Ground Penetrating Radar Survey, Coll and Tiree

Alistair Rennie and Jim Hansom

Principles

Ground-Penetrating Radar (GPR) is comparable to other geophysical reflection techniques such as Seismic and Sonar. GPR emits a short pulse of high frequency electromagnetic energy, which passes into the ground (Davis & Annan 1989). The signal path is dependant on the high frequency dielectric properties of the ground. Stratigraphic layers and archaeology (via isolated objects) with differing dielectric properties will reflect the radar signal to differing extents. The reflected signals are stored, manipulated and interpreted to account for the dielectric properties of tomographical profiles. The time taken for the radar wave to pass into the ground, hit a reflector and return to the surface is a function of depth, and is known as the two-way travel time. Using an approximate speed for the sound wave (dependent on the sediment type and water conditions) the two-way travel times is used as an analogue for depth.

Procedures

The archaeological prospecting was carried out using a Pulse Ekko 1000 GPR system loaned from NERC. The system has a variety of antenna configurations, however during the field period the radar system was deployed in a reflection mode using fixed off-set reflection profiling. Target features illustrated within this report were subsurface archaeological features (approx. 0.5-2m in height and length) extending to a depth of approx. 2-3m. For these reasons the 225MHz antenna was used to achieve the target depth and resolve features of the appropriate size. Experiments were also undertaken with the 450 MHz antennae, but, as expected, it was found that the penetration was too shallow with this set up. The system set-up was taken from levels advised in the users manual (Sensors & Software 1999). These are conservative 'rule of thumb' guidelines, which when recalculated and checked, proved to be adequate.

Figure 24 GPR equipment in use on Coll

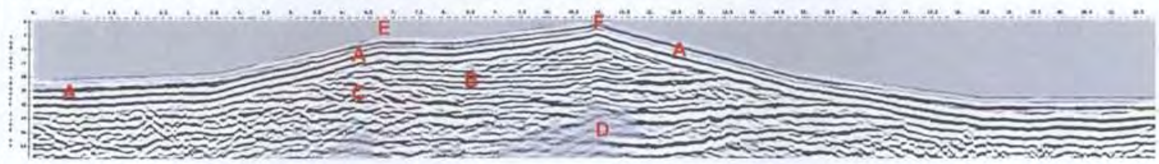
Archaeological targets were isolated by remote-sensing techniques and then located on the ground using a survey grid over the targets. The initial GPR profiles highlighted areas of interest and disturbance and were then focussed upon in increasing detail. The tomographical profiles presented in Profiles 1-6 are a selection of some of the surveys. Although only initial data processing has been applied, the main features of the internal architecture has been accounted for. This is especially evident with the cairn and graveyard.

Preliminary interpretation

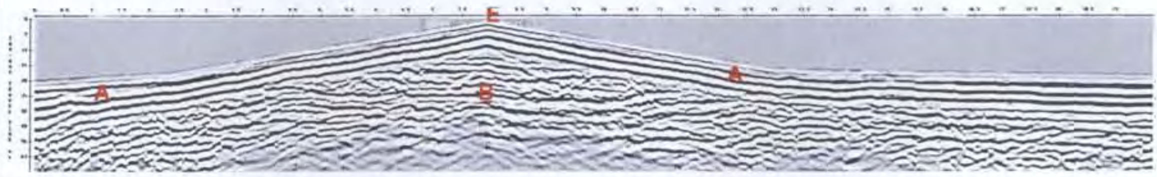
<u>Cairn at A'Chrois, Tiree (96250E, 747870N)</u> (see figure 23)

The Cairn is ellipsoidal in shape, covered in grass with isolated stones showing. Profile 1 passes over the long axis and is intersected at 11m and 7m by Profiles 2 and 3 respectively. Generally the first ground parallel reflectors (A) are a function of the air and ground waves and can be ignored. Below these reflectors the internal architecture can be seen, including horizontal reflectors (B), disturbed ground (C) and a strong central reflector (G). Signal attenuation was noted at point D, this was below the highest point of the cairn, and subsequently the area where the signal had to travel further. The profile seen is consistent with the internal architecture of a stone-built cairn surrounding a strong central reflector of an unknown nature, possibly a slab or slabs.

