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LAMPROITES FROM THE EASTERN MARGIN OF THE BHANDARA CRATON, ORISSA, INDIA: AN EXPLORATION CASE STUDY

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INTRODUCTION

The discovery of Mainpur Kimberlite Field (MKF) on the south western margin of the Proterozoic Khariar sedimentary basin attracted diamond mining companies to the Bhandara (Bastar) Craton in the states of Chhattisgarh, Orissa, Madhya Pradesh and Maharashtra. De Beers carried out detailed exploration for locating kimberlitic rocks in different areas around MKF. The study area covers 9610 km2 in the western parts of Orissa (Fig. 1) and straddles the boundary between the eastern margin of the Bhandara Craton and the Eastern Ghats Mobile Belt (EGMB). The EGMB is recognised as an accreted terrain with high-grade metamorphic rocks. Late Proterozoic detached basins containing un-metamorphosed sediments overlie the Archaean rocks of the Bhandara Craton. The study area is constrained within the drainage basin of the River Tel, a tributary of the River Mahanadi. Multi-disciplinary studies were carried out by De Beers India Exploration which led to the discovery of lamproitic rocks in the area. The topography in most parts of the area is favourable for stream sediment sampling.

SAMPLING

A total of 924 stream samples and 114 loam samples were collected for indicator mineral analysis. The sample results (Fig.1) helped in targeting areas for geophysical surveys. The predominance of lower chrome (<~60 wt.% Cr2O3) xenocrystic spinels in the lamproites as well as the stream samples indicates that sampling of spinel-bearing lithologies by the lamproites was concentrated outside the diamond stability field. Recovery of higher interest “harzburgitic garnets” appears to be limited to the southern parts of the area and is scarce in the central and northern parts of the area.

AIRBORNE GEOPHYSICAL SURVEYS

Airborne magnetic and electromagnetic surveys were carried out over the Umarkote and Sinapalli (Fig 2) areas of the study area. A total of 18514 line kilometers were flown with a line spacing of 200m at 120m terrain clearance. Airborne magnetic data over the Umarkote block produced excellent anomalies with good magnetic contrast. A number of linear high magnetic features were associated with dolerite dykes. A total of 117 airborne magnetic and 64 electromagnetic anomalies were followed up with ground magnetic, ground electromagnetic and ground gravity surveys at 50 or 100m line spacing. However, most of the anomalies were explained by amphibolites, granodiorites, charnockites, as well as pyroxenite bodies.

AIRBORNE HYPERSPECTRAL SCANNER SURVEY

The Airborne Hyperspectral Scanner (AHS)

