Mapping depth-to-bedrock and shallow aggregate resources with airborne electromagnetics

S. Caven[1] (sarc1@bgs.ac.uk), D. Beamish[2], M. Desissa[1], M. Patton[1] & M. Young[1]
[1]Geological Survey of Northern Ireland, Stranmillis, Belfast BT9 5BF
[2]British Geological Survey, Keyworth, Nottingham NG12 5GG

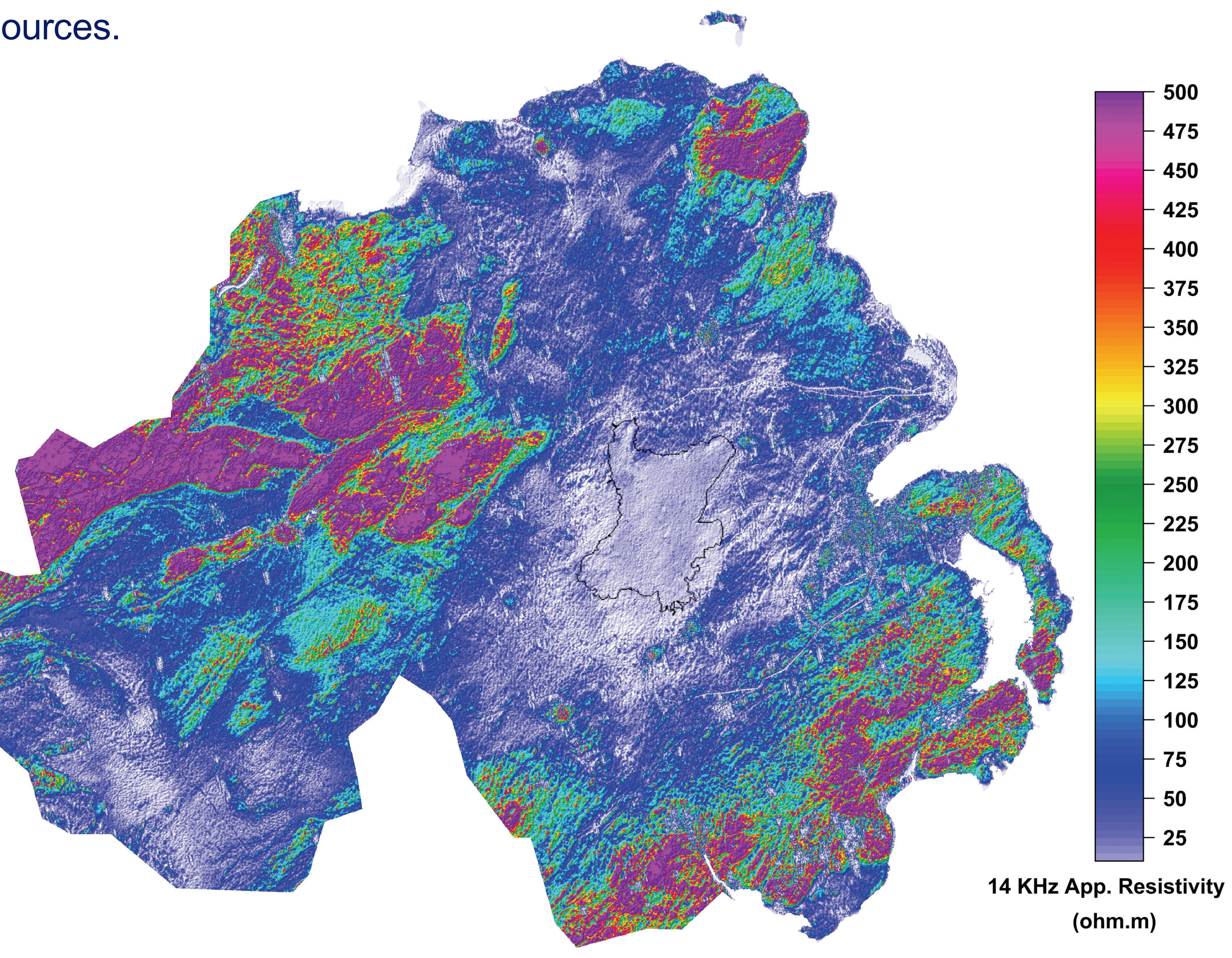
Introduction

This study examines the use of airborne electromagnetic (EM) data for estimating depth-to-bedrock and for mapping shallow aggregate resources.

