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A petrological and geochemical reappraisal of the Mesoproterozoic diamondiferous Majhgawan pipe of central India: evidence for transitional kimberlite – orangeite (group II kimberlite) – lamproite rock type

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Summary

The Mesoproterozoic diamondiferous Majhgawan pipe of central India is re-examined in the light of new and recently published petrological, geochemical and isotope data. This investigation reveals that its tectonic setting is similar to that of lamproites and orangeites (Group II kimberlite of southern Africa) and not that of a typical kimberlite. The petrography and mineralogy are comparable to lamproite and to some extent to orangeite, whereas the major element geochemistry is more akin to that of kimberlite. Trace element geochemistry is closer to that of lamproite but Nd isotope systematics are atypical of lamproite or orangeite. The inferred petrogenesis of the Majhgawan pipe is also similar to that of other such potassic 'metasomatised mantle magmas' without any strong affinity to a particular clan/group.

It is demonstrated in this study that the Majhgawan pipe shares the petrological, geochemical and isotope characteristics of all three rock types. It is therefore suggested to constitute a transitional kimberlite–orangeite (Group II kimberlite)–lamproite rock. The existence of such transitional magmas in space and time in other cratons, outside India, is also highlighted. The name *majhgawanite* is proposed for this rock – keeping in mind the antiquity of the Majhgawan pipe, its intriguing petrological and geochemical characteristics and also on the basis of India's legacy for introducing diamond to the world – to designate such mafic potassic-ultrapotassic transitional rock types so as to distinguish them from the classical kimberlite, lamproite or orangeite.

It is concluded that the correlations between kimberlite petrography, geochemistry and isotopic types (viz., Group I and II), as established for kimberlites in southern Africa, need not be necessarily valid elsewhere. Hence, the recommendations of I.U.G.S. on classification of kimberlite, orangeite and lamproite are clearly inadequate when dealing with the transitional mafic potassic ultrapotassic rocks. It is further stressed that mineralogical, geochemical and isotopic aspects of mafic potassic-ultrapotassic rocks need to be considered in unison before assigning any name as the nomenclature of such exotic and rare alkaline rock types invariably implies economic and tectono-magmatic (regional) significance.

Introduction

Diamond was first introduced to the world by India about 2500 years ago and it remained the sole producer and supplier of diamonds till the discovery of diamond fields of Brazil in 1725 and South Africa in 1880's (*Janse*, 1995). The diamondiferous Majhgawan pipe (24°38′30″ N: 80°02′ E) in the Panna area of central India, which contributes nearly 99% of India's diamond production, was reported by Captain *J. Franklin* as early as in 1827 (see *Halder* and *Ghosh*, 1978, p. 2). This was some 60 years prior to the time when the word 'kimberlite' was coined by *Henry Carvill Lewis* (1887) to the primary source rock for diamond in South Africa.

Much of the earlier work on the Majhgawan pipe mainly concerned its economic aspects and preliminary petrography (e.g. *Medlicott*, 1859; *Dubey* and *Merh*, 1949; *Merh*, 1952; *Mathur*, 1953, 1958; *Mathur* and *Singh*, 1963). *Sinor* (1930) referred to it as 'agglomeritic tuff' whereas *Dasgupta* and *Phukan* (1971) preferred to term it 'serpentine rock'. However, it was recognised to be a kimberlite or 'micaceous kimberlite' (cf *Wagner*, 1914) only in the 1970's (e.g. *Mathur* and *Singh*, 1971; *Paul* et al., 1975a,b; *Halder* and *Ghosh*, 1978, 1981) and was continued to be referred to by that name for more than a decade until *Scott-Smith* (1989) assigned a lamproitic status to it based on petrography and mineral chemistry. *Kharikov* et al. (1991) and *Chatterjee* and *Rao* (1995), however, opined that the geologic, petrographic and geochemical features of Majhgawan pipe rock are intermediate in several aspects between typical kimberlite and lamproite. Recently, *Ravi Shankar* et al. (2001, 2002), based on petrological and geochemical grounds, re-classified the Majhgawan pipe rock (and its satellite body at Hinota 24°39′ N: 80°02′ E,which is about 3 km from Majhgawan, also in the Panna area of central India) as orangeite (Group II kimberlite of South Africa). However, the latters' work was criticized by *Madhavan* (2002) for their failure to consider the landmark paper by *Scott-Smith* (1989) and also for ignoring the essential geochemical criteria such as per-alkaline and per-potassic indices as required by the typical orangeite.

These intense (and at times even passionate) debates have prompted this author to re-examine the Majhgawan pipe in light of the recently published data and in conjunction with the new geochemical data generated by him during the course of the detailed investigations on Indian kimberlites and lamproites (*Chalapathi Rao* et al., 2004). Much impetus for the present paper was, however, provided by the recent Nd isotopic work of *Lehmann* et al. (2002) which, according to the present author's opinion, is conclusive in disproving the suggestions that the Majhgawan pipe could be a lamproite (*Scott-Smith*, 1989) or a typical orangeite (*Ravi Shankar* et al., 2001, 2002).

Based on the petrological, geochemical and isotopic comparisons of the Majhgawan pipe with kimberlites, lamproites and orangeites from South Africa, southern India and elsewhere and also by taking into consideration the guide lines set by I.U.G.S Sub-commission on Igneous rock systematics for classification of kimberlites, lamproites and orangeites (*Woolley* et al., 1996), I show in this paper that the Majhgawan pipe cannot be uniequivocally characterized as a kimberlite or orangeite or lamproite. This pipe, in fact, inherits the traits of all these above three rocks and hence is suggested to constitute a transitional kimberlite–orangeite–lamproite rock type. The significance of this recognition is also highlighted.

Geological and tectonic aspects of Majhgawan pipe

The Majhgawan pipe intrudes the Baghan Quartzite formation of the Kaimur Group which is part of the Vindhyan Super Group (Fig. 1). The latter includes Meso- to mid Neo-Proterozoic rocks with an age range from 1631 ± 8 Ma (*Ray* et al., 2003) to ~550 Ma (*Crawford* and *Compston*, 1970). The Vindhyan sediments are believed to overlie the Archaean basement of the Bundelkhand craton comprising primarily granites and gneisses along with small enclaves of older metamorphic rocks and basic and ultrabasic intrusive rocks (*Naqvi* and *Rogers*, 1987). The southern margin of the Vindhyan basin is flanked by a major tectonic lineament of the Indian sub-continent, the Narmada-Son lineament, which is considered to have been formed along the Archaean structural trends and remained active throughout the geological history till the present day (*Naqvi* and *Rogers*, 1987; *Chakraborty* and *Bhattacharya*, 1996). Seismic investigations have revealed the existence of several E-W oriented deep fractures underlying the Vindhyans, some of which extend down to the Moho (*Kaila* et al., 1989). These fractures have been interpreted to be of Archaean age and vertical movements along them have been inferred to have occurred at different times during the deposition of the Vindhyan sediments (*Kaila* et al., 1989). The Majhgawan pipe occurs on the western limit of the Panna diamond belt (80×50 km) and is localized in a NE-SW to ENE-WSW trending crestal zone of the upwarped eastern margin of the Bundelkhand craton (*Halder* and *Ghosh*, 1978). According to *Janse* (1992) the Majhgawan pipe is located at the margin of the Aravalli Archon (Bundelkhand craton).

The Majhgawan pipe is pear-shaped on the surface with dimensions of 500 m×330 m with its western end showing a slight pointed bulge (*Halder* and *Ghosh*, 1978). Payable body is elliptical in shape, 320 m×280 m in size and has a surface area of 6.5 ha (*Indian Bureau of Mines*, 1996). This pipe has been drilled to a depth of about 250 m and it has the shape of a cone and the contact with the host rock dips at fairly constant angle of 70° to 80° inwards (*Halder* and *Ghosh*, 1978; *Chatterjee* and *Rao*, 1995). Eventhough the shape of the Majhgawan pipe is dissimilar to that of many known lamproite occurrences (*Mitchell* and *Bergman*, 1991), it should be mentioned here that the highly diamondiferous Argyle lamproite (also of Meso-Proterozoic age) in Western Australia also has steep contacts with the host rocks (*Jaques* et al., 1989). Thus, the Majhgawan pipe is more similar

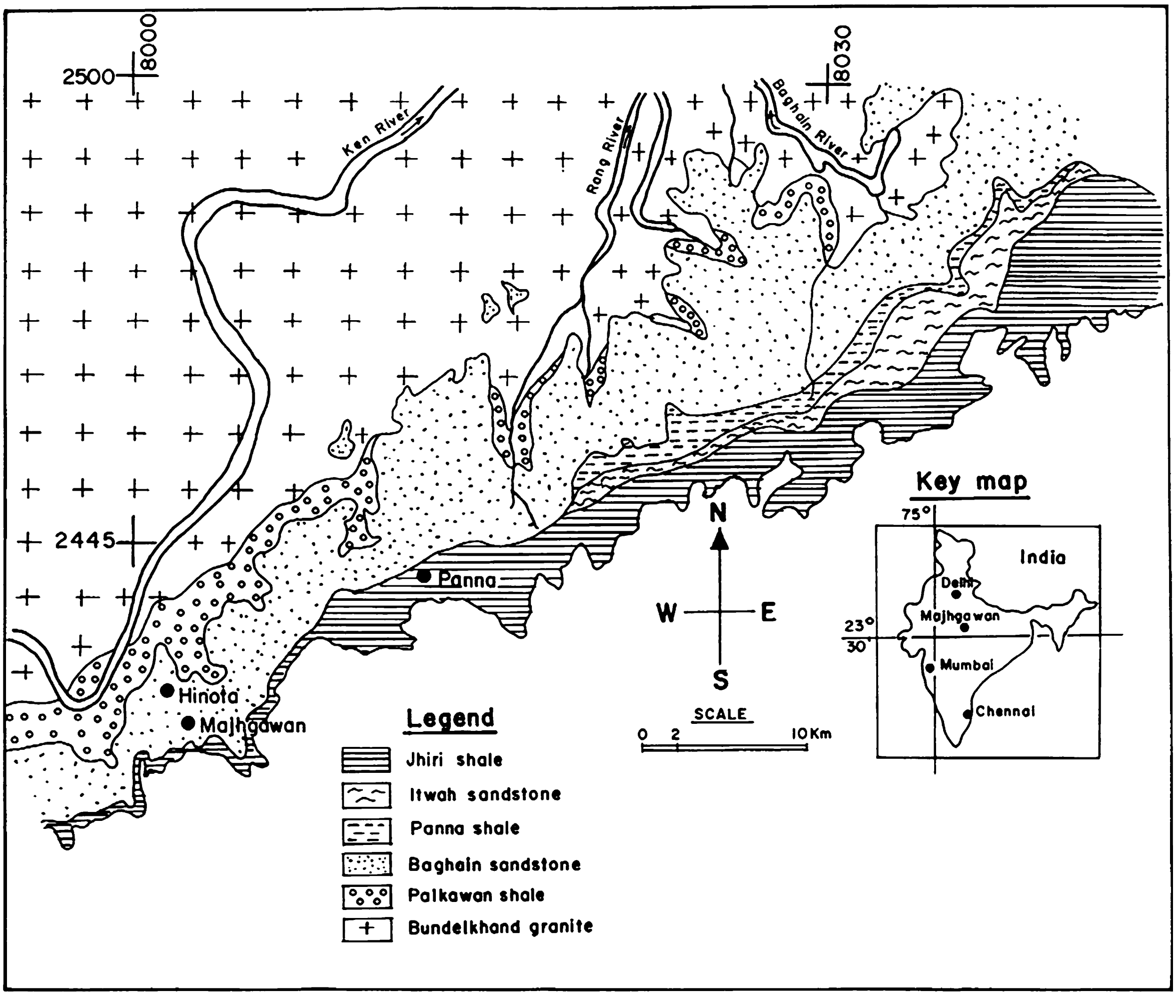

Fig. 1. Location of the Majhgawan pipe in the Vindhyan basin of central India (adopted from *Chatterjee* and *Rao*, 1995)

in shape and form to kimberlites than lamproites, as the former in all cases have diatremes sloping at an average 82° – the shape of all deep explosive vents.

