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The relationship between optical properties and occurrence of some black tourmalines from northern Nigeria

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SUMMARY. Seventy-nine black tourmalines collected over a 12 000 km^2 area of Precambrian to lower Palaeozoic rocks in northern Nigeria show a close correlation between maximum R.I., absorption colour, and occurrence in non-feldspathic micaceous schists and schorl rocks on the one hand, and in gneisses, migmatites, and feldspathic pegmatites on the other. Pleochroism is known to depend upon the total iron content and the $Fe^{2+}Fe^{3+}$ interaction. Colour variations may thus provide useful indicators of the geochemical environment during crystallization.

Limited published data, supplemented by additional measurements on four tourmalines from outside the original area, suggest that similar correlations would be obtained for the rest of Nigeria.

Selective processes of boron metasomatism may have been important in the association of different coloured tourmalines with feldspathic and non-feldspathic rocks, and the apparent lack of biotite in most tourmaline-rich rocks. The source of the boron probably lay within the upper Proterozoic to lower Palaeozoic metasedimentary belts with which the tourmaline is most strongly associated.

BLACK tourmaline (schorl) is widespread in the recently mapped 12 000 km^2 area around Zaria, northern Nigeria (fig. 1; McCurry, 1970). The most concentrated occurrences are in or marginal to late Precambrian metasedimentary belts, which occupy north-south trending synclinal downfolds in a reactivated crystalline complex of gneisses and migmatites. Both crystalline rocks and metasediments are intruded by a suite of syn- to late-tectonic granites. The tourmaline is found in pegmatites, quartz veins, massive schorl rocks, and impregnating the country rocks. It forms euhedral crystals ranging in size from microscopic in most of the schists and crystalline rocks, to striated prisms up to 5 cm long in many pegmatites. Crystalline aggregates are typical of the schorl rocks and some pegmatites.

Pleochroism is strong, maximum absorption colours varying from pale yellow-brown, through shades of green and blue, to dark inky-blue or black, with ω ranging from $1{\cdot}652\pm0{\cdot}002$ to $1{\cdot}666\pm0{\cdot}002$. Zoning is common parallel to the crystal faces, and varies generally from pale browns and greens in the outer rim to darker colours in the centre, the different colour zones being sharply defined.

Optical properties related to occurrence. A study of R.I.$_\omega$ and absorption colour ω was made of 79 black tourmalines collected from this area. Forty-six of the specimens were from schorl rocks and quartz veins, 18 from pegmatites, and 8 and 7 from mica schists and crystalline rocks respectively. The latter figures are low partly because of the difficulty of extracting scattered microscopic tourmalines from the rocks. The

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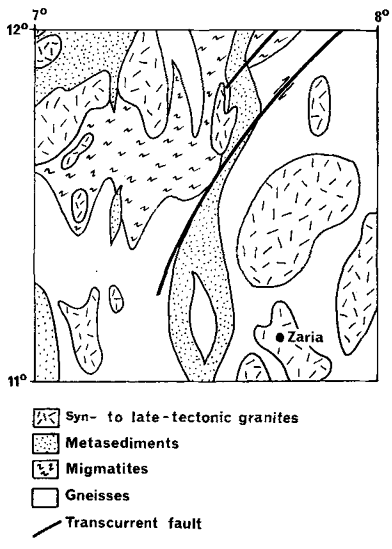