A detailed low-level airborne survey of Northern Ireland was flown in 2005-6. Magnetic, gamma-radiation and electro-magnetic (EM) data were acquired[1].

EM data were acquired with a range of frequencies and have been inverted into apparent resistivity.

EM depth penetration varies inversely with frequency (ie, low frequency provides greater penetration).

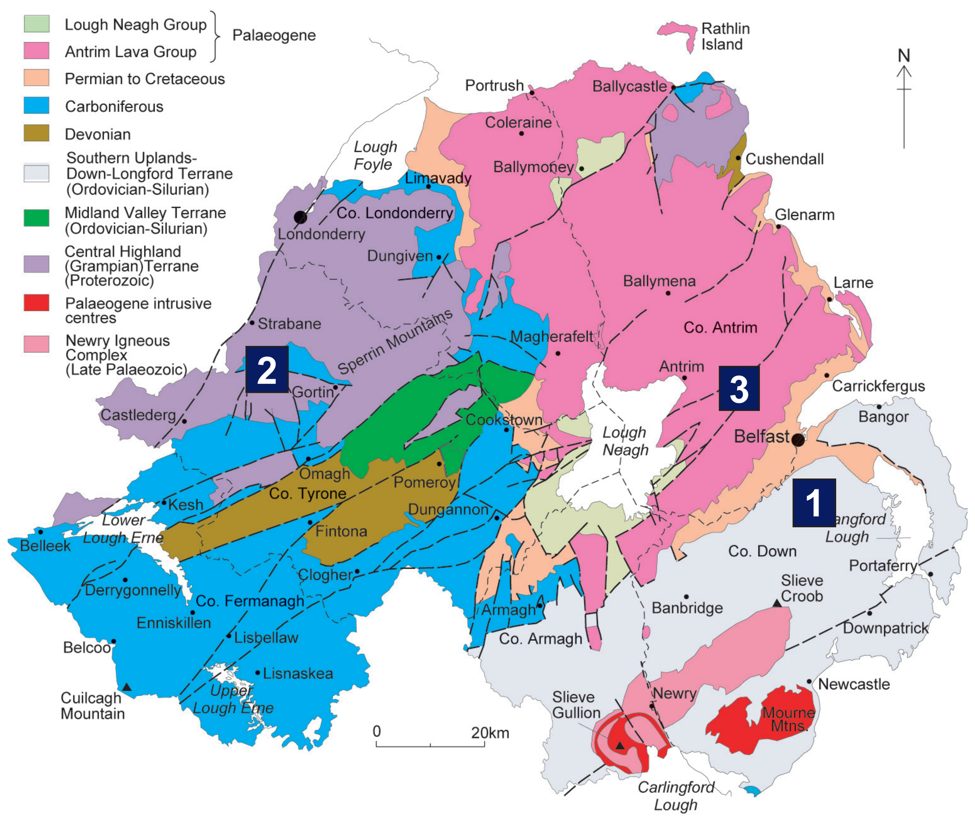


Electrical resistivity of rocks is a function mainly of porosity, porewater salinity, saturation and clay content. 'Apparent' resistivity is a complex function of these variables, of the geometry of the measuring system, and of local geology. The thickness and resistivity of the superficial layer are prominent factors. Depth-to-bedrock may only be determined uniquely where other parameters are consistent, where some local borehole control exists and where there is a contrast in apparent resistivity between bedrock and cover.

Study areas

Three study areas of contrasting geology were selected to investigate links between EM response and depth to bedrock and to examine how geological variables may affect this response.

1. An area of Co. Down underlain by Silurian greywacke sandstones with intercalated shales covered by glacial drift deposits within a drumlinised landscape.
2. An area within Co. Tyrone where Quaternary sands and gravels overlie bedrock of meta-sediments and sediments.
3. An area within Co. Antrim where basalt bedrock is overlain by variable superficial deposits, including sand and gravel.

