GEOPHYSICAL MODEL OF DIAMOND PIPES (REVISED)

COX AND SINGER MODEL No. 12
Geophysically similar models-No. 10 Carbonatites;
No. 29b, Olympic Dam

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(Dec. 1993)

A. Geologic Setting

- Kimberlite or lamproite diatremes emplaced along zones of basement weakness within or on the margins of stable cratons; (Dawson, 1971, 1980) often in groups of three or more.
- Often spatially related to carbonatites, but not normally occurring along same zones of crustal weakness (Dawson, 1967; Garson, 1984) . A genetic relationship is open to question.

B. Geologic Environment Definition

Regional magnetic, gravity, and remote sensing surveys may identify deep-seated fracture systems and related anteclises or syneclises that define zones of weak crust favorable for emplacement (de Boarder, 1982; Tsyganov, and others, 1988; Jennings, 1990).

C. Deposit Definition

Individual diatremes generally appear as circular to elliptical bodies in remote sensing images, and on magnetic, gravity, or resistivity maps. The diatremes may show as distinct magnetic highs (Yakutia, West Africa) of hundreds to a few thousand nT, but high remanence or magnetic host rocks can result in negative or no anomalies. Gravity (order of 1 regal), resistivity, and seismic velocity anomalies generally show as lows over the diatremes related to serpentization and weathering of the mafic rocks. Radioelement surveys have generally not been effective, although in Yakutia Fedynsky and others (1967) report that they have been used to differentiate between diamond-bearing basaltic kimberlites from barren micaceous kimberlites and carbonatites (da Costa, 1989; Kamara, 1981; Gerryts, 1970; Macnae, 1979; Guptasarma and others, 1989; Jennings, 1990; Carlson and others, 1984).

D. **Size and Shape of**

	Shape	**Average Size/Range**
Deposit	Vertical cone, carrot-like	0.1 to 5 km diameter; generally 0.4 to 1 km depth to about 2 km
Alteration haloe	Irregular about pipe	thin, not geophy. significant
Cap	Elliptical cylinder	0.1 to 5 km, 0-10’s m thick

E. Physical Properties (units)	Deposit	Alteration	Cap	Host
	kimberlites or lamproite pipe	Si, CO_2, K metasomatism	clay-rich weathering zone-blue and yellow ground	any cratonic unit
1. Density (gm/cm^3)	2.751[10] 2.64-3.12[4,10,19] 2.35-2.55[16]	?	2.35?[21] 2.5-2.62[4]	*
2. Porosity	low-moderate	low?	high[4]	*
3. Susceptibility (cgs)	$1x10^{-4}$-$1x10^{-2}$[16] to $2.3x10^{-3}$[11]	?	$1X10^{-5}$-$1X10^{-3}$[16] to $2X10^{-5}$[11]	*
4. Remanence (Q)	variable O-0.8-2.0[22]	?	variable	*
5. Resistivity (ohm-m)	100-2000[4,16,19,21]	medium-high	2-100[4,16,19,21]	*
6. IP Effect (msec.)	low	low?	low,0-4([18])	*
7. Seismic Velocity (km/see)	2.6-3.3[4]	high?	1.5[4] 0.3-2.4[2]	*
8. Radioelements				
K (%)	2.6 average 0.07-6.7[3] 1.9[2]	medium	medium?	*
U (ppm)	0.26, average 0.07-0.8[3] 3. 8[2]	low	very low	*
Th (ppm)	0.44, average 0.17-0.9[3] 9.3[2]	low	low	*

F. Remote Sensing Characteristics

Visible and near IR-Remote sensing techniques can identify lineaments which may reflect zones of crustal weakness along which pipes were emplaced. Lineament intersections may be favored locations (Tsyganov and others, 1988). Vegetation anomalies related to drainage and lithologies can be used for location. Alteration products of kimberlites, such as serpentine, chlorite, and vermiculite show distinct spectral absorption features that can be detected by a variety of methods (Kingston, 1989; Jennings, 1990).

