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A New kimberlite pipe in Balkamthota Vanka, Pennahobilam, Anantapur district, Andhra Pradesh, India. Field aspects and preliminary investigations

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ABSTRACT

Systematic closely spaced geological traverses conducted in the year 2010, in Lattavaram Kimberlite Cluster (LKC) of Anantapur district, Andhra Pradesh, India, have led to the discovery of a new kimberlite pipe outcrop in the river bed of Balkamthota Vanka (name of the stream used by local farmers) at its confluence with Penna River, close to Pennahobilam. This new pipe occurs at a distance of 1.5 km in NE direction to hitherto reported pipes-5 and 13 occurring at Muligiripalli and Tummatapalli respectively in the LKC of the Wajrakarur Kimberlite Field (WKF). With this pipe, the total number of kimberlite pipes in the WKF raises to 48, considering all the kimberlites discovered by various public and private organizations so far. Preliminary petrography, geochemistry, petrogenetic aspects and diamond prospectivity of the new occurrence have been presented here. Mineralogically, the kimberlite constitutes olivine macrocrysts, serpentinsed olivine psuedomorphs with xenocrystic ilmenite, phlogopite, perovskite, magnetite, Cr-diopside, garnet along with calcite veins. The kimberlite is classified as hypabyssal macrocrystic calcite- phlogopite kimberlite. Mineralogically, the new kimberlite pipe appears as archetypal Group- I kimberlite however, geochemically; the kimberlite shows character of both Group- I and II varieties, more close to lamproitic character. Although it is too early to comment, based on limited analyses carried out in this study, the diamond potentiality of this pipe is not encouraging; it is noteworthy that it highly warrants detailed investigations involving bulk rock geochemistry and drilling to assess its definite geochemical status, petrogenesis and diamond potentiality.

Keywords: New Kimberlite pipe; Group-I and II; Petrography; Geochemistry; Petrogenesis; Diamond Prospectivity; Pennahobilam.

INTRODUCTION

Kimberlite is an ultrapotassic rock that solidifies from magma violently ascending to earth's surface from deep mantle below a depth of more than 150 km. Kimberlites are rich in volatiles like H_2O and CO_2 with enriched olivine and carries mantle rocks like eclogite, lherzolite, harzburgite, dunite etc. (Bailey, 1985). Geotectonically, the eastern Dharwar craton (EDC) forms a favourable province for kimberlite occurrences (Chalapathi Rao et al., 2016) and has recorded more than 150 kimberlites in the WKF so far, by various public and private organizations (Smith et al., 2013). The EDC along with other cratonic parts of India conforms to be categorised as an "Archon" (Janse, 1992, Chalapathi Rao, 2008) which is considered to be the most ideal tectonic setting for the occurrence of diamondiferous kimberlites. A majority of kimberlite pipes, known so far in the EDC, occur in the state of Andhra Pradesh and Telangana states except few occurrences in the adjacent areas of Karnataka. These kimberlite pipes are distributed in four fields, the Wajrakarur (WKF), the Tungabhadra (TKF), the Raichur (RKF) and the Narayanpet Kimberlite Field (NKF) (Akella et al., 1979; Rao et al., 1998; Nayak and Kudari, 1999; Murthy and Dayal, 2001; Neelakantam, 2001; Ravi et al., 2007; Ravi and Satyanarayana, 2007; Srinivas Choudary et al., 2007; Lynn, 2005; Lynn et al., 2013, Dongre et al., 2016; Shaikh et al., 2016). According to Shaikh et al. (2016), the WKF so far has witnessed to contain 48 pipes, among which 34 are situated in four spatially distinct clusters viz., (1) northern Wajrakarur-Lattavaram cluster with 16 pipes, (2) south-eastern Chigicherla cluster with 5 pipes, (4) southwestern Kalyanadurgam cluster with 7 pipes and (5) south-western Timmasamudram cluster with 6 pipes. The remaining 14 pipes were discovered by Rio Tinto Exploration India Ltd., occurring as Kalyandurg (B1), Golla (2-167, 2-173); Wajrakarur- Lattavaram (3-008, 3-016, 3-021, 3-055) and Gooty cluster (4-007, 4-036, 5-018, 5-019, 5-022, 5-023, 5-119) (CRAEI, 2004; Srinivas Choudary et al., 2007; Smith et al., 2013, Shaikh et al., 2016) (Figure1a).

Kimberlites are usually small in their areal extent and surface expression. They are often masked by alluvial/ colluvial debris or calcrete which makes them undetectable by using satellite imagery. Therefore, to locate kimberlite pipes, geological field traverses are mandatory in the initial stages of exploration. During the course of searching favourable ground for applying exploration permit by M/s. Ramgad Minerals & Mining Ltd., authors have conducted close spaced field gological traverses in the year 2010 in the vicinity of known kimberlite pipes in and around Lattavaram of Anantapur district, Andhra Pradesh, southern India. This field investigation has led to the discovery of a new kimberlite pipe at Pennahobilam emplaced within the granitoid rocks of peninisular gneissic

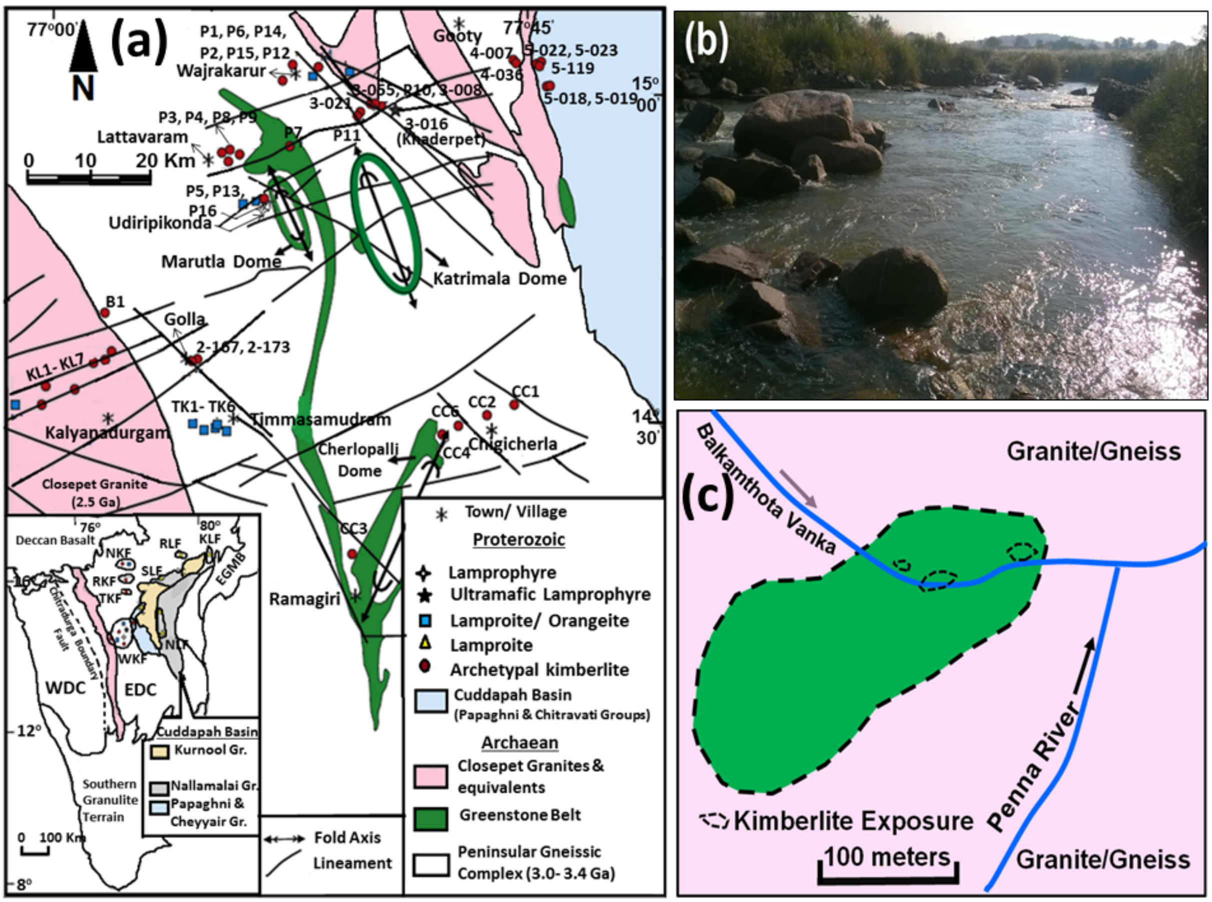


Figure 1. a) Location map of the new kimberlite pipe, P16 (Modified after Shaikh et al., 2016). Lineaments interpreted from satellite image (Phani, 2015). b. Outcrop submerged under water during post-monsson season. Photo facing east. and c. Approximate outline of the pipe. WDC- Western Dharwar Craton, EDC- Eastern Dharwar Craton, Kimberlite Fields (KF: WKF- Wajrakarur, TKF- Tungabhadra, RKF- Raichur, NKF- Narayanpet, Lamproite Fields (LF): NLF- Nallamalai, RLF- Ramadugu, KLF- Krishna, SLF- Somasila. Lineaments after Phani (2015).

complex in the EDC, southern India (see 3. Supplementary file1.pdf). Later in the year 2012, Geological Survey of India (GSI) also located this pipe and named it as P-16 (Shaikh et al., 2016). In this context, the authors wish to keep the nomenclature unchanged, as proposed by the GSI personnel for this new pipe. The purpose of this paper is to record occurrence of this new pipe and present first-hand data from preliminary investigations pertaining to its field aspects and preliminary petrological details.

