

A chromian tourmaline from Swat, West Pakistan

M. QASIM JAN

Department of Geology, University of Peshawar, West Pakistan

D. R. C. KEMPE and R. F. SYMES

Department of Mineralogy, British Museum (Natural History), London S.W. 7.

SUMMARY. Traces of a green chromian tourmaline occur in calcareous rocks in contact with serpentinite near Alpurai, Swat, West Pakistan. The petrography of the rocks and the optical properties of the tourmaline are presented along with its chemistry (it contains over 8 % Cr_2O_3 and about 0.2 % V_2O_5). The mineral is compared with other chromian tourmalines and its paragenesis discussed: it is thought to have been produced by silica-rich hydrothermal (or gaseous) solutions, which have crystallized as thin quartz veins in the calcareous rocks, introducing boron and other constituents.

CALCAREOUS rocks, containing minor quantities of fuchsite, are found intruded by a lenticular serpentinite body (over 8 miles long) and cut by quartz veins, near Alpurai, Swat, West Pakistan ($35^\circ 54' \text{ N.}$; $72^\circ 39' \text{ E.}$). A similar association of rocks yields gem quality emerald near Mingora, Swat (Davies, 1962), and in Mohmand Agency (Jan, 1968, and in press, 1970), when subsequently penetrated by appropriate hydrothermal or pegmatitic solutions. Examination, confirmed by X-ray powder photograph, of rocks collected from Alpurai showed that some samples contained traces of a clear, emerald-green chromian tourmaline, a relatively rare mineral. This paper presents detailed data on the tourmaline and its associated rocks.

Petrography. The calcareous rocks (Palaeozoic according to Martin *et al.*, 1962) are medium-grained and saccharoidal in texture, with some degree of parallel alignment in the smaller quartz grains around larger crystals of calcite and quartz. Calcite (about 60 %) and quartz (about 30 %) make up most of the rocks, the remainder consisting of micaceous minerals and iron ore, with tourmaline present in a few. Some of the rocks are rich in talc, and a few contain a higher than average amount of micaceous minerals; in these the parallel alignment or schistosity is very distinct. Some of the rocks are massive to thick-bedded, others thin-bedded. Quartz veins and lenses are common, the latter in particular occurring in mica-rich calcareous schists.

The calcite, which is poorly twinned and cleaved, is frequently strained and fractured. Some grains have been partially dissolved and later replaced by quartz or, rarely, by tourmaline. Quartz, which is anhedral, is usually strained and may contain sericitic inclusions, sometimes stained green. The ore mineral is mainly chromian magnetite but some is oxidized to hematite and hydroxides. Much of it is in rounded droplets, some in distinctly elongated 'prisms'. Biotite, present only in some rocks, is pleochroic from pale green to greenish-brown, and partially chloritized. It occurs

twisted around other grains. The fuchsite is pale green and pleochroic; some is sericitic and may be dusted with ore. In general, the fuchsite content increases towards the contact with the serpentinite.

The calcareous rocks are locally stained brown by iron oxide leaching; rarely, they are stained green, particularly along fractures near the contact, probably by chromium-bearing solutions.

The serpentinite, probably Cretaceous (Jan and Tahirkheli, 1969), is composed of abundant antigorite, iron ore, and minor calcite. In some the ore is concentrated locally and is almost absent in other areas. Thin streaks of ore dust traverse these areas, sometimes linking the ore-rich parts. The calcite is probably secondary, introduced by extraneous solutions, since much of it occurs along thin micro-fractures. Some of the sections, from other parts of the serpentinite, contain about 40 % carbonate, some of it being primary. Asbestiform serpentine sometimes occurs along fractures.

The chromian tourmaline is found only locally in the calcareous rocks and does not appear to exceed 2 %. It occurs in distinct grains but some is found growing around or between the calcite grains. Sometimes it surrounds the calcite in the form of girdles of minute granules adjacent to each other. In a few cases, it is growing at the expense of partially dissolved calcite. Nowhere is the tourmaline completely surrounded by quartz; it is either contained in calcite, or formed between calcite and quartz boundaries, generally tending to occur in the former (fig. 1).