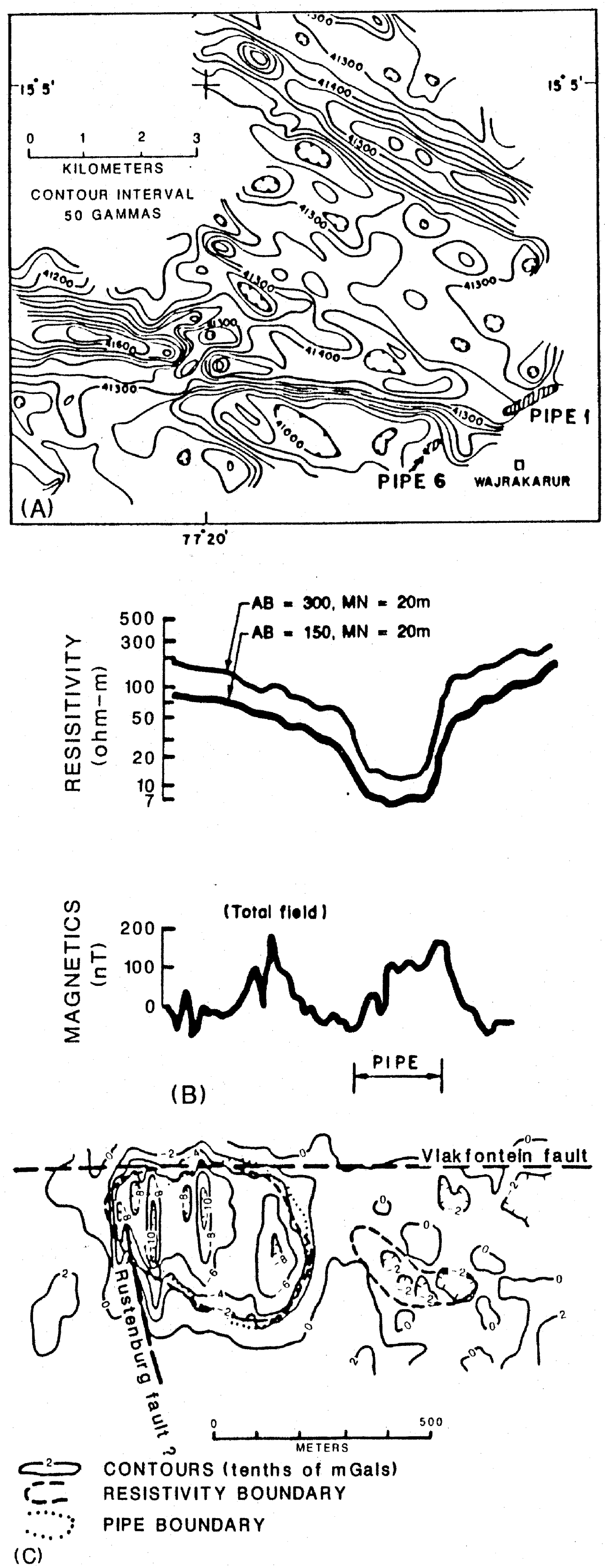
G. Comments

The relatively small size, 0.4-1.0 km, of most pipes requires detailed coverage for identification. The geophysical signature differs from carbonatites in, reduced amplitude of magnetic anomaly, and by a small negative gravity anomaly in contrast to the large positive anomaly of carbonatites. A combination of magnetic, gravity, and resistivity methods are most used in exploration. No single method is universally applicable. Radioelement methods have had relatively little use, although they should have some application in differentiating varieties of kimberlites and lamproite. Some Russian literature (Ratnikov, 1970), gives very low values of density for kimberlites. These probably refer to serpentinized or weathered samples and are not representative of unaltered rock. Gerryts (1967) gives a rule-of-thumb of 1 mgal/183 meters (200 yards) of pipe diameter for the gravity low. A broad gravity high ring about the central low, due to dense, deeper, kimberlites has not been observed. Guptasarma and others (1989) report both positive and negative gravity and magnetic responses over kimberlites in India. Jennings (1990) notes that less than 25% of kimberlite-like magnetic features in an area of Botswana were kimberlites, when drilled. Johnson and Seigel (1986) show airborne magnetic and EM data over three pipes in Tanzania, only two of which show a magnetic signature, but all three have a strong, positive conductivity anomaly. Bose (1980) suggests that gravity highs, magnetic highs and resistivity highs are seen over fresh unweathered kimberlites, while gravity, magnetic and resistivity lows are seen over weathered kimberlites in India. Carlson and others (1984) show results for gravity, magnetic, EM, galvanic resistivity, gamma-ray, and seismic refraction studies over several diatremes in the State-Line district of Colorado-Wyoming, concluding that magnetic, resistivity and EM methods were clearly the most effective. Their data appear to show fenitization up to 15 m around the pipe.

