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APPLICATION OF GROUND PENETRATING RADAR

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ABSTRACT

Since the first ground penetrating radar (GPR) survey in 1929, applications of ground penetrating radar have expanded at an incredible pace. GPR system manufacturers estimate there are thousands of systems around the world, yet GPR is often misapplied as well as properly applied (acquired, processed and modeled) to a variety of problems from archaeology to geology, glaciology, environmental, engineering, mining, and many other applications.

Key words: ground penetrating radar, GPR, history, location, modeling, processing

INTRODUCTION

The first ground penetrating radar survey was to determine the depth of a glacier, reported in 1929 (Stern, 1929, 1930). Then the technology was lost until the late 1950’s when planes crashing into the Greenland ice cap reawakened interest in the subject (see further history in Clarke, 1987; Young, 1996). The 1929 method of radiointerferometry was independently re-discovered for the 1972 Apollo 17 mission to the moon (Simmons et al., 1972).

Most ground penetrating radar systems today are short impulse time domain systems similar to Barringer (1965) or Caldecott (1967) and used in simple imaging mode to map subsurface events like the occurrence of the water table (Barringer, 1966; Caldecott et al., 1972; Morey, 1974). Applications are legion as demonstrated by the proceedings of the various radar conferences (Hanninen and Autio, 1992; Pilon, 1992; WCGR, 1994) and numerous specialty conferences (such as SAGEEP, 1988-1996, or DDESB, 1996). There is neither time nor space to briefly introduce let alone discuss these applications properly. Instead, consider the generic methods of application and misapplication of GPR.

GENERIC GPR APPLICATION

Acquisition

The first mistake often made in the application of GPR to a problem is in the decision whether or not to use GPR. Some people still think that GPR can not see through a water table: only true if the water is highly conductive. Others dismiss any site containing clays: only mineralogic clays like montmorillonite are a problem for GPR (and only at frequencies below about 400 MHz); engineering size fraction clays (rock flours) are not a problem. Even in mineralogical clays, GPR sometimes produces useful data in the near field, working more like a metal detector at very shallow depths. Others dismiss GPR if there's too much metal, but the high resolution of GPR often allows it to see between the metallic clutter interference (or like rebar, orient the antenna polarization to minimize the rebar coupling). Others get into trouble (especially with low frequency unshielded antennas) by not considering scattering from above or to the side of the antenna. All of these issues arise because the people making the decision do not understand the physics of ground penetrating radar systems nor the impacts of geological material properties on electromagnetic wave propagation (Olhoeft, 1987; Olhoeft and Capron, 1994; Powers, 1995).

Location

Most problems are approached by applying GPR as a simple imaging tool to produce approximate cross-sections of the subsurface. Many times the data are not even recorded. GPR provides the highest resolution location for lost objects like buried utilities and unexploded ordnance, or for quick mapping of areas of interest at archaeology sites. The accuracy of location is entirely dependent upon knowing where the antenna was and how it was oriented -- information that is often lost by not properly marking the radar records and surveying the locations of the marks. GPR may completely fail to detect objects such as when the antenna E-field polarization is perpendicular to the long axis of a buried wire, indicative of the importance of antenna orientation. It usually provides horizontal position with little or no depth information.

To provide depth, the radar two-way travel time must be calibrated, and though there are several methods to do this (time to buried object at known depth, wide angle walk away, diffraction shape fitting), it is not often done properly. Most time to depth conversions are still guess work based upon tabulated or assumed material properties. In an unfortunately large number of papers not only is there no indication of how time was turned into depth, but there are many published radar records with no time or depth scales at all (see for example papers in the recent SAGEEP, 1996).

True Geometry Cross Section (Processing)

Instead of simple location, often the problem is to find the spatial relationship between objects, such as the topography of the water table versus that of the surface of the earth or stratigraphic relationships. This requires cross sections corrected in 3D space by rubber sheeting and velocity or depth migration back to true geometry. Such corrections may be performed in low loss materials (like polar ice, rock salt, clean granite or clean sand as in Fischer et al., 1992, or Grasmueck, 1996) as they are done in petroleum seismic exploration, but more often GPR violates six of the common assumptions of seismic migration (Yilmaz, 1987) and can lead into trouble (see Figure 44 in Powers, 1995). The accuracy with which such processing may be performed is limited by the knowledge of wavelet shape, antenna position and radiation pattern, and electromagnetic properties in the subsurface.

Quantitative Material Properties (Modeling)

In addition to geometric relationships, it is often desired to know material properties, especially density and fluid content. As dielectric properties are sensitive to water content, GPR has been used to determine density and water content (Powers and Olhoeft, 1995), and more recently organic chemical concentration (Sander, 1994) through electromagnetic modeling. Full up 3D electromagnetic vector field modeling is possible, but computationally still expensive (parallel supercomputer CPU days), so most modeling is still performed through simplifications involving assumptions about things that may be neglected. Problems are encountered when the assumptions are invalid: 1D and 2D models in 3D situations (Olhoeft, 1994), ignoring magnetic permeability in iron bearing soils (Olhoeft and Capron, 1994), and so forth.

SUMMARY

Like any tool, GPR can be misused and inappropriately applied to problem solution (worse than a hammer used to drive a screw). Despite the actual history of misuse and consequent failure, GPR has had and continues to have a remarkable string of successes in solving problems that other techniques cannot approach. The key to success is to understand the radar system and the material properties of the site being addressed, how it is most appropriately applied in data acquisition, and what the implications of various simplifying assumptions are to data processing and modeling.

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