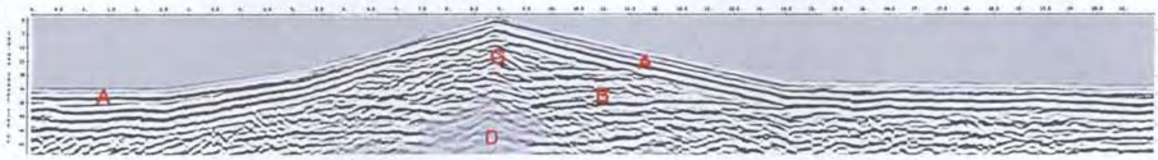
Profile 1; transect T0022b, The internal structure of the Cairn via the long axis.



Profile 2; transect T0024b, The internal structure of the Cairn across the lower crest (7m).



Profile 3; transect T0023b, The internal structure of the Cairn across the highest crest (11m)



Point A: Air and Initial Ground waves can be ignored,

Point B: Sub horizontal reflectors continue across the cairn,

Point C: Area of disturbance,

Point D: Signal attenuation,

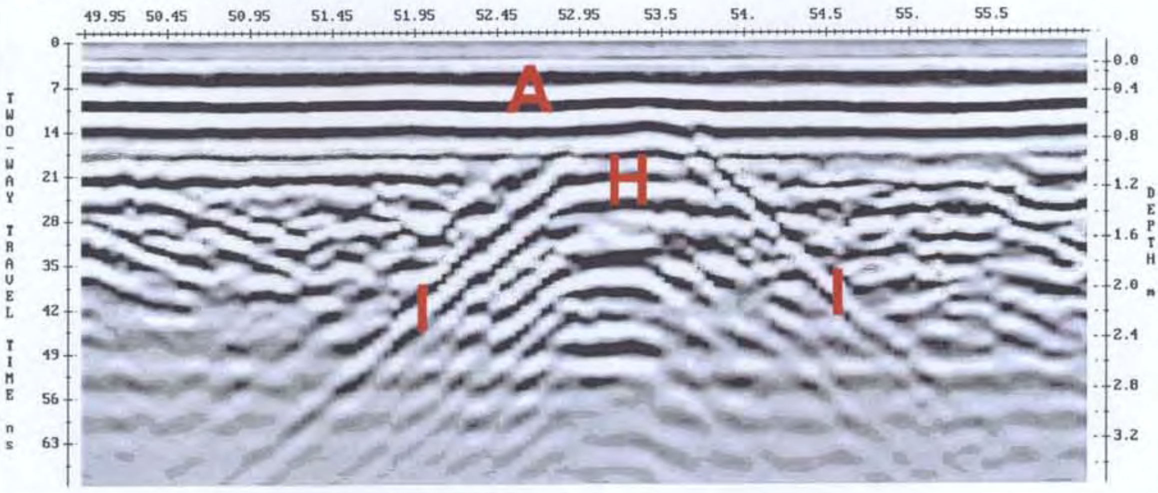
Point E & F: location of profiles 2 and 3,

Point G: Strong central reflector

Grave at A'Chrois, Tiree (96595E, 748125N) (see figure 21)

The target is a horizontally topped structure located in a field behind A'Chrois. Profile 4 (presented below) is comparable with other reflectors found in the immediate vicinity, whose juxtaposition suggested alignment in two parallel rows. Further investigations showed these targets to be non-continuous targets approximately 2m in length and 0.5m in width. The profile has not yet been topographically adjusted as the surface above the target was flat. As with the previous profiles the first ground parallel reflectors are a function of the air and ground waves and can be ignored. Below these, 0.5m horizontal reflectors are present. The radar cone intersects the reflectors as it approaches from an angle and this produces the steeply sloping rising and falling limbs (Point I) on either side. This pattern is consistent with that expected from a capstone of a grave.