Sinor (1930) termed the Majhgawan pipe rock to be an 'agglomeritic tuff'. Subsequently, different varieties of pipe rock have been recognized i.e., yellow green volcanic rock, dark coloured volcanic rock and weathered tuffaceous material (*Mathur* and *Singh*, 1971). *Scott-Smith* (1989) suggests that the Majhgawan pipe is an example of lamproitic crater composed predominantly of volcaniclastic rocks and marked by absence of typical infilling of kimberlite pipes and intrusive tuffisitic kimberlite breccias.

From an extensive study of about 450 kimberlites, lamproites and lamprophyres in Australia, *Jaques* and *Milligan* (2003) have recently concluded that typical kimberlites occur within and at the margin of the Archaean cratons, lamproites at the cratonic margins and near mobile belts and lamprophyres at margins of cratons only. Likewise *Skinner* et al. (1992), from the distribution of

229 orangeites and 580 archetypal kimberlites in the Kaapvaal craton of southern Africa have shown that orangeite (Group II kimberlite) occurrences are found predominantly at the edge of the Kaapvaal craton whereas those of kimberlites are characterisitically confined to on-cratonic settings.

Thus, it can be inferred that the disposition of the Majhgawan pipe at the cratonic margin of the Bundelkhand craton has more similarities to the tectonic setting of a lamproite or orangeite than a kimberlite.

Geochronological aspects

Radiometric age determinations of Majhgawan pipe carried out by different workers are summarised in Table 1. Considering that the whole rock ages are likely to be less reliable than the age determinations made on the groundmass phlogopite mineral separates, the age of the pipe can be accepted to be close to 1060 Ma thereby implying its emplacement in the Mesoproterozoic.

The Group I kimberlites (kimberlite *sensu stricto*) of similar age are those of Premier (1202 ± 72 Ma; *Kramers* and *Smith*, 1983) and National (1180 ± 30 Ma; *Allsopp* et al., 1989) in the Kaapvaal craton of South Africa and also those at Wajrakarur, Lattavaram, Muligiripalle, Mudalabad and Kotakonda in the Dharwar craton of southern India whose ages range from 940–1150 Ma (*Paul* et al., 1975a; *Basu* and *Tatsumoto*, 1979; *Anil Kumar* et al., 1993, 2001a; *Chalapathi Rao* et al., 1996, 1999). Likewise, the lamproites of Argyle (1126 ± 9 Ma; *Skinner* et al., 1985), Western Australia and Zangamarajupalle (1070 ± 22 Ma; *Anil Kumar* et al., 2001a), southern India, are of comparable age to the Majhgawan pipe. Orangeites (Group II kimberlite), on the other hand, have so far known to be confined only to southern Africa and are much younger with an age range of 110 Ma to 200 Ma (*Skinner*, 1989; *Mitchell*, 1995a).

Even though, *Kent* et al. (1998a, b) tentatively term the ultramafic intrusions (113–116 Ma) in the Damodar Valley of Eastern India to be orangeites, this inference appears to be drawn more from the similarities in the mineralogical and radiometric age data rather than on chemical and isotopic grounds (*Madhavan*, 2002). The Damodar Valley rocks indeed appear to be transitional rocks which cannot be uniequivocally assigned to the orangeite, kimberlite and lamproite clans

Table 1. *Radiometric age determinations of the Majhgawan pipe*

Radiometric method	Age in Ma	Reference
K–Ar (Phl)	1056	*McDougall* in *Crawford* and *Compston* (1970)
Rb–Sr (Phl)	1140 ± 20*	*Crawford* and *Compston* (1970)
K–Ar (W.R.)	974–1170	*Paul* et al. (1975a)
Rb–Sr (W.R.)	1630 ± 353	*Paul* (1979)
Rb–Sr (Phl)	1044 ± 22	*C. B. Smith* in *Anil Kumar* et al. (1993)
Rb–Sr (Phl)	1067 ± 31	*Anil Kumar* et al. (1993)

Phl Phlogopite; *W.R.* Whole rock; * recalculated using ^{87}Rb decay constant of 1.42×10^{-11} yr^{1} (*Steiger* and *Jäger*, 1977)

(*Middlemost* et al., 1988; *Rock* and *Paul*, 1989; *Basu* et al., 1997). The available radiometric dates of similar transitional kimberlites rocks, elsewhere (see Table 7 for details and references) suggests that they range in age from 1732 ± 82 Ma (Guaniamo; Venezuela) to 85 Ma (Tres Ranchos; Brazil).

Thus, the emplacement age of the Majhgawan pipe is indistinguishable from that of an archetypal kimberlite, lamproite and transitional kimberlite but dissimilar to that of an orangeite.

Petrography and mineralogical aspects

Detailed petrological studies on the Majhgawan pipe carried out by a number of previous workers (e.g. *Mathur* and *Singh*, 1971; *Dasgupta* and *Phukan*, 1971; *Paul* et al., 1975a; *Kresten* and *Paul*, 1976; *Halder* and *Ghosh*, 1978, 1981; *Middlemost* and *Paul*, 1984; *Gupta* et al., 1986; *Scott-Smith*, 1989; *Ravi Shankar* et al., 2001, 2002) have revealed that, all the rock material so far obtained from Majhgawan pipe represents different varieties of magmaclastic agglomeritic tuff. The tuffs contain juvenile lapilli or magmaclasts which could be described as being of magmatic derivation. These magmaclasts are macrocrystic as they contain two generations of altered olivine, viz., large, anhedral and corroded macrocrysts (which could be xenocrysts) as well as subhedral to euhedral phenocrysts (representing primary olivines crystallised from the magma). Both these altered olivine types are set in a fine to cryptocrystalline, brownish and turbid groundmass predominantly consisting of serpentine group minerals, iddingsite, phlogopite, glass, apatite, carbonate minerals (calcite and dolomite), illite, vermiculite, montmorillonite, polygarskite, perovskite, rutile, chlorite, spinel group minerals, barite and diamond. The groundmass occasionally contains vesicles and juvenile lapilli tuffs. The pipe rock is also traversed by numerous veinlets of calcite, especially in the uppermost portion.

It should be emphasized here that much of the earlier work has been carried out by employing the conventional transmitted and reflected light microscopy. Hence, only those minerals identified by different workers by employing various electron beam and X-ray methods are summarized in Table 2 and compared and contrasted with the mineralogy of the archetypal kimberlite, lamproite and orangeite. The representative compositions of various mineral phases are summarized in Table 3. The salient petrographic details of selected minerals and their chemistry, where data are available, are provided below.

Olivine

Olivine has been completely altered and no chemical analyses for fresh olivine are available (*Dasgupta* and *Phukan*, 1971; *Paul*, 1991). Serpentine is the major alteration phase but iddingsite also forms an important alteration phase (*Mathur* and *Singh*, 1971). The olivine macrocrystals (mostly <5 mm, but rarely up to 10 mm) are predominantly anhedral and occasionally subhedral. The smaller phenocrysts (<0.5 mm) are euhedral. A few of the megacrysts have also been replaced by carbonates (*Middlemost* and *Paul*, 1984). Some of the olivine macrocrysts exhibit

Table 2. *Comparison of the mineralogy of Group I kimberlites, orangeites and lamproites with the Majhgawan pipe*

Mineral	Kimberlite*	Orangeite*	Lamproite**	Majhgawan diatreme	References
Olivine:					
Macrocryst	Abundant	Common	Rare	Present (complex shaped)	1, 2, 3
Phenocryst	Common (subhedral to euhedral)	Common (subhedral/ euhedral/skeletal)	Common Resorbed/dog's tooth	Abundant (crystal aggregates) Both are thoroughly serpentinised; No fresh olivine ever reported	
Mica (Phlogopite):					
Macrocryst	Minor	Common	Rare	All the three types of grains present. Phenocrystal & groundmass micas are typically Fe and Ti-enriched and Al-poor.	2, 3, 5
Phenocryst	Common	Abundant	Common (Ti-rich)		
Groundmass	Common	Abundant, Ti-poor, Fe rich	Common, Ti-Fe rich		
Spinels	Large (0.01–0.1 mm), Mg chromite to Mg ulvospinel	Mg chromite common, Mg ulvospinels absent	Rare, Mg chromite – Ti-magnetite	Magnetite, magnesio-chromite and titano-magnetite present	5
Monticellite	Common	Absent	Absent	Absent/not reported	–
Diopside	Primary diopside absent	Common to rare; zoned to Ti-aegirine	Common; Al–Ti-poor	Clinopyroxene microlites present	3

(*continued*)

Table 2 (*continued*)

Mineral	Kimberlite*	Orangeite*	Lamproite**	Majhgawan diatreme	References
Perovskite	Common; SrO poor (<1 wt%) and $(REE)_2O_3$ poor (<7 wt%)	Rare; SrO (<1 wt%) and $(REE)_2O_3$ rich (3–16 wt%)	Rare; Sr-REE rich	Present but rare	2, 3
Apatite	Common	Abundant; Sr-REE rich	Common; Sr-REE rich	Common (F-rich)	1
Carbonates	Common; calcite (mostly) & dolomite (rarely)	Common; calcite, Common: Sr–Mn–Fe dolomites, minor witherite, strontianite, norsethite	Primary carbonate absent. Secondary carbonate may be present.	Both primary and secondary varieties of calcite present Minor dolomite present	1, 4 2
Serpentine	Abundant secondary lizardite	Common secondary	Rare secondary	Abundant; secondary (mostly lizardite)	1, 2, 3, 5
Sanidine	Absent	Rare	Common	Absent/not reported	–
K-richterite	Absent	Rare	Common	Absent/not reported	–
K–Ba Hollandite	Very rare	Common	Common	Absent/not reported	–
Mn-Ilmenite	Rare	Common	Very rare	Present (Mg-rich and Mn-poor)	2, 5
Zr silicates	Very rare	Common	Common	Absent/not reported	–
Leucite	Absent	Rare	Common	Absent/not reported	–
Barite	Rare	Common	Common	Present	2, 4, 5
Rutile	Common (Nb & Cr-rich; Fe-poor)	Common (Nb-rich)	Uncommon	Present (Nb-poor & Cr-poor)	5
Glass	Absent	Absent	Present	Present	3
Quartz	Absent	Minor	Absent	Present	4, 5
Monazite	Absent	Present	Absent	Present	4, 5

Data source: * *Mitchell* (1995a), *Hammond* and *Mitchell* (2002); ** *Mitchell* (1996); *1 Kresten* and *Paul* (1976); *2 Middlemost* and *Paul* (1984); *3 Scott-Smith* (1989); *4 Ravi Shankar* et al. (2001); *5 Ravi Shankar* et al. (2002)

Table 3. *Mineral chemistry data (electron microprobe analyses) for the various mineral phases in the Majhgawan pipe*