GEOLOGICAL SETTING, LOCATION AND FIELD ASPECTS

The regional geology of the EDC shows prevalence of granitoid rocks of Archaean age. The EDC of the southern Indian shield exposes a granite- greenstone terrane composed predominantly of greenstone belts, gneisses, granitoids, late- to post-tectonic intrusive granites (the Closepet granite and its equivalents of ~2,500 Ma), platformal Proterozoic sedimentary basins (the Cuddapah and Bhima basins comprising quartzites, shale, conglomerate, dolomite and limestone) and widespread mafic dyke swarms (Chadwick et al., 2000). In general the location is made up of granites, gneisses intruded by dolerite dykes. The new pipe occurs at the intersection of two major lineaments trending NE-SW, and NW-SE at the peripheries of Marutla dome (Figure 1a). It is observed that the new pipe, pipes-5 and 13 are aligned along a NE-SW trending lineament. This trend in turn is more or less parallel to that of pipe-7 of Venkatampalli (NE-SW), which occurs towards NE at 10 km distance from the new pipe.

The kimberlite outcrop is exposed in the river bed at the confluence of a 4th order stream (locally called as Balkamthota Vanka) and Penna River. The outcrop is submerged under water and only observable during low water periods especially pre-monsson season (Figure1b). The outcrop is situated at 1.5 km towards NE from the location of pipe-5 (Muligiripalli) and 1 km NE from the Penna River bridge on the Anantapur- Uravakonda highway. The pipe location is easily accessible and the pipe is exposed in the form of three to four in-situ outcrops of ~20x10 meters size each. Based on distribution of outcrops, kimberlitic calcrete and taking granite outcrops into consideration as boundary, the surficial extent of the pipe has been approximately mapped and measured to be 100x200 meters with a fairly developed elongation in NE-SW direction (Figure 1c). The northern and southern extents are covered under alluvial debris where sporadic occurrence of kimberlite float is observed amidst gneissic/ granitoid country. In general, most of the WKF kimberlites are capped by ~1-2 meter thick calcrete. The new kimberlite pipe also is covered with calcrete which mostly looks granitic and ~4-5 meter thick alluvial soil away from the river bank in the SW part. However, no pitting has been carried out to ascertain the presence of kimberlite below this calcrete, in the present study. The pipe intrusion occurs in sharp contact with the granitoid country rocks (Figure 2a,b,c,d). The terrain is flat to gently sloping forming pediplain with an average relief of 360 MSL. The first order streams that make up the Balkamthota Vanka stream course originate right at the uplands comprising well-known Lattavaram pipes (3, 4, 8 and 9).

The majority of kimberlites of Wajrakarur- Lattavaram and adjoining clusters in the WKF are characterised by the presence of well-rounded macrocrystic olivines (>2 mm) predominating over the euhedral to subhedral serpentinised olivine phenocrysts (~0.5 mm) (Chalapathi Rao, 2008). The new kimberlite pipe rock macroscopically exhibits dark-green colour with predominance of olivine macrocrysts ranging from 0.5-2 cm size, abundant ilmenite xenocrysts of 0.5-1.5 mm size along with crustal xenoliths (0.5-20 cm) of granite, amphibolite etc., giving rise to inequigranular texture. The olivine macrocrysts are often serpentinised to form olivine pseudomorphs. In hand specimens, the rock exhibits two generations of olivine. Earlier generation of olivine forms macrocrysts ranging in size from 3 mm to 9 mm of serpentinised olivine with subrounded to rounded grain outlines indicating resorbed original grain morphology which are presumably mantle derived xenocrysts. The other minerals observed at hand- scale include Cr-diopside, phlogopite, magnetite and chromite. At places, the pipe rock shows development of parallel bands indicating flow patterns characteristic of vent facies (Figure 2d) and the fluvial weathering produced parallel burrows generated after removal of irresistant mineral constituents (Figure 2e). Olivine macrocrysts are ubiquitous (Figure 2f). Macroscopic examination of the rock samples at hand-scale reveals that the crustal xenoliths include mainly grey granite, dolerite and few amphibolite, similar to Pipe 5 and 13, at Muligiripalli and Tummatapalli respectively. The country rock granitoid shows metasomatic alteration or fenitization at some places, represented by enrichment of deep red alkali feldspar, in the contact zone with the pipe rock (Figure 2g). Otherwise the pipe intrusion shows a sharp contact with the granitoid country rocks (Figure 2h). Typical alteration of olivine to serpentine to greenish clay (probably smectite) is occasionally observed in some hand specimens of the outcrop. In hand specimen, typical olivine macrocrysts (0.5 to 2 cm) and a large xenocryst of garnet (1.5 cm) are observed (Figure 3 a,b).

SAMPLING AND ANALYSIS

Five samples were collected from the outcrop, out of which one sample was discarded due to presence of excess crustal fagments. Each sample was divided into two, one half for petrographic examination and the other for whole rock geochemistry. About 12 Thin-sections were prepared

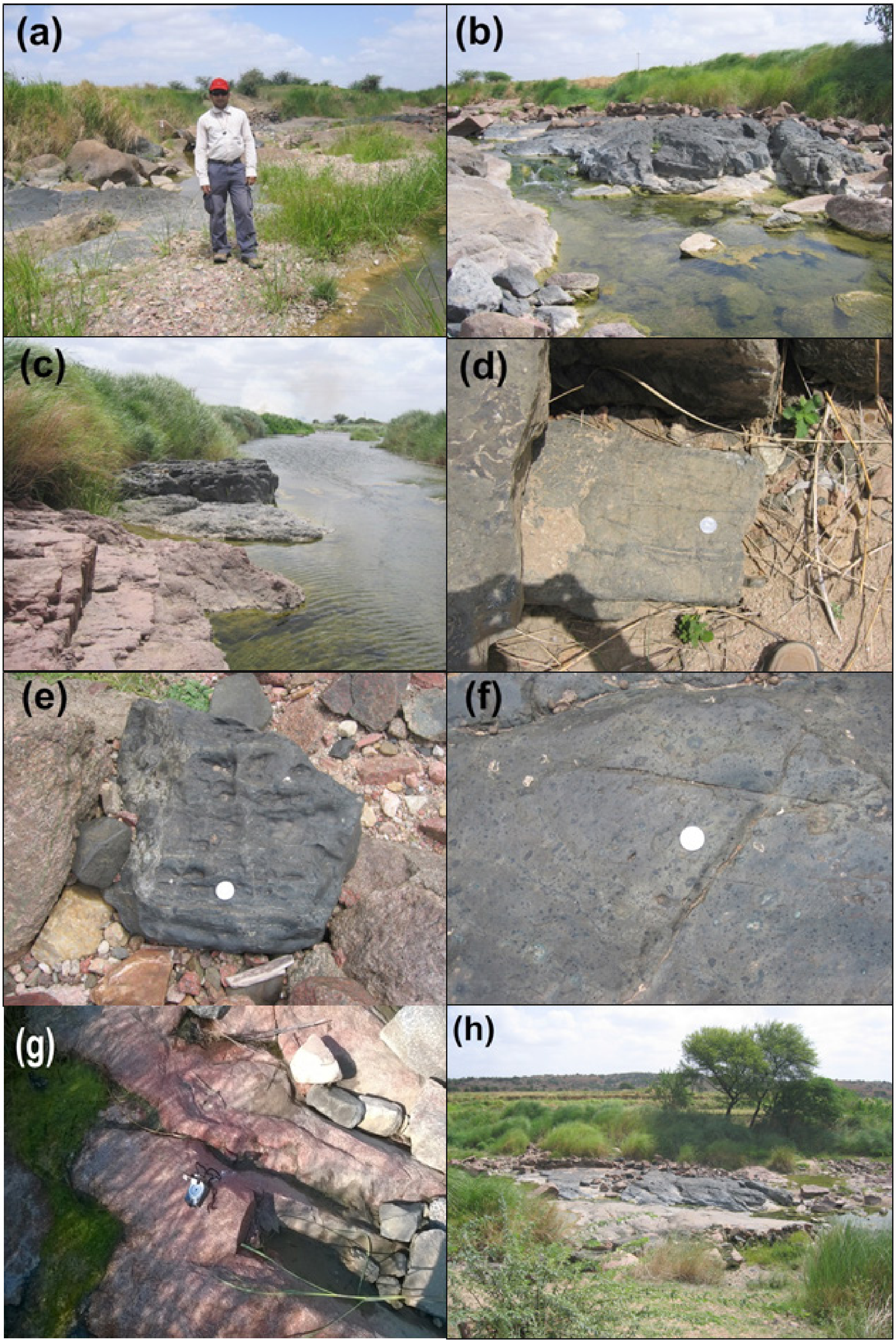


Figure 2. Field photographs. a) Outcrop of new kimberlite pipe with author standing on it; b) Sharp contact between pipe instrusion and the coutry rock granitoids; c) Olivine macrocrysts; d) Flow banding structure; e) Burrows developed after removal of mineral constituents due to fluvial weathering; f) Olivine macrocrysts; g) Deeply reddened feldspars in country rock granitioid; h) Pipe intrusion within granite country rock forming sharp contact.

