THE GEOPHYSICAL EQUIPMENT FACILITY PROJECT 912 SCIENTIFIC REPORT

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The Interface of Geophysical & Geochemical Survey in Archaeological Prospection

Abstract

A GPR system was requested from GEF to collect data during two fieldwork seasons of an on-going NERC PhD project. A total of 310 GPR B-scans were collected and an area of 755.4m² was mapped at five challenging and contrasting archaeological study sites in Scotland. A GPS Leica System 1200 was also required during the second field season to accurately locate the survey grids, to correct some GPR data and to assist to other instruments. The GPR survey produced good results and succeeded in locating the known archaeological targets.

1. Background

The NERC PhD project, which was object of the GEF loan, is using a new approach which combines both geophysics and geochemistry to understand the soil properties that influence the results of geophysical techniques at five challenging and contrasting archaeological sites in Scotland (Figure 1). These sites are characterised either by difficult superficial deposits (*e.g*. wind blown sand in Orkney) or sites with low magnetic contrast (*e.g*. Forteviot).

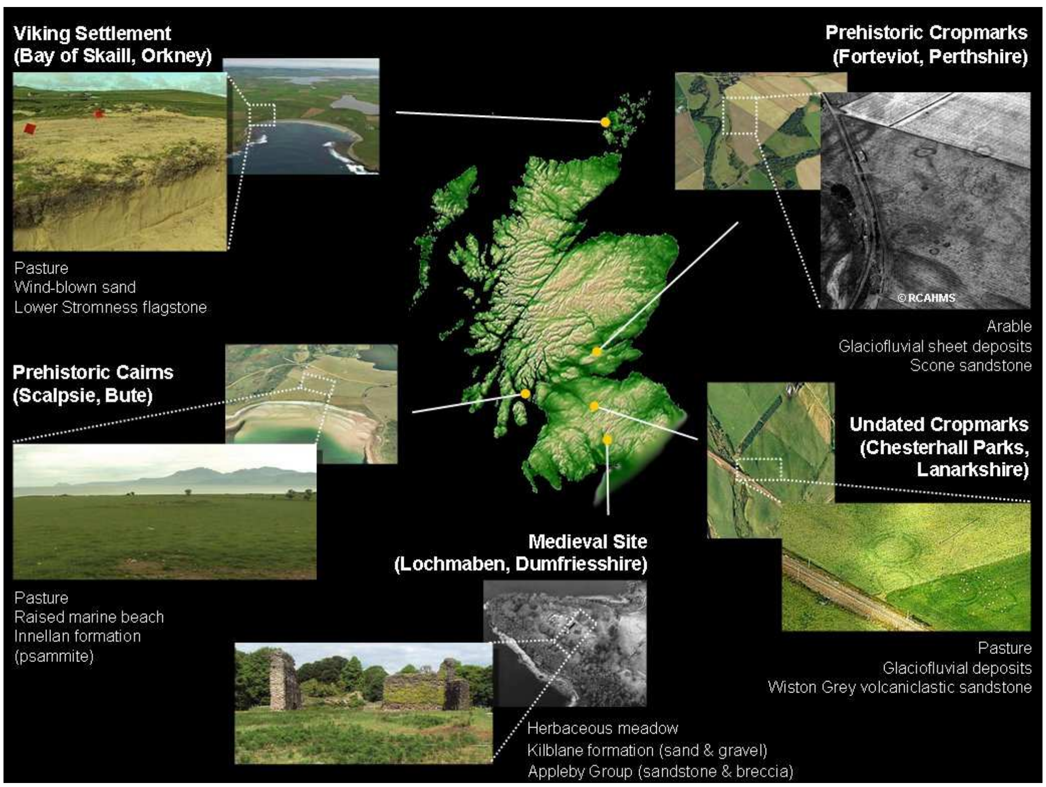


Figure 1. Map of Scotland showing the location of the five case study sites, survey areas and general description of the land use, hard & drift geology.