Oxides (wt%)	Serpentine				Glass matrix		Baryte	Dolomite	Ilmenite	Monazite	Rutile	Phlogopite (Macrocrysts)		Phlogopite (Phenocrysts)			
	1	2	3 (n = 22)		4	5	6	7	8	9	10	11	12	13	14	15	16
			x	s			n = 2	n = 3						n = 5			
SiO_2	41.40	38.28	40.62	(2.0)	36.64	41.88	–	–	nd	–	–	39.75	37.67	40.08	–	38.85	39.19
TiO_2	0.38	0.45	11.00	–	4.24	0.15	–	–	52.13–53.69	–	84–96	6.15	6.40	5.16	6.66	7.24	6.95
Al_2O_3	1.29	2.77	2.00	(0.93)	5.92	3.62	–	–	<0.1	–	–	11.97	11.33	11.51	–	12.81	12.40
Cr_2O_3	nd	nd	–	–	nd	nd	–	–	<0.1	–	0.16–0.40	0.06	0.76	–	–	1.24	0.84
FeO_T	6.30	7.18	9.26	(2.48)	7.80	6.81	–	2.38	41.67–43.44	–	0.67–1.62	5.07	4.50	5.40	5.26	5.53	4.76
MnO	0.05	0.06	0.08	(0.05)	0.08	0.06	–	3.88		–	<1	0.03	nd	–	–	0.03	0.04
MgO	38.31	30.40	35.86	(1.75)	22.74	30.44	–	18.74	<0.1	–	–	22.86	22.39	22.80	21.86	21.22	21.78
CaO	0.02	4.11	–		0.07	0.13	–	29.52	0.4	1.5–5.7	–	0.02	nd	–	–	0.02	0.03
Na_2O	0.02	0.05	–		5.81	0.04	–	–		–	–	0.08	0.12	–	–	0.08	0.08
K_2O	0.01	0.37	–		0.06	0.11	–	–		–	–	10.13	10.45	10.07	–	10.16	10.36
NiO	0.04	0.08	–		0.06	0.12	–	–	<0.1	–	<1	0.10	–	–	–	0.13	0.11
Cl	–	–	–		–	–	–	–		–	–	–	–	–	–	–	–
F	–	–	–		–	–	–	–		–	–	–	–	–	–	–	–
P_2O_5	–	–	–		–	–	–	–		19.4–22.5	–	–	–	–	–	–	–
BaO	–	–	–		–	–	64.79	–		–	–	–	–	–	–		
SO_3	–	–	–		–	–	34.46	–		–	–	–	–	–	–		
REE_2O_3	–	–	–		–	–	–	–		53–66	–	–	–	–	–		
Nb_2O_5	–	–	–		–	–	–	–		2.1–3.4	–	–	–	–	–		
ZrO_2	–	–	–	–	–	–	–	–	–	–	0.08–2.77	–	–	–			
Total	87.82	83.75	87.9		88.73	83.36	99.25	–		–		96.22	93.62	95.0		96.31	96.54

Data source: *1, 2, 4, 5, 11, 15 and 16 Scott-Smith* (1989); *3, 6, 7 and 13 Middlemost* and *Paul* (1984); *8, 9 and 10 Ravi Shankar* et al. (2002); *12 Mukherjee* et al. (1997); *14 Gupta* et al. (1986); *nd* not detected; (–) not reported/measured complex shapes (probably imposed morphology) whereas certain phenocrysts occur as crystal aggregates. *Scott-Smith* (1989) considers such olivines to be atypical of kimberlites but similar to those of olivine lamproites at Ellendale and Argyle of Western Australia (*Jaques* et al., 1986), Prairie Creek in Arkansas (*Scott-Smith* and *Skinner*, 1984a) and Kapamba in Zambia (*Scott-Smith* et al., 1989).

Serpentine

Serpentine occurs predominantly as an alteration product pseudomorphous after olivine. Its chemical composition is more or less constant (Table 3) with high FeO_T contents (6.30 to 9.26 wt%) and corresponds to that of a lizardite. *Middlemost* and *Paul* (1984) remark that such high-Fe serpentines are unique to kimberlites (cf *Emeleus* and *Andrews*, 1975).

Phlogopite

Distribution of phlogopite in the pipe is erratic but it constitutes an important phase (*Paul* et al., 1975a). Phlogopites of the Majhgawan pipe are generally pleochroic ranging from pale brown to orange colour. Phlogopites of three parageneses have been recorded- (i) macrocrysts (up to 4 mm), which are anhedral to subhedral and erratically distributed in the pipe, (ii) phenocrysts (up to 1.5 mm) which are most

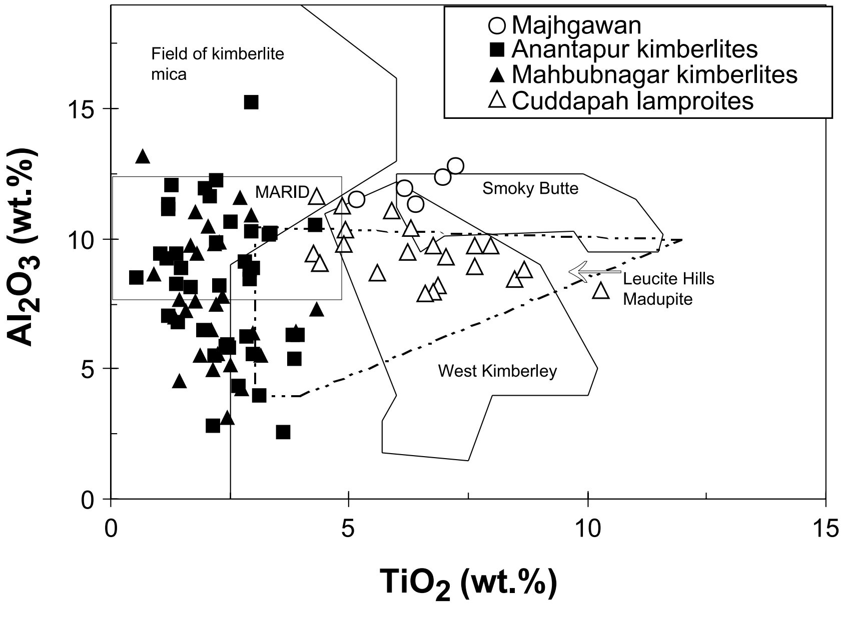

Fig. 2. TiO_2 versus Al_2O_3 for micas from the Majhgawan pipe compared to those from other areas. Fields for selected Group I and II kimberlites, lamproites, and the MARID (Mica–amphibole–rutile–ilmenite–diopside) suite of xenoliths are from: *Dawson* and *Smith* (1977); *Smith* et al. (1978); *Scott-Smith* et al. (1989); *Mitchell* and *Bergman* (1991). The data for the Anantapur and Mahbubnagar kimberlites and the Cuddapah lamproites (India) are from *Chalapathi Rao* et al. (2004)

abundant and occur as slender laths, the majority of them displaying polysynthetic twinning and (iii) groundmass microphenocrysts (0.04 mm) present as lath-like equant crystals (*Middlemost* and *Paul*, 1984; *Scott-Smith*, 1989). There is little difference in the composition of macrocrysts and phenocrysts (Table 3) except for relatively high TiO_2 and FeO_T contents in the phenocrysts. Their mg# is >80. The phlogopites are clearly titanium-enriched in contrast to the titanium-poor micas of archetypal kimberlites (*Mitchell*, 1995a).

In the TiO_2 versus Al_2O_3 (wt%) bivariate plot (Fig. 2) the phlogopites of the Majhgawan pipe compositionally vary similar to the lamproite micas (*Scott-Smith*, 1989); they differ from kimberlites, orangeites and MARID-suite of xenoliths.

Glass

Devitrified glass constitutes an important phase in the groundmass (*Mathur* and *Singh*, 1971; *Scott-Smith*, 1989) and its composition is given in Table 3. The low totals for glass are probably due to high water content. The occurrence of glass is uncommon in archetypal kimberlites and orangeites (*Kent* et al., 1998a) but is well known from lamproites (*Scott-Smith* and *Skinner*, 1984b; *Dawson*, 1987).

Other accessory phases

Monazite and barite are present in the Majhgawan pipe. Monazite is also known to occur in orangeites of Southern Africa but is atypical of archetypal kimberlites and lamproites (Table 2). Even though barite is uncommon in lamproites, many of the Australian lamproites do contain a relatively high proportion of it (*E. M. W. Skinner*, pers. comm. 2003). Magnetite, magnesio-chromite and titano-magnetite constitute the spinel group minerals (*Ravi Shankar* et al., 2002). Hematite, leucoxene, ilmenite, rutile, anatase and perovskite are the other various identified opaque mineral phases (*Mathur* and *Singh*, 1971). A number of heavy minerals such as ilmenite, kyanite, epidote, clinozoisite, spinel, zircon, garnet and tourmaline have been reported from the pipe (*Venkataraman*, 1960; *Grantham*, 1964). Pyrite, chalcopyrite, sphalerite and pentlandite constitute the reported sulphide phases (*Ravi Shankar* et al., 2002).

The petrographical and mineralogical aspects of the Majhgawan pipe reveal that their utility in the nomenclature of the pipe rock is not straight-forward. It is also pertinent to note here that even though *Ravi Shankar* et al. (2001) remark that "there was hardly any attempt at investigating the chemistry of mineral constituents" by previous workers, such data are indeed available in the literature (e.g. *Middlemost* and *Paul*, 1984; *Gupta* et al., 1986 and *Scott-Smith*, 1989). The complex morphology of olivine macrocrysts, presence of glass and scoracious juvenile lapilli and titanium-rich phenocrysts of phlogopite are indeed characterisitic features of lamproites, as first suggested by *Scott-Smith* (1989). To date, vesicles and glass are common only in Forte a la Corne type kimberlites in Canada (*E. M. W. Skinner*, pers. comm. 2003) and are not found in kimberlites of South Africa. However, primary carbonate (see Table 2) is atypical of the lamproites (*Dawson*, 1987; *Hammond* and *Mitchell*, 2002). On the other hand, monazite and barite are reported from orangeites but uncommon in archetypal kimberlite or lamproite

(Table 2; see also *Ravi Shankar* et al., 2001). Thus, it can be inferred that the petrography and mineralogy of the Majhgawan pipe is more similar to that of a lamproite and to some extent that of an orangeite than that of an archetypal kimberlite.

Geochemical aspects

During this investigation, it has become increasingly clear that even though a lot of geochemical data has been built up over the years on the Majhgawan pipe, it predominantly concerns the major oxides (e.g. *Paul* et al., 1975a; *Halder* and *Ghosh*, 1981; *Paul* and *Rock*, 1989; *Paul*, 1991). Major oxide and trace element (including REE) data analysed for the *same* samples of the Majhgawan pipe are extremely few and even those available (e.g. *Gupta* et al., 1986; *Paul* et al., 1975b) do not include concentrations of all the trace elements of petrological interest. The major oxide and trace element data of the Majhgawan pipe are provided in Tables 4 and 5 respectively. Some of the critical major and trace element ratios are given in Table 6 and are compared and contrasted with those from elsewhere.

