Mineralogy and Geochemistry of Wajrakarur Kimberlites, Southern India

S. C. Patel[1], S. Ravi[2], C. R. M. Rao[2], G. Rama Rao[2] and S. S. Nayak[2]
[1]*Department of Earth Sciences, Indian Institute of Technology, Powai, Mumbai 400076, India*
[2]*Geological Survey of India, Bandlaguda Complex, Hyderabad 500068, India*

Petrography, mineral chemistry and bulk-rock major and trace element data of 42 kimberlite samples from 17 pipes covering three clusters of the Wajrakarur Kimberlite Field (WKF) of southern India allow recognition of similarities and differences in their mineralogy, and provide constraints to be placed on their genesis. The samples examined are from KL1 to KL3 pipes of the Kalyandurg cluster, P1 to P13 (except P6, P7 and P9) pipes of the Wajrakarur-Lattavaram cluster, and CC1 to CC5 (except CC3) pipes of the Chigicherla cluster. The kimberlite pipes were emplaced into the eastern Dharwar craton at ~ 1100 Ma. Most of the WKF pipes are diamondiferous.

Petrographically kimberlites from all the pipes except P1 are of macrocrystal hypabyssal facies. The P1 pipe contains tuffisitic kimberlite breccia of diatreme facies in addition to hypabyssal facies kimberlite. CC5 kimberlite is unique in that it contains spectacular globular segregations which impact the rock a pseudo-conglomeratic appearance. The globules are up to 6 cm in diameter, and sometimes show concentric or spiral structure (Fig. 1).

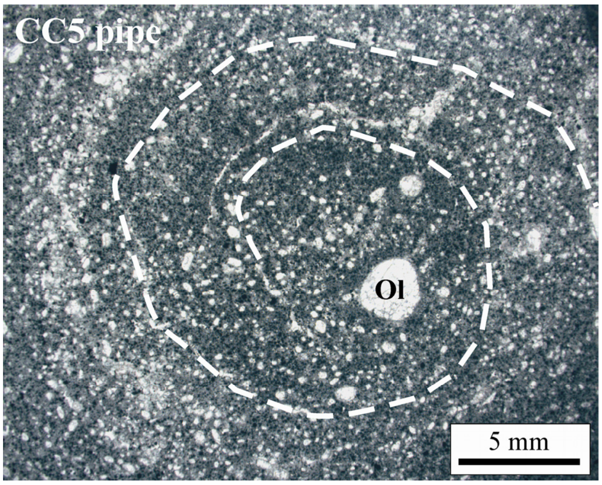

Fig. 1 Photomicrograph in plane polarized light (PPL) of a globule in CC5 kimberlite showing spiral trail (dashed line). The trail is defined by apatite and calcite. Olivine (Ol) rarely occurs as macrocryst, and is common as microphenocryst. The groundmass comprises serpentine, calcite, spinel and perovskite

The hypabyssal facies kimberlites of WKF commonly contain abundant macrocrysts and microphenocrysts of olivine in a groundmass comprising widely varying proportions of serpentine, perovskite, spinel, phlogopite, calcite and apatite. Atoll spinels are present in most of the kimberlites. Monticellite is a groundmass phase in a few pipes of the Wajrakarur-Lattavaram cluster. Groundmass phlogopite is either colourless or pleochroic in shades of reddish brown (Fig. 2). Yellowish brown to reddish brown phlogopite occasionally occurs as macrocryst. Macrocrysts of ilmenite are often present in Kalyandurg kimberlites, whereas apatite is a common groundmass phase in Chigicherla kimberlites.

Olivine is often is replaced by deuteric serpentine and calcite. In several kimberlites the groundmass contains a felted mass of fine crystals of diopside set in a serpentine base. Crystallisation of diopside appears to have been induced by the assimilation of siliceous xenoliths. The activity of silica was sufficiently high in parts of KL1 pipe to promote crystallisation of sphene. Diopside replaces macro- and microcrysts of olivine in a few kimberlites in which kirschsteinite is found as a groundmass phase (Fig. 2). Kirschsteinite seems to be a stable phase under conditions of high silica activity similar to those described by Frost and Lindsley (1992) for Fe-rich igneous systems.

