GEOCHEMICAL AND MICROPROBE STUDIES OF DIAMOND-BEARING ULTRAMAFIC ROCKS FROM CENTRAL AND SOUTH INDIA

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INTRODUCTION

There are five kimberlite bodies in and around Lattavaram (14°55'30"N, 77°17'30"E) and Wajrakharur, and one near Muligiripalli (14°51'N, 77°18'30"). Wajrakharur is located 9 km NNE of Lattavaram, whereas Muligiripalli lies 15 km west of Wajrakharur. All these localities are in Anantapur district of Andhra Pradesh, south India.

An ultramafic intrusive, allegedly containing diamond occurs at Chelima (15° 26' N, 78° 42' E) also in south India.

There are three kimberlite pipes near Panna (24°40'N, 80°12'E) in the state of Madhya Pradesh, central India: (1) one at Majhgawan, 20 km south of Panna, (2) one at Hinota about 3.5 km northwest of Majhgawan and (3) the third one occurring 65 km south of Majhgawan.

Kimberlites from Wajrakhurur, Anantapur District

Of the three pipes present in Wajrakharur, one lies just north of Wajrakharur village (P-1, aereal extent : 1010x180m^2, oval-shaped, trending N60°E). The second one (P-2, aereal extent 180x70m^2, sickle shaped) is located in the same village. The third one (P-6, not exposed; projected aereal extent 240x260 m^2) is situated 2 km west of the first one (P-1). Two pipes are located at a distance of 1 km (P-3) and 1.6 km (P-4) east of Lattavaram village. One of the pipes (P-3, crescent-shaped, trend, E-W) has an aereal extent of 120x40m^2. Both these pipes often include large megacrysts of olivine (up to 10 cm and 6 cm) and granitic xenoliths. The pipe at Muligiripalli is massive and extended over an area of 240x45m^2 and trend N75°E (P-5).

The chemical analyses of these ultramafic pipes are given in Tables 1 and 2. Detailed studies on the Wajrakharur kimberlites are in progress, but the analyses of the opaque phases (P-1) show that this pipe is characterised by two types of chromian spinels. The first is Mg-rich [Mg/(Mg + Fe) = 0.6] with high Cr content [Cr/(Cr + Al) = 0.79] and low concentration of Ti and without Fe^{3+} appears to be a mantle product, whereas the other one (a titaniferous chromite, poor in Mg, Al and enriched in Fe) presumably crystallised later in the kimberlitic melt. the Mg-rich ilmenite present as xenocryst in P-1, is a high pressure product. Two garnet xenocryst in P-1, is a high pressure product. Garnet xenocrysts occur in P-1 and P-6. Most are chrome pyropes belonging to garnet cluster group 9 of Dawson and Stephens but some Ti-pyropes (group 1) are also present.

The Lattavaram kimberlite is characterised by the presence of phenocrysts of olivine ($Fa_{7.26-9.53}$), phlogopite (MgO:26.63%, FeO:7.88%, TiO_2:1.69%) and chromian spinel [$(Mg_{0.52+0.03}\ Fe^{2+}_{0.49+0.03})(Cr_{1.37+0.08}\ Al_{0.47+0.03}\ Ti^{3+}_{0.07+0.02})O_4$] set in a groundmass of ankerite, perovskite, phlogopite, diopside and magnetite.

The Muligiripalli kimberlite contains phenocrystal olivine ($Fa_{15.04-16.15}$) and phlogopite (FeO:10.15%, TiO_2:1.97%, MgO:23.23%) in a groundmass of clinopyroxene (salite to diopside), K-richterite (K_2O/Na_2O ratio = 13), perovskite, calcite, phlogopite and serpentine. Studies of Kushiro and Erlank (1970) indicate that in presence of garnet, K-richterite is not stable even at 1000°C and 20 kb. It is noteworthy that garnet is absent from the Muligiripalli rock. The assemblage K-richterite, phlogopite + diopside + calcite noted in this pipe may be a low pressure product and is represented under higher pressures by the assemblage, olivine + enstatite + garnet + diopside$_2$ + fluid (containing H_2O, CO_2, K_2O, etc; Erlank and Rickard, 1977).

Majhgawan Pipe, Madhyapradesh

The Majhgawan pipe (7) occurs as a funnel-shaped body intruding into Kaimur sandstone, and was emplaced 910-940 (±30) Ma. The pipe is eliptical in cross section, trending N 30° E covering a distance of 360m, with a maximum width of 235m.

The pipe is characterised by serpentine (pseudomorphus after olivine), phenocrystal phlogopite (FeO:5.24-5.29; MgO:21.86; TiO_2:5.69-7.46%, MgO:21.20-21.86%) in a groundmass of rutile, titanomagnetite, calcite, phlogopite and serpentine. Reference to the study of Buddington and Lindsley (1964) suggests that the titanomagnetite with 15 mole % ulvospinel with ilmenite intergrowth, crystallised at 550°C under FMQ buffer. It is concluded that the talc and the carbonate phase present in the groundmass was formed by reaction between forsteritic olivine with a CO_2 and H_2O-rich vapour phase, under near surface condition at a temperature of 450 ±25°C. The chemistry of the Majhgawan pipe is summarised in Tables 1 and 2.

Chelima Dyke

The ultramafic dyke at Chelima trends WNW-ESE and intrudes a rock sequence of Upper Precambrian quartzite and shale intercalated with limestone, dolomite and cherts. Based on ancient workings within the pipe, it is speculated that the dyke was mined for diamond in the past (Sen and Rao, 1967).