Profile 4 Grave at A'Chrois, Tiree



Point A: Air and Initial Ground waves can be ignored,

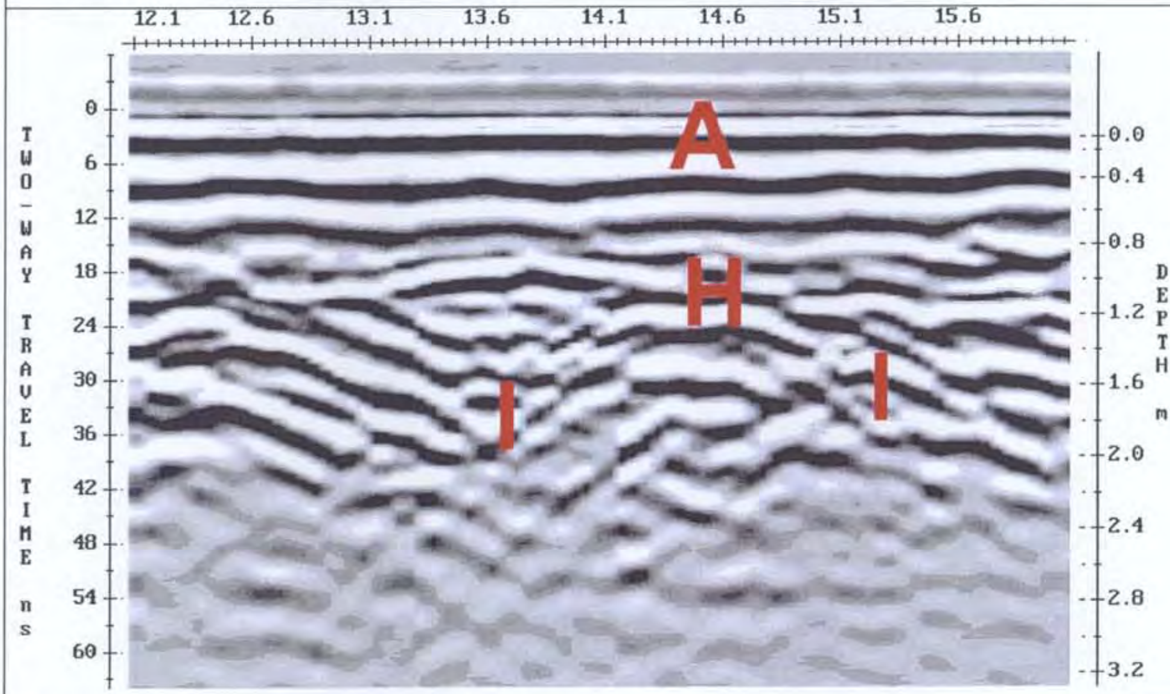
Point H: Strong horizontal reflectors

Point I: Steeply sloping reflectors

Grave - dated to 1918 - within existing graveyard at Crossapol (10126E, 7532N)

This profile is currently being topographically corrected. However, when this is done, the following changes to the architecture will be evident. Central point H will become more upstanding and the lines at points I will steepen since the ground surface domes at this point over the axis of the 1918 grave. At the same time, the lines at points I will flatten. The resultant GPR profile will then resemble that of Profiles 4 and 6. However it is known that this grave is modern and thus has no capstone. Although there is a strong horizontal reflector, it is probably not composed of stone. In this respect it probably differs from the others and so its GPR signature is more muted.

Profile 5 Known Graves at Crossapol



Point A: Air and Initial Ground waves can be ignored

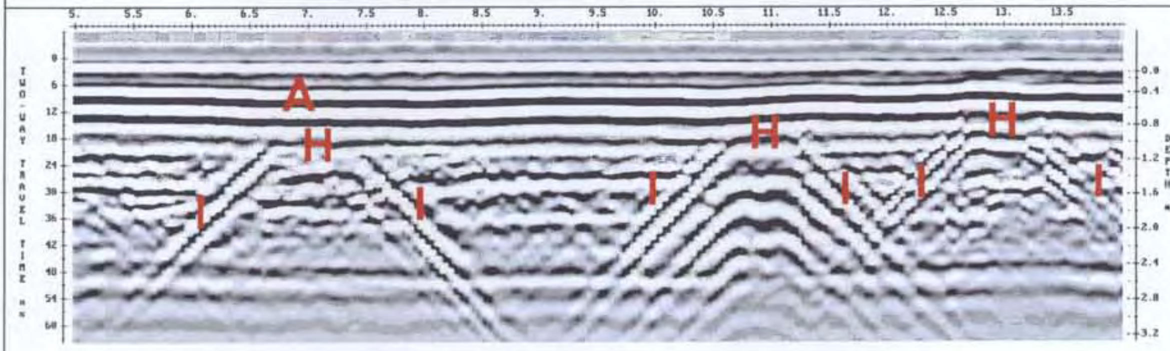
Point H: Strong horizontal reflectors,

Point I: Steeply sloping reflectors

Graves within extended graveyard at Crossapol (10126E, 7532N)