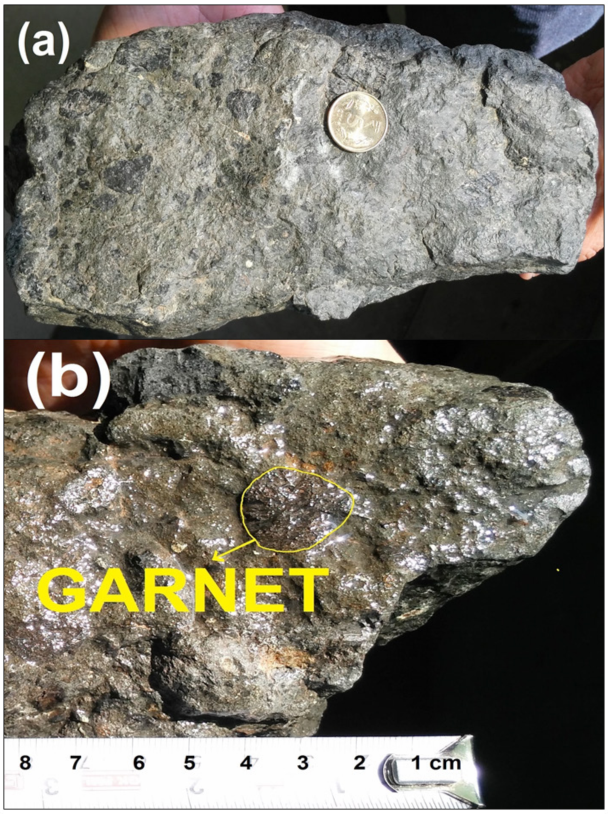


Figure 3. Hand specimen of new kimberlite pipe rock showing a- rounded olivine macrocrysts and fine-grained groundmass. b- large garnet xenocryst.

at Petology Division, Geologcal Survey of India (G.S.I.) and also at Gita Laboratory, Kolkota. The four samples were analysed for whole rock geochemistry at an NABL (National Accreditation Board for Testing and Calibration Laboratories) accredited laboratory at Bangalore for major, trace and rare earth element (REE) analyses. The major element content was determined by using X-Ray Fluoroscence Spectrometry (XRF) and trace and rare earth elements using ICP-MS with ICP-OES finish following standard sample preparation and dissolution techniques. One sample each from already reported pipes-5 and 13 were also sampled and analysed afresh in this study for comparison along with average analyses of south African kimberlites (Wesselton and De Beers mines) published by le Roex et al., (2003) to understand their petrography and geochemistry.

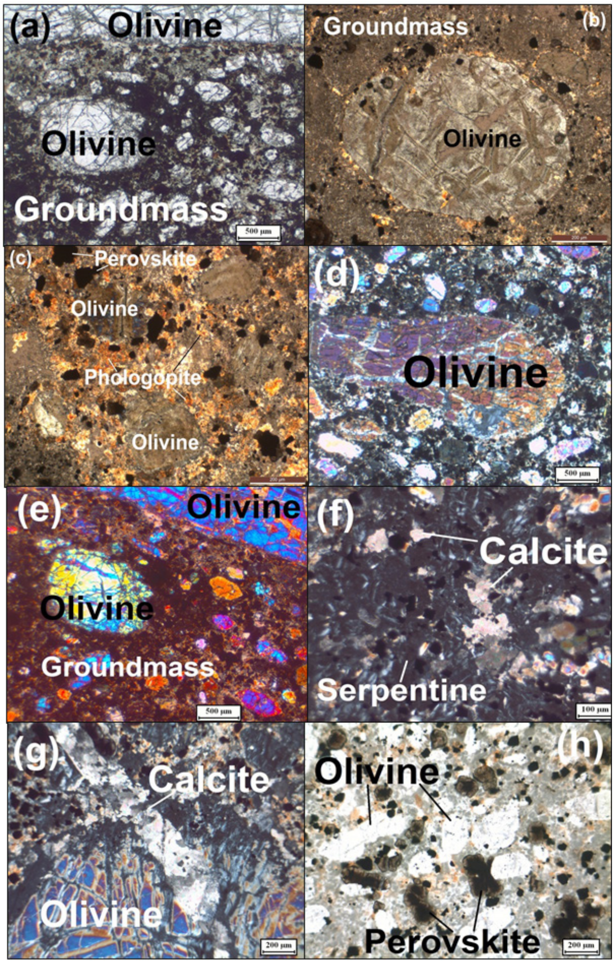
PETROGRAPHY

Under the microscope, the pipe rock reported here (P-16), displays inequigranular texture. It is observed that the predominant mineral phase comprises pale green coloured anhedral to subhedral olivine macrocrysts which are often serpentinised within the fine-grained groundmass composed of microcrystic olivine, serpentine, phlogopite etc. and display intense carbonation. Phlogopite is abundant and characterised by pale orange to deep brown pleochroic colours, with irregular outlines exhibiting poikilitic relation with the fine-grained groundmass (Figure 4 a,b and c). In thin-sections also, olivine occurs as mixed assemblage of two generations of origin represented by macrocrystic and micro-phenocrystic euhedral to subhedral grains. The groundmass calcite is turbid and anhedral. Magnetite occurs in brownish grey color and as euhedral to subhedral grains. (Figure 4 d,e). The groundmass serpentine and calcite possess irregular grain morphology indicating their late development among groundmass minerals. (Figure 4f). Micro-veins of secondary calcite are observed and replacement by calcite in olivine macrocrysts leading to heavy alteration to serpentine and in turn to calcite is not uncommon. (Figure 4g). Perovskites are brown colored near opaque and are anhedral, resembling cauliflower shape, showing light brown color in the borders and dark brown at the centre. Both perovskite and phlogopite phenocrysts are noticed to exhibit zoning (Figure 4 h,i,j). Under the microscope, the nearby pipes-5 and 13 show petrographic similarities to the new pipe in terms of the presence of zoned perovskite and abundance of poikilitic phlogopite within serpenitinised olivine grains (Figure 4 k,l). As seen in the outcrop of host rock granite, in thin-section also, the metasomatic effect on country rock due to the kimberlite emplacement is noticeable which is evidenced by the presence of irregular and herringbone fractures filled with iron oxide (Figure 5 a,b). Based on petrographic examination, the modal abundances are macro phenocrystal olivine 57%, perovskite 5%, phologopite 8%, magnetite 2%, groundmass serpentine 15%, groundmass and remobilized calcite 13%.

According to Reddy (1987), Haggerty and Birkett (2004), Paul et al., (2006) and Kaur et al., (2013), it was opined that pipes-5 and 13 are lamproites which were hitherto classified as archetypal Group- I kimberlites. According to the definition of micaceous kimberlite/ lamproite (Rabhkin et al., 1962), the modal abundance of phologopite requires to be >5%. The new kimberlite pipe is also observed to possess 8% of phlogopite and hence it is presumed to be of lamproitic variety. However, the peculiar mineral assemblages of lamproite, such as sanidine, leucite, apatite etc. (Madhavan, 2001) were not noticed in the thin-sections. Based on petrographic studies, the new kimberlite pipe rock may be classified as hypabyssal macrocrystic calcite- phlogopite kimberlite.

GEOCHEMISTRY

Major, trace and rare earth element data shown in Table 1 and 2, has been used to plot various binary and ternary diagrams. The geochemical data has been compared with



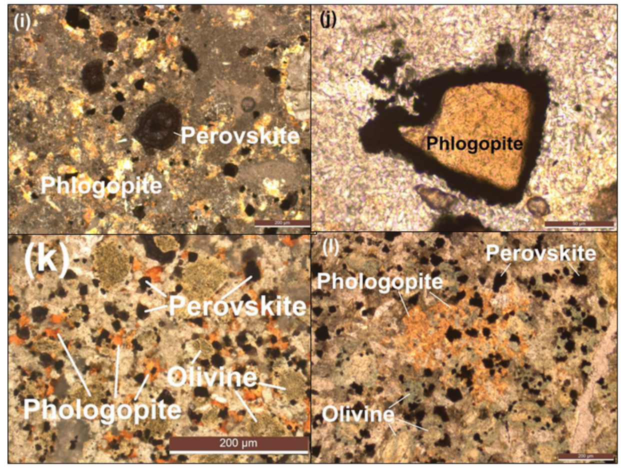


Figure 4. Photomicrographs. a) Inequigranular texture showing altered olvine macrocrysts (PPL); b) Large olivine macrocryst affected by aleration into calcite (XPL); c) Poikilitic intergrowths of phlogopite between olivine macrocsts (XPL); d) Large macrocrystic olivine set in a fine-grained matrix (XPL); e) Two generations of olivine (XPL); f) Irregular grain morphology of groundmass serpentine and calcite (XPL); g) Vein of calcite (XPL); h) Enriched phlogopite content. Note zoned perovskite phenocryst (PPL); i) Zoning in perovskite phenocryst (XPL); j) Zoning in phlogopite phenocryst (XPL); k) Pipe-5 (Muligiripalli) showing olivine macrocrysts within groundmass of phlogopite, perovskite and altered olivine; l)Pipe-13 (Tummatapalli) showing altered olivine, perovskite poikilitic growth of phologopite and calcite veins.

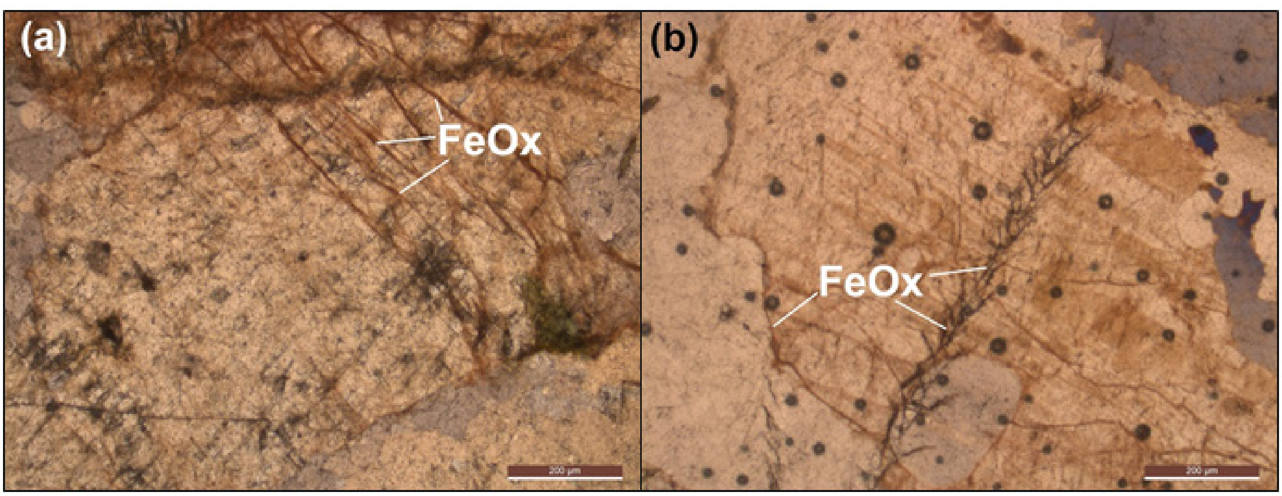


Figure 5. a) Iron oxide (FeOx) stainings indicating fenitisation in granitoid country rock (PPL).b) Herringbone iron oxide (FeOx) veins in country rock granitoid (PPL).