Table 4. *Major element (oxide wt%) data of the Majhgawan pipe*

Oxide (wt%)	MJW	M	MG6	MG50	UG11a	UG191	7	H & G
SiO_2	37.94	34.82	36.29	34.82	34.90	36.50	33.69	34.39
TiO_2	4.79	5.7	5.11	4.62	5.51	3.76	6.04	6.00
Al_2O_3	2.90	2.88	2.63	3.93	2.79	6.07	3.28	2.53
$Fe_2O_3^{*}$	8.94	10.49	6.39	4.42	6.62	3.87	–	6.53
FeO	–	–	2.32	3.06	3.22	3.85	10.98	3.08
MnO	0.14	0.19	0.14	0.19	0.16	0.14	0.11	0.11
MgO	29.85	25.73	26.29	27.28	23.73	25.45	24.4	24.72
CaO	2.58	3.63	3.10	3.67	3.58	3.40	3.78	5.37
Na_2O	0.02	0.26	0.05	0.06	0.21	0.18	0.11	0.15
K_2O	0.77	0.81	0.55	0.73	0.89	1.21	0.86	0.68
P_2O_5	1.82	2.47	1.89	2.28	2.45	1.87	2.65	2.34
H_2O^+	–	–	9.62	9.79	9.67	9.33	–	–
H_2O^-	–	–	5.15	4.22	4.99	3.37	–	–
H_2O_T	–	–	–	–	–	–	–	12.45
CO_2	–	–	0.24	0.39	0.45	0.74	–	0.76
SO_3	–	–	–	–	–	–	1.66	–
BaO	–	–	–	–	–	–	3.05	–
Cr_2O_3	–	–	–	–	–	–	0.17	–
LOI**	10.32	11.84	–	–	–	–	8.12	–
Total	99.96	98.82	99.77	99.46	99.26	99.74	98.90	99.11
C.I.***	1.33	1.39	1.45	1.39	1.42	1.60	1.47	1.46
Ilm. I****	0.44	0.59	0.50	0.42	0.60	0.41	0.60	0.60

Data source: *MJW* this work; *M Lehmann* et al. (2002); *MG6, MG50, UG11a and UG191 Paul* et al. (1975b); *7 Gupta* et al. (1986); *H & G* average of ten analyses from *Halder* and *Ghosh* (1981); * total iron; ** Loss on Ignition; *** Contamination Index (*Clement*, 1982); **** Ilmenite Index (*Taylor* et al., 1994)

Table 5. *Trace elements, including REE, (in ppm) chemistry of Majhgawan pipe*

Trace elements (ppm)	MJW	M	MG6	MG50	UG11a	UG191	7
Ba	1884	1734	7760	1640	7260	2400	–
Cr	1456	996	–	–	–	–	–
Cs	3.39	–	–	–	–	–	–
Cu	44	52	–	–	–	–	42
Hf	20.3	5.1	19.3	24.5	23.8	16.7	–
Nb	177.3	228	–	–	–	–	214
Ni	1455.9	1071	–	–	–	–	1059
Pb	20.2	23.5	–	–	–	–	41
Rb	39.4	56.3	–	–	–	–	76
Sc	17.1	19	–	–	–	–	21
Sr	1043.7	1694	–	–	–	–	1835
Ta	11.67	16	13	15.5	16.8	10.1	–
Th	12.8	16.2	12.8	16.8	16.1	17.6	15
U	3.06	3.5	–	–	–	–	–
V	52.8	33	–	–	–	–	55
Y	15.57	26.5	–	–	–	–	35
Zn	62	85	–	–	–	–	80
Zr	754.7	973	–	–	–	–	1079
REE							
La	186	239	156	188	179	161	410
Ce	423.7	525	371.8	508.8	472.7	332.3	826
Pr	50.73	66.6	–	–	–	–	–
Nd	185.3	230	159	241.9	225.9	140.5	361
Sm	24.9	29.3	22.5	31.9	33.3	22.2	–
Eu	6.26	7.08	5	6.5	6.5	5.2	–
Gd	20.23	16.4	8	16.8	17.8	9.8	–
Tb	1.68	1.74	1.32	1.85	2.07	1.81	–
Dy	5.09	7.41	–	–	–	–	–
Ho	0.73	1.09	–	–	–	–	–
Er	1.32	2.24	–	–	–	–	–
Tm	0.16	0.24	–	–	–	–	–
Yb	1	1.31	0.98	1.3	1.33	1.98	–
Lu	0.1	0.21	0.11	0.12	0.13	0.29	–

Data source: *MJW* This work; *M Lehmann* et al. (2002); *MG6, MG50, UG11a and UG 191 Paul* et al. (1975b); *7 Gupta* et al. (1986)

Whole-rock XRF (X-Ray fluorescence) analyses for major and some trace elements (Sr, Rb, Zn, Cu, Ni, Cr, V and Sc) of *MJW sample* (Tables 4 and 5) were carried out at the Grant Institute of Geology and Geophysics, University of Edinburgh, using a Philips PW 1480 automatic XRF spectrometer. The procedure described by *Norrish* and *Hutton* (1969) was adopted. Major element data quality was assessed by several repetitions as well as by employing internal standards. Typical uncertainties for major oxides are <5% and <10% for trace elements.

Table 6. *Average major element and trace element ratios of selected rock types*

Ratio	Majhgawan diatreme India	Olivine lamproite*	Aries kimberlite (Australia)*	Cuddapah lamproites (India)**	Koidu kimberlite (West Africa)*	Group-I kimberlite (South Africa)*	Orangeite (South Africa)*	Anantapur kimberlites (India)**	Mahbubnagar kimberlites (India)**
FeO_T/MgO	0.33	0.33	0.4	0.73	0.34	0.32	0.30	0.49	0.61
Ni/MgO	41.84	34	61	43.63	42	40	49	50.27	36.44
TiO_2/K_2O	6.62	0.84	0.48	1.87	1.27	1.7	0.42	2.31	7.69
Nb/Zr	0.23	0.2	4.2	0.28	2.7	1.1	0.48	1.13	0.55
Ba/Rb	39.34	20	12	13.2	24	26	19	24.43	17.53
Nb/La	1.09	0.8	1.7	0.74	1.4	1.8	0.7	1.33	1.57

Data source: Majhgawan pipe (this work; Tables 4 & 5); * from *Taylor* et al. (1994); ** *Chalapathi Rao* et al. (2004)

Rare Earth Elements (REE) and trace elements (Y, Zr, Nb, Cs, Ba, Hf, Ta, Pb, Th and U) of *MJW sample* (Table 5) were analysed using a VG Plasma Quad PQ2 STE machine at the NERC ICP-MS facility at Silwood Park, Ascot, London. Samples were prepared following the open digestion method of *Jarvis* (1988, 1990). Overall, the difference in concentration for individual LREE and MREE in replicate samples is in general <10%.

Major elements

Kimberlites and lamproites incorporate varying proportions of crustal and mantle xenoliths during their rapid ascent from the mantle to the Earth's surface. As a result, the bulk composition of the magma seldom approximates to primary magma. The contamination index (C.I.) of *Clement* (1982) is widely used in kimberlite/lamproite petrology (*Mitchell*, 1986; *Taylor* et al., 1994; *Beard* et al., 2000) to assess the role of crustal assimilation on the bulk chemistry of samples where C.I. = $(SiO_2 + Al_2O_3 + Na_2O)/(MgO + K_2O)$. In altered and highly contaminated rocks, this index is of little use in assessing the role of crustal contamination. Kimberlites with a C.I. < 1.4 are generally regarded as uncontaminated or fresh. The C.I. values for the majority of the samples (Table 4) of Majhgawan pipe are low and vary from 1.3 to 1.4.

The Ilmenite Index (Ilm. I) of *Taylor* et al. (1994) is also used to identify kimberlites and lamproites that may have accumulated ilmenite megacrysts and xenocrysts. This index is defined as: Ilm. I = $(FeO_T + TiO_2)/(2K_2O + MgO)$. Samples with Ilm. I < 0.52 are regarded as uncontaminated. The Ilm. I for majority of the Majhgawan pipe samples is either <0.52 or close to it (Table 4). The Ilm. I *vs* C.I. plot (Fig. 3) clearly depicts the Majhgawan samples predominantly plotting in the archetypal kimberlite (Group I) field or in its overlap with the lamproites.

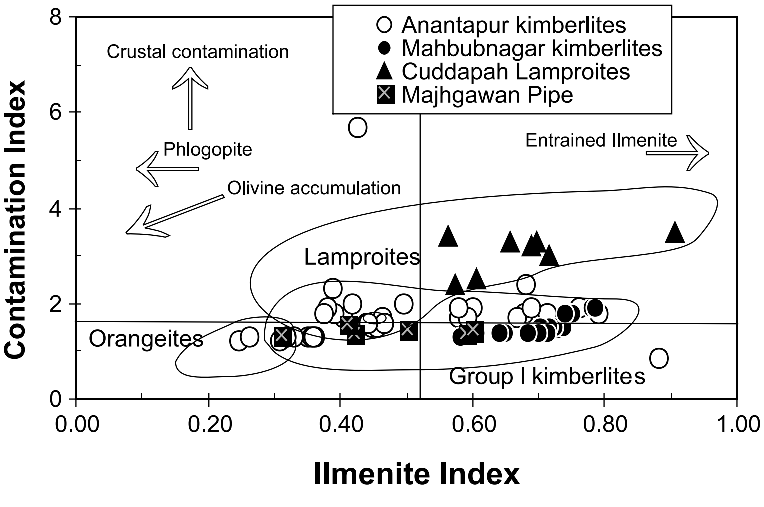

Fig. 3. Contamination Index (*Clement*, 1982) versus Ilmenite Index (*Taylor* et al., 1994). The fields of worldwide lamproites, Group I and II kimberlites are shown for comparison. Data sources are as follows: *Fraser* (1987); *Greenwood* et al. (1999); *Gurney* and *Ebrahim* (1973); *Spriggs* (1988); *Scott* (1979); *Smith* et al. (1985); *Tainton* (1992); *Taylor* et al. (1994)

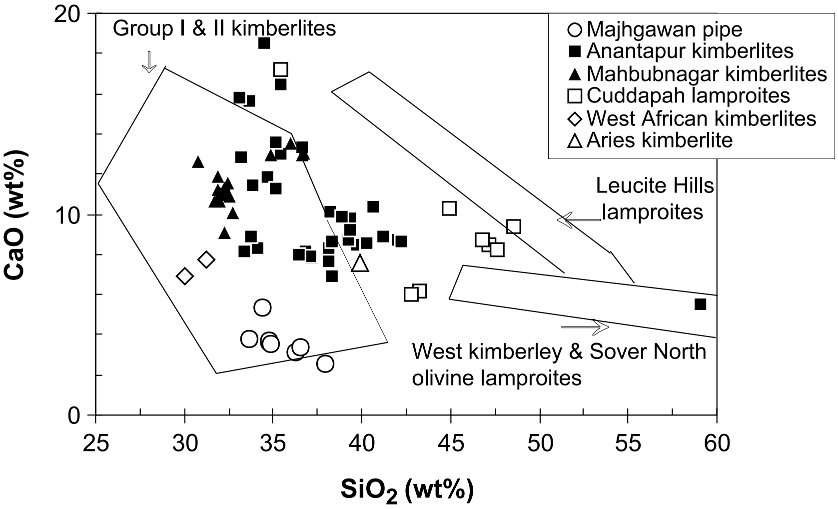

Fig. 4. Compositional range of SiO_2 and CaO for the Majhgawan pipe. Data sources are as follows: West Kimberley olivine lamproites and Leucite Hills lamproites – *Fraser* (1987); Group I and II kimberlites – *Greenwood* et al. (1998), *Gurney* and *Ebrahim* (1973), *Spriggs* (1988), *Scott* (1979), *Smith* et al. (1985), *Tainton* (1992), *Taylor* et al. (1994); Anantapur kimberlites, Mahbubnagar kimberlites and Cuddapah lamproites, India – *Chalapathi Rao* et al. (2004); Aries kimberlite (Australia)- *Edwards* et al. (1992); West African kimberlites – *Taylor* et al. (1994)

The Majhagwan pipe is silica-undersaturated (SiO_2 contents: 33.69 wt%–37.94 wt%) similar to those of kimberlites, and orangeites (Fig. 4). However, its CaO contents are remarkably low (predominantly 2.58–3.78 wt%; see Table 4) compared to kimberlites and orangeites and are similar to those of olivine lamproites (Fig. 4). On the other hand, the MgO (23–29 wt%) and $Fe_2O_3^*$ (~10 wt%) contents are high. The Mg numbers (Mg/Mg + Fe) of the available data are >0.70 and highlight the mafic-ultramafic nature. The K_2O contents are low (0.55–1.21 wt%), due to low phlogopite contents, but the K_2O/Na_2O ratios are high (>3) thereby displaying the potassic-ultrapotassic nature of these rocks (*Foley* et al., 1987). The TiO_2 contents are very high (3.76–6.04 wt%) relative to those of Group II kimberlites (orangeites) or leucite lamproites but are similar to those of archetypal kimberlites (Fig. 5). P_2O_5 contents range from 1.82 to 2.65 wt% and are primarily contributed by apatite and to a very limited extent by monazite. The peralkaline [molar $(Na_2O + K_2O)/Al_2O_3$] and perpotassic (molar K_2O/Al_2O_3) indices of Majhagwan pipe are essentially <1. These ratios are similar to those of archetypal kimberlites (≤ 1) but are very different from those (>1) of orangeites (*Mitchell*, 1995a) and lamproites (*Bergman*, 1987).

