AURORA GEOSCIENCES

TECHNICAL NOTE 2004-1

GROUND RADAR SURVEYS IN KIMBERLITE EXPLORATION

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Ground penetrating radar (GPR) is a geophysical method used to map the conductivity and dielectric properties of the earth at shallow depths. The technique has been successfully employed to locate and delineate kimberlite pipes and dykes. This note describes the use of GPR surveys in kimberlite exploration based on recent experience in the Slave Craton and surrounding areas.

GPR is a time domain electromagnetic method which employs timed pulses of electromagnetic energy to detect changes in the earth's conductivity and dielectric constant at depth. GPR systems operate at centre frequencies in the 12.5 MHz to 1 GHz band. At the low frequencies used in mineral exploration, systems require separate transmitting and receiving antennas with attached signal generation and detection units. Transmitter and receiver consoles are linked to a central controller by fibre optic cables. The controller triggers a signal at the transmitter and simultaneously initiates recording at the receiver where direct and reflected energy is recorded over a short interval. Signals are commonly stacked and the summed traces sent to the controller upon completion of a reading sequence. GPR systems are triggered by wheel odometers, string odometers or by timers to collect data at fixed intervals along survey lines. Data processing similar to that performed on 2D seismic reflection data is generally required to extract the maximum quantum of information from the data. Data is commonly presented in time or depth sections (radargrams), similar to seismic reflection data.

Figure 1. 100 MHz GPR - kimberlite dyke exploration on Victoria Island

Radar waves reflect at the boundary between materials with contrasting dielectric constant and electrical conductivity. Liquid water content exerts a very strong control on the dielectric constant of common earth materials and GPR reflections tend to originate primarily between materials with different liquid water content. In kimberlite exploration in the Shield, a strong contrast in dielectric constant exists between crater facies kimberlite and surrounding dry country rocks. Lesser dielectric contrasts exist between diatreme and hypabyssal facies kimberlite and country rock; these contrasts are controlled largely by secondary alteration.

Both land and lake based kimberlite pipes are readily detectible by GPR surveys. Figure 2 illustrates the response of a lake-based kimberlite pipe. Strong, clear shallow dipping reflections are produced by the conductive bedded crater facies kimberlite at the top of the pipe. In this case it is a conductivity contrast rather than a change in dielectric constant that causes reflections. Lake bottom sediments produce reflections overlying the kimberlite reflections in this section. The kimberlite reflections are rapidly attenuated at depth by ohmic losses in the conductive kimberlite. In contrast, diffraction trails are abundant within the fractured granite surrounding the pipe and the apparent depth of investigation is much greater in these rocks.

GPR responses over land-based pipes are often degraded by scattering and attenuation. Figure 3 illustrates GPR responses at 12.5 and 25 MHz over a land-based pipe subcropping beneath 40 m of boulder till. At 25 MHz (Fig. 3(a)), the GPR radiation is scattered by boulders whose dimensions are similar to the signal wavelength. At 12.5 MHz (Fig. 3(b)), the GPR signal is not scattered by the boulder till and a strong reflection from the top of the pipe is recorded. In general, the lowest possible operating frequency should be used in exploring for land-based pipes to minimize scattering and attenuation losses.

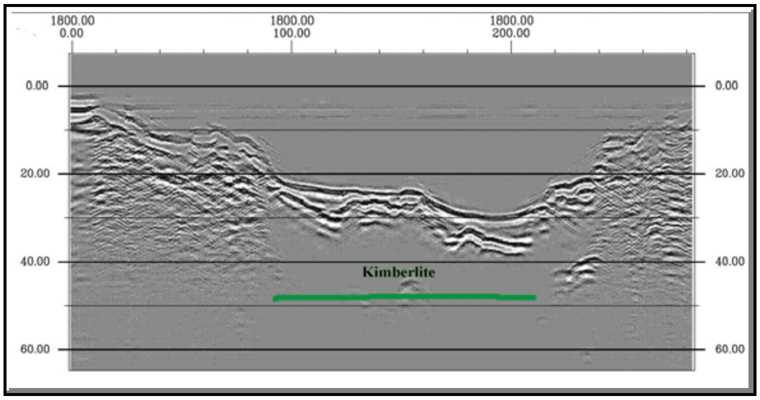

Figure 2. GPR response over a lake-based kimberlite at 25 MHz

GPR surveys are not recommended as primary exploration tools for locating kimberlite pipes. There are a wide variety of surficial features which can generate responses similar to those seen over kimberlite pipes - particularly if the target is beneath a lake. Following discovery of a pipe by drilling, a GPR survey is useful in delineating the extent of the pipe and in determining optimum locations from which to conduct further drilling.