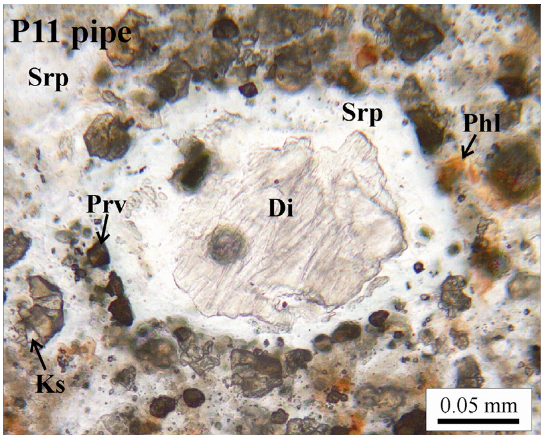

Fig. 2 Photomicrograph of kimberlite in PPL showing microphenocryst of olivine, which is pseudomorphed by serpentine (Srp) at the rim and diopside (Di) at the core. The groundmass comprises serpentine, phlogopite (Phl), kirschsteinite (Ks) and perovskite (Prv).

Compositional difference exists between anhedral macrocrysts of olivine (Fo_{91} to Fo_{94}) and macro- and micro-phenocrysts of olivine (Fo_{82} to Fo_{90}). Kirschsteinite shows a trend of enrichment in larnite component (Fig. 3).

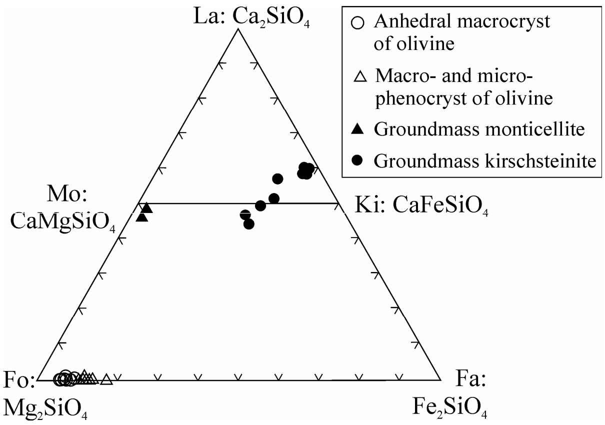

Fig. 3 Compositions of olivines plotted in the ternary system forsterite-fayalite-larnite. Monticellite analyses are from P3 kimberlite, and kirschsteinite analyses are from CC2 and P11 kimberlites.

Spinel compositions show three trends when plotted in the reduced spinel prism (Fig. 4). Trend T1 is the magmatic trend typical of archetypal kimberlites (Mitchell, 1986), and is shown by all Chigicherla kimberlites and a few Wajrakarur-Lattavaram kimberlites. All Kalyandurg kimberlites and most Wajrakarur-Lattavaram kimberlites exhibit the magmatic trend T2. This trend is uncommon in archetypal kimberlites, and is known to be present in those kimberlites which are rich in macrocrystal phlogopite. However, in the WKF the T2 trend is displayed even by those kimberlites which lack in macrocrystal phlogopite. The third trend is the AMC trend which is shown by a few macrocrysts of Al-Mg-rich chromite occurring in P10 kimberlite.