The objectives of this investigation are:

a. To assess the capabilities of five geophysical techniques (Earth resistance, gradiometry, GPR and conductivity survey) commonly used in archaeological prospection.

b. To experiment with sequential/repetitive geophysical surveys & soil sampling to evaluate the effects of the topsoil and weather conditions on the geophysical data.

c. To characterise the geophysical response of archaeological features vs. soil matrix in terms of chemical composition & other soil properties to understand the factors involved in the creation the geophysical anomalies.

The final outcome of this project is to validate a series of field/lab-based strategies to help in the planning of geophysical surveys. This will allow a more meaningful interpretation of the geophysical results and a more confident prediction of the appropriate survey strategy to be used at a given site.

Two loans were required for this investigation. A Sensors & Software PulseEKKO GPR 1000 system was acquired to carry out a pilot survey with the aim of to collect the first GPR data at some key sites. The surveys were carried out over known archaeological features at some key contrasting sites to fulfill objectives a & b. This first loan was from 22 June 2009 to 5th October 2009 and examples of the results at Forteviot were summarized in the application for the second GEF loan. The following year, the same GPR (plus a GPS system) was borrowed to collect data during the main survey season. The aim of this survey was to collect a second GPR data set at all the case study sites. The GPS was used to locate the survey grid or random GPR transects, to correct the GPR data when required and to be attached to an EM38 instrument used for the conductivity survey. The second loan was from 16th April 2010 to 30th September 2010.

2. Survey Procedure

The overall method strategy used at each study site is summarised in Figure 2.

2.1 The GPS Survey

Each OS reference active station was identified prior survey at each site. The GPS base stations were set up in each site to record data in static mode for at least 2h to improve positional accuracy of the GPS survey. The base stations were located on secure and stable points in the proximity of the survey and with good sky visibility. The data was logged to a compact flash card, downloaded to a laptop and then processed. The corrected OS coordinates were introduced into the GPS base station during the following day of survey. The RTK survey was carried out with the rover configuration in pole mode. The geophysical grids and the corrections of the GPS data were surveyed in this mode to ensure high accuracy. The lower resolution pillar mode was used for the EM38 survey because this was the only possible way to attach the GPS to the EM38 instrument. The conductivity data was output in real-time via a standard serial RS232 digital interface supporting NMEA messages.

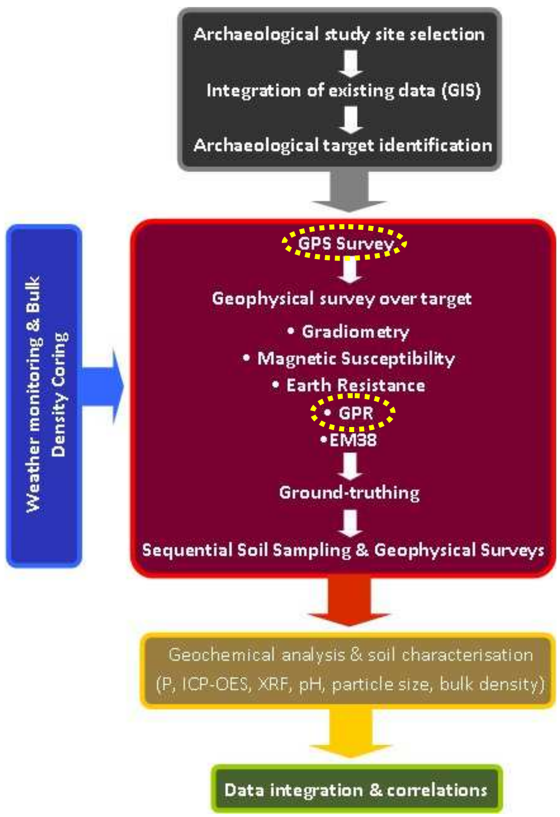


Figure 2. The flowchart shows the methods & overall survey procedure followed at each study site.