The mineral occurs in minute anhedral to subhedral grains, some of which reach two mm in length. It is free of impurities and is only slightly fractured. It is pleochroic from greenish-yellow (ϵ) to deep green (ω), with refractive indices ϵ 1.627 and ω 1.660 (± 0.003), close to those of Urals material. The chromium appears to have a similar (but greater) effect to iron (see Deer *et al.*, 1962, p. 312) in raising the refractive indices and birefringence of the tourmalines ($\omega - \epsilon$ 0.031—0.049).

Owing to the limited amount of material available a partial analysis by electron microprobe was undertaken of five grains in a polished thin section. An average of three of these grains gave: SiO_2 36.4 %, TiO_2 0.09, Al_2O_3 29.0, Cr_2O_3 8.5, V_2O_5 0.25, FeO (total Fe as FeO) 1.2, NiO 0.75, MgO 8.2, CaO 0.03, Na_2O 2.8, K_2O 0.04; there was little variation in the elements determined. The analysis was made using a

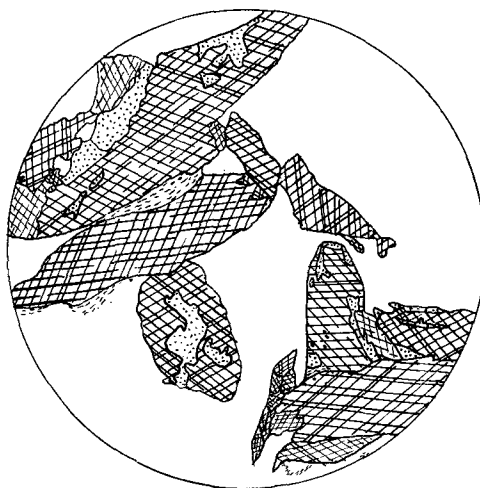


FIG. 1. Drawing of a calcareous rock penetrated by a quartz vein. The rock is composed mainly of calcite (cleaved); microcrystalline quartz (clear areas); and minor tourmaline (stippled), micaceous minerals—mainly fuchsite and green chlorite (dashed), and ore dust. Note the occurrence of tourmaline in the calcite. Diameter of circle: 5 mm.

Cambridge Instruments Geoscan not modified for the detection of the low atomic number elements (N less than 11); boron and fluorine were therefore not determined.

Analyses were made for Si, Al, Mg, Na, and K using an accelerating voltage of 15 kV and a current of $0.5 \mu\text{A}$.; silicates of known composition were used as standards. Pure metal standards were used for the elements Cr, V, Ni, and Fe, with an accelerating voltage of 20 kV and a current of $0.9 \mu\text{A}$. Care was taken to avoid any overlap between chromium and vanadium lines. Since boron and fluorine were not determined, only partial corrections after the method outlined by Sweatman and Long (1969) were made. It is thought that the figures shown are correct to $\pm 2\%$ of the amount present for the major elements but that the relative errors in the minor constituents are probably greater than this.

In general, the chromian tourmalines seem to be poor in alumina; the Alpurai material is very low in lime. In other constituents they appear to resemble normal dravites closely.

Paragenesis. The sporadic occurrence of the tourmaline in carbonate rocks, its high chromium content, and its interstitial and replacement character indicate that the mineral was not developed as a recrystallization product of the calcareous sediments, but was formed later. Since neither granites nor pegmatites occur close by, it is thought that silica-rich hydrothermal (or gaseous) solutions, resulting in quartz veins cutting the calcareous rocks, carried in boron and other constituents, which locally formed tourmaline. The necessary chromium and magnesium could have been derived from the serpentinite, and the alumina from micaceous minerals already present in the calcareous rocks. The chromium and other constituents from the serpentinite may have been introduced by the leaching effect of the hydrothermal solutions passing through the ultramafic rocks before entering the calcareous rocks, or by metasomatism. Such an origin has already been proposed by one of the authors (Jan, 1970) for the emerald occurrences in Mohmand Agency.

