DISCOVERY OF THE VERY LARGE CRATER-FACIES KIMBERLITE SYSTEM OF TOKAPAL, BASTAR DISTRICT, CHHATTISGARH, INDIA

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INTRODUCTION

The discovery of diamondiferous kimberlites on the Bastar craton during the early 90's in the Mainpur Kimberlite Field (MKF), Raipur district of (Chatterjee, et al., 1995, Mainkar, et al. 1997, Varma, et al., 1997) urged to investigate for kimberlites in similar geological environment. Interpretation of Indian Remote Sensing Satellite data identified an anomalous spectral signature of a hitherto as "ultramafic intrusion" known rock unit (Ramakrishnan, 1987, p.152) near Tokapal village (Fig. 1), about 135 km south of MKF. Mineralogic, petrographic and geochemical studies led to a reinterpretation of this rock unit as crater facie kimberlite in 1995-96. The large surface area, physical features, ambiguity in petrographic and geochemical characteristics, and the surface expression of the rock raised several doubts.

1. Enormously wide spread exposures of the rock, with a wide range of textural features.
2. Ba, Nb and Sr concentrations are much below average kimberlite.
3. Petrographically, the unusual texture and appearance of the rock and degree of visible freshness of this rock
4. Absence of significant indicator minerals like pyrope, although Babu (1998) recorded the presence of this mineral along with other important indicator minerals.
5. No diamonds have been recovered so far.

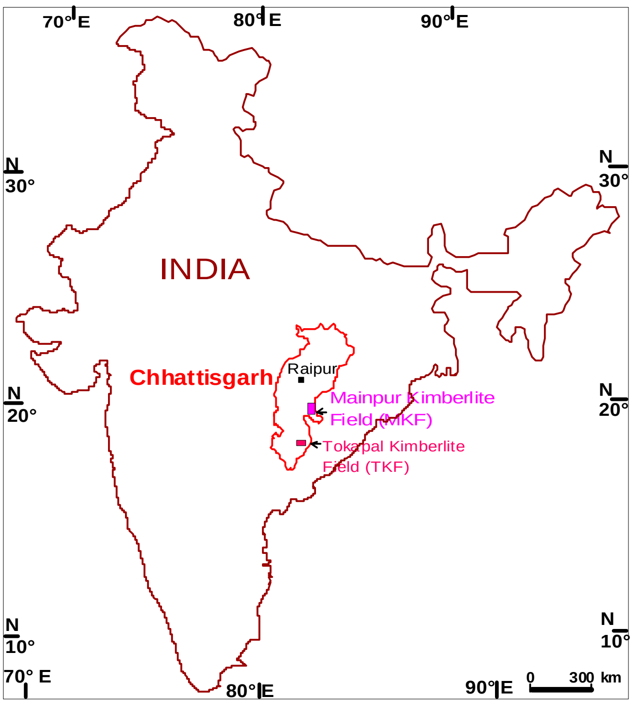

Figure 1: Location Map

These issues were critically examined through sinking of exploratory boreholes, pits and mineralogical, petrographic and geochemical studies that led to confirm the existence of a very large crater facies kimberlite body at Tokapal.

GEOLOGY

The Tokapal Kimberlite Field (TKF) is intrusive into the chemoclastic sediments of the intracratonic middle to upper Proterozoic Indravati Group of the Indravati basin (1400-570 Ma), which unconformably rests over the Archaean crystalline basement of the centrally located Bastar craton within the Indian Peninsular Shield. Chemoclastic sediments of the Jagdalpur Formation of the Indravati Group overlie the kimberlite.

KIMBERLITE EVENT

The Indravati basin comprises a Lower Indravati Group of rocks consisting of the Tirathgarh (quartzitic sandstone), Cherakur (ferruginous/micaceous shale) and Kanger (limestone) Formations and an Upper Indravati Group consisting of the Jagdalpur Formation (sandstone, shale and limestone) (Mainkar, et al., 2001). The kimberlitic event was followed by the younger chemoclastic sedimentary sequence of the Jagdalpur Formation that preserved this Proterozoic crater facies kimberlite. Geochronological data suggest that the Bastar craton has suffered multiple tectonothermal events (Sarkar, et al., 1990). The TKF is stratigraphically in a similar position to the Central Indian kimberlitic magmatism, which is constrained as being emplaced around 1050 ± 100 Ma (Sarkar, et al., 1990).