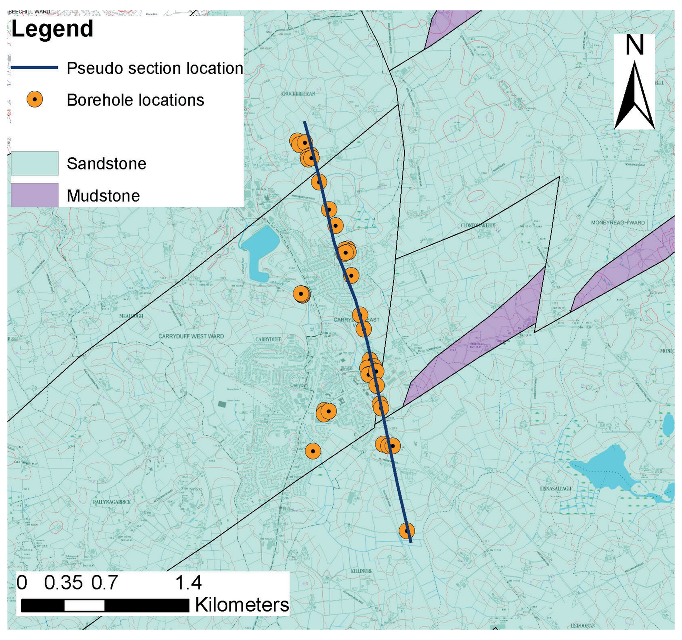


Initially, apparent resistivity inverted from high frequency EM data[2] were simply compared to depth to bedrock as recorded in borehole logs. (High frequency data are most diagnostic for shallow investigations). Scatter plots were used to test for correlations in selected sample areas with consistent geology.

Secondly, 'pseudosections'[3] were created for the Co. Down and Co. Antrim areas, where two high frequency data sets had been collected (25 kHz and 12 kHz). Pseudosections were created where good borehole control allowed for qualitative comparisons of depth-to-bedrock and apparent resistivity.

1. Co. Down - initial test area with pseudo section analysis

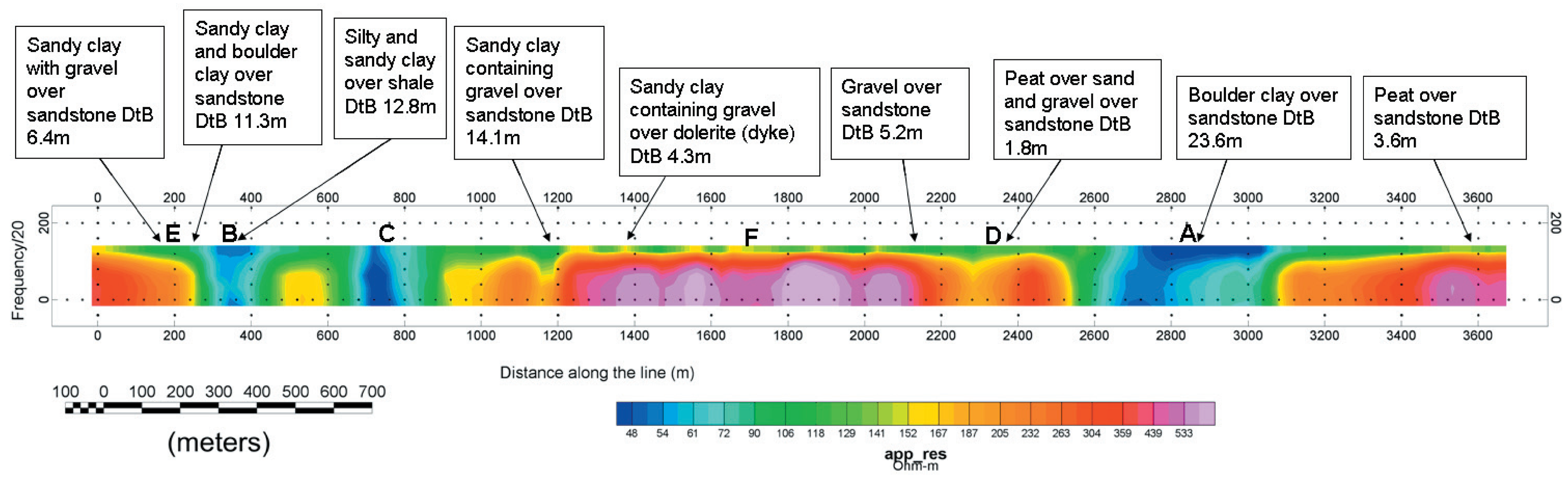
At this test site sandstones and greywackes of the Gala Group are overlain by glacial deposits. The bedrock incorporates clay rich interbeds, and varied superficial deposits. Pseudosections were employed to illustrate the gross lateral variations in apparent resistivity. The north-south pseudosection shown below corresponds with several boreholes which intersected bedrock.