Few chromiferous dravites have so far been described. The earliest and richest in Cr_2O_3 (10.86 %) occurs in serpentinites interbedded with talc- and chlorite-schists from Sysert district in the Urals (Cossa and Arzruni, 1883). Amongst other chromium-bearing minerals, fuchsite is also present. In Finland, vanadium-bearing chromian tourmaline (with fuchsite, etc.) occurs at Outokumpu (9.60 % Cr_2O_3 ; 0.61 % V_2O_5) and Kaavi (8.97 % Cr_2O_3) (Peltola *et al.*, 1968). At the first of these localities it is found in chromium-bearing contact skarns between serpentinites (with dolomitic haloes) and quartzites; in the second, in fuchsite gneiss. A third instance, containing less chromium (1.60 % Cr_2O_3), was recorded from (apparently sedimentary) metamorphic rocks from Krivoi Rog (Shenderova, 1955).

Vanadiferous tourmaline (1.50 % V_2O_5) from the Gerevi Hills, Tanga Province, north-eastern Tanzania, was described by Bassett (1956a, p. 93; McKie, 1958), where it occurs in the gneiss above another similar rock in which chromiferous turquoise is found (Bassett, 1956b, p. 100); the two minerals are never found together. No chromium is reported from this example but Usagaran (\equiv Mozambiquian) rocks containing turquoise and redondite from other localities in this region also contain

fuchsite and green (possibly chromian) tourmaline (see Kempe, 1965, p. 48). In Tanzania the rock associations include dolomites and ultrabasic rocks as well as granulite facies metasediments.

Thus it would seem that the most common associations for chromian tourmalines include serpentinites (and other ultrabasic rocks) and carbonates (including dolomites). Also, that they often contain vanadium and occur in association with fuchsite.

Acknowledgements. Miss E. E. Fejer is thanked for her assistance in the preparation of this paper.

REFERENCES

- BASSETT (H.), 1956a. *Records Geol. Survey Tanganyika*, **3** (for 1953), 93–6.
— 1956b. *Ibid.*, 100–3.
COSSA (A.) and ARZRUNI (A.), 1883. *Zeits. Kryst.* **7**, 1–16.
DAVIES (R. G.), 1962. *Geol. Bull. Panjab Univ.* **2**, 51–2.
DEER (W. A.), HOWIE (R. A.), and ZUSSMAN (J.), 1962. *Rock-forming minerals*, **1**, London, Longmans.
JAN (M. Q.), 1968. *Geol. Bull. Univ. Peshawar*, **3**, 10–11.
— in press, 1970. *Proc. Nat. Sem. Min. Development, Lahore*.
— and TAHIRKHELI (R. A. K.), 1969. *Geol. Bull. Univ. Peshawar*, **4**, 1–13.
KEMPE (D. R. C.), 1965. *Records Geol. Survey Tanganyika*, **11** (for 1961), 44–53.
MCKIE (D.), 1958. *Ibid.* **5** (for 1955), 81–94.
MARTIN (N. R.), SIDDIQUI (S. F. A.), and KING (B. H.), 1962. *Geol. Bull. Panjab Univ.* **2**, 1–13.
PELTOLA (E.), VUORELAINEN (Y.), and HAKLI (T. A.), 1968. *Bull. Geol. Soc. Finland*, **40**, 35–8.
[SHENDEROVA (A. G.) Шендерова (А. Г.), 1955. Мин. сборник Львов геол. общ. (*Min. Mag. Lvov. Geol. Soc.*), no. 9, 324–6 [M.A. 13–187].

SWEATMAN (T. R.) and LONG (J. V. P.), 1969. *Journ. Petrology*, **10**, 332–76.

[*Manuscript received 19 May 1971*]