2.2. The GPR Survey

The GPR system was equipped with antennae of nominal centre frequency of 450 MHz, to map the archaeological target in detail by creating time-slices. The survey grid of parallel traverses was orientated, where possible, perpendicular to the archaeological targets. The traverse spacing was, 0.25m or 0.5m, depending on the approximate size of the

Parameter	450 MHz	225 MHz
Operating mode	Continuos/Step	
Start delay	3"	
Delay	0.5"	
Pause Trace	vary	
Time Window	120ns/150ns	
Number Stacks	16	
Sampling Interval	200ps	400ps
Step Size	0.05m	0.10m
Traverse Spacing	0.25m/0.5m	0.5m

Table 1. General survey parameters.

archaeological features and following recommendations in archaeological practice (David et al. 2008). The spatial step size along traverses was 0.05m to avoid spatial aliasing. 225 MHz antennae were also used to map deeper archaeological targets (e.g. Orkney). The step size here was incremented to 0.10m. Table 1 shows a summary of the survey parameters used for the GPR surveys, although these parameters varied slightly from site to site. The size of the survey grids was different at each site. Single GPR transects were also collected with both antennae frequencies to compare and assess the effect topsoil and weather conditions.

3. Data Processing

3.1 The GPS Data

The GPS data points were imported to a laptop. The OS corrections were extracted from the OS Net RINEX data server and then processed with Leica Geo Office software. Then corrected GPS data points were imported to ArchMap and they were used to georeference the geophysical surveys and to create the interpretation maps.

3.2 The GPR Data

The GPR data was processed with the Sandmeier software ReflexW Version 5.6. A fairly standard processing flow was generally carried out with the GPR data (Table 2). The result of this processing step flow is shown in Figure 3. Migration and depth conversion were based on an average velocity calculated by hyperbola adaptation. Some further processing such us topographic correction was needed at some sites. Finite-width time-slices were produced and single time-slices were georeferenced to GPS points in ArcMap.

Processing		Software
Editing	Edit Fileheader	ReflexW 2D
Basic Processing	Dewow Static Correction Background Removal Manual Gain (y) Fix Profile Lengh Time Cut	
Migration	Hyperbola adaptation	
Depth conversion		
Time-slices	Finite-width	ReflexW 3D

Table 2. General data processing flow.

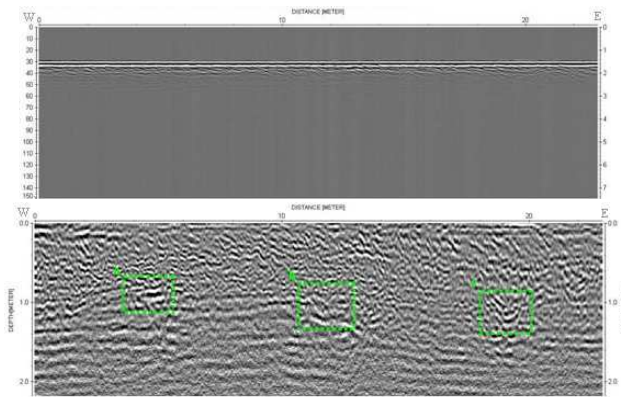


Figure 3. Raw and processed GPR B-scan (Line 30= 7m) over a prehistoric double ditch enclosure at Forteviot: a) westernmost outer ditch, b) pit of a cist burial and c) easternmost outer ditch.

4. GPR Data Quality & Interpretation

A total of 310 GPR B-scans were collected during both GEF loans (88 in 2009 & 222 in 2010) The GPR system mapped total area of 755.4m². The quality of the data collected was generally good. Some errors related to console laptop communication, low battery, twisted cable or presence of hidden metallic object did interfere during the data collection.