These strongly reflecting signatures are very similar to those in Profile 4 and of a similar size and spacing. The profile was taken at an angle over the target area and so the dimensions probably reflect the long axis of the suspected graves and this may also explain the spacing. This pattern is consistent with that expected from a series of capstoned graves.

Profile 6 Graves in extended grave yard at Crossapol



Point A: Air and Initial Ground waves can be ignored,

Point H: Strong horizontal reflectors

Point I: Steeply sloping reflectors

Discussion

The following discussion is based on the images (Figures 14 –23) and GPR Profiles (1-6) displayed in this report.

Figure 14 shows an area where a chapel is known to have existed. A graveyard, badly affected by coastal erosion, still exists close to the sea. A flat area of improved machair exists around the farm at Crossapol. This is easily distinguishable on the 9, 7, 3 false colour composite from the area of dunes to the east and the boggier land to the west. The daytime thermal image helps to highlight a wall running across the improved land. It also shows areas of disturbed ground on either side of the wall. A field visit indicated that there was rabbit disturbance within the area, but pottery was found within the rabbit scrapes. The area was subjected to a GPR survey. This detected the buried wall and the area of disturbance. It has not yet been possible to characterise the nature of the disturbance, but there is a possibility that it relates to the lost chapel.

A GPR survey was also carried out within the known graveyard (Profile 5). A line outside the graveyard wall was also surveyed, and this indicated that the area of burials extends beyond the present graveyard boundary (Profile 6).

Figure 15 shows a former area of cultivation within a dune field on Coll. No houses exist today in this area. The 9, 7, 3 false colour composite is again good at showing areas of improved land from the surrounding dunes and areas of bog. The daytime thermal image is very good at highlighting low grass-covered walls that form the enclosures and other boundaries. The night-time image helps to differentiate between ditches, tracks and walls, not easily done on the other images.

Figure 16 also shows an area of former cultivation on Coll. In this image the 9, 7, 3 false colour composite clearly indicates areas of agricultural ridging. A group of cairns was found within this area, and these are detectable on the daytime thermal image. By comparing the thermal image with the 4, 3, 2 true colour composite it is possible to distinguish them from areas of bare sand.

Figure 17 shows and abandoned farmstead that now exists only as a series of low, grass-covered humps. The farmstead is shown on the First Edition Ordnance Survey map as a ruin. It is detectable on all images, but it is the daytime thermal image that gives the greatest definition, allowing individual buildings to be seen. The GPR was used to confirm the size and nature of the buried farmstead.

A buried track, also known from the First Edition map, shows up on the night-time thermal image in one field. It is not visible on any of the other images within this field. Its visibility on the night-time thermal image is due to the type of vegetation cover within the field at the time that the image data were collected.

Figure 18 shows the course of an old field boundary within a ploughed field. Very few fields were ploughed at the time that the image data were collected. The boundary shows up clearly on the daytime thermal image. GPR was used to determine the nature of the boundary. It was not able to detect any buried stone, suggesting that it was not stone-built.

The image also shows numerous drainage ditches. Some of these are still in use, others are not. The night-time thermal image clearly shows which of the ditches contain water.

Figure 19 shows the area around the Kirkapol chapels. A wall running from the chapel to the graveyard was confirmed by GPR survey. The survey also suggested the presence of several burials in the area.