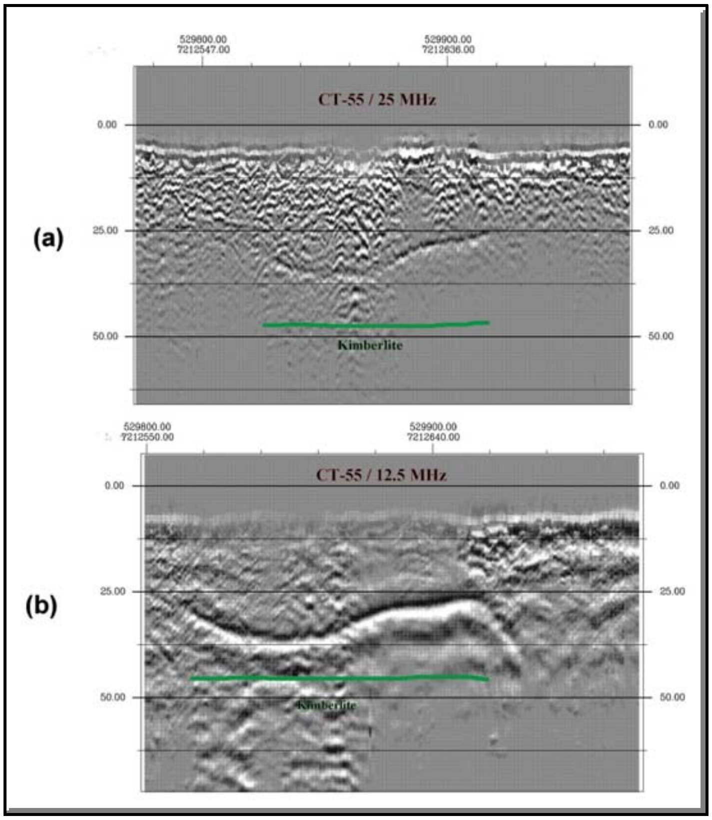

Figure 3. GPR response of a land-based kimberlite pipe. Crater facies kimberlite subcrops beneath up to 40 m of frozen boulder till. (a) Response at 25 MHz. (b) Response at 12.5 MHz.

GPR is proving to be a valuable first pass tool in exploring for kimberlite dykes however. In situations where a wide indicator mineral train is detected and a dyke source is suspected, GPR surveys are useful in detecting moderate to steeply dipping targets (dykes, veins and faults) within the likely source area. Reflections from dykes and faults can be readily identified by their characteristic responses in radargrams and by diffraction trails from the edges of intrusions. Figure 4 illustrates common dyke responses. Fig. 4(a) illustrates the case of a shallow dipping kimberlite dyke intruded along the footwall of a diabase dyke. The kimberlite produces only a weak reflection and the primary reflection is from the altered selvage of the diabase dyke. Figure 4(b), illustrates the GPR response of a vertical dyke intruded into bedded limestone. The margins of the 25 m wide dyke are clearly visible as breaks in the horizontal reflections from limestone bedding planes and joints. In addition, steeply dipping diffraction trails are generated at the contact between the joint sets or bedding planes and the margins of the dyke. The dyke contains hypabyssal facies kimberlite which is often a difficult GPR target. Fortunately, in this case, the change in the response of the surrounding limestone rather than the response of the dyke itself is diagnostic. In summary, kimberlite pipes and dykes produce distinctive GPR responses which are best developed at low frequencies. The method is most useful in delineating the extent of kimberlite pipes following discovery and in searching for kimberlite dykes.

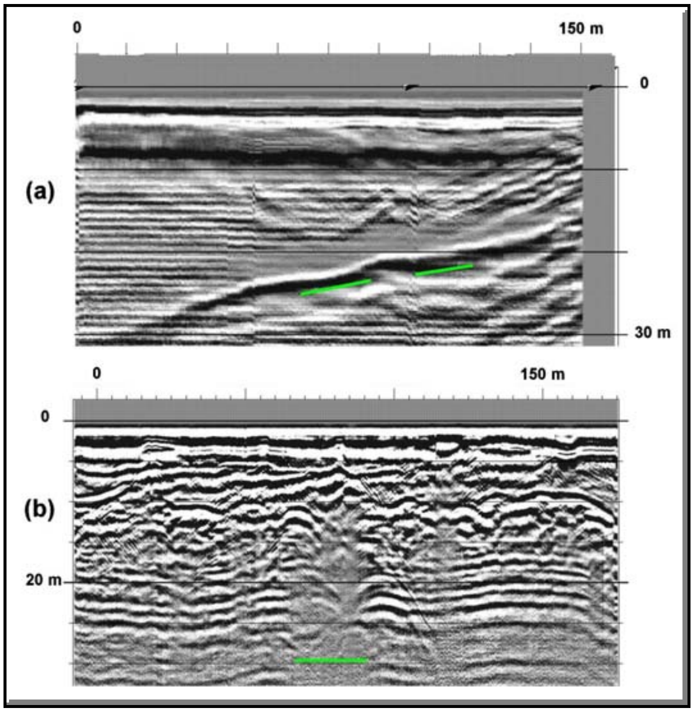

Figure 4. GPR response of kimberlite dykes. (a) Thin kimberlite dyke intruded beneath a shallow dipping diabase dyke; most of the response at 25 MHz is from the top of the dyke. (b) Vertical dyke within flat-lying bedded limestone. The dyke subcrops beneath 10 m of overburden.

Acknowledgments

The author would like to thank Diamondex Resources Ltd., Diamonds North Resources Ltd. and Snowfield Development Corporation for permission to display extracts of their data.