4.1. The Prehistoric Cairns at Scalpsie Bay (Isle of Bute)

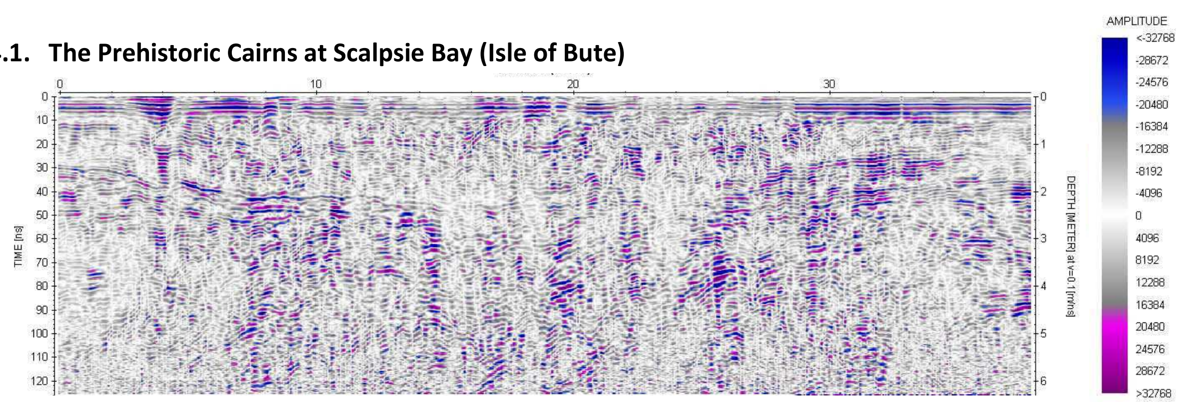


Figure 4. An example of the GPR data results (Line 58 at 225 MHz) over a cairn on raised marine beach deposits. The GPR B-scans shows reflections related to the underground structure of a cairn. Ground-thruthing will be carried out in this site in the near future.

4.2. Prehistoric Cropmarks at Forteviot Perthshire

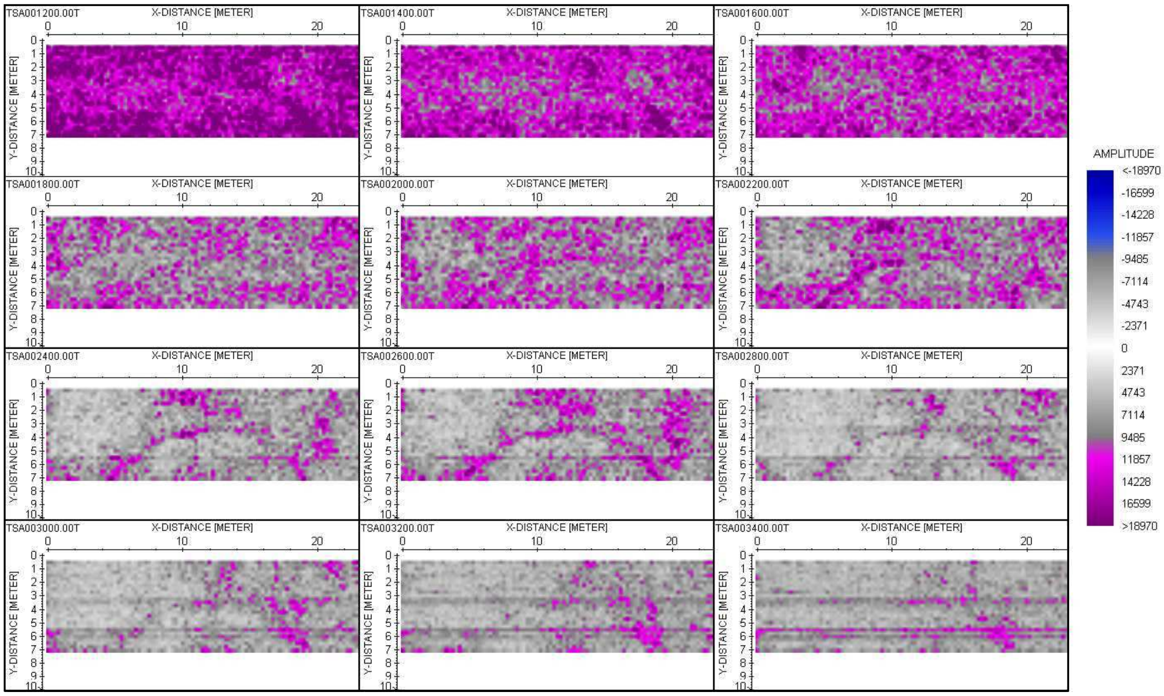
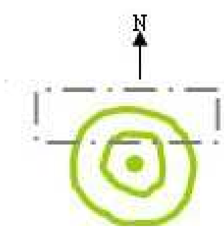
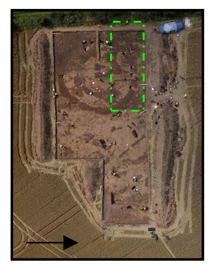