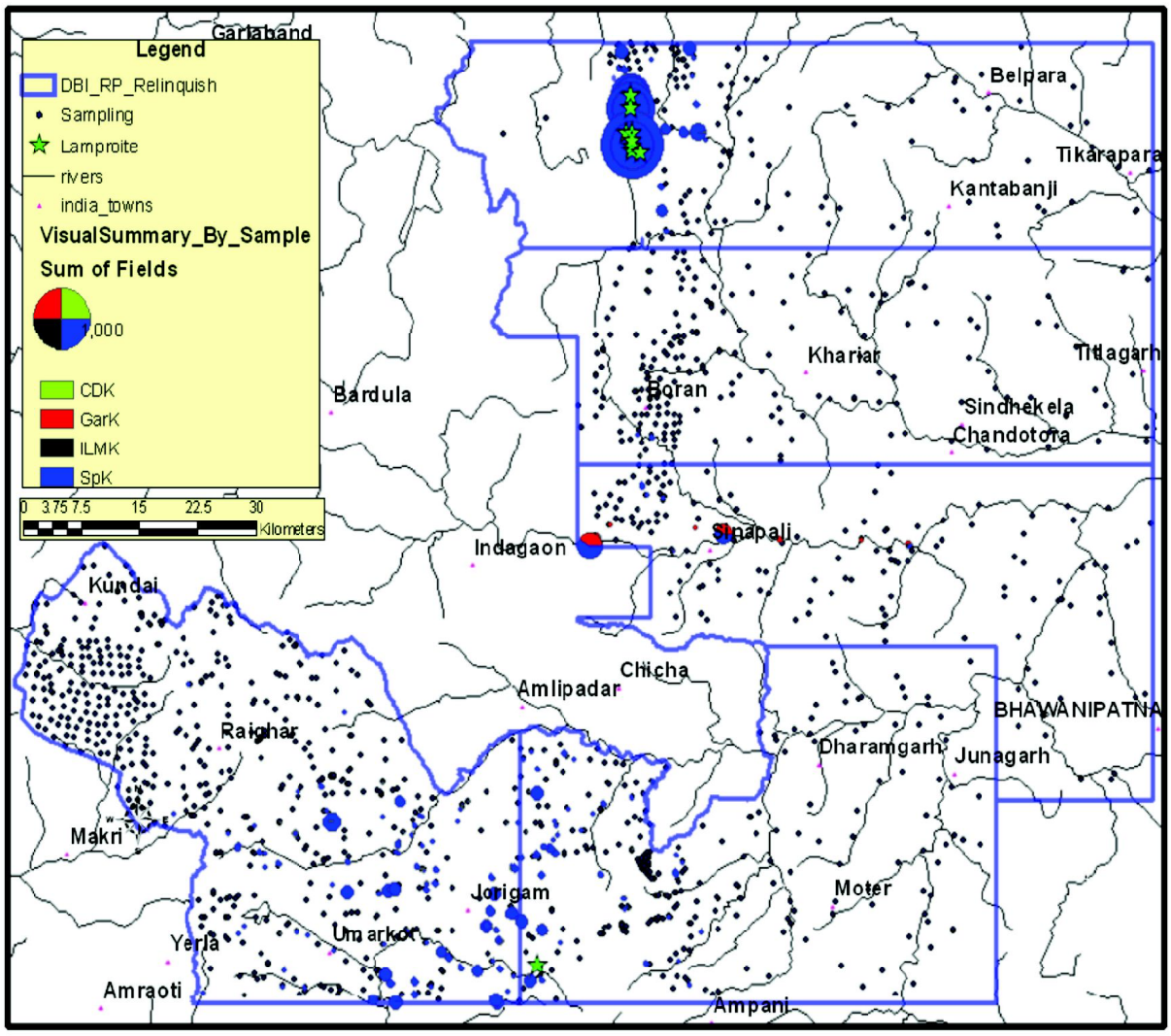

Fig1: Sampling and results in the area explored by De Beers in Orissa

and Data Acquisition System was used in India for the first time in 2002 and then in 2005 for the current study area. The Airborne hyperspectral survey captures and process spectra obtained by measuring reflectance of narrow wavelength bands of sunlight reflected from the Earth's surface. Natural radiation gets absorbed by various clays (hydroxides of Magnesium, Iron and Aluminum) in varying degrees. These clays are more commonly derived from the weathering of mafic and ultramafic litho-units. For the purpose of diamond exploration, anomalies are selected targeting the alteration and weathering products of kimberlitic minerals in the surface environment. These are primarily Mg-rich minerals and clays. The principal target minerals include: Talc, Saponite, Serpentine, Nontronite and Carbonates. In highly weathered terrains, kimberlite may produce montmorillonite, kaolinite and silica. Since a major portion of the study area is underlain by granite-gneiss-granulite terrain, the exploration team decided that the AHS survey is one of the