The overall major element data of Majhgawan pipe are more similar to that of an archetypal kimberlite than those of orangeite and lamproite.

Trace elements (including REE)

The variability of compatible element abundances in kimberlites is shown not to be representative of the liquids from which they form, but is due to widely varying

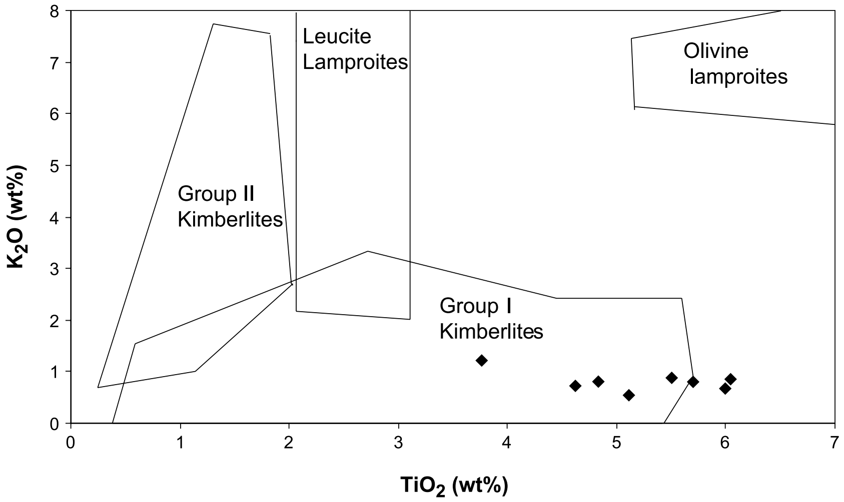

Fig. 5. TiO_2 versus K_2O for the Majhgawan pipe. Data sources are as follows: *Fraser* et al. (1987); *Greenwood* et al. (1998); *Gurney* and *Ebrahim* (1973); *Spriggs* (1988); *Scott* (1979); *Smith* et al. (1985); *Tainton* (1992); *Taylor* et al. (1994)

macrocryst/phenocryst – matrix ratios (*Mitchell*, 1986). In kimberlites, Sc is primarily hosted by phlogopite whereas in lamproites by K-richterite (*Mitchell*, 1995a). The Sc contents in the Majhgawan pipe (~20 ppm) overlap with those from the southern Indian kimberlites (13–27 ppm) and lamproites (~20 ppm) (*Chalapathi Rao* et al., 2004). Vanadium in kimberlites and lamproites is hosted primarily by phlogopite and spinel. The Majhgawan pipe has relatively low V abundances (33–55 ppm), compared to the kimberlites (75–355 ppm) and lamproites (72–160 ppm) from southern India (*Chalapathi Rao* et al., 2004). Nickel in kimberlites and lamproites is principally hosted by olivine and hence its abundance is directly proportional to the of olivine macrocrysts content. The high Ni/MgO ratios (41.84) of the Majhgawan pipe are very similar (Table 6) to those of the Group I kimberlites of South Africa (40) and Koidu kimberlites of Western Africa (42). Chromium (996–1456 ppm) contents of Majhgawan pipe are within the range for those of orangeites (315–2865 ppm), kimberlite (430–2554 ppm) as well as olivine lamproites (379–1703 ppm) (source data: *Mitchell*, 1995a).

The Ba contents of the Majhgawan pipe are extremely high (1640–7760 ppm) compared to those from other occurrences (Tables 5 and 6) and reflect the high barite content. *Scott-Smith* and *Skinner* (1984a) have used Zr versus Nb plots to distinguish between kimberlites and lamproites. These elements have been also shown to be least mobile amongst incompatible elements whilst alteration (*Taylor* et al., 1994). The Nb and Zr contents of the Majhgawan pipe plot very well within the olivine lamproite field (Fig. 6). The P_2O_5 content of the Majhgawan pipe exhibits very good positive correlation with Ce content (Fig. 7) thereby demonstrating that phosphatic phase (e.g. apatite) to be the main host of LREE. Also, Fig. 7 displays that Ce contents of Majhgawan pipe are substantially higher than those of the kimberlites and orangeites but are similar to those of the olivine lamproites.

The Majhgawan pipe is strongly enriched in LREE with La abundances being 700–800×chondrite. Abundances of HREE are low, 5–7×chondrite.

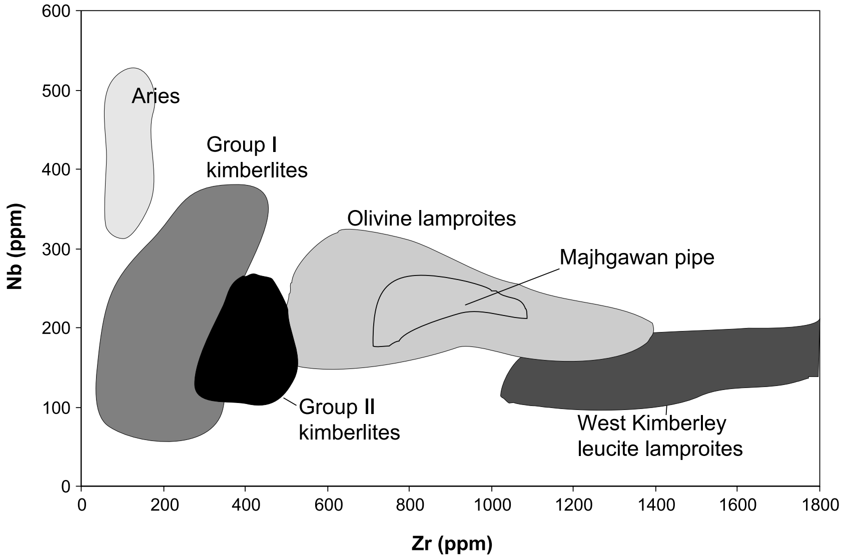

Fig. 6. Zr versus Nb diagram for the Majhgawan pipe. Data sources for the shown fields are from *Edwards* et al. (1992) and *Taylor* et al. (1994)

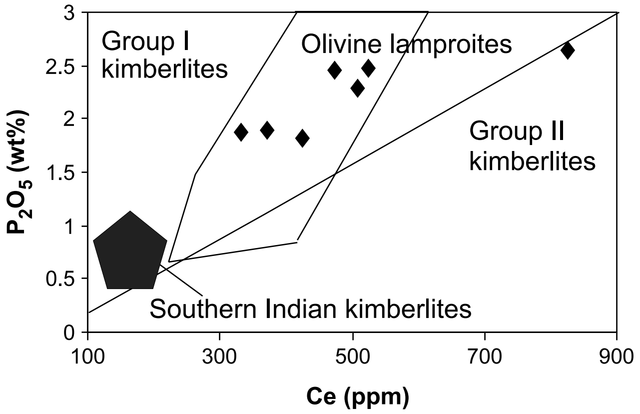

Fig. 7. P_2O_5 (Oxide weight %) versus Ce (ppm) plot for the Majhgawan pipe. Data sources for the displayed fields: *Mitchell* (1995a) and *Chalapathi Rao* et al. (2004)

Consequently, La/Yb ratios are high and range from 80–186. The Majhgawan pipe appears to be enriched in LREE (Fig. 8) compared to the archetypal kimberlite and orangeite but resembles those of the Chelima lamproite. Eventhough REE patterns cannot be used to distinguish kimberlites from orangeites (*Mitchell*, 1995a) the REE pattern of Majhgawan pipe nevertheless parallels those of others (Fig. 8) thereby demonstrating that similar processes were involved in the generation of these magmas. The REE patterns (Fig. 8) do not show any apparent depletion of MREE (Eu to Ho) and lack a downward concave shape which is a characteristic feature of some of the other Gondwanaland kimberlites e.g. Aries kimberlite of Western Australia (*Edwards* et al., 1992) and Koidu kimberlite of West Africa (*Taylor* et al., 1994).

On normalized multi-element plots (Fig. 9) the Majhgawan pipe exhibits negative troughs at K and also at Rb. Such negative anomalies either reflect

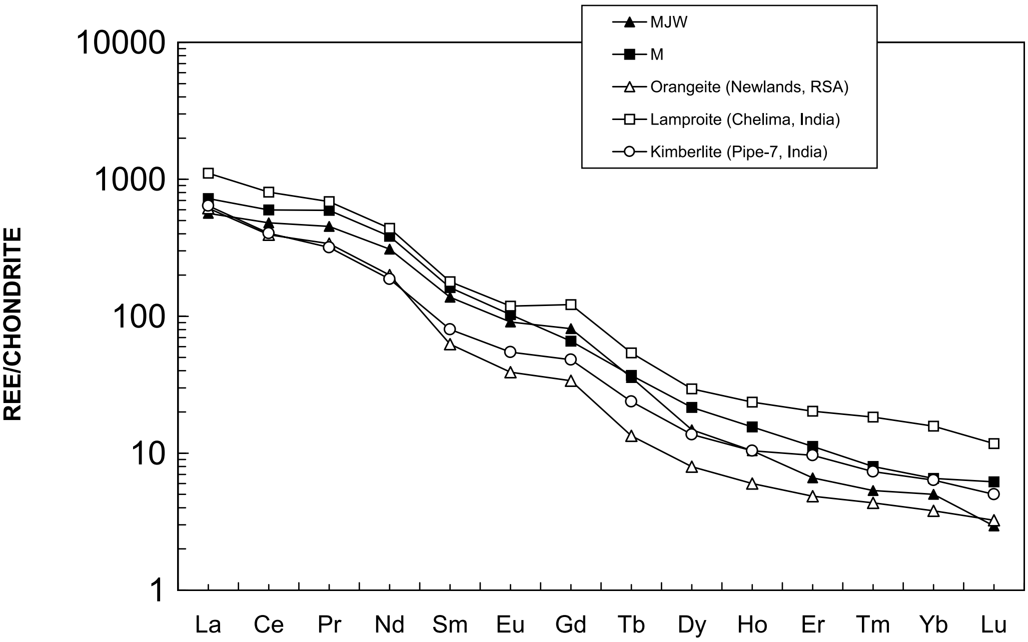

Fig. 8. Chondrite-normalized (*Haskin* et al., 1968) Rare Earth Element patterns for the Majhgawan pipe compared with those from elsewhere. Data for Indian kimberlites from *Chalapathi Rao* et al. (2004); Orangeite from *Mitchell* (1995a)

