ALKALINE DIATREMES IN THE HUDSON BAY LOWLANDS, CANADA EXPLORATION METHODS, PETROLOGY AND GEOCHEMISTRY

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LOCALITY AND GEOLOGY

A kimberlite exploration programme in the Hudson Bay Lowlands of Northern Ontario resulted in the discovery, in 1980, of a group of alkaline, ultrabasic diatremes with kimberlitic affinities. The programme was conducted by Selco Mining Corporation in partnership with Esso Minerals Canada. The Lowlands form a large area of relatively flat, poorly drained land along the southwestern shore of Hudson Bay and the western shore of James Bay (Fig.1) which extends inland for some 300 km and has an elevation ranging from zero to about 200m. At their southern margin, the Lowlands are underlain by rocks and unconsolidated deposits ranging in age from Archean to Recent.

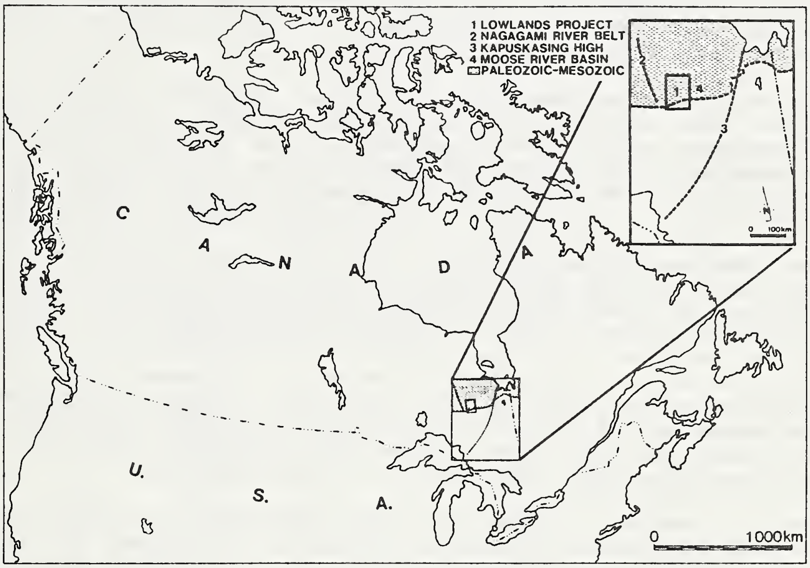

Fig. 1: Location of Lowlands Project.

The project area is located some 30 km north of Hearst, Ontario. Archean crystalline rocks, belonging to the Superior Province of the Canadian Shield, slope northwards beneath a cover of Paleozoic carbonates and clastic sediments up to 800m thick. The Paleozoic rocks are in turn overlain by glacial and recent deposits varying in thickness from 25m to more than 150m. The nature of this cover renders prospecting for kimberlites by conventional heavy mineral sampling impractical. Therefore, the exploration method used in this project was low-level airborne magnetic surveying, followed, where appropriate, by detailed ground geophysics and drilling.

The selection of the particular area to be flown was based on general geotectonic principles with reference being made to all available published geophysical and geological data. Important considerations were the presumed downwarping of the crystalline basement at the margin of the Lowlands some 20 km to the south, the presence of local flexures in the basement, primarily the sharply depressed Moose River Basin just to the east, and the avoidance of major groups of alkaline complexes, such as the Nagagami River Belt to the west. The presence of overlying, undisturbed Paleozoic sedimentary rocks was considered a favourable factor; firstly, because such rocks filter out magnetic 'noise' from the basement rocks so that anomalies due to younger intrusions are more easily identified; and secondly, because the presence of these rocks may mean that post-Paleozoic erosion has not been profound enough to remove Mesozoic or younger intrusions.

GEOPHYSICS

Magnetometer surveying has been employed in the search for kimberlites in a number of places in the world. New aeromagnetic surveys were required in the study area as the existing magnetic coverage flown for the Canadian government was not sufficiently detailed (800m line separations), and not at a low enough terraine clearance (300m) to be effective in detecting the target bodies. Surveys were flown using fluxgate magnetometers in tail stinger assemblies on fixed wing aircraft. The total field magnetometer data is accurate to one nano-Tesla (nT). The sensors were flown at an elevation of 60m, at a flight line interval of 250m, in a north-south direction. The line spacing chosen was such that most, if not all, bodies of economically significant size (greater than 200m) would be detected as long as they were magnetic. It was recognized that not all kimberlites demonstrate significant magnetism, but it was felt that a sufficient number in any kimberlite field would be magnetic to make possible the detection of the field. The flying elevation was chosen to be as low as was considered safe.

The earliest survey results observed magnetic responses of a few tens to a few hundred nT. It is known that the Paleozoic rocks in this area are not magnetic, and that the magnetic rocks of the Precambrian basement generally lie several hundred metres below the ground surface. The observed magnetic responses were very distinctive, and suggested the kind of anomalous response one would expect from pipe-like bodies with tops 20 to 50m below the ground surface. Identification of these targets was carried out using line profiles and contour maps of the survey data. Estimations of source depths were made using Peter's half-slope method. While more sophisticated computer-based modelling interpretation techniques were available, it was realized that the "rule of thumb" method identified the targets quickly and simply. However, some processed products, such as apparent susceptibility and regional/residual filters were generated. These enhanced not only the responses from the target bodies but also enhanced the high frequency elements of the basement responses, degrading the resolution of the target bodies. The natural separation of responses between shallow intrusives and the deep basement by the magnetically neutral Paleozoic rocks, provided the best filter of the data. Accordingly, the total field data rather than processed data were used for the anomaly selection.

