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Ground Penetrating Radar: A review of the basics

What is Ground Penetrating Radar?

Ground Penetrating Radar (GPR) is a relatively fast technique for remotely detecting buried objects. Radiowaves are sent into the ground and are reflected, refracted or absorbed by buried objects. A receiver antenna detects and records the time taken for signals to be reflected back to the surface, which can then be used to determine the depth to the reflective feature below the ground.

An object's reflectivity to radiowaves is determined by its 'relative dielectric permittivity' (RDP), the measure of its electrical conductivity and magnetic susceptibility. Objects of high RDP absorb radiowaves, rather than reflecting them or allowing them to pass through the object.

Metals are such an object, due to their high electrical conductivity and magnetic susceptibility. This effect can be noticed while listening to a car radio. If a large vehicle or truck drives beside you, the radio will play static. This is due to the fact that the metal in the vehicle is absorbing the electrical energy in radiowaves, and so the signal is blocked from reaching the car's radio antenna.

Waterlogged soils, including clays, also exhibit a high RDP. Imaging of objects buried within these soil matrices may have limited success using GPR: other methods may be employed instead.

For archaeological purposes, GPR units transmit radiowaves at frequencies typically ranging from 100MHz to 1GHz, with radiowaves of frequencies between 250MHz and 500MHz the most commonly employed. Due to their nature, higher frequency radiowaves travel through a greater quantity of material than lower frequency waves, even when travelling the same distance. This means that higher frequency waves are absorbed more rapidly into the soil (rather than being reflected or being transmitted through the soil to a deeper level); the net result is that higher frequency radiowaves are unable to penetrate as deep into the ground as can lower frequency radiowaves. However, higher frequency radiowaves are also more likely to 'hit' a target, and so are better suited to finding smaller buried features.

A 2GHz signal is useful for imaging small plastic pipes (less than three centimetres in diametre) in concrete and is often used in construction work. However, the signal is only capable of penetrating less than thirty centimetres into the ground, so has little use in archaeology. A 500MHz radiowave would be capable of penetrating to about 2-4 metres below ground, but would not be able to detect the same pipe.

How are GPR surveys undertaken?

GPR units consist of a transmitter antenna, a receiver antenna and a controlling computer, which are often incorporated into a cart system. These cart-based systems are manufactured by companies including Mala Geoscience, Sensors and Software Inc., and Geophysical Survey Systems, Inc. (GSSI). The assembly is moved along parallel survey lines, collecting data at regular intervals; cart-based systems use an odometer wheel to automate the data collection process. Individual data points can be as little as five centimetres apart. The entire survey area may be surveyed additionally along lines perpendicular to the original survey lines to ensure that smaller features have not been missed by the survey. Survey lines may be set out using measuring tapes or a total station or real-time kinematic GPS may be employed, depending on topographic conditions. Topographic data may also be collected to assist with data interpretation.

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Following data collection, a period of time of usually three times the duration spent collecting data is required to process the data and make interpretations of buried features based on the collected data.

Raw GPR data is assembled into survey lines known as 'radargrams', (an example is provided in figure 1), which show various features below ground in a cross-section view. In figure 1, negative amplitude (strength) reflections are shown in darker shades of black while positive amplitude reflections in lighter greys and white.