FIG. 1

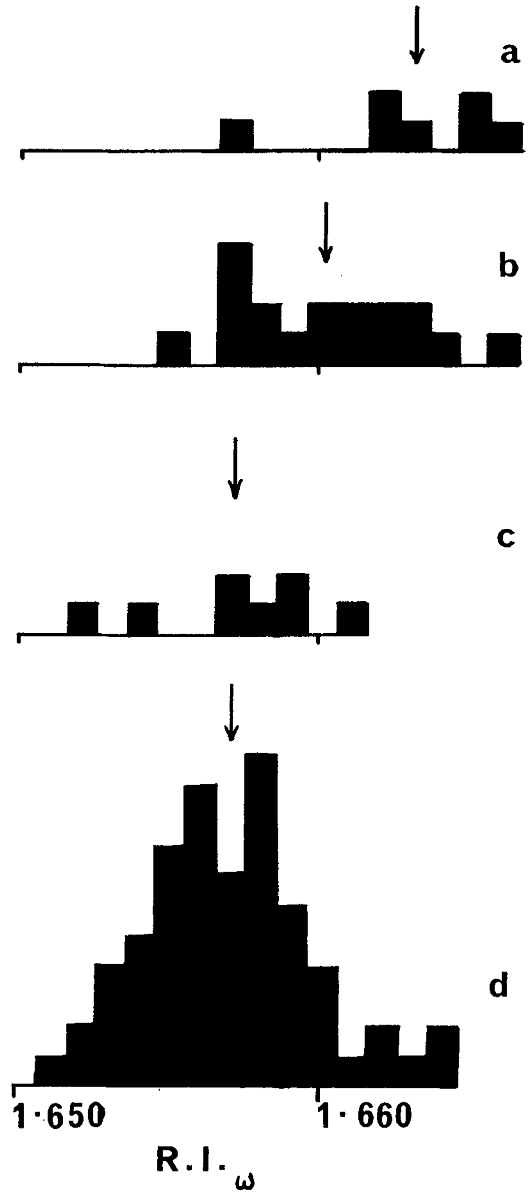

FIG. 2

FIGS. 1 and 2: FIG. 1 (left). Geological sketch map of degree sheet 21 (Zaria), Nigeria. FIG. 2 (right). Histograms of maximum R.I. values for seventy-nine tourmalines of different occurrences. Arrows indicate mean R.I. values, which show a progressive shift from 1·657 in schists (c) and schorl rocks (d), to 1·660 in the pegmatite veins (b), and 1·663 in the crystalline rocks (a). In each case the mean and median correspond, and the standard deviation from these values, s, is 0·006 except for the pegmatite veins, for which it is 0·003. (All data for figs. 2 and 3 are tabulated in appendix to McCurry, 1970.)

results of these studies are summarized in figs. 2 and 3 which show a strong relationship between optical properties of the tourmaline and its mode of occurrence. The observed frequencies were tested for independence of association using a test for 3×2 contingency tables based on the multinomial distribution (expanded from that described by Bailey, 1959, p. 61). The probability values obtained were: frequency of occurrence v. refractive index, 2×10^{-6} %; frequency of occurrence v. colour, 9×10^{-2} %; and frequency of colour v. refr. ind., 6×10^{-4} %. As all these results are well below the 5 % level, the probability that the distribution is wholly a chance one with no association must be dismissed, and it is assumed that the correlations suggested in figs. 2 and 3 are valid.

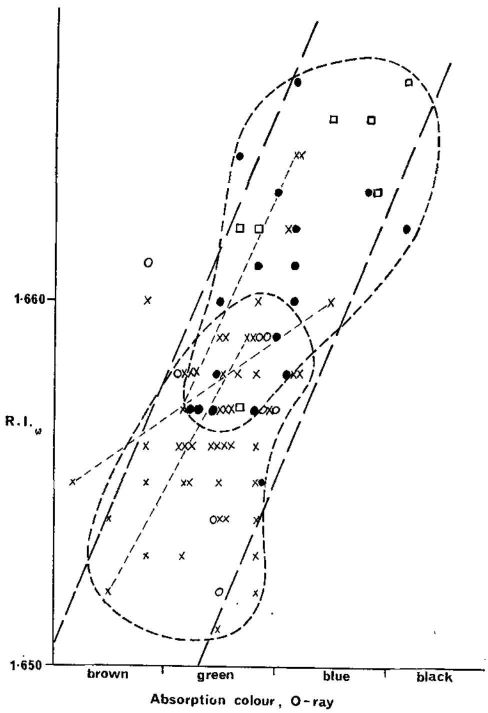

FIG. 3. Graph of maximum absorption colour against maximum R.I. for seventy-nine tourmalines of different occurrences. Two parallel long-dash lines, between which lie 90% of all the points plotted, show the direct relationship between colour and R.I. Variations in three zoned crystals, shown by short-dash lines, also approximate to this trend. Two major fields of occurrence are delimited: one of schists and schorl rocks; and the other of pegmatites and crystalline rocks, with a small area of overlap between the two. □, crystalline rocks; ●, pegmatite veins; ○, schists; ×, schorl rocks.

