

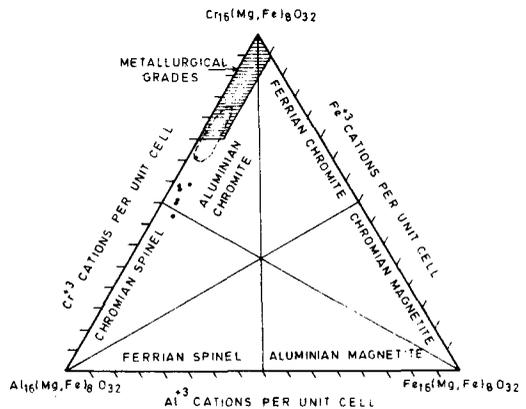
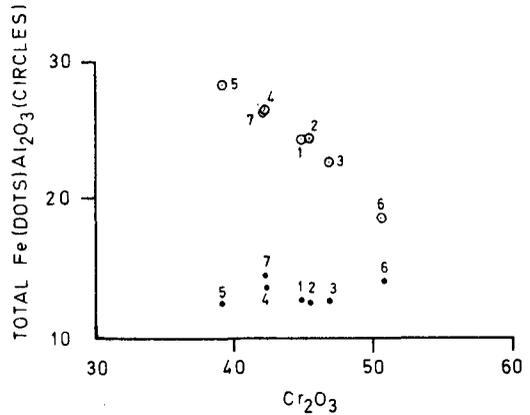
Chromite from Sakhakot-Qila area, Malakand Agency, Pakistan

CHROMITE-BEARING ultramafites occur in a belt paralleling the NW. frontier of Pakistan (fig. 1). The most northerly occurring chromite deposits are located in a peridotite-gabbro complex that extends from Sakhakot in the east to Qila in the west, a distance of 24 km, in the Malakand Agency. The complex is enclosed by low-grade (greenschist facies) metamorphic rocks ranging from pelitic to calcareous and carbonaceous types. The ultramafites are dominantly harzburgite and peridotite; both containing randomly distributed minor bodies of dunite and thin pyroxenite veins. Serpentinization is very weak, except in an envelope along the outer contact. The major element composition of various rocks (Uppal, 1972) does not show large variations. In the north, foliated gabbro occurs as two small bodies, concordantly elongated.

The chrome ore forms layers, veins, lenses, pods, pencils, and irregular bodies. Unlike most podiform deposits, the chromite layers in this area show a considerable lateral persistence. But their podiform nature is revealed by their textural features.



FIG. 1. Map of Pakistan showing location of Sakhakot-Qila area (solid rectangle) and other chromite occurrences (squares).



FIGS. 2 and 3: FIG. 2 (above). Plots of weight % total Fe and weight % Al against weight % Cr_2O_3 . FIG. 3 (below). Distribution of Sakhakot-Qila chromites (dots) in the Cr-Al- Fe^{3+} triangular classification. Shaded area encloses plots of chromites from the Zhob valley, Pakistan.

Nodular texture is developed at many outcrops. Chromite grains invariably display rounded outlines. Cataclastic shattering, healed by serpentine, is widespread. Octahedral (III) cleavage is well developed in most of the samples. The textural types of chromite, in order of decreasing abundance, are: disseminated, massive, banded, nodular, chromite-net, and, rarely, graded layered. In

TABLE I. *Chemical composition and physical properties of purified chromites from Sakhakot-Qila area, Pakistan*

	1	2	3	4	5	6	7
SiO ₂	0.26	0.16	0.21	0.32	0.23	0.06	nil
Al ₂ O ₃	24.12	24.30	22.62	26.68	28.24	18.86	26.29
Cr ₂ O ₃	44.93	45.49	46.95	42.21	39.06	50.66	42.05
Fe ₂ O ₃	1.77	1.96	4.41	3.67	4.48	1.70	3.07
FeO	14.93	14.42	12.36	13.52	11.99	16.49	15.19
MgO	13.51	13.02	12.72	12.82	15.52	11.84	12.83
CaO	0.08	0.09	0.07	0.06	0.04	0.06	0.09
MnO	0.15	0.20	0.18	0.28	0.25	0.17	0.26
TiO ₂	0.12	0.18	0.22	0.22	0.14	0.18	0.16
V ₂ O ₅	tr	nil	nil	nil	0.04	nil	tr
NiO	tr	tr	tr	0.05	0.06	tr	tr
H ₂ O ⁺	0.05	0.10	0.08	0.06	—	—	0.02
Total	99.92	99.87	99.82	99.84	100.05	100.02	99.96
Cr/Fe	2.39	2.47	2.53	2.21	2.21	2.47	2.06
RO/R ₂ O ₃	1.01	0.98	0.97	0.95	0.98	0.98	0.96
MgO/RO	0.60	0.61	0.50	0.48	0.70	0.56	0.60
Fe ₂ O ₃ /R ₂ O ₃	0.02	0.02	0.05	0.04	0.05	0.02	0.04
MgO/MgO + FeO	0.47	0.47	0.51	0.49	0.58	0.42	0.46
Cr ₂ O ₃ /Cr ₂ O ₃ + Al ₂ O ₃	0.65	0.65	0.67	0.61	0.58	0.73	0.61
<i>Number of cations on the basis of 32(O)</i>							
Cr	8.76	8.71	8.86	8.04	7.31	10.08	7.99
Al	6.91	6.94	6.35	7.29	7.89	5.60	7.45
Fe ³⁺	0.33	0.35	0.79	0.67	0.80	0.32	0.56
Fe ²⁺	3.31	3.08	3.30	2.87	2.31	3.50	3.18
Mg	4.69	4.92	4.70	5.13	5.69	4.50	4.82
<i>End-member percentages: (a) Formula percentages</i>							
Spinel	43.20	43.35	39.71	45.58	49.30	35.01	46.57
Magnesiochromite	15.49	18.21	19.08	18.59	21.83	21.20	13.74
Ferromagnetite	39.26	36.22	36.28	31.67	23.89	41.78	36.22
Magnetite	2.05	2.22	4.93	4.16	4.98	2.01	3.47
<i>(b) Weight percentages</i>							
Spinel	33.39	33.67	30.45	35.76	39.59	26.38	36.45
Magnesiochromite	16.18	19.12	19.45	19.71	23.71	21.61	14.51
Ferromagnetite	47.84	44.39	43.90	39.19	30.21	49.57	44.64
Magnetite	2.54	2.82	6.20	5.34	6.49	2.45	4.40
Reflectivity	11.90	11.90	12.10	11.40			
	±0.05	±0.10	±0.05	±0.02			
Mean VHN	1402	1392	1335	1405			
S.D. of VHN	59	38	40	68			
Unit Cell edge (a)	n.d.	8.280 Å	8.262 Å				