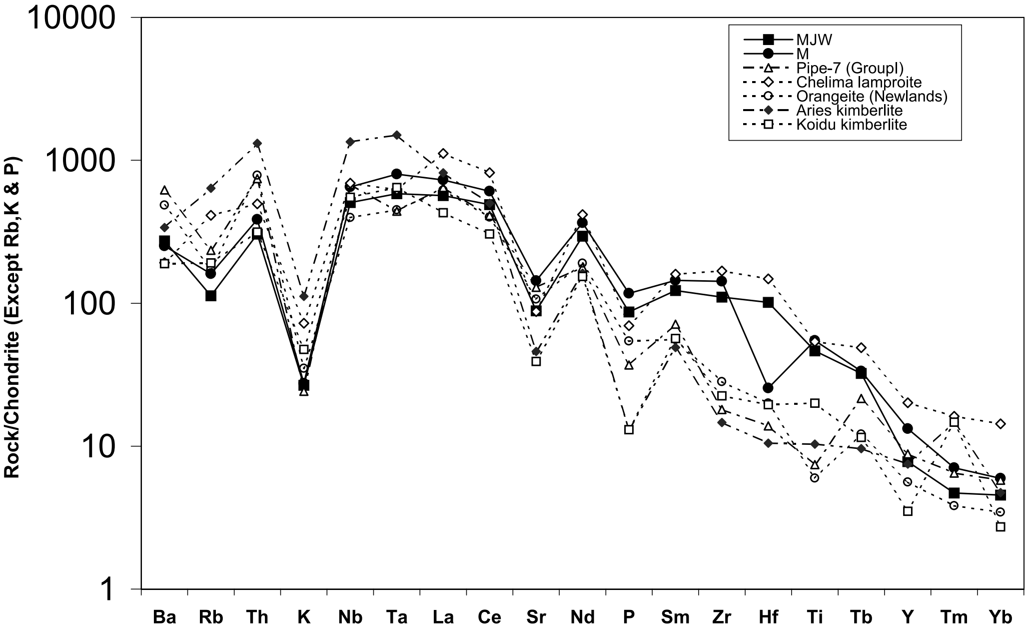

Fig. 9. Trace element abundance patterns normalized against chondrite (except Rb, K and P, which are normalized to primitive mantle; *Thompson* et al., 1984) of the Majhgawan pipe compared with those from elsewhere. Data sources are from *Mitchell* (1995a); *Edwards* et al. (1992); *Taylor* et al. (1994); *Chalapathi Rao* et al. (2004)

hydrothermal alteration or the presence of residual phases in the melt source regions. The LOI contents, which are similar to those from unaltered potassic-ultrapotassic rocks from elsewhere (*Mitchell*, 1986), and low contamination indices (Table 4) suggest that these negative anomalies are likely to be source related. The possibility of phlogopite fractionation being responsible for the negative troughs at K and Rb is negated by the lack of evidence for phlogopite accumulation (Fig. 3; see vector for phlogopite). Negative Rb and K anomalies were recorded in kimberlites and orangeites from southern Africa and an almost ubiquitous trough at K is seen in many mafic potassic rocks from Alto Paranaiba Province, Brazil (*Gibson* et al., 1995). Depletions of P and Sr are also apparent in Fig. 9. Negative troughs at P can be accounted by the presence of apatite in the source. Depletions in Sr can be attributed either to the presence of residual phases such as clinopyroxene (*Smith* et al., 1985) or phosphate (*Mitchell*, 1995a) or due to the depletion of the mantle source in Sr during a previous phase of melt extraction (*Tainton* and *McKenzie*, 1994). The troughs at Sr were, in fact, considered by *Foley* et al. (1987) to be a fairly common feature of mafic-ultramafic strongly alkaline rocks.

The Nb/Zr (0.23) ratios of the Majhagwan pipe (Table 6) are strikingly similar to those of olivine lamproites (0.20) and Cuddapah lamproites (0.28) than those of kimberlites (1.1) and orangeites (0.48). On the other hand, the Nb/La ratios (Table 6) of olivine lamproites (0.8), Cuddapah lamproites (0.74), Koidu kimberlites (1.4) and orangeites (0.7) are closest to those of the Majhagwan pipe (1.09).

The trace element contents and ratios strongly suggests that Majhgawan pipe has more affinities to lamproites than archetypal kimberlites and orangeites.

Isotopic aspects

The initial $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios for the Majhgawan pipe are compiled in Table 7 along with those for selected Group I and II kimberlites, lamproites and 'transitional kimberlites'. The initial Sr ratios for the Majhgawan pipe range from 0.7030–0.7064 (*Paul*, 1979) whereas the initial Nd ratio determined on a single sample gives a value of 0.511742 ± 10 (*Lehmann* et al., 2002).

The southern African kimberlites were recognized to be Group I and II primarily based on isotopes (*Smith*, 1983a) and subsequently on the basis of trace element data (*Fraser* et al., 1985; *Smith* et al., 1985). The Group I kimberlites have significantly lower $^{87}Sr/^{86}Sr$ and Rb/Sr ratios and higher $^{143}Nd/^{144}Nd$ and $^{206}Pb/^{204}Pb$ ratios than Group II kimberlites (orangeites). In the Nd–Sr isotope plot (Fig. 10) the southern Africa Group I kimberlites are characterized by possessing a Bulk-Silicate Earth (BSE)-like Sr isotopic composition and predominantly positive εNd values ranging from +0.3 to +6.9 (Table 7) that they plot in the 'depleted' quadrant of the conventional εNd–Sr_i diagram. The slightly depleted source region of Group I kimberlites, relative to BSE, was suggested as an evidence for their asthenospheric origin as their isotopic signatures are similar to those of most Ocean Island Basalts (e.g. *Smith*, 1983a; *Mitchell*, 1995a). However, an alternate view favours a lithospheric origin of Group I kimberlites and proposes that the source enrichment of kimberlites and orangeites to have had occurred at different times, but not by different processes (*Tainton* and *McKenzie*, 1994; *Chalapathi Rao* et al., 2004).

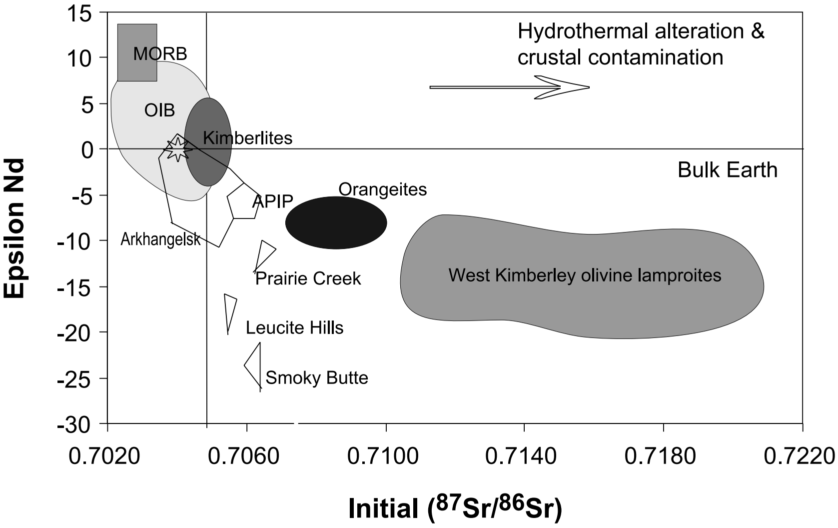

Fig. 10. Initial $^{87}Sr/^{86}Sr$ versus epsilon Nd for kimberlites, lamproites and orangeites. Data sources are Table 7 and those given by *Gibson* et al. (1995), *Mahotkin* et al. (2000) and *Chalapathi Rao* et al. (2004). The asterisk shows the position of the Majhgawan pipe

The long term incompatible element enrichments relative to that of Bulk-Silicate Earth of Group II kimberlites (orangeites) make their field distinct from those of Group I kimberlites (Fig. 10). Group II kimberlites have unradiogenic Nd (εNd -6.2 to -13.5) and radiogenic Sr isotope composition (0.70713 to 0.70983) so that they plot in the "enriched" quadrant of the Nd–Sr isotope diagram. There is general agreement that their source regions are an ancient and highly metasomatised sub-continental lithospheric mantle (e.g. *Smith*, 1983a; *Fraser* and *Hawkesworth*, 1992; *Mitchell*, 1995a).

The term 'transitional kimberlite' was first introduced by *Skinner* et al. (1994) on the basis of the intermediate Sr–Nd isotopic characteristics of some of the kimberlites of the Prieska district of South Africa (*Clarke* et al., 1991). Subsequently, such 'kimberlites' have been recognized from the other cratons as well such as those at Arkhangelsk, Russia (e.g. *Mahotkin* et al., 2000; *Beard* et al., 2000), Alto Paranaiba, Brazil (e.g. *Bizzi* et al., 1994; *Gibson* et al., 1995), Guaniamo, Venezuela (*Kaminsky* et al., 2003) and from the North West Territories of Canada (*Dowall* et al., 2000) (Table 7 and Fig. 10). These magmas have been variously explained as having been derived by some mixing or contamination between Group I-like and other, much more enriched, sources which might reside in the sub-continental lithospheric mantle (*Clarke* et al., 1991) or at greater depths (*Taylor* et al., 1994).

In one of the first isotopic studies on lamproites, *McCulloch* et al. (1983) have shown that the diamondiferous lamproites from the Fitzroy Trough of Western Australia have low εNd (-7.4 to -15.4; see Table 7) and high $^{87}Sr/^{86}Sr_i$ 0.7104 to 0.7187 indicating their derivation from ancient ($>$1 Ga), enriched (high Rb/Sr, Nd/Sm) mantle sources. Thus, the Western Australian lamproites show a closer similarity to Group II kimberlites (orangeites) than archetypal kimberlites (e.g. *Dawson*, 1987). Both of them plot in the bottom right quadrant of the

Table 7. *Initial $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ composition of kimberlites, orangeites, lamproites and 'transitional kimberlites' (including Majhgawan pipe)*

Name of pipe	^{87}Sr/^{86}Sr	^{143}Nd/^{144}Nd	εNd	Age (Ma)	References
Group I kimberlites:					
Jagersfontein (R.S.A.)	0.7044	0.51275	+4.4	86	*Smith* (1983a)
Monastery (R.S.A.)	0.7033	0.51276	+4.7	90	*Smith* (1983a)
Frank Smith (R.S.A.)	0.7044	0.51251	+0.3	114	*Smith* (1983a)
Mbuji Mayi (Zaire)	0.7040–0.7099	0.51264–0.51290	+1.9 to +6.9	71	*Weis* and *Demaiffe* (1985)
Maddur (India)	0.70705	0.51106	+3.95	1400	*Chalapathi Rao* et al. (2004)
Kotakonda (India)	0.70275	0.51107	+4.24	1400	*Chalapathi Rao* et al. (2004)
Pipe-7 (India)	0.70744	0.51125	+0.44	1090	*Chalapathi Rao* et al. (2004)
Group II kimberlites (orangeites):					
Finsch (R.S.A.)	0.70777–0.70983	0.51202–0.51217	−6.2 to −9.7	118	*Mitchell* (1995a)
Sover North (R.S.A.)	0.70713–0.70721	0.51180–0.51181	−13.1 to −13.4	120	*Mitchell* (1995a)
Bellsbank (R.S.A.)	0.70847–0.70896	0.51204–0.51206	−9.4 to −9.6	121	*Mitchell* (1995a)
Newlands (R.S.A.)	0.70764–0.70773	0.51202–0.51206	−9.3 to −9.6	114	*Mitchell* (1995a)
Sover (R.S.A.)	0.70741–0.70776	0.51195–0.51196	−10.1 to −10.4	115	*Mitchell* (1995a)
Postmasburg (R.S.A.)	0.70718–0.70886	0.51190–0.51216	−7.6 to −12.5	100?	*Mitchell* (1995a)
Lamproites:					
West Kimberley (Australia)	0.71055–0.71865	0.51104–0.51144	−7.4 to −15.4	20	*McCulloch* et al. (1983)
Argyle (Australia)	0.71316–0.71961	0.510658–0.510715	−3.9 to −5.6	1180	*Jaques* et al. (1989)
Chelima (India)	0.71689	0.51046	−6.76	1400	*Chalapathi Rao* et al. (2004)
Zangamarajupalle (India)	0.72209	0.51044	−7.17	1400	*Chalapathi Rao* et al. (2004)
Ramannapeta (India)	0.70518	0.51134	−6.23	1400	*Chalapathi Rao* et al. (2004)
Prairie Creek (USA)	Not provided	0.512032–0.512044	−9.9 to −10.9	106	*Lambert* et al. (1995)