Figure 5. Time-slices obtained in the time window 12-34ns two travel time. The north area of a double ditch enclosure is shown as an inverted semicircular anomaly as high amplitudes (a, below). The outer ditch was visible both in B-scans (see Fig.3) and timeslices. The inner ditch was only visible in the time slices at 12ns-14ns. This survey was carried out over flattened barley crops with fairly stony topsoil (b, below). The contact of the antennae with the surface was not always good. Despite the clayey topsoil and the uneasy dragging of the antennae, the GPR succeeded in detecting the archaeological targets (c, below).



a) Sketch of the GPR survey area location

b) Topsoil stripping



c) Fresh archaeological features

4.3. Undated Cropmarks (Chesterhall Parks Farm, Lanarkshire)

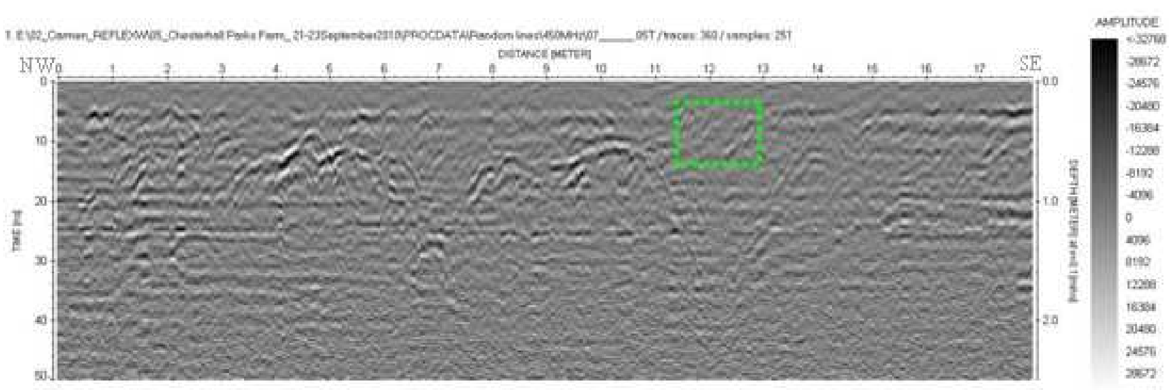


Figure 6. An example of the GPR data results (Line 07 at 225 MHz) over undated cropmarks on glaciofluvial deposits with very clayey and waterlogged topsoil. The target, a circular cropmark produced very week magnetic results. The depth of penetration of the GPR signal was very weak perhaps due to the clayey content the thick topsoil. However, the target was detected (in green). The proximity of a metallic fence and rough surface may have affected to this data set.

