SHORT COMMUNICATIONS

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Magnesian ilmenites in picrite basalts from Siberian and Deccan Traps—additional mineralogical evidence for primary melt compositions(?)

ILMENITES with appreciable amounts of the geikielite ($MgTiO_3$) component in solid solution are uncommon in normal basaltic rocks. However, they are frequently found in rocks such as kimberlites (Mitchell, 1977), upper-mantle nodules (Haggerty, 1991), basanites (Binns, 1969; Kyle, 1981), and carbonatites (Frost and Lindsley, 1991). They have also been reported from picritic rocks (Bristow, 1984; Cawthorn *et al.*, 1988). In comparative studies on the Deccan and Siberian Traps, we have encountered magnesian ilmenites in three picritic rock samples, namely, two flows of picrite basalts from the Deccan in Western India and one from a picritic flow or sill(?) from Mt. Sundook, in the Siberian Traps.

The picritic rock sample from Mt. Sundook (located *c.* 150 km east of Noril'sk town) occurs interlayered with a sequence of basalt flows and tuff horizons (about 315 m deep) and forms part of the Gudchikhinsky suite (Zolotukin and Al'-mukhamedov, 1988). It is about 7 m thick and its contact relations with the enclosing basalts are not clear due to soil and vegetation cover. The rock is fresh, medium to fine-grained, melanocratic and fairly dense (*c.* 3.00 g cm^{-3}). In thin section it shows an intergranular to poikilo-ophitic texture comprising small granules of olivine (Fo_{78}), endiopside to diopsidic augite (Wo_{47-41} En_{52-46} Fs_{16-9}), bronzite (En_{87-76} Fs_{24-13}), plagioclase (An_{68}), chrome spinel and plates (up to 1 × 0.1 mm) of primary ilmenite, with no exsolution features. Variolitic structures are seen in the irregular devitrified patches of the groundmass. Field relations, textural features and mineralogical associations suggest a sill-like(?) form for the picrite body.

One of the picrite basalt flows (oceanite-type) of the Deccan Traps is from the Pawagarh Hill, a prominent outlier of the Deccan Traps with an elevation of a 830 m (*c.* 40 km from Baroda in Western India). It contains a thick sequence of some 40 flows comprising picrite basalts, basalts, andesites and rhyolites. The picrite basalt under study occurs at a height of 650 m and is about 20 m thick. It is strongly porphyritic and contains mainly olivine phenocrysts (Fo_{88-85}) marginally altered to iddingsite, with extremely fine-grained groundmass comprising chromian diopside (Wo_{42} En_{45} Fs_{13}), chrome spinel, plagioclase microlites (An_{45}) and magnesian ilmenite (20–30 μm across). The second sample of picrite basalt flow is from Anila, located about 100 km SW of Ahmedabad in Western India. It is from a well cutting located at a height of 30 m from mean sea level. The rock is strongly porphyritic with phenocrysts (up to 2 cm across) of olivine (Fo_{86}), chrome diopside (Wo_{47}, En_{46} Fs_7), chrome spinel, magnesian ilmenite (about 50 μm across) and plagioclase microlites (An_{52}) with a fine-grained groundmass.

The mineralogy and chemistry of the coexisting phases such as forsteritic olivines (Fo_{88-86}) in the two Deccan samples, chrome diopsidic augite (up to 1.24% Cr_2O_3 in the core), bronzite and chrome spinel in the Siberian sample indicate that they could have been derived from considerable depths (about 100 km). The Ca/(Ca + Mg) ratio (0.015) and Mg/(Mg + Fe^{2+}) ratio (0.85) of the orthopyroxene from Mt. Sundook indicate a pressure of crystallisation of >40 kbar (Hensen, 1973).

The ilmenites under study do not show any exsolution features and are homogeneous. Electron probe analyses of the three magnesian ilmenites are given in Table 1. It can be seen that the R_2O_3 contents are very minor and the MnO ranges from 0.28–0.69%. Cr_2O_3 contents (0.03–0.08%) are, however, much lower compared with those reported (0.26%) from the Lebombo picritic basalt (Bristow, 1984) and the basal picritic members of the Insizwa complex (over 1% Cr_2O_3; Cawthorn *et al.*, 1988).