Table 1. Major-element data of the new pipe and pipes-5 and 13 in comparison with South African data of Wesselton and De Beers mines (le Roex et al., 2003).

	New Pipe				Muligiripalli	Tummatapalli	South Africa
Sample No.	PK1-11	PK1-12	PK1-09	PK1-03	P5-01	P13-01	Weeseelton and De Beers
SiO_2	34.25	33.56	31.25	32.23	34.42	35.18	31.36
$Al2O_3$	3.24	2.98	3.14	2.7	3.64	3.11	2.04
Fe_2O3	13.33	12.67	14.5	11.45	9.7	11.46	8.37
MnO	0.19	0.17	0.21	0.18	0.12	0.15	0.16
MgO	22.93	24.2	23.4	21.34	25.75	26.58	32.29
CaO	10.31	9.4	11.34	8.96	11.23	7.99	9.14
Na_2O	0.44	0.37	0.39	0.34	0.15	0.01	0.19
K_2O	0.92	1.2	1.23	1.43	0.59	2.26	1.12
TiO_2	4.3	4.45	4.23	4.8	6.17	6.62	1.38
P_2O_5	0.6	0.57	0.73	0.7	0.62	0.68	0.5
LOI	8.46	6.54	7.34	6.65	5.66	5.23	
Total	99.02	96.11	97.76	90.75	98.05	99.27	86.56
Mg#	59.77	62.17	58.21	61.64	69.63	66.68	76.9
Contamination Index	2.01	1.92	2.05	1.8	1.68	1.81	1.54
Ilmenite Index	3.13	2.92	0.16	0.2	0.23	0.21	0.04

that of pipe-5, 13 and southern African (De Beers and Wesselton Group-I kimberlite pipes). The new kimberlite pipe rock is obviously undersaturated (SiO_2: 31.25-34.25 wt%) and rich in MgO (21.34-24.2 wt%) which is comparable with pipes-5 and 13 and south African kimberlites. The TiO_2 content in the new pipe ranges from 4.23-4.8 (wt%) which is less than that of pipes-5 and 13 and much higher than south African pipes (1.38 wt%). (Table 1). The Mg# of the new pipe (58.2-62.16) is also comparable with that of pipes-5 and 13 (69.63 and 66.68 respectively), however it is low when compared to south African kimberlites (76.90). From trace and REE data (Table 2), it is observed that the concentration ranges of compatible trace elements in the new kimberlite are Cr (76.5- 83.59 ppm), Ni (892-1120 ppm), Sc (15.12-16.2 ppm) and V (191-198.12 ppm). The high Ni content is attributed to presence of liquidous olivine. Among the incompatible elements, the large ion lithofile elements (LILE) have concentration ranges- Ba (978-1621 ppm), Rb (85.96-87.6 ppm) and Sr (964.5-1021.45 ppm). The high field strength elements (HFSE) have concentrations- Hf (8.3-10.2 ppm), Nb (135.15-142.2 ppm), Th (15.9-17.23 ppm), U (3.29-4.22 ppm), Zr (397.3-421.1 ppm). In general kimberlites exhibit extensive variation in their REE concentrations ranging from approximately 100 ppm (Mir Kimberlite of Russia) to 400 ppm (de Bruyn kimberlite of south Africa). However, the Group- II kimberlites comprise abundantly higher REE content than Group- I kimberlites (Mitchell and Brunfelt, 1975; Shravan Kumar, 2013). In general, the kimberlites of the EDC exhibit linear LREE enrichment trend with low abundances of HREE content. The La/Yb ratios are significantly higher (50-200) than in the other mantle rock. The La/Yb ratio ranges from 50 to 100 ppm for Group-I kimberlites, and from 130 to 170 ppm for the Group-II kimberlites (Shravan Kumar, 2013). The EDC kimberlites are characterised by La/Yb ratio of 70-170 ppm (Chalapathi Rao, 2008). Similar to this observation, the new kimberlite pipe samples show a high La/Yb ratio ranging from 105-121 ppm. Yet another parameter is La/Sm ratio. The EDC kimberlites are also characterised by enrichment of LREE relative to MREE with La/Sm ratios ranging from 7-20 ppm (Chalapthi Rao, 2008). In the new kimberlite pipe, the La/Sm ratio ranges from 7.18 to 8.26 ppm close to the values of pipes-5 and 13. Furthermore, it is observed that the secondary processes like leaching,

Table 2. Trace-element and REE analyses of the new pipe and pipes-5 and 13 in comparison with South African data of Wesselton and De Beers mines (le Roex et al., 2003).

	New Pipe				Muligiripalli	Tummatapalli	South Africa
Sample No.	PK1-11	PK1-12	PK1-09	PK1-03	P5-01	P13-01	Weeseelton and De Beers
				TRACE ELEMENTS			
Ba	1120	1621	978	1021	359	1995	1392.57
Be	2.52	3.1	3.1	2.8			
Bi	0.26	0.28	0.17	0.21			
Cd	0.48	0.4	0.41	0.38			
Co	83.59	81.2	78.3	76.5	76.64	91.81	86.89
Cr	890	1120	1021	920	1077	1491.5	1527.05
Cs	7.28	7.21	8.23	7.23	4.38	3.02	
Cu	113.55	116.7	112.1	111.34	96.52	144.9	47.84
Ga	11.14	10.1	12.3	9.89	26.84	30.91	
Hf	8.52	8.3	9.1	10.2	10.49	14.23	5.88
Mo	1.74	1.81	1.5	1.23			
Nb	135.15	136.3	141.2	142.2	209.86	190.77	138.43
Ni	898.06	923.12	921.3	892	650	796	1281.13
Pb	8.39	7.98	9.2	9.12	7.73	8.25	8.38
Rb	85.96	86.3	87.6	86.32	59.97	170.58	61.89
Sc	15.58	15.12	16.2	15.15	13.67	19.73	16.91
Sr	972.35	1002.2	964.5	1021.45	662	667	1099.04
Ta	8.5	7.89	9.23	9.43	16.51	10.88	
Th	16.6	15.9	17.23	16.34	19.37	16.85	13.48
Tl	1.13	1.12	1.11	1.21			
U	3.37	3.29	4.12	4.22	3.32	3.5	3.24
V	197.18	191	198.12	194.5	221.77	220.66	112.09
Y	18.87	18.9	17.2	18.23	23.14	26.19	30.26
Zn	86.54	79.8	84.5	83.12	69.53	124.86	65.34
Zr	403.52	397.3	421.2	418.34	437.07	630.11	287.68
				RARE EARTH ELEMENTS			
La	115.42	117.80	119.23	120.21	149.29	130.98	118.36
Ce	237.71	221.7	246.2	254.32	283.4	249.03	241.84
Pr	24.54	27.45	26.3	28.23	32.21	28.1	27.71
Nd	92.19	89.9	94.3	92.34	120.01	104.97	103.18
Sm	14.65	16.40	14.44	15.89	18.71	16.39	15.09
Eu	3.99	4.2	3.78	3.67	4.4	4.42	3.85
Gd	11.75	12.1	10.12	11.87	13.81	11.64	9.15
Tb	1.28	0.98	0.98	1.11	1.64	1.43	1
Dy	5.12	4.9	5.67	5.42	7.6	6.67	4.23
Ho	0.84	0.79	0.87	0.78	1.1	1.01	0.61
Er	2.07	2.01	2.12	2.18	2.56	2.31	8.69
Tm	0.19	0.21	0.11	0.18	0.31	0.27	0.14
Yb	1.1	0.98	0.98	1.12	1.54	1.49	0.7
Lu	0.15	0.14	0.17	0.14	0.19	0.2	0.09
ΣREE	511.01	499.56	525.27	537.46	636.77	558.9`	534.64
La/Yb	105.01	120.2	121.66	107.33	96.94	87.91	169.31
Ce/Yb	216.26	226.22	251.22	227.07	184.03	167.13	345.93
La/Sm	7.88	7.18	8.26	7.57	7.98	7.99	7.84

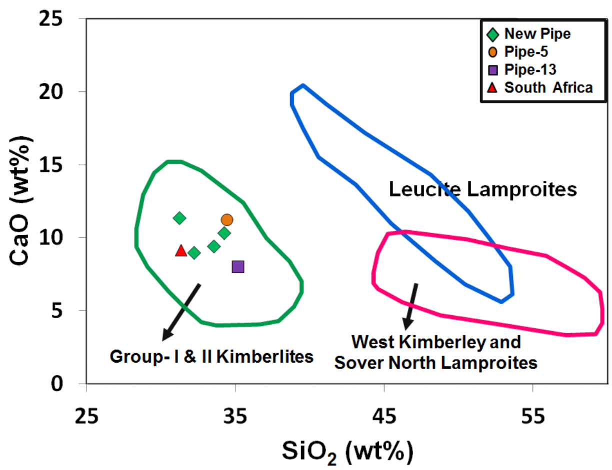


Figure 6. Binary diagram between Cao and SiO_2 (wt%) of the new pipe in comparison with pipes-5, 13 and South African kimberlites. Fields: Kimberlite- after Smith et al. (1985), Taylor et al. (1994) and Lamproites- after Fraser (1987). Adopted from Shravan Kumar (2013).

