

The cleavage is rhombohedral, but no attempt was made to distinguish between the *r* and *z* rhombohedra. Thin sections show many unoriented needles of an unidentified mineral (not rutile), a large number of cracks, fractures, and tiny holes that probably contained fluid inclusions. Partial chemical analyses were made of the rose quartz, which was crushed to pass 200 mesh and cleaned with a magnetic separator and heavy liquids; alkalis were determined with a flame photometer. The results were: SiO<sub>2</sub> 99.45, Na<sub>2</sub>O 0.26, K<sub>2</sub>O 0.09 %. A spectrogram indicated traces of Al, Ti, Fe, Mn, and Ca.

The irregularities in the spacing and persistence of the cleavage surfaces (see fig. 2) suggest that they are not primary growth features, but secondary features of the quartz, possibly resulting from stress of the quartz body, as indicated by its cracked and granular texture. The relation of some cleavage surfaces to cracks is also suggestive of a stress-related origin for the cleavages.

Anderson (1945) showed that *r*, *z*, and *d* were preferred rupture planes in the vein quartz fillings of the Antietam quartzites; he described the rhombohedral deformation planes as being 'characterized by sharp fracture containing neither opaque nor fluid inclusions' (pp. 413-14). He also noted irregularities of continuity in the 'sharp fractures' (p. 411). Halden (1955) also noted breakage parallel to rhombohedral faces of some massive quartz from California.

The occurrence and characteristics of the Nigerian cleaved quartz are similar to those of some other reported occurrences.

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*Department of Geology, University of Ife  
Ibadan Branch, Ibadan, Nigeria*

A. A. KAYODE

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## Rodingite from Naranji Sar, Dargai ultramafic complex, Malakand, West Pakistan

THE rodingite described here (which has been sold locally as 'jade') occurs at Naranji Sar (71° 46' E., 34° 28' N.), a hill south of the village of Mena, about 20 miles west of

Dargai (with which it is connected by a jeep road), Malakand. The hill forms part of the northern edge of the Dargai ultramafic complex, consisting mainly of peridotites such as harzburgite and dunite, the latter enveloping bodies of chromite. In addition, gabbroic rocks are found in places along the northern and eastern contacts with the metasediments (northward dipping phyllites, chlorite schists and, on the north side, talc schists), into which the ultramafic rocks are intruded. Within both the peridotites and gabbros intense serpentinization or chloritization or both is found locally. The rodingite occurs in strings of ovoid lenses, individually up to 2.5 m long and 0.7 m wide, in the altered gabbroic areas, at Naranji Sar trending nearly east-west, to the north and Musa Mena on the east.

*Petrography of the rodingite.* A typical rodingite lens has a hard, compact core, white to greenish-white in colour, with green speckles. Locally, the rock is a uniform light green, greasy to the touch. No individual grains of garnet can be identified in hand specimen or separated in the laboratory. The core is surrounded by a dark greenish-black chloritic zone, within which occur druses containing euhedral honey-brown crystals of grossular.

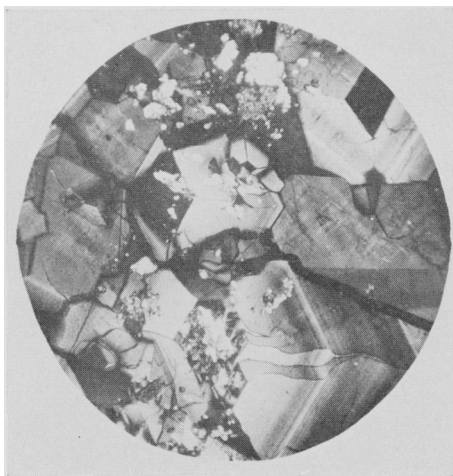


FIG. 1. Grossular, showing morphology and zoning. Specks are of epidote. Crossed nicols,  $\times 60$ .

In thin section, the core is seen to vary from almost pure grossular, with a little idocrase, to an intergrowth of garnet and idocrase with veins and patches of serpentine after olivine, and some altered orthopyroxene. At the rim of the lens, the garnet-idocrase core grades through a cloudy zone, consisting mainly of orthopyroxene altering to colourless chlorite, with some chromite and magnetite, into fine-grained massive serpentine.

The honey-brown garnets from the druses are colourless and euhedral and exhibit strong anisotropism. The birefringent areas are arranged in zones, illustrating the dodecahedral morphology of the crystals (fig. 1). Small amounts of epidote and calcite are intergrown in the garnets.

*X-ray powder photographs* of the greenish-white and honey-brown garnets were taken and measured, and their  $d$  spacings found to be very close to those of grossular given in the A.S.T.M. index. Broad and diffuse reflections at 9.31, 5.23, 4.29, and 3.53 Å, present in both, are presumably attributable to chlorite impurities. The cell edge of both garnets was computed as 11.82 Å, that for grossular being given as 11.85 Å. A powder photograph of the outer chlorite zone gave a pattern close to chlorite (sheridanite).

*D.T.A. curves* for the three samples showed no change for the honey-brown garnet, J-2, but a small endothermic peak in the greenish-white garnet, J-1, between 550 and

650 °C, with a small peak at 620 °C. This is attributed to the impurities, probably chlorite or idocrase.