SURFACE EXPRESSION

The aerial extent of the multiple Tokapal kimberlite system is outlined to about 2.5 km diameter, according to the signature on remote sensing data and by observations of a number of dug- and tube-wells from cultivated land, as well as exploratory boreholes. Enhanced LANDSAT TM image (Fig. 2) exhibits the surface expression of the Tokapal kimberlitic spread that occupies about 550 ha, comprising a central feeder dyke/pipe, surrounded by a

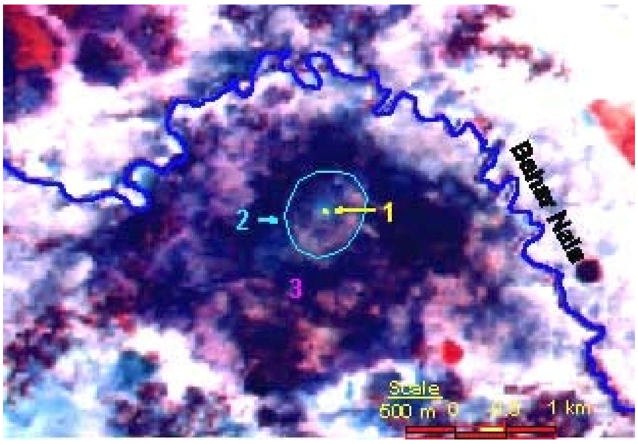

Figure 2: Enhanced LANDSAT TM 457 (RGB) image, 1. Feeder dyke, 2. Collar, 3. Tokapal kimberlitic spread

collar, pyroclastic litho units and overall bounded by the annular stream course of the Bahar Nala.

Tokapal kimberlite is intrusive at the contact of the Cherakur and Jagdalpur formation. Lapilli tuffs (extrusive facies) are the main exposed litho-unit with diminishing thickness from several tens of m to a few tens of m away from the feeder (Mainkar, 2001). Exploratory boreholes located at about 1.4 and 1.7 km south of the feeder dyke revealed the continuity of lapilli tuffs sandwiched between the underlying older formation (Kanger limestone) and overlying younger sediments (Jagdalpur Formation). Relict pyroclastic tuffs (ash beds) and breccias are exposed in the western parts at the stream (Bahar Nala) banks and beds, respectively. This stream is structurally controlled exhibiting an annular drainage pattern that accentuates the margin of the kimberlite system (Fig. 3). Uppermost shale horizon is followed by kimberlitic ash (tuff) and lapilli tuffs in BH-3 borehole, while lapilli tuffs were directly encountered below shale horizon in the BH-4 borehole (Fig. 4). The structural and sedimentation history evidenced to establish intra-formational position of the kimberlite within the geochronology of the Indravati basin. The occurrence of such widely spread kimberlitic rocks including the variety of consolidated and loosely packed volcaniclastic rocks suggest that the Tokapal system is one of the oldest and largest preserved crater-facies kimberlite system known in the world.

FEATURES OF SURFACE EXPOSURE OF KIMBERLITIC ROCKS

The extensive Tokapal kimberlite body is generally covered by alluvial soil and cultivated land, rarely exposing the kimberlitic rocks. Proximal epiclastic and lapilli tuff varieties are generally under thick soil cover. Distal lapilli tuffs and a pyroclastic relict rim forming volcanic breccia, and poorly consolidated tephra deposits of tuff (ash) beds are only exposed in the western parts of Tokapal kimberlite and included in the extra crater parts of the body. Crustal xenoliths are common in all pyroclastic rocks with varying shape, size, and population.

Epiclastic rocks

A small circular exposure of fragmental rocks, having a clast-supported texture, is noted within the centrally located feeder (Fig. 3). Actinolite/tremolite needles are common within this whitish-gray, inequigranular, porphyritic, crustal xenolith rich, and highly weathered rock, which is megascopically difficult to identify. It is identified as an epiclastic rock by thin section study under the microscope. There is no obvious evidence of reworking.