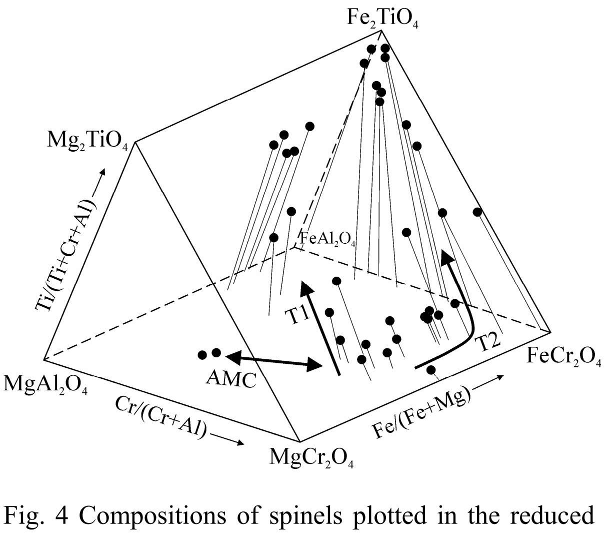

Fig. 4 Compositions of spinels plotted in the reduced spinel prism. T1 = magnesian ulvöspinel trend, T2 = Ti-magnetite trend, AMC = aluminous magnesian chromite trend

Groundmass micas of WKF kimberlites exhibit a wide range in composition (<0.6 wt% Cr_2O_3, <3.9 wt% TiO_2, 0.3-7.7 wt% BaO, 2.5-11.9 wt% FeO, 2.5-18.2 wt% Al_2O_3). Macrocrystal micas are Ba-poor (<0.1 wt% BaO), aluminous (10.5-12.5 wt% Al_2O_3) phlogopites with significant variation in Cr_2O_3 (0-2.3 wt%) and TiO_2 (1.1-5.1 wt%). The compositional variation of micas is illustrated in Fig. 5, which shows that there is an evolutionary trend towards tetraferriphlogopite. Such trend is less common in archetypal kimberlites, and more common in orangeites (Mitchell, 1995). However, tetraferriphlogopites in orangeites are commonly depleted in Ba relative to those in kimberlites. The tetraferriphlogopites of WKF kimberlites (e.g. Fig. 2) contain significant Ba (1.5-4.1 wt% BaO).

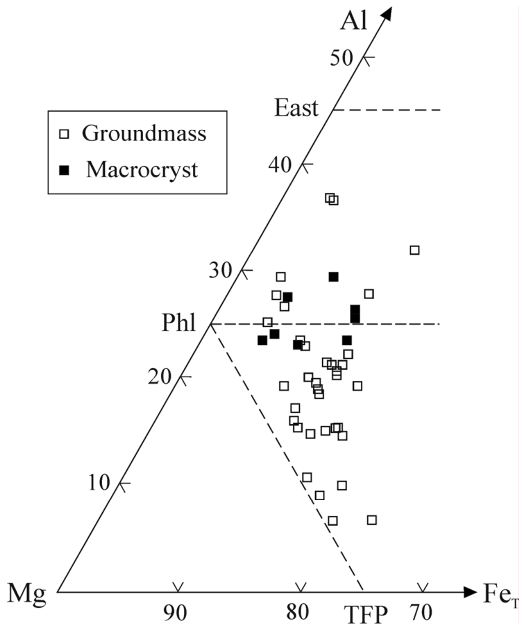

Fig. 5 Compositions of micas plotted in the ternary system Al-Mg-Fe_T. Fe_T = total iron expressed as Fe^{2+}, East = eastonite, Phl = phlogopite, TFP = tetraferriphlogopite

Perovskite is a major rare earth element (REE)-bering phase in kimberlites. Microprobe analysis of REEs in the perovskites of some WKF kimberlites yields 0.10-0.21 wt% La_2O_3, 0.39-0.51 wt% Ce_2O_3, and 0.19-0.49 Nd_2O_3.

Bulk rock major elements indicate that despite the great care that was taken in powder preparation, there is a crustal component in some samples. Nevertheless, coherent K/Rb, Y/Ce, Nb/La, Th/U ratios and REE patterns illustrate that this contamination has had mostly dilutive effect and that the kimberlites of all the three clusters form a compositionally cohesive group of rocks. K/Rb ratios vary significantly within and between pipes, and lie mostly between 50 and 100. Samples with high proportions of macrocrystal ilmenite have elevated concentrations of Nb (up to 2611 ppm) at a given La content (Fig. 6).