(*continued*)

Table 7 (*continued*)

Name of pipe	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$	εNd	Age (Ma)	References
"Transitional" kimberlites:					
Majhgawan (India)	0.7030–0.7064	0.511742 ± 10	0.0	1080	*Paul* (1979); *Lehmann* et al. (2002)
Aries (Australia)	Not provided	Not provided	−1	820	*Edwards* et al. (1992)
Koidu (West Africa)	0.7040–0.7043	0.512416–0.512628	−1.5 to +2.5	115	*Taylor* et al. (1994)
Tres Ranchos (Brazil)	0.704658	0.512300	−4.3	85	*Gibson* et al. (1995)
Guaniamo (Venezuela)	0.7085–0.7088	0.511037–0.51047	+1.4 to −0.6	1732 ± 82	*Nixon* et al. (1992)
Arkhangelsk-Kola (Russia)	0.70342–0.70868	0.51192–0.51229	+1.7 to −5.4	360	*Beard* et al. (2000)
Prieska (R.S.A.)	0.70557–0.70792	0.51220–0.51244	−0.8 to −5.5	120	*Skinner* et al. (1994)

conventional εNd versus $^{87}Sr/^{86}Sr_i$ plot (see Fig. 10). However, the Western Australian lamproites have greater source enrichment ages (>1.2 Ga) than the orangeites (<1.2 Ga; *Smith* et al., 1985; *Tainton*, 1992). Whereas orangeites of southern Africa and lamproites of Western Australia form a continuum (Fig. 10), lamproites from Smoky Butte (Montana) and Leucite Hills (Wyoming) show a wide range in their εNd values of -21.6 to -25.9 and -10.5 to -17.9 (*Vollmer* et al., 1984; *Fraser* et al., 1985; Fig. 10). Most of the models on lamproite genesis propose that the unusual isotopic characteristics of lamproites require their sources evolved in isolation from the convecting mantle for long periods of time and, therefore, subcontinental lithospheric metasomatised mantle is commonly suggested to be the most obvious source where such distinct isotopic signatures evolve (e.g. *Nelson* et al., 1986; *Mitchell* and *Bergman*, 1991; *Foley* et al., 1996). However, *Murphy* et al. (2002) have suggested that lamproites of Gaussberg, Antarctica to be possible transition zone melts of Archaean subducted sediments.

The initial εNd value of zero ($\varepsilon Nd = 0.0$) for the Majhgawan pipe can be interpreted as resulting from a relatively undifferentiated chondritic mantle source (*Lehmann* et al., 2002; *Basu* and *Tatsumoto*, 1979, 1980) or a source with slight time integrated depletion of light rare earth elements (e.g. *Kramers* et al., 1981; *Smith*, 1983a; *le Roux*, 1986). Thus, the initial $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic compositions of the Majhgawan pipe (Table 7 and Fig. 10) have been inferred to be similar do those of archetypal kimberlites (and some of the 'transitional kimberlites') but are clearly atypical of lamproites or orangeites.

Xenoliths and indicator minerals

The pipe consists of cognate (juveline lapilli or magmaclasts) as well as crustal xenoliths (*Mathur* and *Singh*, 1971). Broken inclusions of Vindhyan rocks are prevalent throughout they pipe and they include argillaceous limestone, black cherty and greenish grey shale and quartz-arenite (*Halder* and *Ghosh*, 1978). Garnets are typical wine red coloured pyropes and have high Cr_2O_3 contents of up to 13 wt% with most of them ranging between 6 wt% to 7 wt% (*Chatterjee* and *Rao*, 1995). Garnets also have high CaO contents varying from 3 wt% to 7 wt%. Sub-calcic garnets are present in minor quantity (*Scott-Smith*, 1992). Based on Q-cluster analysis of garnets recovered from tailings, G1, G2, G9, G10 and G11 varities have been recognized (*Mukherjee* et al., 1997b). Mantle xenoliths are extremely rare. Their rarity has been explained with the long residence time in the upper mantle and slow travel time on the basis of resorption phenomenon observed in the phlogopite and olivine megacrysts (*Mukherjee* et al., 1997b). Geothermometry and oxygen barometry of the co-existing magnetite-ilmenite pair, based on *Spencer* and *Lindsley* (1981) method, indicates a temperature of 1150 °C. The values of fO_2, temperature and pressure fall in the equilibrium field defined by iron-wüstite and wüstite-magnetite and indicate a depth of sampling of about 155 km and corresponding pressure of 46 kbar (*Mukherjee* et al., 1997a).

The paucity of mantle xenoliths in the Majhgawan pipe precludes direct information about the petrological nature of the sub-continental mantle beneath the Bundelkhand craton.

Economic aspects

Majhgawan is the only diamondiferous pipe presently mined on a commercial scale in India with an annual production of about 40 000 carats. The diamond incidence in the Majhgawan pipe varies between 3 to 25 carats/100 tonnes with an average of 10 to 12 carats/100 tonnes (*Ghosh*, 2002). It has been firmly established that the average grade diamond yield is highest in the center (13 to 14 carats pht) and lower in the periphery of the pipe (6 to 7 carats pht). The variation of micro-diamond incidence is also consistent with the diamond grade (*Chatterjee* and *Rao*, 1995). The largest yet recovered stone is 29.25 ct but above 10 ct stones are seldom found. Majhgawan diamonds are of very high quality with 42% being of gem quality, which is one of the highest in the world for rough diamonds. The form of the Majhgawan diamonds is mostly a combination of octahedron and dodecahedron; a large variety of them are predominantly curve-faced modified forms indicating signs of resorption (*Chatterjee* and *Rao*, 1995).

The diamond content of the Majhgawan pipe is indistinguishable from that of diamondiferous archetypal kimberlites, orangeites, lamproites and transitional kimberlites.

Petrogenetic aspects

It is now well established that the geochemistry of the mafic potassic-ultrapotassic magmas can be utilised to investigate the relative contribution of lithosphere, upper- and deeper-mantle (convective) components in their genesis and also to probe compositional variations in the sub-continental lithospheric mantle (e.g. *Gibson* et al., 1995; *Mahotki*n et al., 2000; *Beard* et al., 1998, 2000). However, it is important to assess the role of crustal contamination in order to constrain the genesis of the Majhgawan pipe.

Role of crustal contamination

Evidence against crustal contamination and for a mantle derivation of the Majhgawan pipe comes from the high abundances of incompatible trace elements such as Sr (1043–1835 ppm), Nb (177–228 ppm) and Zr (755–1075 ppm), which are much greater than in the continental crust. All the analysed rocks have Mg/(Mg + Fe) ratios >0.70 and high Ni contents (1055–1455 ppm), which are indicative of the "primitive" nature of the magma. Moreover, the major oxide composition of the pipe rock shows low abundances of Al_2O_3 (2.53–6.07 wt%) and Na_2O (0.02–0.26 wt%) that cannot be accounted by crustal contamination. The presence of diamond and xenocrysts also support its mantle derivation.

Geochemical data on the Vindhyan sediments is meagre but those available for the Lower Vindhyan shales (*Raza* et al., 2002) suggest that they are much lower in Zr (60–406 ppm), Nb (11–63 ppm), Sr (9–163 ppm) and Ni (10–138 ppm); they therefore cannot account for the much higher values for these elements in the pipe. The strongly LREE-enriched REE patterns (700–800 × chondrites), absence of positive Eu anomalies and the low HREE and Y contents of the pipe rock provide further additional evidence against crustal contamination. Thus, it can be concluded that the major oxide, trace element and isotopic signatures of the Majhgawan pipe are not affected significantly by crustal contamination but reflect that of the melt source regions.

Nature of the mantle source and its metasomatic enrichment

Mantle xenoliths are either very rare or not reported from the Majhgawan pipe. Hence, little information is available as to the nature of the mantle beneath this part of the Vindhyan basin and the Bundelkhand craton. Nevertheless, the following inferences can be drawn from the present study so as to constrain the petrogenesis of the Majhgawan pipe:

1. As Majhgawan pipe is richly diamondiferous, the Proterozoic geothermal gradient beneath Bundelkhand craton must have passed through the diamond stability field. Therefore, the source magma should have originated at a depth of at least 150 km.
2. The high TiO_2 contents of the phenocrystal and macrocrystal phlogopites could reflect the high titanium content of the parent magmas (e.g. *Bachinskii* and *Simpson*, 1984) implying a Ti-enriched mantle source.
3. High Ba contents (i.e. presence of barite) also indicate that the source was significantly enriched in barium. This barium was possibly contributed either by Ba-rich phlogopite occurring as a stock-work within the mantle source (*Foley*, 1992) or by a complex K–Ba phosphatic metasomatic mineral phase, recognized in the 7 GPa near-solidus experimental studies of lamproites (*Mitchell*, 1995c).
4. From the normalized multi-element plots (Fig. 9) it can be inferred (see above) that phlogopite, apatite and clinopyroxene are the residual phases in the melt sources.
5. The pipe rock is strongly LREE enriched and significantly depleted in HREE (Fig. 8). It is now well established that such melts with high La/Yb ratios (60–180) can be produced by very small (<1%) degrees of partial melting of a phlogopite-garnet lherzolite (e.g. *Mitchell* and *Brunfelt*, 1975; *Mitchell* and *Bergman*, 1991).
6. Furthermore, to generate such melts with high incompatible trace element and LREE abundances it is also well known that such a mantle source must have been previously metasomatically enriched (e.g. *Menzies* and *Wass*, 1983; *Vollmer* and *Norry*, 1983).
7. Multi-element plots (Fig. 9) do not show any subduction-related characteristics, such as large negative anomalies at Ta and Nb (e.g. *Ellam* et al., 1989; *Peacock*, 1990; *Maury* et al., 1992), and therefore, the source enrichment is attributed to volatile and K-rich, extremely low-viscosity melts that leak continuously to semi-continuously from the asthenosphere and accumulate in the overlying lithosphere (e.g. *McKenzie*, 1989; *Gibson* et al., 1995; *Wilson* et al., 1995) rather than by subduction-derived melts (e.g. *Murphy* et al., 2002).
8. There is no evidence from the available data to decide whether the composition of the metasomatising melt could be strictly silicic (e.g. *McKenzie*, 1985; *Watson* et al., 1990) or carbonate (e.g. *Eggler*, 1987; *Rudnick* et al., 1993; *Dobson* et al., 1996) in nature or both.

9. The εNd_i values for the Majhgawan pipe can be interpreted as resulting from a relatively undifferentiated chondritic mantle source (*Lehmann* et al., 2002) or a source with very slight time-integrated depletion of light rare earth elements (e.g. *Kramers* et al., 1981; *Smith*, 1983a; *Le Roex*, 1986).
10. Although the incompatible trace element contents (Zr, Nb etc.) of the Majhgawan pipe are highly enriched, the initial εNd_i values are nearer to the Bulk Earth values (Fig. 10) suggesting that the source metasomatism was relatively recent prior to melting. The Sr and Nd systematics of Majhgawan pipe also reveal that it has archetypal kimberlite-like isotope signature and that its source region has not experienced ancient enrichment event(s) that are characteristic of orangeite or lamproite mantle sources.