Lapilli tuffs

Lapilli tuffs are rarely exposed around the feeder and are forming a collar. Widespread lapilli tuffs form a pyroclastic apron in distal parts of Tokapal kimberlite. Based on the physical characters and megascopically distinct textures they can be differentiated at least in three classes and one of them is widely exposed in the southern parts of the kimberlite. These lapilli tuffs contain horizontally oriented sub-rounded to oval and sub-angular crustal boulder, cobble and pebble fragments (up to 15 cm) embedded in kimberlitic matrix exhibiting evidences of air fall, lava flows and base surges. These tuffs are highly jointed, layered and also exhibit stratification and gravity slumping (Fig. 5). The lapilli tuff variety exposed in the northern periphery of the collar is inequigranular with a fine to medium grained dark gray to green matrix containing phenocrysts/xenocrysts and crustal fragments up to 4 cm size. Lapilli tuff exposed at the southern periphery of the collar is compact, inequigranular, porphyritic rock composed of a fine-grained, pale green matrix with prominently dark phenocrysts (<5 mm) and a

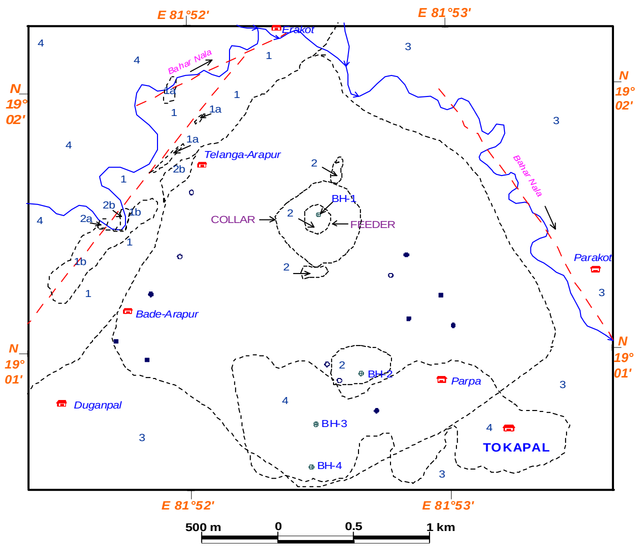

Figure 3: Geological Map of Tokapal Area, 1 Cherakur (1 Shale, 1a – Meta-micro-conglomerates, 1b – Ironstone), 2 Kimberlitic Exposures (2 - Epiclastic/lapilli tuff, 2a - Volcanic breccia, 2b – Tuffs) , 3 Jagdalpur Fm., 4 Laterite cover
● Tubewell, ○ Dugwell, ⊕ TS-5 Exploratory borehole

moderately low concentration of crustal fragments of <6 cm size.