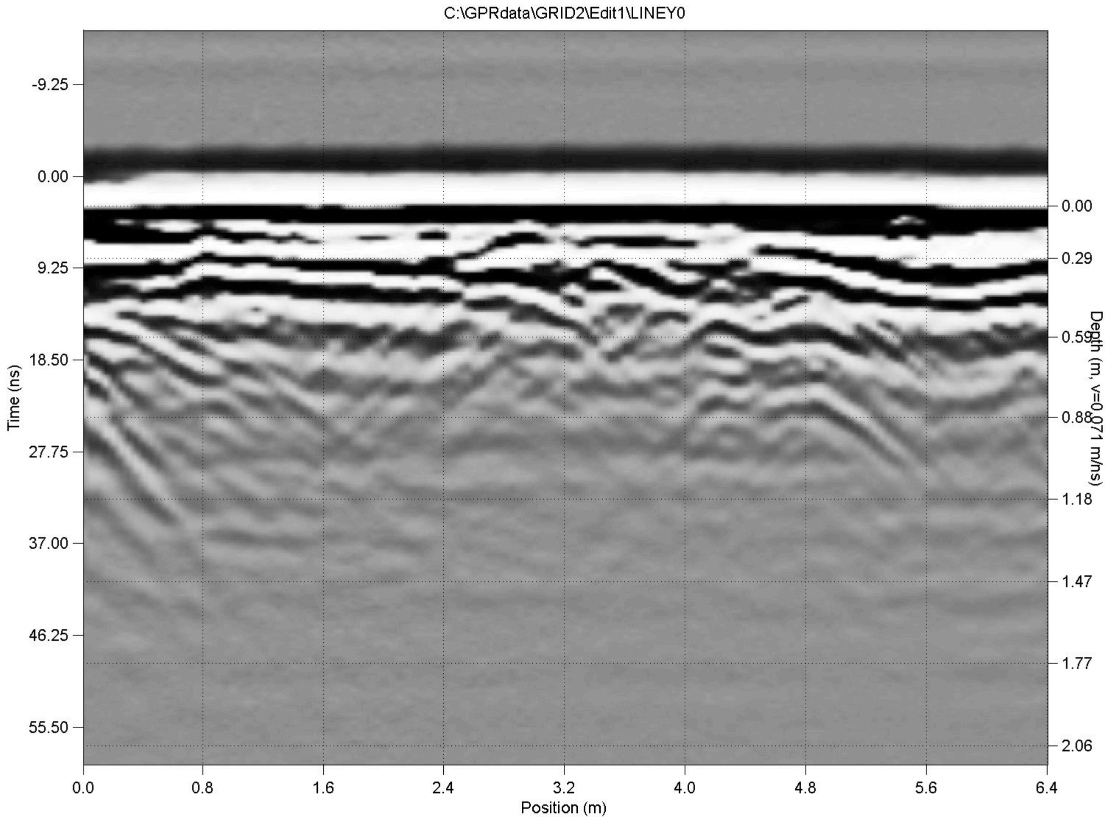

Figure 1: A radargram showing reflective layers beneath the ground surface. From 80 centimetres to about 3.2 metres along the radargram, anomalies at a depth of 30-60 centimetres are present, reflections most likely from gravels left behind from a buried garden footpath. This interpretation was aided by building plans.

All of the radargrams collected from a survey area can be merged together to create what are known as 'depth slices', which provide a bird's eye view of the reflectivity of the entire site at different depths. Figures 2, 3 and 4 show depth-slices of a circular garden bed, surrounded by a circular gravel carriageway at differing depths.

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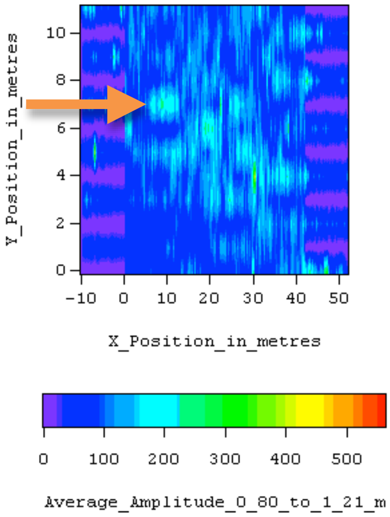

Figure 2: A depth slice showing reflectivity of radiowaves at a depth from 80cm to 1.2 metres.

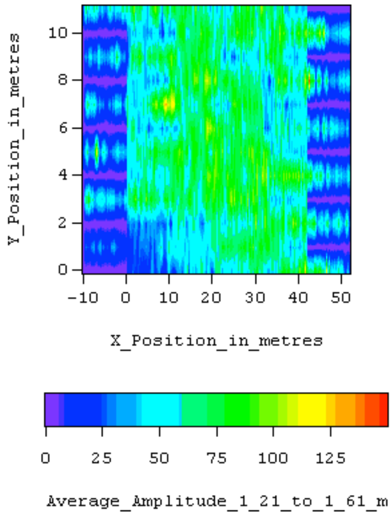

Figure 3: A depth slice showing reflectivity of radiowaves at a depth from 1.2 to 1.6 metres.

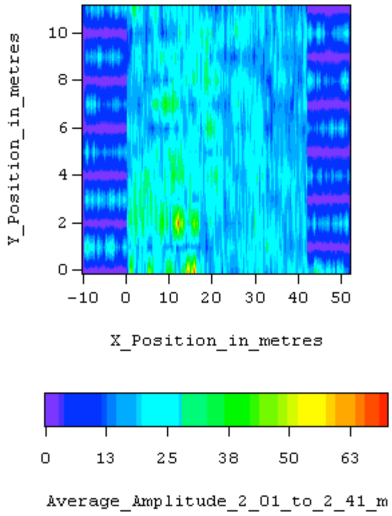

Figure 4: A depth slice showing reflectivity of radiowaves at a depth from 2 metres to 2.4 metres.

Figure 2 shows a circular gravel driveway, which can be seen as a light blue ring surrounding a darker blue ring in the upper-left corner of the plot. The light blue anomaly (at which the orange arrow points) surrounded by the darker blue ring anomaly is believed to be the former location of a tree. The dark blue ring surrounding the light blue anomaly is interpreted as being a grassed area between the gravel driveway and the tree in the centre. Interpretations have been assisted by the examination of historical evidence.

Finally, all of the data collected during a survey may be used to create a three-dimensional model of detected features beneath the ground. Figure 5 (below) shows a three-dimensional model of human graves, using data that Hunter Geophysics collected at a cemetery in Tasmania. These three-dimensional models show areas of specific reflection amplitude in user-defined colours, which can assist the surveyor when interpreting the collected data.

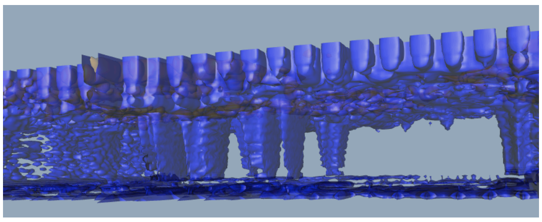

Figure 5 shows a three-dimensional, side-on view of human grave-cuts. The grave-cuts are the dark blue spikes extending from the top to the bottom of the display, in the centre. Other blue areas to the far left of the display are tree roots and other soil disturbances.