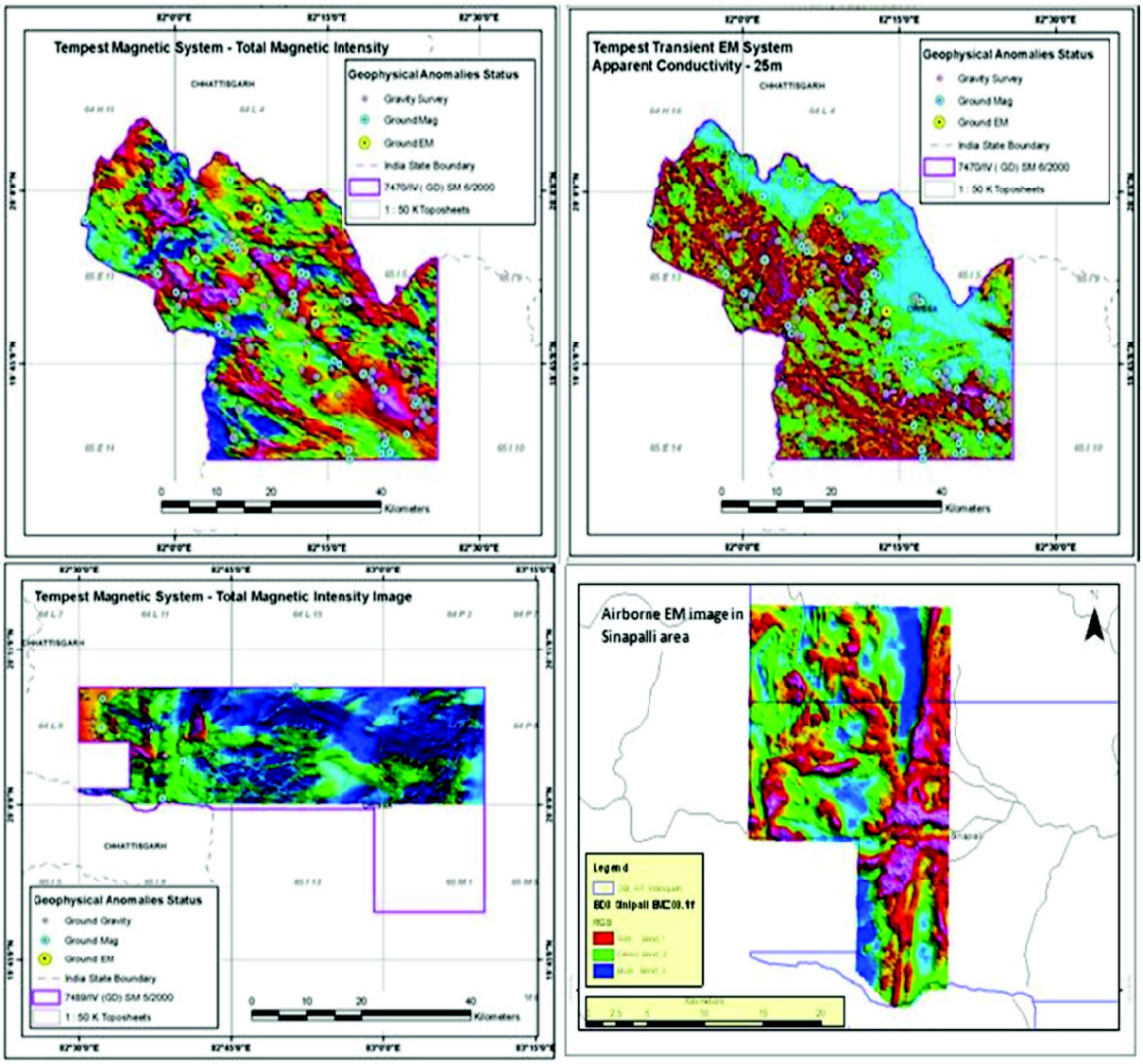

Fig 2: Airborne mag and EM images over Umerkote and Sinapalli areas.

quicker and efficient methods to explore for exposed or partly exposed and weathered ultramafic intrusions.Previous exploration in Karnataka and Andhra Pradesh in 2002 revealed that the weathered kimberlites tend to be rich in saponite, serpentine, carbonate and montronite. Based on these observations a generic mineral combination and matched filter image was developed which effectively mapped kimberlite targets. The AHS generated numerous anomalies (over 300 anomalies were identified) and depending on the shape, size and quality of absorption spectra each anomaly was rated. Anomalies identified were checked on the ground for associated lithotype, geological setting etc. Soil and/ rock samples were collected for cross verification (using Portable Infrared Mineral Analyser-PIMA), for mineral indicators (in case

of soil sample) or for whole rock geochemistry (in case of suspected rock sample). Nine lamproite dykes were discovered by the AHS survey. One of the lamproites was proven to be ~3km in length by percussion drilling (Fig 3).

HOLI LAMPROITE- A CASE STUDY

The discovery of Holi Lamproite (named after the festival of Holi) resulted from an interesting AHS anomaly identified (Fig 4) from AHS. Surface float samples of suspected ultramafic/mafic rock and soil sample werecollected from the anomaly area. Subsequent PIMA analysis was conducted and found that the absorption spectra of the soil is matching but the rock sample collected did not match with AHS survey spectra.

A float sample of weathered and talcose lamproite was collected from the hill slope. PIMA analysis of weathered talc bearing sample identified spectral signature corresponding to phlogopite, talc, anhydrite and nontronite. Whole rock geochemistry results confirmed the lamproitic nature of the rock.