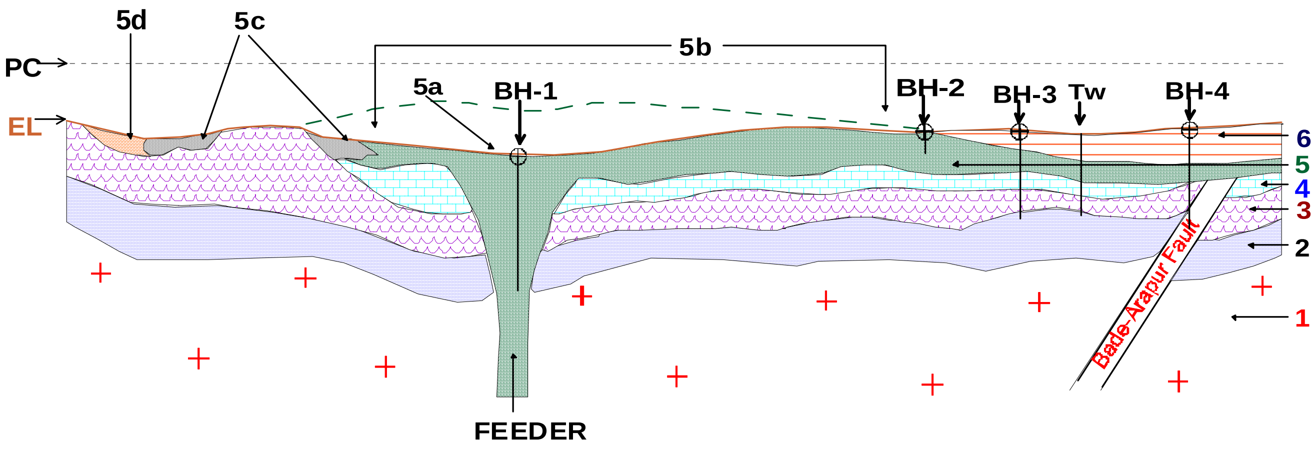

Figure. 4: Schematic cross section across Tokapal kimberlite, 1 Granite, 2 Tirathgarh, 3 Cherakur, 4 Kanger, 5 Kimberlite (5a epiclastic, 5b lapilli tuffs, 5c tuff beds, 5d volcanic breccia) 6 Jagdalpur, BH-* Borehole, PC Protection cover, EL Current level, Tw Tubewell

Tuff (ash) Beds

Tuff beds are exposed in the western parts of the kimberlite along the Bahar Nala bank, containing completely altered crustal fragments of limestone and shale. This gray, poorly consolidated, soft, soapy, vesicular, stratified tuff/ash beds are gently dipping towards the feeder with undulatory warping. These tuff beds demarcate the extreme limits of Tokapal kimberlite apron and represent relict portion of the preserved pyroclastic ring.

Pyroclastic Breccia

Pyroclastic breccia rocks are exposed along the Bahar Nala -bed in adjacent western parts the tuff beds. This compact rock consists of gray to brownish green, medium grained kimberlitic groundmass incorporating large amounts of angular blocks, boulders and lapilli (<40cm), mostly of limestone, shale, and rarely sandstone. These volcaniclastic rocks represent relict portions of the preserved pyroclastic ring (Nixon et al., 1995) of the Tokapal kimberlite.

PETROGRAPHY

The lapilli tuffs are the main lithounits characterized by a wide textural spectrum, and are extensively altered by olivine-destructive secondary processes of this inequigranular rock. The dominant component is represented by pseudomorphed olivine representing two generations. Single macrocrystals of pseudomorphed olivine also occur in variable proportions. The lavas and tuffs consist of juvenile lapilli set in a fine-grained talc-serpentine-carbonate matrix with abundant groundmass spinel and sphene. Phlogopite is rare. The rock contains crustal xenoliths and locally exhibits a bedded texture. Flowage is conspicuous in a few samples. Thin section study indicates juvenile lapilli tuffs typical of root less kimberlites, such as those found in the Canadian prairies (B.H. Scott Smith, 2000, personal communication).

GEOCHEMISTRY

Most of the analyses are from weathered surface samples. The geochemistry of the samples indicates that major oxides and the trace elements Ni, Co, Cr, Ce and REEs are similar to average kimberlite but Ba, Sr and Rb are very low probably, due to weathering. Rock samples from the system have moderate degree of contamination. Trace element patterns are typical of Group I kimberlites, with mobile elements strongly leached due to intense weathering/alteration processes. Chemical bulk-rock data are listed in Table 1 and relevant data is plotted in figure 6. Sample A1, B1, C1, D1 and E1 are of lapilli tuffs, while F1 and G1 represent tuff (ash) beds and volcanic breccia, respectively.

The chondrite normalized REE distribution plot of five samples of lapilli tuff and one each of tuff bed and volcanic breccia from the Tokapal kimberlite indicates that all samples are very similar (Fig 6).

INDICATOR MINERALS

Chrome spinels are the only indicator heavy mineral grains recovered from this kimberlite, which include diamond inclusion type of xenocrysts, similar to Timber Creek diamondiferous kimberlites of Australia. On the contrary to Babu, (1998), no other typical kimberlite indicators, including garnets or diamonds, have been found so far in the area. However, the diamond potential remains to be tested in bulk samples, as the Tokapal kimberlite system is broadly similar to the diamondiferous Timber Creek

Figure 5: Photograph showing gravity slumping in lapilli tuffs of Tokapal kimberlite