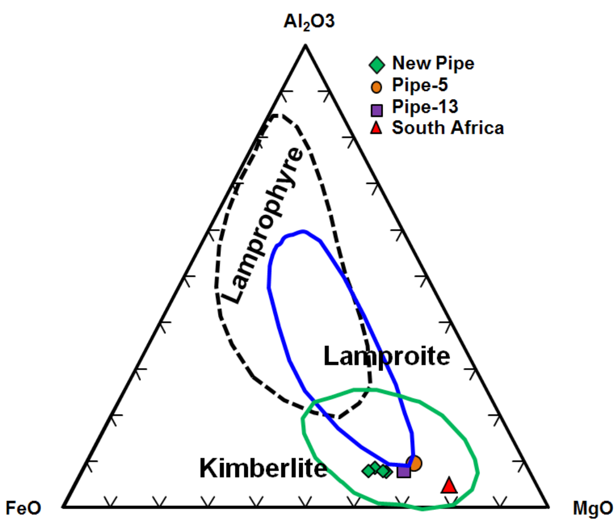


Figure 7. Ternary diagram of Al_2O_3-FeO-MgO showing the new pipe in comparison with pipes-5, 13 and South African kimberlites. Fields after Bergman (1987).

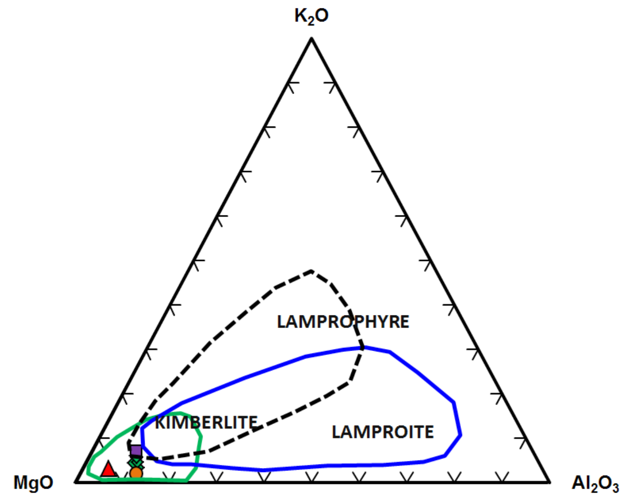


Figure 8. Ternary diagram of K_2O-MgO-Al_2O_3 showing the new pipe in comparison with pipes-5, 13 and South African kimberlites. Symbols as in Figure 7. Fields after Bergman (1987).

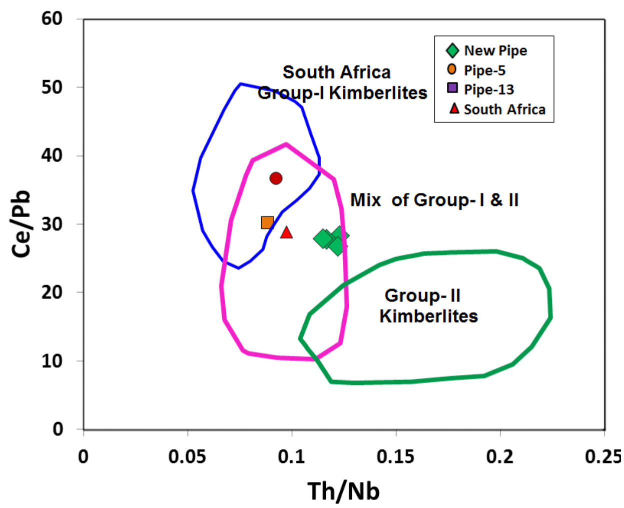


Figure 9. Binary diagram between Th/Nb and Ce/Pb rations for the new pipe in comparison with pipes-5, 13 and South African kimberlites. Fields after Becker and le Roex (2007).

weathering, alteration and crustal contamination do not disturb the REE concentrations. Thus the new kimberlite presumably shows affinity to Group-I class.

In the major element binary diagram involving SiO_2-CaO conent, the new kimberlite plots in the common field of Group-I and II (Figure 6). The major element compositions on ternary diagrams (Bergman, 1987), with fields for kimberlite, lamproite and lamprophyre, show that the new kimberlite along with pipes-5 and 13 plots within the “kimberlite” field but on the peripheries of “lamproite“ field (Figures 7 and 8). The Th/Nb and Ce/Pb ratio diagram (Becker et al., 2007) reflects that the new kimberlite plots in the fields of mixture of Group-I and II (Figure 9). The chondrite normalized (Sun and McDonough, 1995) plot shows that REE of the new kimberlite more or less follows the trend of south African samples and remarkably similar to trend of pipes-5, 13 (Figure 10). By this study, it may be stated that this kimberlite might belong to transitional type of both Group-I and II and however it invokes a comprehensive investigation.

Geochemically the new pipe shows similarity to Group-I class of southern Africa but plots close to Group-II class. It should be noted that the nearby pipes-5 and 13 are reported to be lamproites (Reddy, 1986; Kaur et al., 2013).

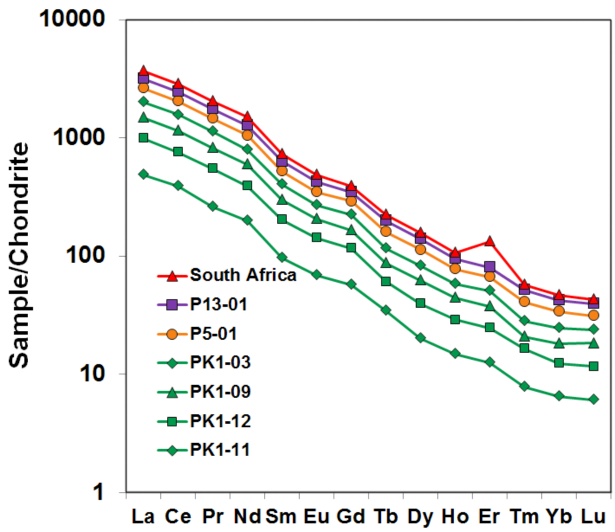


Figure 10. Chondrite normalised (Sun and McDonough, 1995) REE patterns of the new pipe in comparison with pipes-5, 13 and South African kimberlites.

According to Mitchell (1991), lamproitic rocks typically possess characters viz., ultrapotassic (molar K_2O/Na_2O>3), peralkaline (molar $K_2O+Na_2O)/Al_2O_3$>1.0) and rich Ba (>2000 ppm, commonly >5000 ppm), Zr (>500 ppm), Sr (>1000 ppm), La (>200 ppm) and F (0.2-0.8 wt%). The geochemical data of the new pipe rock shows affinity towards lamproitic nature owing to the concentration of K_2O/Na_2O ratio (3.17) in accordance with the ranges given by Mitchell (1991). However, on the contrary, the ratio $K_2O+Na_2O)/Al_2O_3$ is 0.53. These two ratios (K_2O/Na_2O and $K_2O+Na_2O)/Al_2O_3$) are similar to those of pipes-5 and 13. Furthermore, field megascopic observations on this outcrop such as non-micaceous/basaltic nature, absence of typical lamproite mineral assemblages such as sanidine, leucite, richterite etc. (e.g. Woolley et al., 1996, Madhavan, 2001) support that this new kimberlite occurrence might be classified as archetypal Group- I kimberlite. However, based on petrography, the rock appears to be enriched in tetraferri groundmass pholognite which is characteristic of Group- II variety akin to pipes-5 and 13 (Kaur et al., 2013). Therefore it is uncertain, at this juncture, with the limited samples analysed in this study, to classify this rock as a typical kimberlite or a lamproite and hence a comprehensive investigation based on mineral chemistry is highly warranted to confirm the geochemical affinities of this new pipe.

PETROGENESIS AND DIAMOND PROSPECTIVITY

Using whole rock geochemical data, the petrogenesis and diamond prospectivity of the new kimberlite has been deciphered. Clement (1982) proposed a 'crustal contamination index (C.I.) to understand the degree of contamination. Mitchell (1986) proposed that contamination increases the whole-rock concentrations of SiO_2, Al_2O_3 and Na_2O in kimberlite. Mitchell (1986) opined that <35 wt% SiO_2 and <5 wt% Al_2O_3 indicate contamination-free kimberlite, and that mixing lines of various contaminants and weathering products could explain variations in kimberlite chemistry.

$$C.I.=\frac{(SiO_2+Al_2O_3+Na_2O_3)}{(MgO+2K_2O)}$$

The Clement's (1982) crustal contamination index (C.I.) ranges from 1.7 to 1.93 for the new pipe rock indicating that it is crustally contaminated with comminuted crustal xenoliths or assimilated them within it. Similarly another parameter viz., ilmenite index (Ilm. I.) of Taylor et al., (1994) ranges from 0.2 to 3.13, indicates a high contamination by ilmenite entrainment.

$$Ilm.I.=\frac{(Fe+TiO_2)}{(2K_2O+MgO)}$$

This indicates an increased sampling of ilmenite bearing magmatic phases during its ascent. The higher proportions of phlogopite, ilmenite and perovskite may be due to either sampling of a source region enriched in these elements or ilmenite fractionation (Mitchell, 1986). As seen in Table 1, the Nb and Ta content similar to pipes-5 and 13. Furthermore, this new pipe also appears to be crustally contaminated with reference to Al_2O_3 and Yb variation diagram (Kjarsgaard et al., 2009) whereas the south African kimberlite plots in the non-contaminated field (Figure 11). At the same time, in the binary diagram between CaO and C.I. (Taylor et al., 1994), the new pipe rock appears to be non-carbonated type, similar to pipes-5, 13 and south African pipes (Figure 12).