Depth of melting: lithosphere versus asthenosphere

Despite a great deal of research, the role of the convecting mantle in kimberlite genesis is a highly contentious issue. The slightly depleted source region of Group I kimberlites, relative to Bulk Silicate Earth, was widely suggested as an evidence for their asthenospheric origin as their isotopic signatures are similar to those of most ocean island basalts (e.g. *Smith*, 1983a; *le Roux*, 1986; *Mitchell*, 1995a). The presence of syngenetic inclusions of majoritic garnets within diamonds (*Moore* et al., 1991) and ultra-deep (>400 km) xenoliths in some southern African kimberlites with ocean-island basalt (OIB)-like isotopic signature, i.e., Group I kimberlites, led some workers to suggest that they were derived from a 'transition zone' source (e.g. *Ringwood* et al., 1992) or even from the core-mantle boundary (e.g. *Haggerty*, 1994, 1999). Broad similarities in major elemental compositions and trace element abundance patterns between Group I and II kimberlites (orangeites) led *Skinner* (1989) to suggest that both of them may have been generated from different domains of the sub-continental lithospheric mantle with volatile input from the asthenosphere.

Tainton and *McKenzie* (1994) have proposed that the REE patterns of the Group I and II kimberlites and lamproites require a three stage melting model involving (i) a lithospheric peridotite source depleted by melt extraction of ~20% in the garnet stability field, (ii) metasomatic enrichment with a MORB type melt and (iii) small fraction melting of this depleted harzburgitic source. Thus, the REE modelling of *Tainton* and *McKenzie* (1994) deduced that the kimberlite component derived from a convecting mantle (the precursor small fraction highly metasomatised melts) were extracted from a depleted continental lithospheric mantle. Similar results were obtained from the REE modelling studies on Proterozoic archetypal kimberlites and lamproites of southern India (*Chalapathi Rao* et al., 2004).

However, *Nowell* et al. (2004), based on the Hf isotope systematics of Group I kimberlites and orangeites of southern Africa, prefer that sources for both are sub-lithospheric. The likely reservoir is an ancient, deeply subducted oceanic basalt that became incorporated into the kimberlite/orangeite source region to varying degrees.

The role of (i) depleted lithospheric peridotite (e.g. high Mg number, high Ni, low HREE), (ii) enrichment (e.g. high LREE, high incompatible trace elemental abundances) of this already depleted source by metasomatising fluids from sub-lithospheric source region and (iii) subsequent small-fraction melting are undoubtedly evident in the genesis of the Majhgawan pipe, as concluded by many workers for potassic-ultrapotassic rock types elsewhere (e.g. *Tainton* and *McKenzie*, 1994; *Le Roex* et al., 2003; *Chalapathi Rao* et al., 2004). The lack of any perceptible igneous activity in the Vindhyan sediments (see *Anil Kumar* et al., 2001b and the references therein), apart from the Majhgawan and Hinota pipes and some minor volcanics plugs at Angor (*Nane*, 1971) and Banda (*Hukku*, 1971), negates extensive mantle melting and do not favour a plume to be the causative factor for the genesis of the Majhgawan pipe. Moreover, comprehensive sedimentalogical studies carried out over the years strongly favour the formation of the Vindhyan basin largely through rift-controlled subsidence under extensional regime (*Bhattacharya*, 1996 and the references therein). Therefore, it appears that extension, rather than decompression melting induced by a plume, seems to have been responsible for the melting of the Majhgawan pipe source region. The available evidence is insufficient to speculate about a more unifying petrogenetic model for the genesis of Majhgawan pipe. It can, therefore, be concluded that the petrogenesis of the Majhjgawan pipe is indistinguishable from that of other similar potassic 'metasomatised mantle magmas' viz., kimberlite, orangeite and lamproite without having any strong affinity to a particular clan/group amongst them.

Discussion

It has been inferred in this study that the Majhgawan pipe is not a typical (*sensu stricto*) kimberlite or lamproite or orangeite, as suggested elsewhere (e.g. *Paul*, 1991; *Scott-Smith*, 1989; *Ravi Shankar* et al., 2001, 2002), but constitutes a transitional mafic potassic-ultrapotassic rock type which shares common characteristics of all three rock types. Hence, the Majhgawan pipe is suggested to represent a transitional kimberlite-orangeite (Group II kimberlite)-lamproite rock type.

Such transitional rocks, as already discussed before, are not unique but have also been recorded elsewhere e.g. from the Kaapvaal craton in southern Africa (*Clarke* et al., 1991; *Skinner* et al., 1994), the Koidu province in West Africa (*Taylor* et al., 1994), the Arkhangelsk region on the Kola-Kuloi craton in Russia (*Parasdanyan* et al., 1996; *Beard* et al., 2000; *Mahotkin* et al., 2000), the Sao Fransisco craton in Brazil (*Bizzi* et al., 1994; *Gibson* et al., 1995), the Kimberley craton in N.W. Australia (*Edwards* et al., 1992), the Singhbum craton in NE India (e.g. *Middlemost* et al., 1988; *Kent* et al., 1998a, b), the NW Territories in Canada (*Dowall* et al., 2000) and the Guyana craton in Venezuela (*Nixon* et al., 1992; *Kaminksy* et al., 2003). However, the most striking aspect is their occurrence in almost every craton with their emplacement age ranging from the Proterozoic to the Mesozoic thereby implying their universal occurrence in space as well as time.

The current understanding of kimberlites and orangeites has been strongly influenced by studies on similar rocks from South Africa. Most of these studies on these exotic rock types, as available in the literature, invariably tend to fit them in the Southern African model of Group I and II kimberlites. However, as pointed out by *Edwards* et al. (1992) it appears that the correlations between kimberlite petrography (micaceous vs non-micaceous) and isotope types (Group I vs Group II), as shown by *Smith* (1983a), indeed, may not always be valid outside southern

Africa. In fact, *Mitchell* (1995a) argued that orangeite (Group II kimberlite) magmatism is unique to the Kaapvaal craton of southern Africa and it was initiated by thermal events related to the mantle plumes associated with the rifting of the South Atlantic and formation of the Karroo basalts.

This study supports the main conclusion of *Mitchell* (1995a) that the archetypal orangeites are confined only to southern Africa and that they are the products of unique metasomatism affecting the Kaapvaal craton. Nevertheless, it is also increasingly becoming clear that there is undoubted convergence in the mineralogical and geochemical traits of kimberlite, orangeite and lamproite in various cratons, as demonstrated above, in the form of transitional potassic-ultrapotassic rock types.

The recognition of such convergence amongst these exotic rock types is not new, but was voiced by many a worker in the past decade or more. For example, based on the similarities in geochemistry and mineralogy between orangeites and olivine lamproites, *Dawson* (1987) suggested that both could be members of the same clan (see also *Nixon*, 1996). Likewise, the Nd–Sr–Pb isotopic similarity between orangeites and olivine lamproites from Prairie Creek (Kansas, U.S.A.) and West Kimberley (Western Australia) prompted *Smith* (1983b) to opine that they are one and the same. A similar conclusion was drawn by *Tainton* (1992) from his detailed work on the Barkley West district orangeites and lamproites of South Africa. *Rock* (1991) placed kimberlites, orangeites, lamproites and lamprophyres in his ‘lamprophyre clan’. In fact, *Scott-Smith* (1995) went on to suggest that all potassic magmas might be considered as a broad group termed ‘Metasomatised Mantle Magmas (MMM)’.

On the other hand, the I.U.G.S. sub-commission on the systematics of igneous rock classification (*Woolley* et al., 1996) has endorsed the view, mainly on the basis of petrological grounds, that kimberlite, lamproite and orangeite constitute separate rock types. However the recommendations of the I.U.G.S. are clearly inadequate, as shown in this work, when dealing with the nomenclature of transitional mafic potassic ultrapotassic rock types.

It is well established that the nomenclature of mafic potassic-ultrapotassic rocks is an extremely important aspect as it dictates the diamond exploration/exploitation models (*Mitchell*, 1991, 1994, 1995b) and also as it imparts regional (tectonic) significance by revealing ancient enrichment and depletion event(s) experienced by the underlying sub-continental lithospheric mantle. In view of this significance, the name *majhgawanite* is proposed – taking into consideration the antiquity of the Majhgawan pipe, its intriguing petrological, geochemical and isotope characteristics and also on the basis of the legacy of India for introducing diamond to the world-to designate all such transitional mafic potassic-ultrapotassic rock types. This also would serve to distinguish them from typical kimberlite or lamproite or orangeite. It may be recalled that in case of alkaline rocks even though most of the modern researchers are defiant to nomenclature of new rock types ‘the introduction of new names is entirely legitimate if a clan or suite of rocks is demonstrably genetically different to rocks belonging to other clans’ (*Mitchell*, 1995a, p. 379). The arguments presented in this paper, certainly present a strong support for such a proposal.

As a primary source, Majhgawan pipe (and its satellite body at Hinota) is grossly inadequate to account for the incidence of diamonds in the Panna area.

However, no other primary sources were discovered in the area so far by the Geological Survey of India despite extensive geophysical and geochemical surveys performed since decades (*Mitra*, 1996). The possibility of the presence of ''transitional'' hitherto undiscovered pipe rocks in the Panna area (within the Vindhyan basin) could be responsible for the previously unsuccessful geophysical/ geochemical exploration. As rightly remarked by *Haggerty* (2003) ''nontraditional rocks need nontraditional exploration techniques, a lamproite lesson well learned''. Therefore, future exploration models for diamond should contemplate these aspects in the successful search for their primary host rocks.

Conclusions

1. The Mesoproterozoic diamondiferous Majhgawan pipe of central India shares petrological, geochemical and isotope characteristics of kimberlite, orangeite (Group II kimberlite) and lamproite. Its Nd isotope signature is atypical of lamproite and orangeite; mineralogical aspects are similar to those of lamproite and orangeite and geochemically it is akin to that of kimberlite as well as lamproite. Hence, it is suggested that the Majhgawan pipe represents a transitional kimberlite-orangeite (Group II kimberlite)-lamproite rock type.
2. This study demonstrates the existence of such transitional varieties of mafic potassic-ultrapotassic rocks, recorded elsewhere, even in this part of Gondwana. The name *majhgawanite* is proposed to encompass all such transitional rock types to distinguish them from archetypal kimberlite, lamproite and orangeite (Group II kimberlite).
3. Since most of the transitional varities of mafic potassic-ultrapotassic rocks are highly diamondiferous, *majhgawanite* constitutes yet another known primary source for diamonds besides kimberlite, lamproite and orangeite.
4. The recommendations of the I.U.G.S. sub-committee on kimberlite, orangeite and lamproite rock nomenclature (*Woolley* et al., 1996) are clearly inadequate, as shown in this work, when dealing with the petrological and geochemical aspects of transitional mafic potassic-ultrapotassic rocks.
5. The correlation between kimberlite petrography, chemistry and isotope characteristics (viz., Group I and II), as established in southern Africa, may not be necessarily valid elsewhere and therefore any attempt to characterize the mafic potassic-ultrapotassic alkaline rocks on this basis alone would not be successful.
6. Detailed petrological, geochemical and isotopic aspects of mafic potassic-ultrapotassic alkaline rocks need to be considered in unison before assigning any name, as the nomenclature of such exotic and rare rock types assumes economic and tectono-magmatic significance.

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