The primary nature of certain types of picrite basalts in continental flood basalt provinces has been inferred from a number of studies (Basaltic Volcanism Study Project, 1981; 409–432). The commonly used diagnostic suite of minerals that indicate a primary status to the picrite basalt (>10% MgO) include forsteritic olivine, chrome diopside, and chrome spinel, phases that are in equilibrium with the host picritic liquid and which

Table 1. Electron probe microanalyses of magnesian ilmenites from Deccan and Siberian Traps

(All data in weight percent)

	1	2	3
SiO_2	0.04	0.14	0.03
TiO_2	51.97	51.06	51.78
Al_2O_3	0.20	0.27	0.09
Cr_2O_3	0.07	0.03	0.08
FeO^*	43.86	40.73	41.10
MnO	0.69	0.44	0.28
MgO	4.12	4.79	5.16
CaO	0.10	0.20	N.A
NiO	0.02	0.14	N.A
Total	101.07	97.80	98.52
Number of ions on the basis of six (O)			
Al	0.012	0.016	0.006
Cr	0.003	0.001	0.004
Fe^{+3}	0.200	0.145	0.162
Ti	1.919	1.928	1.940
Mg	0.302	0.359	0.383
Fe^{+2}	1.601	1.566	1.550
Mn	0.029	0.019	0.012
Total	4.066	4.034	4.057

*Total iron as FeO; Fe^{3+} = Fe- (Al+Cr)/2) - (Ti-Mn-Mg)

N.A. - Not analysed.

1. Pawagarh, Deccan Trap. Sample No.PB-52 (average of three analyses.
2. Anila, Deccan Trap, Sample No.SK-3-82 (one analysis)
3. Mt. Sundook, Siberian Trap. Sample No.30-GL-90 (average of four analyses)

in turn can remain in equilibrium with both fertile and barren source peridotite at upper mantle depths. We suggest here that magnesian ilmenites can also be added to the list of minerals which can provide evidence for the primary status of the picrite basalts. This is also consistent with the findings of Lovering and Widdowson (1968), Cawthorn and Groves (1985) and Cawthorn *et al.*, (1988) wherein the influence of a magnesian-rich bulk chemistry of the magma in effecting appreciable substitution by the geikielite component in ilmenites, has been indicated.

The amount of the geikielite component in ilmenite depends upon several factors such as the initial bulk chemistry (notably the MgO contents) of the host rock, depth of emplacement, duration and rate of olivine crystallisation and oxygen fugacity (cf. Haggerty, 1976). The comparative scarcity of high-magnesian ilmenites in basic suites has been attributed to the early crystallisation of olivine (Stormer, 1972). The presence of magnesian ilmenites in the three samples considered here can be attributed to the high MgO content of the host rocks—16.78% MgO in the Pawagarh sample (Krishnamurthy, 1974) and 18.26% for an analogous sample from Mt. Sundook (Sharma *et al.*, 1991). Absence of forsteritic olivines in picritic rocks are generally taken as an evidence for their cumulus origin. However, mixing of primary picritic and evolved iron-rich composition may result in picritic liquids which can crystallise olivines with relatively less forsteritic composition (K. G. Cox, pers. comm.). Therefore, picritic rocks which lack forsteritic olivines but otherwise contain minerals suggesting a primary status, as in the Mt. Sundook sample, need to be evaluated more critically.

The presence of magnesian ilmenites in some picrite basalts and their absence in others is probably indicative of the differences in the crystallisation history of the picrite, notably olivine, and probably also variations in the oxygen fugacity. Thus the presence of magnesian ilmenites in the picritic rocks as well as other mantle derived primary rock compositions clearly indicate that it could be used as important additional mineralogical evidence for inferring primary picritic compositions.

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