Over 130 anomalous responses were identified across an area about 70 km long by 30 km wide. The long axis is in a north-northeasterly direction. The responses appear to cluster in two large areas with groups of anomalies lying along lines which tend to identify with linear events in the basement as seen by the magnetics. Evidently there is some control by the basement structure over the emplacement of the shallow magnetic bodies. Circular and oval responses predominate although a few elongate or dyke like features are evident. The horizontal dimensions of the source bodies, indicated by the airborne responses, range from less than 100m to over 1 km. Diameters of a few hundred metres are most frequently observed.

Selected anomalies were followed up on the ground using total field proton precession magnetometers accurate to one nT. Readings were taken at 25m intervals along north-south lines 100m apart across the anomalous areas. The ground responses generally support the airborne interpretation, but with greater detail and spatial precision. Again, simple "rules of thumb" were used for depth, location and shape information. Ground data over a number of the bodies suggest they contain some remanent magnetism with a magnetic pole orientation toward the north-west. This would be consistent with an age of emplacement (or at least the last thermal event) in the mid to late Mesozoic.

Drill targets were selected on the basis of the ground magnetic responses. The amplitude was not considered significant in the selection of drill targets, so that among the bodies sampled, a range of anomalous responses was identified. Ground responses were a few hundred to a few thousand nT. Subsequent to drilling, magnetic susceptibility measurements on the core indicated a range of response from 0.1 to 1.6×10^{-3} cgs units. The surface and airborne magnetometer readings were entirely consistent with these levels of magnetism in the rocks.

PETROLOGY AND GEOCHEMISTRY

The targets drilled proved to be a suite of heavily serpentinised, alkaline intrusions. Although there is considerable overlap in their mineralogy, texture and chemistry, the rocks can conveniently be divided into three groups, viz: ultramafic tuff breccias, massive alnoites, and carbonatites. Thirty-four of the forty-five intrusions drilled fall in the first group, four in the second, and seven in the third.

The tuff breccias characteristically contain an abundance of autoliths and crustal xenoliths as well as scattered xenocrysts and macrocrysts of garnet, olivine, clinopyroxene and ilmenite. Their matrices consist of serpentine and subordinate carbonate in which are scattered fine spinels and perovskite grains. There are two varieties of autoliths: sub-rounded to sub-angular pellets of heavily serpentinized, microporphyritic ultramafic rock, and nucleated autoliths. The nucleii of the latter are composed of grains of clinopyroxene, mica or serpentinized olivine. The bulk chemistry of these rocks is similar to that of kimberlites, except for their generally lower MgO and higher CaO contents. Trace element analyses shows them to be deficient in chromium and nickel relative to most kimberlites. Microprobe analyses of selected grains of garnet, pyroxene, spinel, mica and ilmenite show that, with rare exceptions, their compositions lie outside the ranges considered to be typical of kimberlites. The relatively high CaO/MgO ratio exhibited by these rocks, reflected by the common occurence of calcite in their matrices, suggests that they be tentatively classed as aillikites.

The rocks identified as alnoites are similar in mineralogy and chemistry to the tuff breccias, but they are much more massive in appearance and do not contain the abundant autoliths and xenoliths observed in the breccias. The occasional presence of melilite, or pseudomorphs after melilite suggests their classification as alnoites.

The carbonatites range in composition from pure varieties containing less than five per cent SiO_2, through to alnoitic types, which contain minor amounts of melilite (or pseudomorphs after melilite), and have SiO_2 contents of around twenty percent. They contain scattered grains of clinopyroxene, spinels, phlogopite, olivine, garnet, hornblende, apatite, barite and a niobium-rich variety of perovskite. Spatially, the carbonatites tend to occur in a cluster more or less in the centre of this suite of intrusions - a pattern reminiscent of the relationships between carbonatites and alnoitic rocks in many other alkalic/carbonatite complexes.

REE analyses were conducted on six samples of the Lowlands intrusions. Chondrite plots for samples of the tuff breccias and alnoites are similar to those obtained from two samples of South African kimberlites, suggesting some similarities in petrogenetic history. Samples of the carbonatites have the intense LREE enrichment typical of the genre.

The tuff breccias are too heavily serpentinized to yield mineral samples suitable for age-dating, but K-Ar ages of 152±8Ma and 180±9Ma were obtained, by Teledyne Isotopes Ltd. using mica concentrates from two of the massive alnoites. These ages are consistent with the geological setting of the intrusions.

CONCLUSION

Kimberlites were not discovered as a result of this project. However, it was demonstrated that alkaline diatremes can be located under heavy glacial cover, by the combined application of geological reasoning and sophisticated geophysical techniques.