The REE patterns considering variation between the ratios of La/Sm and Gd/Yb indicate that the new pipe might have originated from a very low partial melting at a range of 0.5 to 1% according to the model of Becker and le Roex, (2006) whereas according to melting trajectories calculated based on partition coefficient values given by Dasgupta et al., (2009) (adopted from Dongre et al., 2016), the new kimberlite plots within a range of 1-2%. At the same time, the degree of partial melting for pipes-5 and 13 slightly higher (1-3%) (Figure 13). Thus the new kimberlite pipe shows a high degree of crutal contamination, non-carbonated and high ilmenite entrainment at the source region at a low degree of partial melting. Chalapathi Rao and Srivastava (2009) reported that EDC kimberlites could have been derived from a complex interaction between sources of both Group-I and Group-II kimberlites, which is similar to those suggested for transitional kimberlites

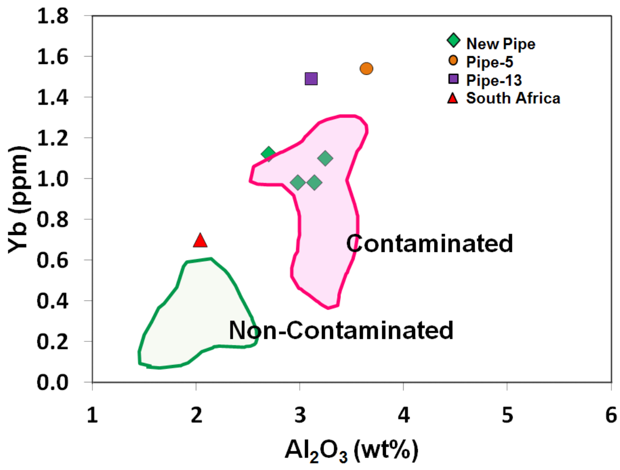


Figure 11. Binary plot showing variations in Al_2O_3 and Yb in the new kimberlite pipe. Fields were drawn engulfing data for Lac de Grass kimberlites from Kjarsgaard et al. (2009).

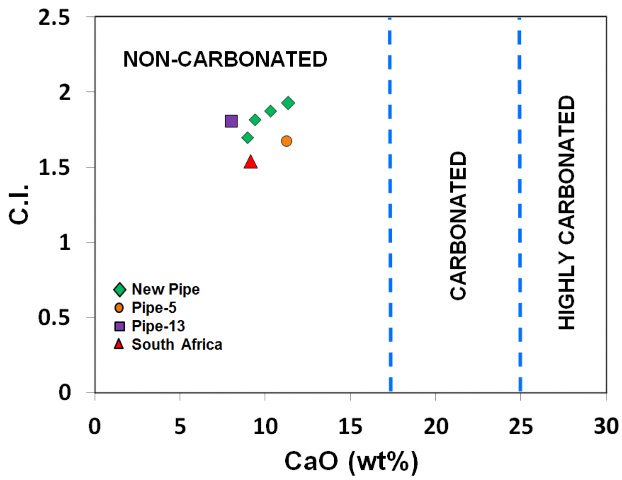


Figure 12. Binary plot showing variations in CaO and crustal contamination index (C.I.). Fields after Taylor et al. (1994).

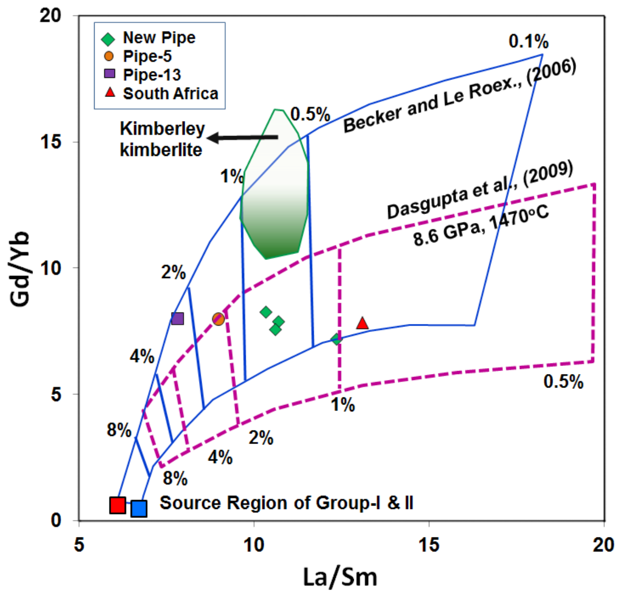


Figure 13. Binary variation diagram with La/Sm and Gd/Yb ratios for the new pipe in comparison with pipes-5, 13 and South African kimberlites. Curves indicate melting trajectories of kimberlites and orangeites source regionsn with numbers showing degree of melting. Melting trajectories: Solid blue- partition coefficients from Becker and le Roex (2006) and Pink dashed- experimentally calculated bulk peridotite/ melt partition coefficients at 8.6 GPa and 1470 ºC (Dasgupet et al., 2009). Source region and Field for Kimberley kimberlites from Becker and le Roex (2006). Adopted from Dongre and Chalapathi Rao (2012) and Dongre et al. (2016).

from south Africa (Becker et al., 2007). This is probably applicable for the new pipe reported here.

In the process of diamond exploration, the prime objective is to discover a kimberlite pipe first and then to assess its diamond potentiality as exploration progresses. To assess the diamond potentiality of a kimberlite, mineral chemistry of mantle xenocrysts is helpful in the initial evaluation (e.g., Rombouts, 2003; Mukherjee et al., 2007; Oliver et al., 2011; Talukdar and Chalapathi Rao, 2015). In course of exploration, a comprehensive investigation of different lithological facies of the kimberlite pipe is inevitable and evaluation of diamond incidence in each litho facies using techniques such as caustic fusion in later stages is a common methodology (Rombouts, 2003).

However, many researchers have attempted to reveal relations between the chemical composition of kimberlites and their diamond grade. Certain geochemical parameters like K_2O/Na_2O ratio (Krutoyarsky et al., 1959), the increased concentrations of Cr and Mg and the decreased contents of Ti, Fe, Al (Blagulkina, 1969) were considered as indicators of diamond potential of kimberlites. The enrichment of these elements is due to the presence of mineral phases like Cr-diopside, chromite, pyrope etc. which are primary kimberlite indicator minerals. Vasilenko et al., (2002) have used regression statistical analysis to correlate bulk rock geochemistry and diamond potentiality that has a worldwide application. An attempt has been made here to envisage the diamond potentiality of the new pipe using whole rock geochemical data. The binary diagram between Fe_2O_3 and Y, with fields for prospective and non-prospective kimberlites (Birkett, 2008), shows that the new kimberlite pipe samples plot in the non-prospective field (Figure 14). Illupin et al., (1974) used cationic wt% of major elements and predicted diamond content of kimberlites. Cationic weight percentages were calculated from major element data and

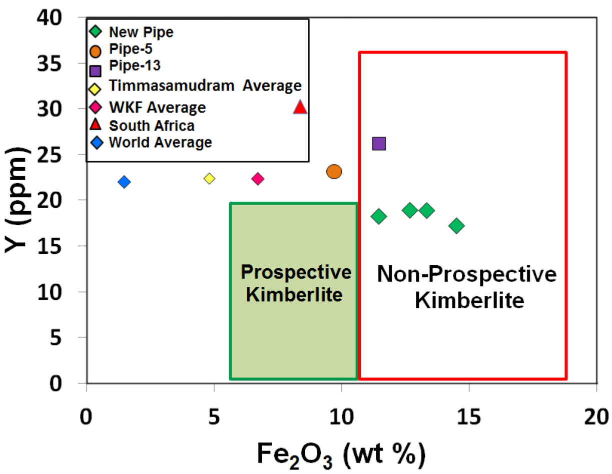


Figure 14. Binary plot between Fe_2O_3 and Y showing the new pipe in comparison with pipes-5, 13 averages of Timmasamudram, WKF, South African and world kimberlites. Fields after Birkett, (2008). Data for Timmasamudram, WKF and world averages from Srinivas Choudary et al. (2007).

plotted to establish a preliminary knowledge regarding diamond prospectivity of this kimberlite. In the binary diagram of K versus Al (%), the samples plot in the border zone of diamondiferous and few + no diamonds field (Figure 15a). The binary plots between various cationic weight percentages of other major elements (K versus Fe, Ti versus Al and Ti versus K %) show that this pipe might be non-diamondiferous. (Figure 15 b,c,d).

The diamond grade (DG) values have been calculated using cationic weight percentages with the aid of following formula (Milashev, 1965) (Table 3).

$$DG=\frac{Fe:Ti}{[\log(Fe+Ti)+2\log(Al+K+Na)]}$$

The diamond grade of the new pipe (1.43-1.96) and pipes-5, 13 (0.93-1) are very low when compared to high DG values of kimberlites of Timmasamudram, WKF, south African and world average (4.14-4.91). The predominance of TiO_2 content is attributed to enrichment of ilmenite mineral content in the pipe rock. In the new

