitic terranes, but have composition within the range reported for the tourmaline from tourmaline-rich rocks (tourmalinite) found in association with submarine hydrothermal deposits (e.g. Sullivan, Ethier & Campbell 1977; Appalachian-Caledonian massive sulfides, Slack, 1982; Taylor & Slack, 1984; Broken Hill, Australia, Plimer 1983; Rosebery, Australia, Plimer & Lees, 1988).

The Tourmalines in these massive sulfide deposits are usually zoned and are found in greater amount in the form of tourmalinites. The studied tourmalines are, however, in lower amount (Traces to 10% by volume) and lacks significant zoning as compared to

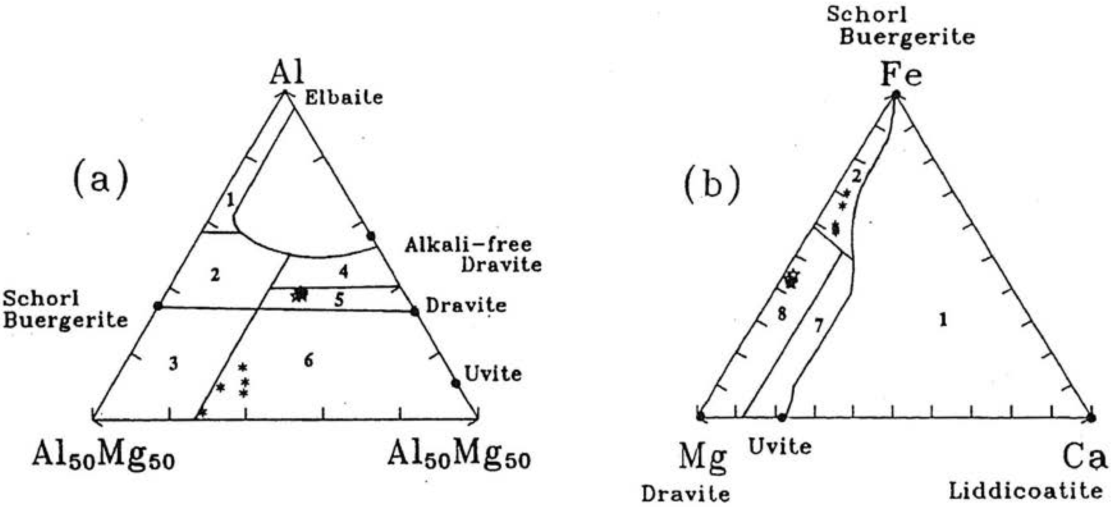

Fig. 1. (a) Al-Fe(total)-Mg and (b) Mg-Fe(total)-Ca diagram (in molecular proportions) for tourmaline from the rocks associated with massive sulfide ores of Pazang group in Besham area. Various fields are after Henry and Guidotti (1985). (1) Li-rich granitoid pegmatites and aplites, (2) Li-poor granitoids and their associated pegmatites and aplites, (3) Fe^{3+}-rich quartz-tourmaline rocks (hydrothermally altered granites), (4) Metapelites and metapsammites coexisting with an Al-saturated phase, (5) Metapelites and metapsammites not coexisting with an Al-saturated phase (6) Fe^{3+}-rich quartz tourmaline rocks, calc-silicate rocks, and metapelites, (7) Ca-rich metapelites, metapsammite and calc-silicate rocks, (8) Ca-poor metapelites, metapsammites and quartz-tourmaline rocks. ☆ = Tourmaline of sample No. B52, ✱ = Tourmaline of sample No. B58.

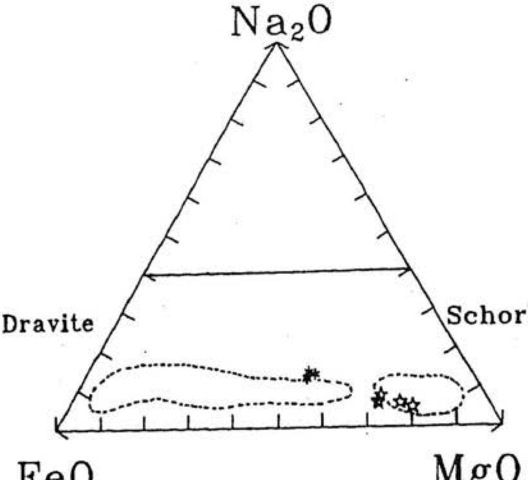

Fig. 2. FeO-Na_2O-FeO diagram of tourmaline from the rocks associated with the massive sulfide ores of Pazang group in Besham area. Field of tourmaline (dashed line) associated with other massive strata-bound ore bodies are after Appel (1985).

the former type. The lack of zoning can be attributed to chemical homogenization during metamorphism of the host rock (see Henry & Guidotti, 1985). The lower concentration of tourmaline may correspond to the limited boron activity and unsuitable mineralogy of the host rock.

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