GEOPHYSICAL SURVEY

Various geophysical methods (Magnetic, Gravity and Electromagnetic) were used to try to

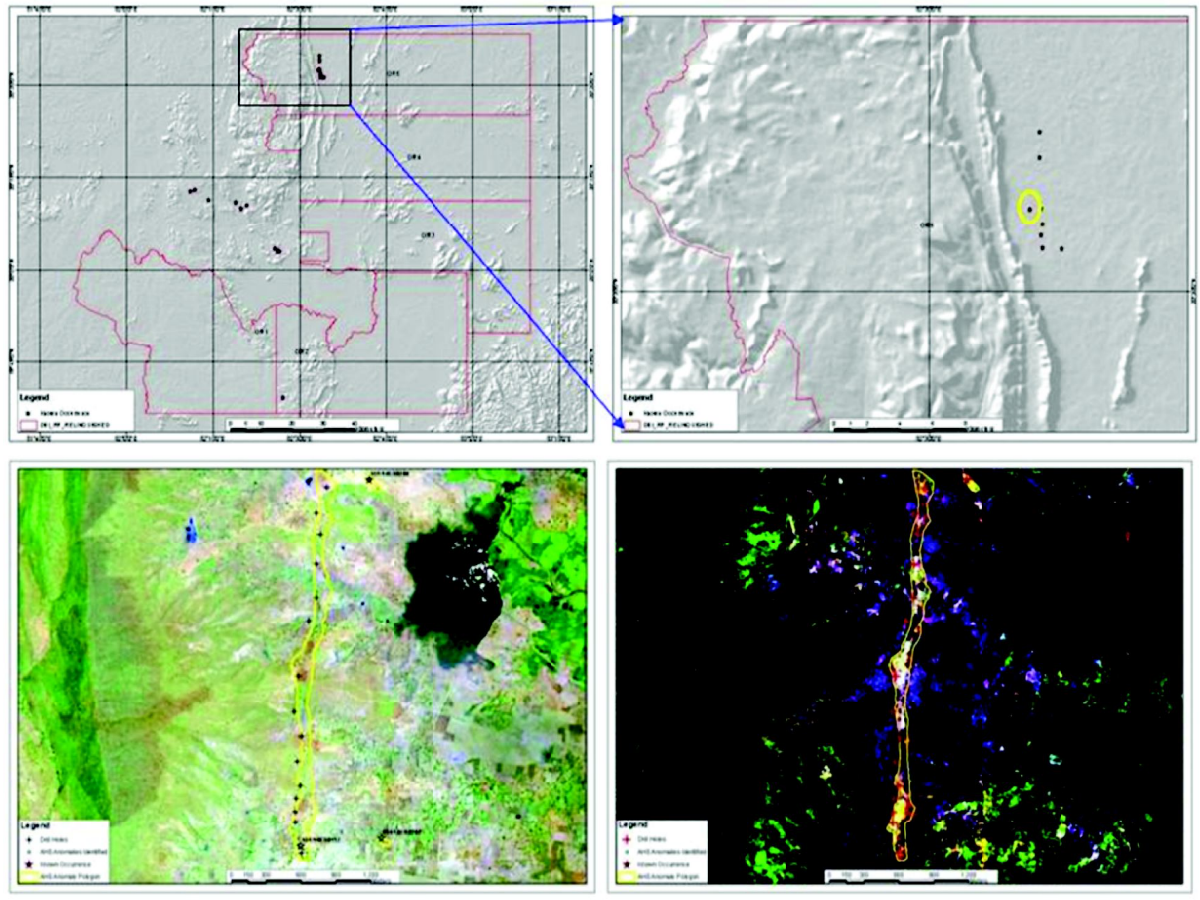

Fig 3: Lamproite traced over 3 km from AHS match filtered image.