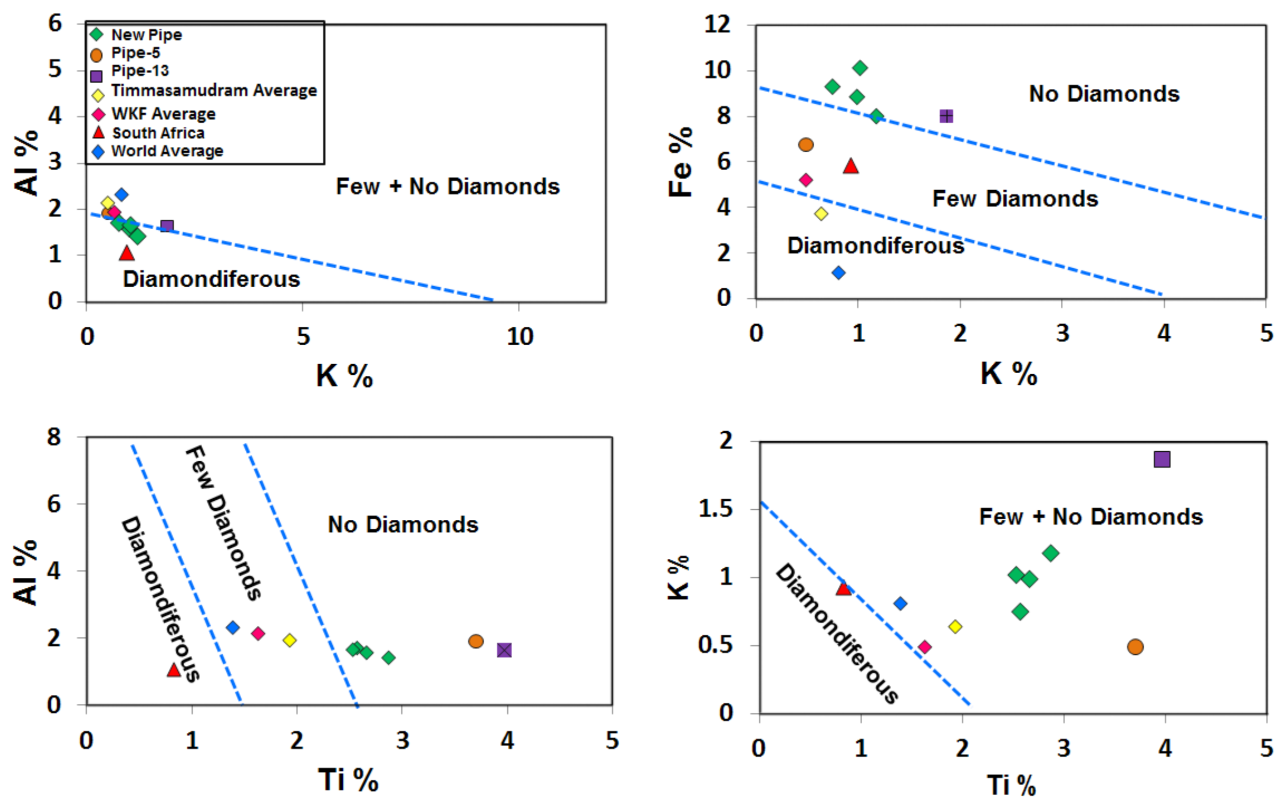


Figure 15. Binary plot between cationic wt% showing the new pipe in comparison with kimberlites of pipes-5, 13, Timmasamudram, WKF, South African and world average. Fields after Illupin (1974).

Table 3. Calculated diamond grade (DG) values for the new kimberlite pipe, pipes-5 and 13 along with DG calculated from averages of Timmasamudram, WKF, World Average (Srinivas Choudary et al., 2007) and south African pipes (le Roex, 2006).

Sample	DG
PK1-11	1.85
PK1-12	1.7
PK1-09	1.96
PK1-03	1.43
P5-01	1
P13-01	0.93
South Africa	4.74
Timmasamudram	4.31
WKF	4.14
World Avge.	4.91

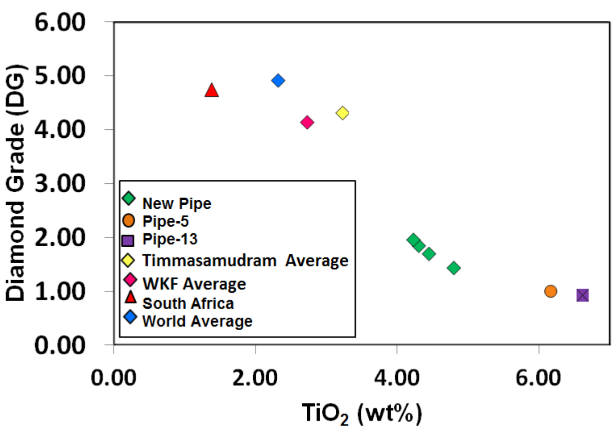


Figure 16. Binary plot between TiO_2 (wt%) and Diamond Grade (DG) values for the new pipe in comparison with that of pipes-5, 13, Timmasamudram, WKF, South African and world average.

kimberlite, diamond grade is observed to be inversely proportional to TiO_2 content (Figure 16) in comparison with kimberlites elsewhere. The adjacent pipes-5 and 13 are reported to be barren and the new pipe shows similarities in terms of petrography and geochemistry to these pipes. Hence it leaves apprehensions on its diamond content, with the limited analyses of this study. Although it is too early to comment on the diamond potentiality of this new pipe, the results of this report indicate that it might be barren like pipes-5 and 13. However, a thorough assessment with the aid of extensive sampling and drilling is highly warranted to decipher the diamond potentiality of this new kimberlite pipe.

CONCLUSIONS

Even though the new kimberlite is akin to Group-I class macroscopically, the petrographic and geochemical studies indicates that the new kimberlite pipe rock shows characteristics of both Group- I and II. Petrographically, the new pipe rock possesses enriched phlogopite content reflecting its affinity towards lamproitic class. However, phlogopite content alone can not confirm its affinity towards lamproite but its mineralogical content needs to be further investigated. As the nearby pipes-5 and 13 are recently reclassified as Group- II variety, a more detailed petrological examination is highly warranted for this pipe. The new pipe rock appears to be non-carbonated. It displays a high degree of contamination by crustal granitic rocks. The degree of partial melting appears to be very low (0.5-1%) which is similar to that of WKF pipes. This indicates a geodynamic setting similar to emplacement of other WKF pipes. The new pipe rock, based on limited samples shows a low diamond grade (DG) values similar to pipes-5 and 13. A more comprehensive investigation with the aid of bulk rock geochemistry and mineral chemistry supported by assessing the deeper horizons of the pipe, both laterally and vertically, will ascertain its appropriate classification, genesis, geodynamic setting and diamond potentiality. However, this discovery encourages kimberlite explorationists to continue investigations in search of new kimberlite pipes in this part of the country.

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APPENDIX

Supplemental material is available for downloading at the journal site.

REFERENCES

Akella J., Rao P.S., McCallister R.H., Boyd F.R., Meyer H.O.A., 1979. Mineralogical studies on the diamondiferous kimberlites of Wajrakarur area, South India. In: Boyd, F.R., Meyer, H.O.A., A., H.O. (Eds.), Kimberlites, Diatremes and Diamonds: Their Geology, Petrology and Geochemistry 1, American Geophysical Union, 172-177.

Bailey D.K., 1985. Fluids, melts, flowage, and styles of eruption in alkaline ultramafic magmatism. Transactions of the Geological Society of South Africa 88, 449-457.

Becker M., Le Roex A.P., 2006. Geochemistry of South African on- and off-craton Group I and II kimberlites: petrogenesis and source region evaluation. Journal of Petrology 47, 673-703.

Becker M., Le Roex A,P., Class C., 2007. Geochemistry and petrogenesis of South African transitional kimberlites located on and off the Kaapvaal Craton. South African Journal of Geology 110, 631-646.

Bergman S.C., 1987. Lamproites and other Pottasium rich alkaline rocks; a review of their occurrence, mineralogy and geochemistry. In: Alkaline Igneous Rocks. Fitton, J.G. and Upton, B.J. (Ed). Geological Society, Lonondon, Special Publication 30, 103-190.

Birkett T.C., 2008. First-row transition elements, Y and Ga in kimberlite and lamproite: applications to diamond prospectivity and paragenesis. The Canadian Mineralogist 46, 1269-1282.

Blagulkina V.A., 1969. Petrochemical types of kimberlites from Siberia. Sov. Geol. 7, 82-91 (in Russian).

Chadwick B., Vasudev V.N., Hegde G.V. 2000. The Dharwar craton, southern India, interpreted as the result of Late Archaean oblique convergence. Precambrian Research 99, 91- 111.

Chalapathi Rao N.V., 2008. Precambrian Alkaline Potassic-Ultrapotassic, Mafic-Ultramafic Magmatism in Peninsular India. Journal of the Geological Society of India, 72, 57-84.

Chalapathi Rao N.V. and Srivastava R.K. 2009. Petrology and geochemistry of diamondiferous Mesoproterozoic kimberlites from Wajrakarur kimberlite field, Eastern Dharwar craton, Southern India: genesis and constrains on mantle source regions. Contributions to Mineralogy and Petrology 157, 245-265.

Chalapathi Rao N.V., Dongre A.N., Wu F.Y., Lehmann B., 2016. A Late Cretaceous (ca. 90 Ma) kimberlite event in southern India: implication for sub-continental lithospheric mantle evolution and diamond exploration Gondwana Research. http://dx.doi.org/10.1016/j.gr.2015.06.006

Clement C.R., 1982. A comparative geological study of some major kimberlite pipes in northern Cape and Orange Free State. Ph.D. Thesis, University of Cape Town.

CRAEI 2004. Final Report of all Exploration for Diamond and Other Mineral Commodities Completed in the Anantapur and Kurnool District of Andhra Pradesh by CRAE (I), during the Term of RP Nos. GOMS No. 24–27 Vol. 1 0f 5, from Jan. 2001 to Feb. 2004. CRA Exploration (India) Pvt. Limited (Rio Tinto Group) (51 p.). http://www.ibm.nic.in/writereaddata/files/07112014113446APR_14_to_17.pdf

Dasgupta R., Hirschman M.M., McDonough W.F., Spiegelman M., Withers A.C., 2009. Trace element partitioning between garnet lherzolite and carbonatite at 6.6 and 8.6 GPa with applications to the geochemistry of the mantle and of mantle-derived melts. Chemical Geology 262, 57-77.

Dongre A.N., Chalapathi Rao N.V., 2012. Narayanpet Kimberlite field, eastern Dharwar craton: a review of petrology and geochemistry. Gondwana Geological Magazine, Special volume 13, 25-36.