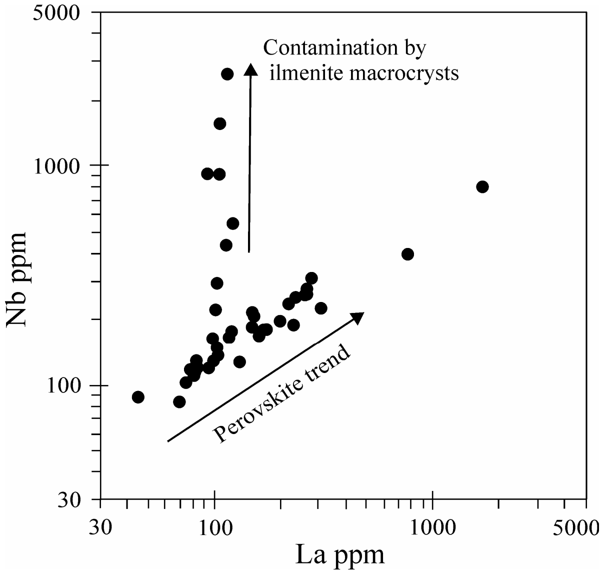

Fig. 6 Nb vs La plot for WKF kimberlites

REE patterns in all the kimberlites are remarkably smooth and parallel (Fig. 7). Fractionation of LREE against HREE is high with $(La/Yb)_N$ ratios mostly in the range of 45 to 127, and is extreme in two samples with this ratio reaching values of 216 and 393.

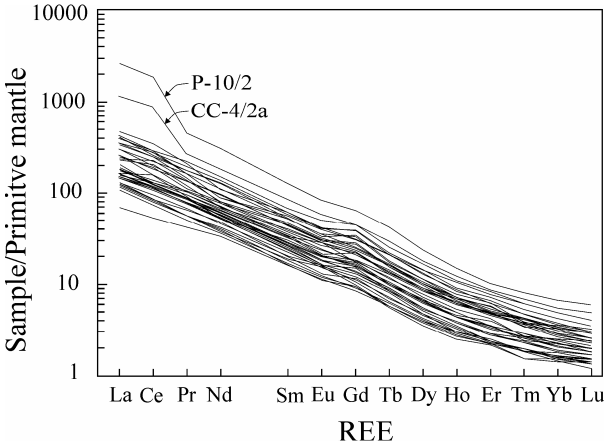

Fig. 7 Primitive mantle normalized (McDonough and Sun, 1995) rare earth element patterns for WKF kimberlites. CC-4/2a and P-10/2 are samples from CC4 pipe and P10 pipe respectively

Multielement spectra display two types of coherent patterns: Type I with a negative K anomaly of variable intensity, and Type II with negative anomalies of K, Th and Hf, and positive anomalies of U and Nb. Both patterns can be found in individual pipes. Type II pattern is displayed, although not exclusively, by samples rich in macrocrystal ilmenite.

High Ni (348-1331 ppm), Cr (547-2258 ppm) and Co (59-112 ppm) in WKF kimberlites attest to a mantle origin for the kimberlite magma. Trace element enrichment and fractionated REE patterns in the kimberlites are consistent with derivation by extensive partial melting of metasomatised mantle (Mitchell, 2004). In this model, La and Yb abundance are essentially direct reflections of the La/Yb ratios of the source regions and not the result of liquid-crystal fractionation. The occurrence of formerly majoritic garnet in a xenolith of enstatite eclogite in the KL2 pipe indicates that the kimberlite magma might have originated in the asthenospheric mantle.

References

Frost, B.R., Lindsley, D.H., 1992. Equilibria among Fe-Ti oxides, pyroxenes, olivine, and quartz: Part II. Applications. American Mineralogist, 77, 987-1003.

McDonough, W.F., Sun, S.S., 1995. The composition of the Earth. Chemical Geology, 120, 223-253.

Mitchell, R.H., 1986. Kimberlites: Mineralogy, Geochemistry and Petrology. Plenum Press, New York and London, 442 p.

Mitchell, R.H., 1995. Kimberlites, Orangeites, and Related Rocks. Plenum Press, New York and London, 410 p.

Mitchell, R.H., 2004. Experimental studies at 5-12 GPa of the Ondermatjie hypabyssal kimberlite. Lithos, 76, 551-564.