Reflectivity was measured at 590 nm wavelength, against a prism of SrTiO₃, no. 229, with given reflectivity of 17.1% at 589 nm wavelength. The microhardness was measured using a 200 g load and 15 seconds contact time on a GKN microhardness tester calibrated against a pyrite standard. The unit cell edge was determined from X-ray powder photographs using Straumanis camera of 114.6 mm diameter. Target radiation used was Cu-K α (1.5418 Å) employing a nickel filter. Pure spinel was used as a standard.

Analysts: Zulfiqar Ahmed (1-4) and Shafeeq Ahmed (5-7).

addition, spindles and irregular forms of coarse-grained massive chromite may be found set in fine-grained chromite. In the nodular type, the nodules may be spherical to oval, and vary in diameter from 3 mm to 2 cm. At one outcrop, nodules occur in clusters. Nodular and chromite-net (Thayer, 1969) textures may occur side by side in the same ore body.

Chemical analyses of seven samples of purified chromite presented in Table I show that they contain 39.06% to 50.66% Cr₂O₃ and their Cr/Fe varies from 2.06 to 2.53. This, together with the reciprocal relationship between Cr₂O₃ and Al₂O₃ (fig. 2), non-relationship between Cr₂O₃ and total iron and a below-16 total iron content (Thayer, 1970) shows that these chromites are chemically comparable to most other refractory grade podiform chromites of the world, such as those described by Thayer (1969, 1970), Zachos (1964), Hutchison (1972), and Jackson and Thayer (1972). Plots of the seven analyses (fig. 3) on the triangular diagram of Stevens (1944) show that six belong to the 'aluminian chromite' field and one to the 'chromian spinel' composition range. None could fall in the metallurgical grade. These chromites are more aluminous than the chromites of the alpine

type Zhob Valley igneous complex of Pakistan, most of which are of high-chromium type and metallurgical grade (Ahmad, 1972; Bilgrami, 1963; Bilgrami and Ingamells, 1960). Reflectivity, micro-hardness, and unit cell edge determinations are also reported in Table I.

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The parental basaltic magma of granites from the Isle of Skye, NW. Scotland

THE origin of the granitic rocks of the Isle of Skye might be accounted for by fractional crystallization of basaltic magma, or alternatively by melting of older sialic crust (Gass and Thorpe, 1976). We have recently argued, using rare-earth element (REE) evidence, that a fractional crystallization origin for the granites is much more likely than an origin by melting of the underlying Lewisian gneiss or Torridonian sandstone, which form the sialic basement of Skye (Thorpe *et al.*, 1977). Matthey *et al.* (1977) have reported REE data for basaltic rocks from Skye that throw more light on the origin of the Skye granites. The purpose of this note is to show that the REE data of Matthey *et al.* (1977) provide further support for a fractional crystallization origin for the Skye granites.

Matthey *et al.* (1977, p. 273) show that 'the basalts of the Skye lava pile and dyke swarm may be divided into three magma types, each of which related to others by low-pressure crystal-liquid shows internal chemical variation but cannot be processes'. These magma types fall into the broad chemical groups olivine tholeiite and alkali basalt and the three groups are: the 'Preshal Mhor' magma type, a high-calcium, low-alkali group showing depletion in light rare-earths and having $Ce_N/Yb_N < 1.0$ (Ce_N = chondrite-normalized Ce concentration); the 'Fairy Bridge' magma type characterized by a flat or light rare-earth-enriched pattern with $Ce_N/Yb_N 1.7-2.4$; and a group of basaltic rocks and their derivatives that are equivalent to the 'Skye Main Lava Series' (SMLS;