The chlorite sample J-3 gave a sharp exothermic peak at 870 °C and a large endothermic peak at 670 °C, the latter representing the breakdown of the chlorite structure (Phillips, 1963).

*Chemistry.* Analyses of the impure grossular rock (rodingite) and the honey-brown grossular are given in table I (analyses 1 and 2).

TABLE I. *Chemical analyses (A. H. K.)*

	J-1	J-2	J-3	J-2 calc. to 24 O		
SiO <sub>2</sub>	36.36	37.45	25.56	Si	5.644	6.000
Al <sub>2</sub> O <sub>3</sub>	25.64	25.65	24.12	Al	0.356	
Cr <sub>2</sub> O <sub>3</sub>	0.06	nil	0.15	Al	4.199	4.312
TiO <sub>2</sub>	nil	nil	nil	Fe <sup>3+</sup>	0.113	
Fe <sub>2</sub> O <sub>3</sub>	0.27	0.99	2.81	Cr <sup>3+</sup>	—	
FeO	0.50	0.21	3.21	Ti	—	
MnO	nil	0.37	0.08	Mg	—	5.789
MgO	3.05	nil	32.85	Fe <sup>2+</sup>	0.026	
CaO	32.50	34.10	0.96	Mn	0.047	
Na <sub>2</sub> O	0.49	0.54	0.69	Na	0.157	
K <sub>2</sub> O	0.14	0.31	0.05	Ca	5.502	0.5
P <sub>2</sub> O <sub>5</sub>	0.05	0.12	0.07	K	0.057	
H <sub>2</sub> O <sup>+</sup>	1.03	0.12	8.18	Mol %		3.1
H <sub>2</sub> O <sup>-</sup>	0.04	0.06	0.38	Almandine		
CO <sub>2</sub>	—	—	0.30	Andradite		95.6
Total	100.13	99.92	99.41	Grossular		
				Spessartine		0.8

J-1 = Impure grossular (rodingite), Naranji Sar, Malakand.

J-2 = Honey-brown grossular in druse, Naranji Sar, Malakand.

J-3 = Chlorite (sheridanite) zone, rimming rodingite, Naranji Sar, Malakand.

The two garnets have practically identical X-ray patterns, and it would seem probable that the combined water in the rodingite is due to the idocrase impurities, rather than that the garnet is hydrogrossular. Frankel (1959), however, has shown that the South African 'jade', which is perhaps similar to the Dargai occurrence, is in fact hydrogrossular and not grossular, and it is notable that most of the rodingite garnets also appear to be hydrogrossular (Deer *et al.*, 1962).

The honey-brown garnet contains 95.6 % grossular, with small amounts of andradite, spessartine, and almandine. The colour is probably due to the manganese ions, whilst the greenish colour of the rodingite garnet is attributed to its small chromium content. An analysis of the chlorite zone rimming the rodingite is also given in table I (analysis 3), and is near sheridanite.

*Petrogenesis.* The occurrence of grossular and hydrogrossular has been attributed to post-magmatic and metasomatic as well as metamorphic processes. Bilgrami and

Howie (1960) have suggested that the serpentinization and garnetization of the peridotites of Pastoki, Hindubagh, West Pakistan, could have been brought about by the breakdown of the pyroxenes, CaO released and transported through the dolerite body by percolating hydrothermal solutions combining with the  $\text{Al}_2\text{O}_3$  from the plagioclase to form hydrogrossular. This occurrence is markedly similar to the Naranji Sar rocks. No analyses of the Naranji Sar peridotites and gabbroic rocks are available, but it is considered that the chlorite and grossular were formed by hydrothermal alteration of diopsidic augite and anorthite.

Christophe Michel-Lévy (1956) has shown that grossular and wollastonite are formed from a 3:1:3 mixture of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{Ca(OH)}_2$  or  $\text{CaCO}_3$ , at 500 °C and  $P_{\text{H}_2\text{O}} = 500$  bars. At 400 °C, garnets were rare and xonotlite and calcite were formed. These temperature–pressure conditions may give an indication of those prevailing in the formation of the Naranji Sar rodingite.

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*Pakistan Council for Scientific and Industrial Research*  
Peshawar  
West Pakistan

M. A. KAISER  
S. MANSOOR AKHTER  
A. H. KHAN

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## Hydrogrossular: $\text{Ca}_3\text{Al}_2(\text{H}_4\text{O}_4)_3$ versus $\text{Ca}_3[\text{Al}(\text{OH})_6]_2$

IN the above title two structural formulas are given for the same composition (i.e., for the composition of synthetic hydrogrossular, which also has been called tricalcium aluminate hexahydrate).<sup>1</sup> Questions immediately arise: Are both formulae acceptable? If both are not acceptable, why not, and which is preferable?

<sup>1</sup> From the viewpoint of comprehension of the structure, 'tricalcium aluminate hexahydrate' [ $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6 \cdot \text{H}_2\text{O}$  or  $\text{Ca}_3(\text{AlO}_3)_2 \cdot 6\text{H}_2\text{O}$ ] is misleading because it implies that protons are bonded to merely half of the oxygen atoms rather than to all of them.