Table 1: Chemical Data of Rock Samples From Tokapal

Sample	SiO_2[1]	TiO_2[1]	Al_2O_3[1]	Fe_2O_3[1]	MnO[1]	MgO[1]	CaO[1]	Na_2O[1]	K_2O[1]	P_2O_5[1]	LOI	Total	C.I.
A1	36.21	2.22	3.81	12.69	0.21	30.93	0.77	<0.01	<0.01	0.51	12.32	99.68	1.29
B1	37.42	1.89	3.91	10.15	0.19	32.35	0.64	<0.01	<0.01	0.42	12.63	99.60	1.28
C1	36.88	2.03	3.50	12.59	0.21	30.71	0.74	<0.01	<0.01	0.51	12.58	99.75	1.31
D1	36.84	2.15	3.43	11.17	0.17	31.61	1.12	<0.01	<0.01	0.58	12.53	99.60	1.27
E1	37.92	1.98	3.51	10.39	0.22	31.69	0.72	0.01	<0.01	0.51	12.70	99.64	1.31
F1	48.66	2.48	3.09	11.34	0.02	26.85	0.64	<0.01	<0.01	0.51	5.93	99.52	1.93
G1	37.04	2.10	2.83	10.87	0.12	25.15	6.32	0.03	<0.01	0.52	13.52	98.50	1.59

Sample	Ba[1]	Ce[1]	Co[1]	Cr[1]	Cu[1]	Dy[2]	Er[2]	Eu[2]	Gd[2]	Hf[2]	Ho[2]	La[2]	Lu[2]	Nb[1]	Ni[1]
A1	41	172	65	1126	74	3.98	1.52	2.63	6.94	6.20	0.674	93.8	0.151	115	1197
B1	41	145	74	1002	52	3.55	1.42	2.33	6.02	5.00	0.594	79.0	0.144	95	1364
C1	53	159	73	1017	61	3.58	1.37	2.19	6.29	5.10	0.554	89.5	0.132	102	1180
D1	43	164	56	1076	57	3.84	1.44	2.53	6.59	4.80	0.641	96.2	0.145	114	1220
E1	51	139	72	992	64	3.57	1.46	2.06	6.11	5.30	0.613	76.9	0.145	104	1274
F1	54	161	87	1739	10	4.83	1.95	2.98	8.40	4.68	0.813	83.4	0.218	116	1239
G1	5511	104	64	1197	<10	3.22	1.27	1.64	5.33	4.18	0.520	62.7	n.d.	113	921

Sample	Nd[2]	Pb[2]	Pr[2]	Rb[2]	Sc[1]	Sm[2]	Sr[2]	Tb[2]	Th[2]	Tm[2]	U[2]	V[1]	Y[2]	Yb[2]	Zn[1]	Zr[1]
A1	68.8	47.1	20.1	<1	16	10.2	27.1	0.841	17.4	0.182	1.7	42	17.0	1.01	84	168
B1	57.0	51.1	17.0	<1	14	9.00	20.7	0.702	16.2	0.185	1.6	83	15.5	0.976	70	153
C1	60.7	15.2	18.2	<1	11	9.13	23.1	0.745	17.0	0.173	2.1	27	15.5	0.966	85	155
D1	63.5	11.9	19.0	<1	16	9.59	29.3	0.802	15.9	0.188	2.1	43	17.1	0.941	73	169
E1	54.4	9.07	16.1	<1	15	8.30	22.0	0.753	16.3	0.181	2.2	24	16.2	0.950	67	154
F1	69.1	17.4	19.3	<1	15	11.2	16.1	0.991	15.2	0.254	2.2	67	23.1	1.41	232	158
G1	43.6	26.5	12.2	<1	14	7.18	12.8	0.641	14.0	0.169	1.8	86	14.0	1.01	117	130

[1] = X-ray fluorescence spectrometry.

[2] = Induced coupled-plasma mass spectrometry (ICP-MS).

C.I. (contamination index) = SiO_2 + Al_2O_3 + Na_2O / MgO + K_2O wt%.

Kimberlites of Northern Territories in Australia with respect to geochemistry, petrography, indicator minerals and age of the thermal event. However, microdiamond analysis proved negative on two samples of about 18 kg each.