Tourmaline is widespread in Nigerian basement rocks (Russ, 1957), and it is conceivable that similar relationships could be established on a more regional basis. The few reports in the Nigerian literature are certainly in accordance with results obtained in this area. Thus blue to mauve tourmaline is described from pegmatites in several parts of Nigeria (Jacobson and Webb, 1946; Raeburn, 1927; Jones and Hockey, 1964), while green tourmaline crystals have been found among micaceous schists (Jones and Hockey, 1964; Truswell and Cope, 1963). To upplement thsee meagre data, measurements were made on four schorl rocks in the Ahmadu Bello University Geology Department collection, from various parts of northern Nigeria outside the studied area. ω values ranged from $1\cdot656\pm0\cdot002$ to $1\cdot659\pm0\cdot002$, and absorption colour from brown-green to grey-green. These values plot unequivocally in the schist/schorl field of fig. 3.

Compositional considerations. Tourmaline pleochroism and R.I. have been shown to increase directly with total iron content (see Deer, Howie, and Zussman, 1962). Applying results obtained by Ward (1931) to the tourmalines in this area the schist/schorl group has 5 to 9% total iron (as Fe_2O_3) and the pegmatite/crystalline rock group 8 to 12 %. Slivko (1957) found that the leading chromophores that determine the colour of tourmaline are $Fe^{2+}Fe^{3+}$ (blue), Fe^{3+} (brown), and Fe^{2+} (green), thus agreeing with the conclusions of Faye, Manning, and Nickel (1968) that tourmaline pleochroism is largely dependent on the $Fe^{2+}Fe^{3+}$ interaction. Slivko (1957) suggests that colour variations can serve as indicators of the geochemical environment during crystallization. The full implications of the preliminary studies conducted in this area have not yet been realized, but with a more systematic survey it is possible that colour and R.I. variations could help to elucidate in greater detail the geological histories of the tourmaline-bearing rocks.

Tourmalinization. Pneumatolytic action of boron in granites is described as attacking biotite first to give yellow tourmaline, subsequently replacing the feldspar by blue to blue-green tourmaline. The quartz is unaffected and if tourmalinization is complete, a quartz-tourmaline rock results (Deer, Howie, and Zussman, 1962).

Similar processes of boron metasomatism may have operated in this area, where there is widespread association of yellow, brown, and pale green tourmaline with essentially non-feldspathic schists and schorl rocks, and of blue to blue-green tourmaline with feldspathic pegmatites and crystalline rocks. Tourmaline and biotite are seldom found together in the pegmatites and crystalline rocks, and where biotite is present, tourmaline pleochroism is invariably in shades of green. Green tourmaline typically accompanies biotite in the micaceous schists. At one locality, tourmalinization is well advanced along certain foliation planes on either side of a discordant band rich in green tourmaline and lacking biotite, though its other constituents (quartz, muscovite, sillimanite, and apatite) are identical to those in the adjacent schists, which carry both biotite and smaller amounts of the green tourmaline.

Both Truswell and Cope (1963) and Jones and Hockey (1964) propose a relationship between tourmaline-bearing rocks and granite bodies in other parts of Nigeria, based partly on similar associations elsewhere in the world (e.g. SW. England). Certainly the formation of the tourmaline-bearing veins and pegmatites was connected with the late-stage granite emplacement, but the scarcity of tourmaline in the granites and the widespread occurrence of tourmaline in or near to the metasedimentary belts would suggest that the source of the boron lay in the metasediments.

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