H. References

1. Bose, R.N., 1980, Some important geophysical histories pertaining to investigations for minerals in various parts of Andhra Pradesh: Jour. Assoc. Expl. Geophys., v. 1, no. 1, p. 21-35.
2. Carlson, J.A., Johnson, R.B., McCallum, M.E., Campbell D.L., and Padgett, J.P., 1984, Evaluation of geophysical techniques for diatreme delineation in the Colorado-Wyoming kimberlites province, <u>in</u> J. Kornprobst, ed., Kimberlites I: Kimberlites and Related Rocks, Elsevier, p. 21-31.
3. Clark, S.P., Jr., Peterman, Z.E., and Keier, K.S., 1966, Abundances of uranium, thorium, and potassium, <u>in</u> Clark, S.P., Jr., ed., Handbook of Physical Constants: G.S.A. Memoir 97, p. 521-542.
4. da Costa, Alberto, J.M., 1989, Palmietfontein kimberlites pipe, South Africa--A case history: Geophysics, v. 54, no. 6, p. 689-700.
5. Dawson, J.B., 1967, Geochemistry and origin of kimberlites, <u>in</u> Wyllie, P.J., ed., Ultramafic and related rocks: Robert E. Krieger, pub., New York, p. 269-279.
6. Dawson, J.B., 1971, Advances in kimberlites geology: Earth-Science Reviews, v. 7, p. 187-214.
7. Dawson, J.B., 1980, Kimberlites and their xenoliths: Springer Verlag, Berlin, 252 p.
8. de Boarder, H., 1982, Deep-reaching fracture zones in the crystalline basement surrounding the West Congo System and their control of mineralization in Angola and Gabon: Geoexploration, v. 20, p. 259-273.
9. Fedynsky, V.V., Brodovoi, V.V., and Gelamkov, V.A., 1967, Geophysics in prospecting and exploration for mineral deposits in the USSR, <u>in</u> Morley, L.W., ed., Mining and Ground Water Geophysics: Geological Survey of Canada, p. 667-687.
10. Garson, M.S., 1984, Relationship of carbonatites to plate tectonics: The Indian Mineralogist, p. 163-188.
11. Gerryts, E., 1967, Diamond prospecting by geophysical methods--A review of current practice, <u>in</u> Morley, L.W., ed., Mining and Ground Water Geophysics: Geological Survey of Canada, p. 439-446.

12. Guptasarma, D., Chettyl T.R.K., Murthyr D.S.N., Ramana Rao, A.V., Venkatanarayana, B., Babu Roo, V., Shanker Reddy B., and Singh, B 1989, Case history of a kimberlites discovery, Wajrakarur area, A.P., South India, in G.P. Garland, ed., Proceedings of Exploration 87, Ontario Geological Survey Special Volume 3, p. 888-897.
13. Hausel, W.D., McCallum, M.E., and and Woodzick, T.L., 1979, Exploration for diamond-bearing kimberlites in Colorado and Wyoming--An evaluation of exploration techniques: Geological Survey of Wyoming Report of Investigations, no. 19, 29 p.
14. Jennings, C.M.H., 1990, Exploration for diamondiferous kimberlites and lamproite, in Beck, L.S., ed., Harper, C.T., eds., Modern Exploration Techniques: Saskatchewan Geological Sot. Special Pub. no. 10.
15. Johnson, I.M., and Seigel, H.O., 1986, Tridem resistivity mapping for natural resources development, in Palacky, G.J., ed., Airborne resistivity mapping: Geological Survey of Canada Paper 86-22, p. 125-129.
16. Kailasam, L.N., 1967, Mining geophysics in India and the role of government in this field, in Morley, L.W., ed., Mining and Ground Water Geophysics: Geological Survey of Canada, p. 439-446.
17. Kamara, A.Y.S., 1981, Review-geophysical methods for kimberlites prospecting: Australian Bulletin of Society of Exploration Geophysics, v. 12, p. 43-51. [Best overview in english]
18. Kingston, M., 1989, Spectral reflectance features of kimberlites and carbonatites: GSA Special Pub. No. 14 Kimberlites and Related Rocks .
19. Litinskii, V.A., 1963, Measurement of magnetic susceptibility in prospecting for kimberlites pipes: The Mining Magazine, v. 109, p. 137-146.
20. Macnae, J.C., 1979, Kimberlites and exploration geophysics: Geophysics, v. 44, p. 1395-1416.
21. Norman, J.W., Price, N.J., and Peters, E.R., 1977, Photogeological fracture trace study of controls of kimberlites intrusion in Lesotho basalts: Trans. Institute Mining and Metall., v. 868, p. 78-90.
22. Ratnikov, V.N., 1970, Diamond deposits of Yakutla, in Klichnikov, V.A., Brodovoy, V.V., Morozov, M.D., and Solovov, A.P., eds., Geophysical Exploration of Ore Deposits, Kazakstan Branch All Union Science Research Institute for Reconnaissance Geophysics, p. 566-575.
23. Romanov, N.N., and Manakov, A.V., 1987, Possibilities of magnetic surveying in prospecting for kimberlites pipes: Geologiya i Geofizika, v. 28, no. 12, p. 73-78.
24. Tsyganov, V.A., Mikoyevl I.I., and Chernyy, S.D., 1988, Local criteria for the structural control of kimberlites magmatism in Western Yakutla: International Geol. Review, v. 30, p. 657-667.



Figures A. Strong regional magnetic linear adjacent to two kimberlite pipes in the Wajradarur area, Andhra Pradesh, India adapted from Guptasarma and others (1989). Contour interval is 50 gamma. B. Resistivity and ground magnetic traverse across the Palmietfontein pipe South Africa adapted from da Costa (1989). C. A residual gravity map of the Palmietfontein pipe also showing its emplacement at the junction of the Vlakfontein and Rustenburg faults, after da Costa (1989).