CONCLUSION

The Tokapal kimberlite system exhibits an extensive spread (>550 ha) of volcaniclastic material and is the only Precambrian kimberlite in the world, preserved in crater facies, comprising a feeder dyke, proximal and extra-crater pyroclastic deposits. Field evidences suggest that these extra-crater rocks include flow/surge deposits that are also observed trapped between Proterozoic formations within the Indravati basin. Extra-crater deposits also include relict of tuff (ash) beds and accidental volcanic breccia at the crater rim margins. High degree of alteration and weathering at the surface exposures, paucity of incompatible elements, mantle xenoliths and almost absence of significant indicator mineral like garnet misleads the identification of the Tokapal kimberlite.

The kimberlitic rock exposures suggest that an enormous volume of kimberlitic material was poured out through a prolonged kimberlitic event at around 1050 ± 100 Ma. It is presumed that the kimberlitic material erupted in a number of pulses possibly through one single feeder although the possibility of more feeders undiscovered so far cannot be overruled. The diamond potentials of this pipe needs further testing.

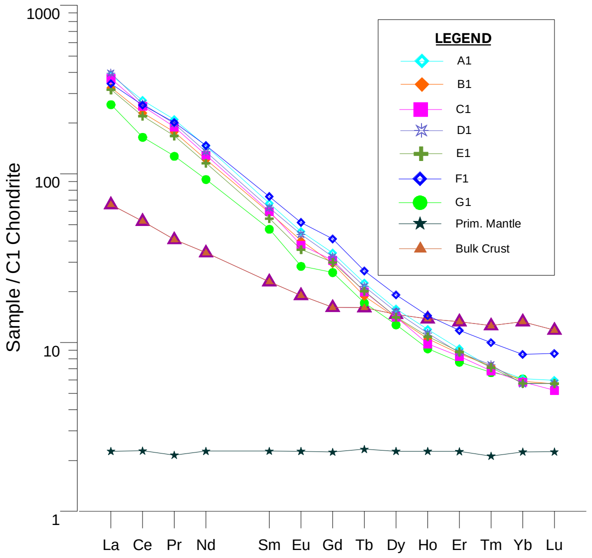

Figure 6: REE distribution pattern of Tokapal Kimberlite sample suite compared with Bulk crust and Primitive mantle (Taylor and McLennan, 1985).

REFERENCES

Babu, T.M., 1998. Diamonds in India, Geol. Soc. of Ind. Pub., 331 p.

Chhatterjee, B., Jha, N., Mishra, B.K. and Kumar, M. 1995. Exploration for Kimberlite in Southeastern Raipur Kimberlite Field, District Raipur, Madhya Pradesh, Rec. Geol. Sur. Of Ind. V128, pp 6

Mainkar, D., Chandrakar, N.K. and Khatedia, M.S., 1997. A Report on the Photogeological Studies in South-Eastern Parts of Raipur District; Madhya Pradesh; Unpub. Rep., F.S 1992-93, Dire. of Geol. & Mining,, Madhya Pradesh.

Mainkar, D., Kankane, S. and Singh, H.P., 2001. INDO-FRG project phase IV, Development of Exploration Model for Diamond, Tokapal Area, Bastar District; Madhya Pradesh; Unpub. Rep., F.S 1995-2000, Dire. of Geol. & Mining,, Chhattisgarh, 184 p.

Nixon, P.H., 1995. The Morphology and Nature of Primary Diamondiferous Occurrences, J. Geochem. Expl. No. 53, pp 41-71.

Ramakrishnan, M., 1987. Stratigraphy, Sedimentary Environment and Evolution of the Late Proterozoic Indravati Basin, Central India; Purana Basins of Peninsular India, J. Geol. Soc. of lnd . Mem . V6, pp 139-156.

Sarkar A.; Sarkar, G.; Paul, D.K. & Mitra, N.D.; (1990): Precambrian geochronology of the central Indian shield A review; GSI Spl. Pub. No. 28: pp 453-482

Taylor, S.R., Mclennan, S.M. & Scott, M., 1985: The continental crust: its composition and elocution, Block well scientific publication: 312 p.

Verma, D.K. and Saxena, V.K., 1997. A Report on Investigation for Diamond and other Precious and Semiprecious Stones in SE Parts of District Raipur, Madhya Pradesh Unpub. Rep., F.S 1992-93-94 Dire. of Geol. & Mining,, Madhya Pradesh Central India; Purana Basins of Peninsular India, J. Geol. Soc. of lnd . Mem . V6, pp 139-156.

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