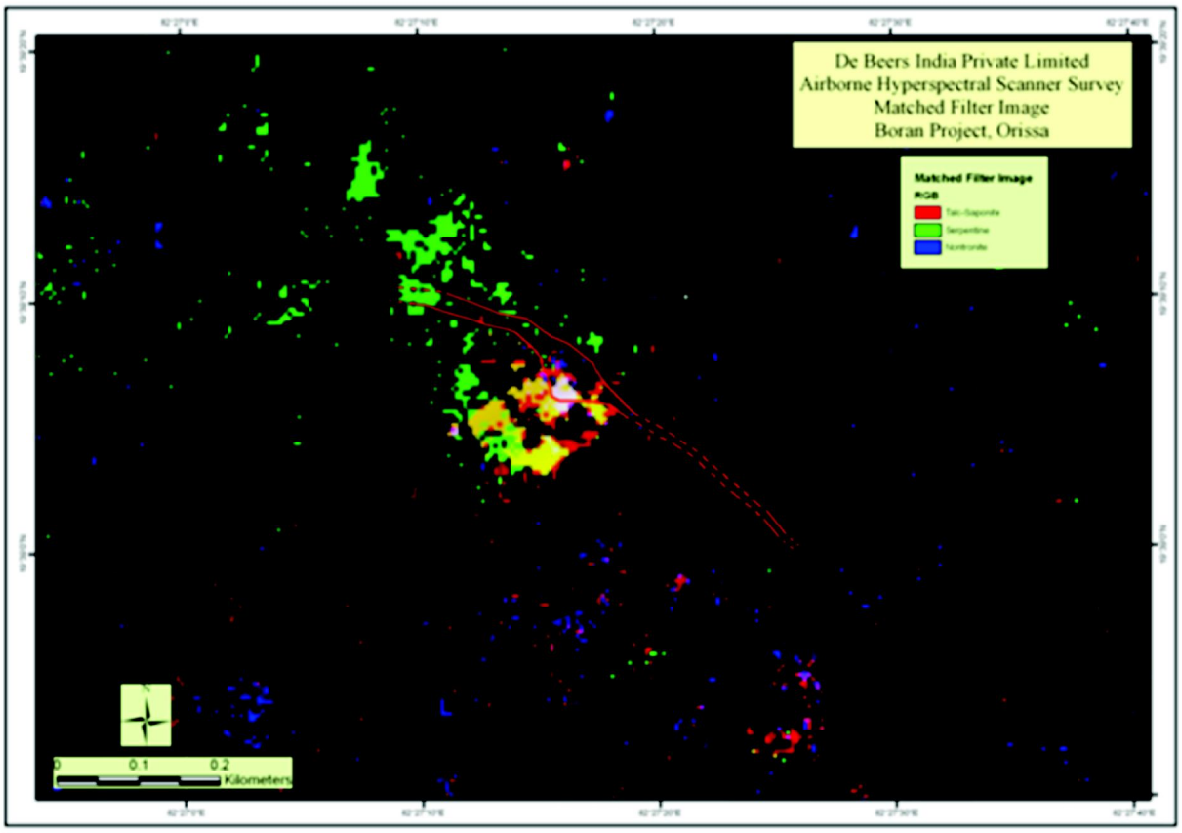

Fig 4: Matched filter (MF) image of AHS survey data overlaid by interpreted anomaly polygon on lamproite.

delineate the shape and size of the lamproite body. Moreover, there was need to determine which of these geophysical techniques respond the best in this area.

MAGNETIC SURVEY

A ground magnetic survey was done using a GSM19W magnetometer in a grid area of 700m X 700m with 50m line spacing. The Reduced to Pole (RTP) image of the ground magnetic data (Fig 5) suggests a small neutral mag anomaly at the center of the grid which corresponds to the intrusion. The background is magnetically active because of the presence of magnetite-bearing granites. The south eastern portion of the grid area is covered by weathered Proterozoic Ampani sediments - which are characterized by low magnetic response. Magnetic susceptibility readings were taken on the surrounding granite outcrops using a KT9 magnetic susceptibility meter. These show very high values (~50-60*10-3SI). Considering the highly magnetic and weathered nature of the background lithology, the small lamproite body is not giving any significant signature in the ground magnetic survey data.

GRAVITY SURVEY

The gravity method is useful where there is a density contrast between the rock formation of interest and the country rock. A ground gravity survey was carried out over the Holi lamproite by using two scintrex CG-5 microprocessor based gravity meters. The surveys were conducted at 50m line spacing and 25m station spacing in a