4.4. Viking Settlement (Bay of Skaill, Orkney)

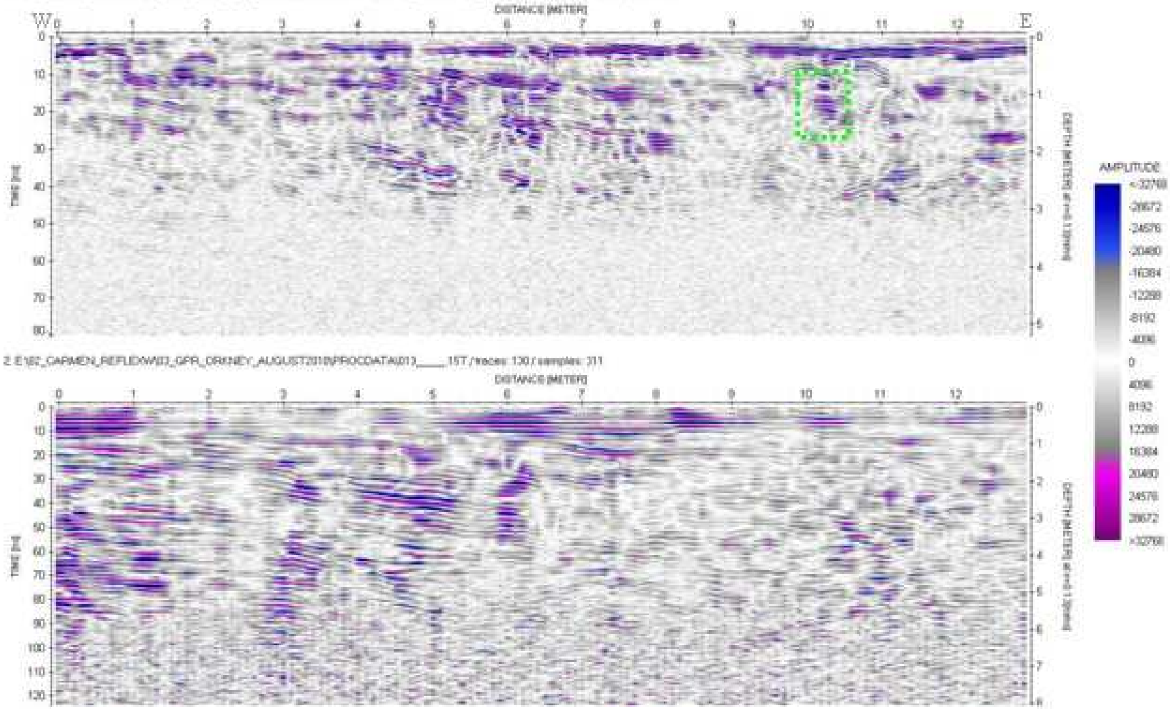


Figure 7. An example of the GPR data results (Line 1 at 450 & 225 MHz) over wind-blown sand at a Viking site in Orkney. The B-scan of the high frequency survey shows the reflections produced by the archaeological target (in green, a wall/drainage running approximately N-S). The low frequency B-scan did not show these reflections to a good spatial resolution at least at this point. However the target was detected in the time slices created with 225MHz B-scans collected 6m south to Line 1.