Dongre A.N., Chalapathi Rao N.V., Vijolen, K.S., Lehmann B., 2016. Petrology, genesis and geodynamic implication of the Mesoproterozoic- Late Cretaceous Timmasamudram kimberlite cluster, Wajrakarur fiels, Eastern Dharwar Craton, southern India. Geoscience Frntiers (In Press), 1-13., http://dx.doi.org/10.1016/j.gsf.2016.05.007.

Fraser K.J., 1987. Petrogenesis of kimberlites from South Africa and lamproites from Western Australia and North America; Unpublished Ph.D. Thesis, The Open University, Milton Keynes, UK.

Haggerty S.E. and Birkett T., 2004. Geological setting and chemistry of kimberlite clan rocks in the Dharwar Craton, India. Lithos 76, 535- 549.

Illupin I.P., Sobolev S.F., Zolotarev B.P. Lebedev, Zenovyev A.A., 1974. Geochemical specialization of kimberlites from various parts of Yakutia. Geochemistry International 11, 357-370.

Janse A.J.A., 1992. Archons and Cratons, New ideas on tectonic control of economic kimberlites. International Round Table Conference on Diamond Exploration and Mining; New Delhi.

Kaur G., Korakoppa, M.M., Fareeduddin, Pruseth K.L., 2013. Petrology of P-5 and P-13 “Kimberlites” from Lattavaram Kimberlite Cluster, Wajrakarur Kimberlite Field, Andhra Pradesh, India: Reclassification as Lamproites. In: D.G. Pearson et al. (Eds.), Proceedings of 10th International Kimberlite Conference, Volume 1, Special Issue of the Journal of the Geological Society of India, 183-194. DOI: 10.1007/978-81-322-1170-9_11, _ Geological Society of India 2013.

Kjarsgaard B.A., Pearson D.G., Tappe S., Nowell G.M., Dowall, D.P., 2009. Geochemistry of hypabyssal kimberlites from Lac de Gras, Canada: Comparisons to a global database and applications to the parent magma problem. Lithos 112, 236-248.

Krutoyarsky M.A., Milashev V.A., Rabkin M.I., 1959. Kimberlites in the basins of Omonos and Ukukita rivers. Proceedings of the NIIGA, vol. 65. Gosnauchtekhisdat, Leningrad, 27- 34. (in Russian).

Le Roex,A.P., Bell D.R., Davis P., 2003. Petrogenesis of Group-I Kimberlites from Kimberley, South Africa: Evidence from Bulk-rock Geochemistry, Journal of Petrology, 44, 2261-228. DOI: 10.1093/petrology/egg077.

Lynn M., 2005. The discovery of kimberlites in the Gulburga and Raichur districts of Karnataka. In: Proceedings of the Group Discussion on Kimberlites and Related Rocks of India, organized by the Geological Society of India, Bangalore, Abstracts, 14, 48-49.

Lynn M., Joy S., Preston S., 2013. The Geology and Geochemistry of the Wadagera kimberlite and the characteristics of the underlying subcontinental lithospheric mantle, Dharwar Craton, India. In: Pearson D.G., et al. (Eds.), Proceedings of 10th IKC. Spl. Issue, Journal of the Geological Society of India 1, 167-181.

Madhavan V., 2001. Rare alkaline rocks from Andhra Pradesh, southern India: an overview, Journal of Asian Earth Sciences 19(3), 321-332.Pearson, D.G., et al. (Eds.), Proceedings of 10th IKC. Special Issue Journal of the Geological Society of India 1, 167-181.

Milashev V.A., 1965. Petrochemistry of Kimberlites Yakutian and Factories of their Diamondiferous. Nedra, Leningrad p. 159 (in Russian).

Mitchell R.H. and Brunfelt A.O., 1975. Rare earth element geochemistry of the Fen alkaline complex, Norway. Contributions to Mineralogy and Petrology 52, 247-259.

Mitchell R.H., 1986. Kimberlites: Mineralogy, Geochemistry and Petrology. Plenum Press.

Mitchell R.H., 1991. Kimberlites and Lamproites: Primary Sources of Diamond, Ore Deposit Models, Geoscoence Canada Reprint Series 6, II, 13-25.

Mukherjee A., Sravan Kumar Ch., Krishna Reddy K., Siddiquie S.N., Chaturvedi L., 2007. Two New Kimberlites in Bommanagapalli Area, Anantapur district, Andhra Pradesh, Based on Systematic Stream Sediment Sampling and Ground Magnetic Survey, Journal of the Geological Society of India 69, 625-640.

Murthy D.S.N. and Dayal A.M., 2001. Geochemical characteristics of kimberlite rock of the Anantapur and Mahbubnagar districts, Andhra Pradesh, South India. Journal of Asian Earth Sciences 19, 311-319.

Nayak S.S. and Kudari S.A.D., 1999. Discovery of diamond-bearing kimberlite in Kalyandurg area, Anantapur district, Andhra Pradesh. Current Science 76, 1077-1079.

Neelakantam S., 2001. Exploration for diamonds in southern India. Geological Survey of India, Special Publication 58, 521-555.

Oliver M.C., Melgarejo J.C., Goncalves A.O., 2011. Use of Indicator Minerals in Diamond Exploration: a Comparison between Barren and Fertile Kimberlites in Angola, Revista de la Sociedad Espanola de Mineralogia, 15, 59-60.

Paul D.K., Nayak S.S., Pant N.C., 2006. Indian kimberlite and related rocks: Petrology and Geochemistry. Journal of the Geological Society of India 67, 328-355.

Phani P.R.C., 2015. Area Selection for Diamond Exploration Based on Geological and Morphostructural Set-Up: Examples from Wajrakarur Kimberlite Field, India, Journal of Advanced Chemical Sciences 1, 102-106.

Rabhkin M.I., Krutoyarsky M.A., Milashev V.A., 1962. The classification of the kimberlitic rocks of Yakutia and their nomenclature.Trudynaucho-issled.Inst. Geol. Arkt (54894), 121 (in Russian).

Rao K.R.P., Reddy T.A.K., Rao K.V.S., Rao K.S.B., Rao N.V., 1998. Geology, petrology and geochemistry of Narayanpet Kimberlite Field in Andhra Pradesh and Karnataka. Journal of the Geological Society of India 52, 663-676.

Ravi S., Rau T.K., Reddy N.S., Nayak, S.S., 2007. Tungabhadra Kimberlite Field, Kurnool district, Andhra Pradesh. Journal of the Geological Society of India 69, 619-624.

Ravi S. and Satyanarayana S.V., 2007. Discovery of kimberlites in Chagapuram area, Mahaboobnagar district, Andhra Pradesh. Journal of the Geological Society of India 70, 689-692.

Reddy T.A.K., 1986. Petrology and geochemistry of Wajrakarur Kimberlties. Records of the Geological Survey of India 115, 5, 54-63.

Reddy T.A.K., 1987. Kimberlite and lamproitic rocks of Wajrakarur area, Andhra Pradesh. Journal of the Geological Society of India 61, 131-146.

Rombouts L., 2003. Assessing the diamond potential of kimberlites from discovery to evaluation bulk sampling, Mineralium Deposita 38, 496-504.

Shaikh A.M., Patel S.C., Ravi S., Behera D., Pruseth K.L., 2016. Mineralogy of the TK1 and TK4 'kimberlites' in the Timmasamudram cluster, Wajrakarur Kimberlite Fiels, India: Implications for lamproite magmatism in a field of kimberlites and ultramafic lamprophyres. Chemical Geology, In Press, 23 p http://dx.doi.org/10.1016/j.chemgeo.2016.10.030.

Shravan Kumar Ch., 2013. Geology, Tectonics and Geochemistry of Kimberlitic Diatremes of Kalyandurg and Timmasamudram, Anantapur district, Andhra Pradesh, India, Ph.D. Thesis, Osmania Unviersity, Hyderabad, India, 218 pp. http://shodhganga.inflibnet.ac.in/handle/10603/20313.

Smith C.B., Gurney J.J., Skinner E.M.W., Clement C.R., Ebrahim N., 1985. Geochemical character of South African kimberlites: A new approach based on isotopic constraints. Trans. Geological Society of South Africa 88, 267-280.

Smith C.B., Haggerty S.E., Chatterjee B., Beard A., Townend R., 2013. Kimberlite, lamproite, ultramafic lamprophyre, and Carbonatite relationships on the Dharwar Craton, India; an example from the Khaderpet pipe, a diamondiferous ultramafic with associated carbonatiteintrusion. Lithos 182-183, 102-113.

Srinivasa Choudary V., Rau T.K., Bhaskara Rao K.S., Sridhar M., Sinha K.K., 2007. Timmasamudram kimberlite cluster, Wajrakarur kimberlite Field; Anantapur district, Andhra Pradesh. Journal of the Geological Society of India 69, 597-610.

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

Talukdar D. and Chalapathi Rao N.V., 2015. Diamond Prospectivity of Mesoproterozoic kimberlites from the Wajrakarur field, southern India: Perovskite oxybarometry and bulk-rock transition element geochemistry constraints, The Journal of Indian Geophysical Union 19, 175-181.

Taylor W.R., Tomkins L.A., Haggerty S.E., 1994. Comparative geochemistry of West African kimberlites: Evidence for a micaceous kimberlite end member of sub-lithospheric origin.

Geochemica et. Cosmochemica Acta 58, 4017-4037.
Vasilenko V.B., Zinchuk N.N., Krasavchikov V.O., Kuznetsova L.G., Khlestov V.V., Volkova N.I., 2002. Diamond potential estimation based on kimberlite major element chemistry. Journal of Geochemical Exploration, 76, 93-112.
Woolley A.R., Bergman S.C., Edgar A.D., le Bas M.J., Mitchell R.H., Rock N.M.S., Scott Smith B.H., 1996. Classification of Lamprophyres, Lamproites, Kimberlites, and the Kalsilitic, Melilitic, and Leucitic rocks, The Canadian Mineralogist 34, 175-186.