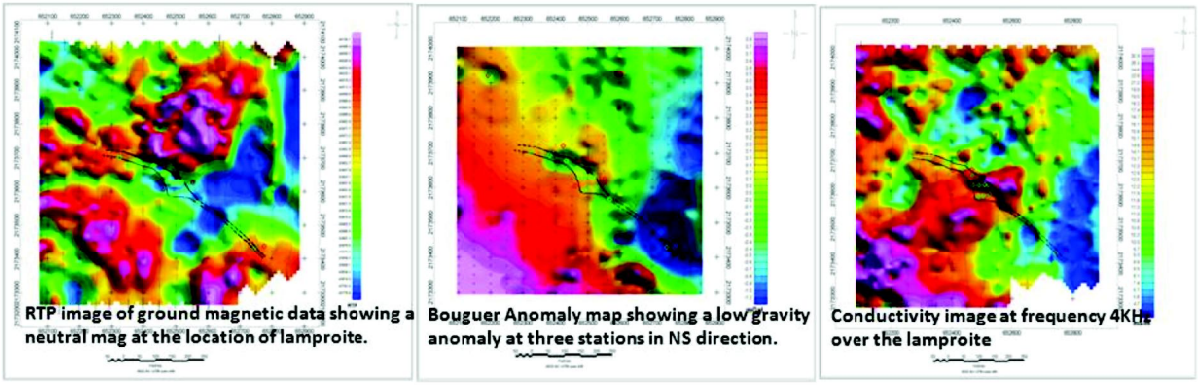

Fig 5: Ground magnetic surveys over the Holi Lamproite.

grid size of 700m X 700m and a total of 464 stations were acquired in 4 days. The bouguer anomaly map of the area is presented in Fig 5. The map shows a bouguer gravity low anomaly of 0.4 mGal trending almost NW-SE, extending across three lines and covering threestations in a NS direction at the centre of the grid area. Due to weathering, the lamproite depicts as a gravity low. Normal corrections have been applied to the raw gravity data for reduction and preparation of anomaly map. For calculating the bouguer anomaly, a density of 2.67g/cc has been chosen and the data has been reduced to the mean sea level using the 1967 International gravity formula. Topographical survey was done by Pixel Softek crews by using a Leica total station instrument with an accuracy of 1-2 cm. There is no clear gravity signature reflected over the lamproite due to its very small size.

ELECTROMAGNETIC SURVEY

The success of the electromagnetic method in detecting kimberlite/lamproite depends on the contrast in the conductivity of the kimberlite/ lamproite to the background geology. In the case of the Holi lamproite, the airborne electromagnetic survey (AEM channels Z03, Z05, Z07) data show a resistive signature. A ground electromagnetic survey was carried out over the lamproite body by using a Geophex GEM-2 frequency domain EM meter. The survey was completed on a 700m X 700m grid with line spacing of 50m (Fig 5). The instrument captures in-phase, quadrature and calculates conductivity at five different frequencies. The anomaly is visible but is not obvious. This suggests the weathered layer of lamproite in this area is thick enough that the lower frequencies (shallow penetration) give a conductive anomaly.

DRILL TESTING

Two boreholes were drilled over sandstone (Proterozoic Ampani sediments) located 200m SE of the mainlamproite outcrop to confirm its continuation as a dyke or a detached sill. The borehole data confirms that the dyke is covered under sediments. The lamproite dyke is probably of middle Proterozoic age.

PETROGRAPHY

Petrographic and whole rock geochemical analyses were carried out on several of the lamproites discovered. The petrographic analysis revealed that the rocks have magmatic texture and have been extensively altered. Texturally, the rocks show large anhedral olivines which have been interpreted as mantle xenocrysts, as well as smaller olivine crystals with phenocrystal shapes and complex growthforms. All the olivines are

severely serpentinized. Large poikilitic phlogopite plates are associated with common clinopyroxene and apatite, which is a feature common in lamproites. Both clinopyroxene and apatite are partly altered. The remainder of the groundmass is pale green serpentine presumably derived mainly from phlogopite alteration. There are few opaque grains but alteration precludes their exact identification.

CLASSIFICATION

The peculiar association of large poikilitic phlogopite plates with common clinopyroxene and apatite is a feature common in lamproites and less common in kimberlites. This together with the observation of complex shaped olivine phenocrysts and the whole rock geochemistry suggest that this rock has more affinity to lamproite. The fact that it contains xenocrystal and phenocrystal olivine is important because olivine lamproites are the only lamproites known to date to be diamondiferous.

CONCLUSION

The AHS methodology could detect exposed highly weathered kimberlitic rocks, irrespective of their size. The geophysical surveys (ground magnetics, ground electromagnetic and ground gravity) on the lamproite were planned to find the shape and size of the body as well as to assess which geophysical method is most appropriate to discover such bodies in the area. Ground electromagnetic data and ground gravity data show significant anomaly over the lamproite, whereas detailed ground magnetic data do not show an anomaly. Considering all the geophysical signatures of this body it may be concluded that the lamproite body is too small to be accurately delineated at the given line and stationspacing. The size of the body is too small and hence not encouraging to do any further work over the body.

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