4.5. Medieval Settlement (Lochmaben, Dumfriesshire)

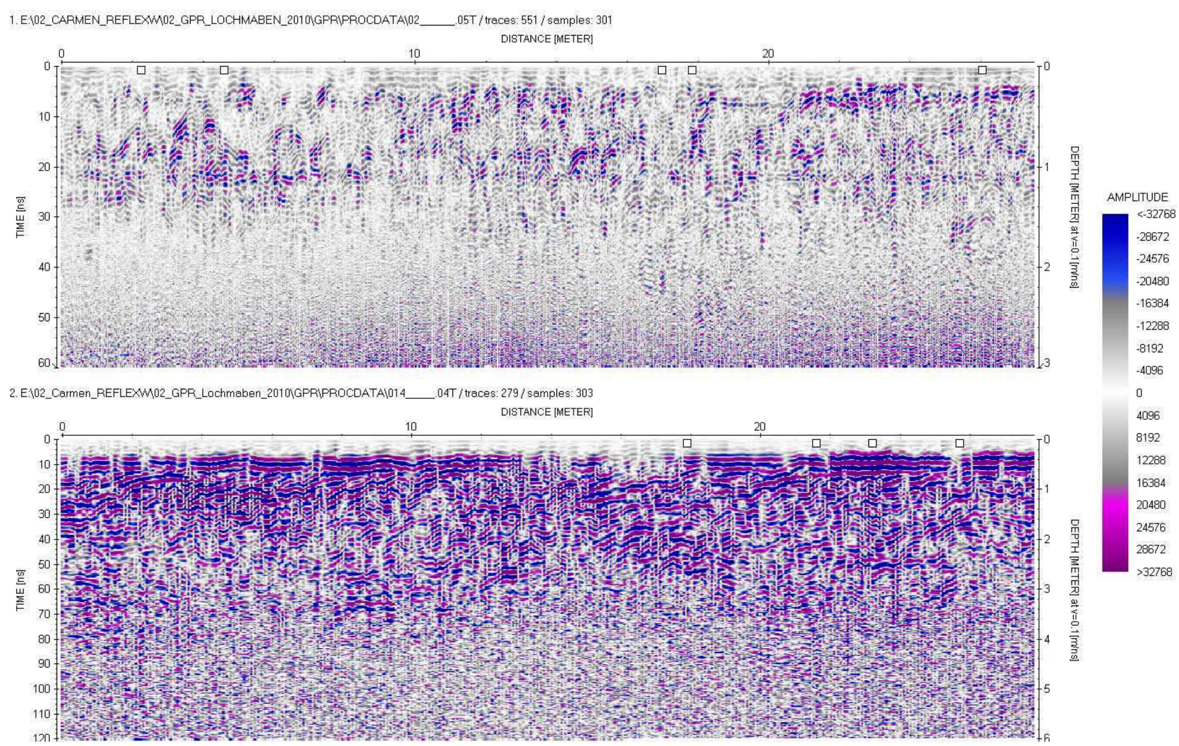


Figure 8. An example of the GPR data results (Line 1 at 450 & 225 MHz) on sands and gravels over low resistance circular anomalies at the medieval site at Lochmaben castle. The dried nettles and rosebay willowherbs did not allowed an easy antennae dragging. The GPR results allowed understanding the nature of the low resistance anomalies which where not detected in the gradiometer survey.

5. Preliminary Findings

The GPR survey produced good results in general. The technique detected the archaeological targets at sites characterised with weak magnetic contrast between the archaeological features and their soil matrix (e.g. Forteviot) and with clayey and saturate topsoil (e.g. Chesterhall Park Farm). Aeolian environments, such us the site at the Bay of Skaill, are particularly ideal for GPR surveys as the depth of penetration of the GPR pulses was good enough even for the high frequency antennae survey. Moreover the flat and smooth surface of the sands facilitates the dragging of the antennae. This provided a good contact between the antennae and the ground, hence energy loss due to antennae coupling problems was thus avoided.

Much progress has been made in this on-going PhD project, which started in November 2008. The multi-technique survey carried out during the 2010 fieldwork season covered a total area of 11.57 hectares and 322 soil samples were gathered. The project is at the geochemistry and soil characterisation stage (Figure 2) and the results from this analysis will build upon the geophysical results.

6. Conclusions & Recommendation

The GPR survey proved to be one of the most successful near-surface geophysical techniques in detecting the archaeological targets for this project. The use of the GPS system made the survey of the geophysical grids and their repositioning very efficient and accurate. However, the use of a more updated GPR system would have speeded the survey time hours.

During the length of these GEF loans, the GPR technique has demonstrated to be a powerful and alternative technique to be used when the more standardized and widely applied geophysisical techniques, such us gradiometry or earth resistance, do not produce good results. The support of GEF to this PhD project has greatly contribute to the pursuit of the objectives of this PhD project, hence to its findings, which will greatly assist in evaluating the potential of geophysics across Scotland and beyond.

7. Presentations

Cuenca-Garcia, C. (2010). The Interface of Geophysical & Geochemical Survey in Archaeological Prospection. Poster presented at the NSGG Day Meeting: Recent Work in Archaeological Geophysics held on 15 December 2010 at the Geological Society, London. The aim of the poster was to present the overall PhD research project and to show some preliminary geophysical survey results.

*More presentations based on the data gathered during GEF loans will be given in forthcoming relevant meetings.

8. References

David A., N. Linford & P. Linford. (2008). Geophysical Survey in Archaeological Field Evaluation. English Heritage.