A compositional plot of the Chelima dyke in a MgO-Al_2O_3-FeO diagram shows that it lies in the lamproite field, whereas the other ultramafic rocks under investigation plot in the kimberlite field. Major and minor element chemistry of the rocks are summarised in Tables 1 and 2. Bergman and Baker (1984) also consider the Chelima dyke to be carbonated lamproite.

The dyke from Chelima is characterised by phenocrystal olivine (now altered to serpentine), phlogopite (FeO:7.25-11.41%, TiO_2:4.60-5.44%) and chromium spinel set in a groundmass of rutile, serpentine, ankerite (CaO:25.08-29.29%, FeO: 7.48-8.43%, MgO:13.30-17.38%), phlogopite and pyrite. Crystallisation of primary serpentine in the groundmass is considered to be due to a reaction between talc and magnesite at a temperature of 350° ±25°C under near surface condition.

Composition of volatile phase in the kimberlites and the lamproite

Textural studies indicate that the carbonate phase in all the Indian kimberlites precipitated at a late stage. Experimental studies of Eggler and Wendlant (1979) on an average kimberlite composition under 55 kb in presence of a volatile with variable $CO_2/(CO_2+H_2O)$ suggests that such a late stage precipitation of the carbonate phases should take place when this ratio is 0:1. Study of Karrick on stability or serpentine suggests that in cases of Indian kimberlites, the ratio of $CO_2/(CO_2+H_2O)$ in the volatiles might have been 0.05 so that serpentine could crystallise in the groundmass at a late stage.

P-T and fO2 conditions of crystallisation

Thermodynamic calculation based on partitioning of Mg and Fe between olivine and chromian spinel in the Lattavaram kimberlite (P-3) suggests a temperature of equilibration between 1090 and 1220°C. This temperature range corresponds to the solidus of an average kimberlite composition (Eggler and Wendlandt, 1979) at pressures between 52-60 kb. The intersection of the Lesotho geotherm (Boyd, 1973) with the solidus of an average kimberlite composition (Eggler and Wendlandt, 1979) occurs at 52 kb and 1130°C, which is within the temperature range calculated for the Lattavaram kimberlite. The point of intersection of the CCO buffer line with the FMQ and MW buffer was considered by Rosenhauer et al (1977) to be the diamond facies region. When the temperature range of 1090-1220°C is plotted in this diamond facies region, the fO_2 condition of crystallisation is estimated to be between 10^{-7} and 10^{-8} bar.

Petrogenetic model

If a lherzolitic mantle (containing 50-60% olivine, 10-15% orthopyroxene, 25-30% clinopyroxene and 10 to 15% garnet, all in volume percentage) is assumed for peninsular India, then using the REE partition coefficients given by Frey et al (1978), it is estimated from thermodynamic calculation (Haskin, 1982) that 1.1 to 1.5% melting of such mantle materials can account for the observed abundance of La, Ce and Nd in the alkali-rich liquid fraction of the ultramafic rocks. The liquid crystallised during the ascent of the crystal-fluid mush. Most of the phenocrysts represent pre-fluidised product from the mantle.

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Table 1
Chemical analyses of Indian kimberlites from Anantapure district

	1	2	3	4	5	7	8
SiO_2	43.22	33.40	32.95	39.30	34.16	33.69	40.08
TiO_2	1.44	2.47	4.45	1.41	4.52	6.04	5.21
Al_2O_3	5.01	5.78	3.59	3.57	3.74	3.28	3.99
Fe_2O_3	4.47	8.48	7.38	4.88	12.99	-	-
FeO	2.94	2.90	5.83	4.49		10.98	9.76
MnO	0.20	0.20	0.19	0.14	0.19	0.11	0.11
MgO	15.70	17.38	20.63	29.44	20.51	24.40	15.93
CaO	20.07	17.41	12.05	7.11	12.68	3.78	7.51
Na_2O	0.12	0.74	0.32	0.21	0.43	0.11	0.06
K_2O	0.04	1.70	1.12	0.92	1.11	0.86	2.41
P_2O_5	0.90	0.95	0.86	0.42	0.91	2.65	1.41
SO_3	<0.01	0.19	0.16	0.03	0.18	1.66	0.11
BaO	0.08	0.32	0.18	0.14	0.18	3.05	0.17
Cr_2O_3	0.10	0.14	0.15	0.21	0.13	0.17	0.07
NiO	0.06	0.06	0.11	0.17			
Rb_2O	<0.01	0.02	0.01	0.01			
SrO	0.07	0.17	0.12	0.06			
ZrO_2	0.03	0.04	0.07	0.02			
I.L.	5.77	7.25	9.93	7.74	7.20	8.12	11.94
Sum	100.22	99.60	100.10	100.27	98.93	98.90	98.76

1, 2, 3, 4 and 5 represent pipes P_1, P_2, P_3, P_4 and P_5 respectively
7: Majhgawan pipe, 8: Chelima dyke. I.L.: ignition loss

Table 2
Trace element geochemistry of kimberlites and a lamproite

	3	5	7	7	8
Sc	10	19	21	23	18
V	82	237	55	80	93
Co	85	85	70	73	68
Ni	1357	779	1059	1017	538
Cu	54	114	42	91	33
Zn	79	79	80	84	72
Rb	106	147	76	80	137
Sr	680	996	1835	2035	1223
Y	14	23	35	48	41
Zr	147	388	1079	1033	958
Nb	87	138	214	214	237
La	417	778	410	382	1721
Ce	116	239	826	801	563
Nd	43	105	361	347	235
Ca	7	13	15	27	13
Th	13	21	15	*	27
Pb	9	13	41	353	6

3, 5, 7 and 8 refer to pipe 3 and 5 in and around Wajraharur; 7 and 8 designate pipes in Majhgawan and Chelima, respectively