Of interest is the way that the extension to the graveyard, barely detectable from its surroundings in the 4, 3, 2 true colour composite, shows up very clearly on the daytime and night-time thermal images.
Figure 20 shows a small enclosure with a structure within it. This was one of several such enclosures noted on Tiree. It does not appear in local or national records. The enclosure and structure are most clearly visible on the daytime thermal image. Also present are several circular features. These were noted in many areas on Coll, but especially in remote dune areas. When first seen, their circular shape and diameter led to speculation that they were hut circles. The night-time images showed hot-spots around the circular features, which did not appear on the other images. A field visit soon revealed these features to be cattle feeders (figure 25). Trampling caused the difference in vegetation and soil temperature; the hotspots were the cows themselves!

Figure 26 Cows around a cattle feeder.

Figure 21 shows the land around A' Chrois, another area that was once the site of a chapel. The 9, 7, 3 false colour composite shows clearly the difference between the areas of dune and the improved machair. It also helps to highlight buried walls and evidence of past agricultural activity. The landowner told us that the field had not been ploughed for at least 50 years, due to worries about sand-blow. The 9, 7, 3 false colour composite image indicates an area of disturbed ground, which is also evident on the daytime thermal image. The area of disturbance is aligned E-W and was subject to a GPR survey. Several transects were made within the area of disturbance and the anomalies encountered have been interpreted as possible burials (Profile 4).
Figure 22 also shows A' Chrois. Buried walls are evident in the images, passing from the area of machair into an encroaching dune field. The walls are evident even when covered with drifting sand. The way that the sand is forming a series of mounds along the line of the wall is clearest in the 9, 7, 3 false colour composite. Recognition of this pattern of burial may make it possible to locate more deeply buried boundaries by observing the pattern of the overlying dunes.
Figure 23 shows a cairn within a dune field. The cairn has been confirmed by a GPR survey (Profiles

1-3). The detection of cairns within such an area is difficult, due to the blown sand forming mounds. It is suggested that the cairn is detectable by looking at a combination of images. It appears warm on the daytime thermal image, as do surrounding humps. On the night-time thermal image it appears uniformly cold. The uniformity of its temperature may be a result of it being stone-built. Other humps, formed of wind blown sand, display a warm side, (facing south) and a cold side (facing north).

Conclusions

The Airborne Remote Sensing project of Coll and Tiree has demonstrated that the technique can be very useful for locating archaeological monuments in areas of sand. As the researchers gained more experience in interpreting the images, so the number of actual sites detected (as opposed to natural features) increased. The features detected ranged from walls, to enclosures, to farmsteads, to individual buildings, to cairns.

Viewing the images on the computer allowed rapid scans of complete areas of landscape to be made. Having a set of different windows open meant that different band combinations could be viewed simultaneously. Larger features, such as field enclosures (figures 15 and 16) were easily detectable, especially on the daytime thermal images. Once a feature was identified the image could be 'zoomed into' allowing greater detail to become apparent. As the images were geo-referenced, co-ordinates for all identified features were immediately available. Ordnance Survey landline maps were also added to the images to allow checking of target location against a map.

The dunes are problematic areas for recognising features, partly due to the nature of the topography. The numerous bumps and hollows display warm (south facing) and cold (north facing) sides, where the sun has had a chance to warm up the ground. This is apparent even in the night-time thermal images. It is thought that by combining the ATM data with LIDAR, it will be possible to make compensations for this effect. Having said that, features were visible within the dunes, examples being the buried wall (figure 22) and the cairn (figure 23).

It is felt that this a very worthwhile technique, but that further work is needed to determine whether other factors play an important role in the ability to locate archaeological features. One factor may be the time of year that the image data are collected. A prolonged spell of cold weather followed by a couple of warm days may encourage thermal differences to become more apparent. Time of year will also have an affect on vegetation cover, and flights flown after long dry periods towards the end of summer will allow the 9, 7, 3 false colour composite to show up vegetational stresses before they become apparent on conventional aerial photography. Flights flown on sunny days will enhance the effect of the sun shining on south-facing slopes, so perhaps dull days would show more differences.

The amount of information contained within the images is enormous, and further analysis of the collected data will be undertaken. Attempts will be made to clean up the night-time thermal images, and other researchers will review the images. Having said that, this initial review of the evidence has demonstrated that the use of Airborne Remote Sensing is appropriate for the large sandy areas around Scotland's coast.

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