Prominent conductive elements (**A** and **B**) correspond with thick, clay rich zones in the superficial cover. This thickening may be related to the coincident faults seen on the 1: 250,000 geological map (right) or to southwest extensions of the mapped mudstone.

Anomaly **C** may also correspond with a NW striking fault.More resistive areas correspond with relatively thinner superficial coverage of sand, gravel and clay over sandstone (**D** and **E**).

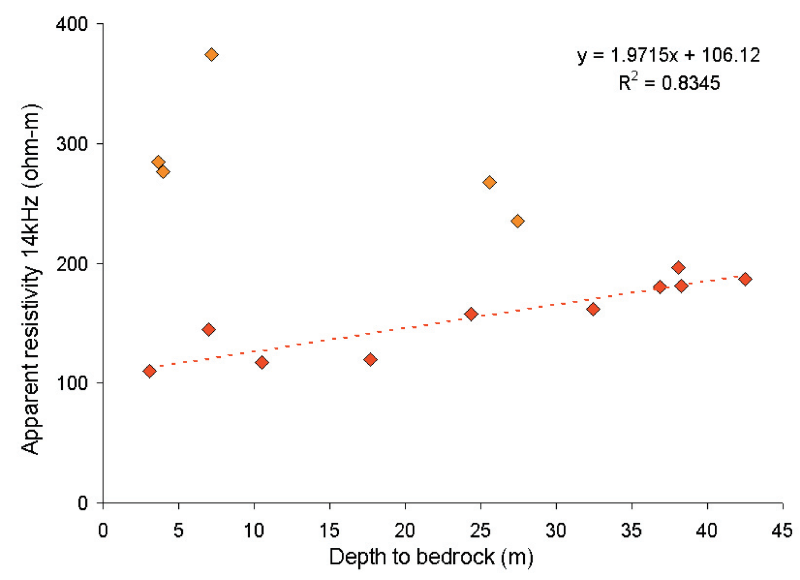
The central portion of the section (**F**) corresponds with an urban zone where the higher flight altitude causes artificially high apparent resistivity.

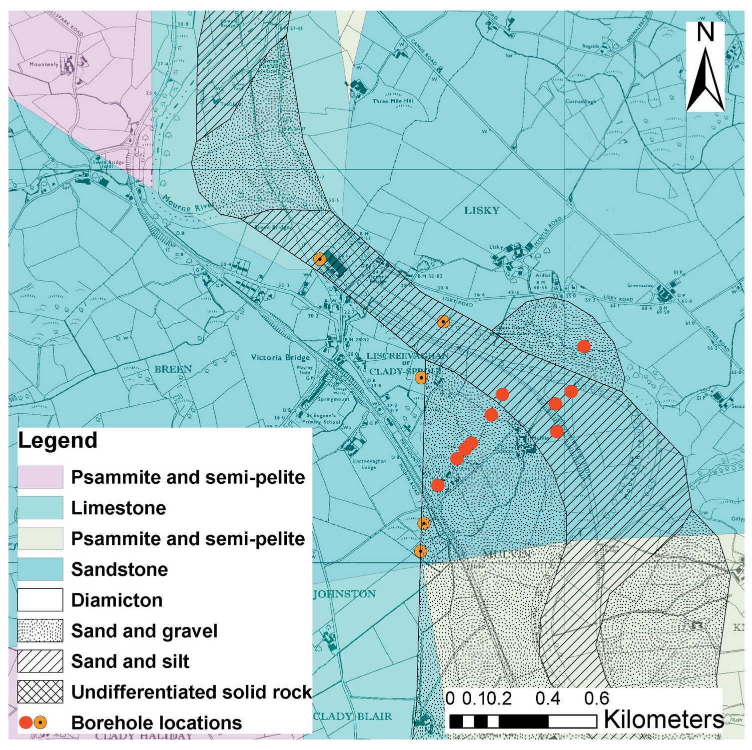


2. Co. Tyrone - correlation between EM response and sand and gravel

In this area Quaternary fluvio-glacial sand and gravel deposits overlie Dalradian sediments and meta-sediments[4].

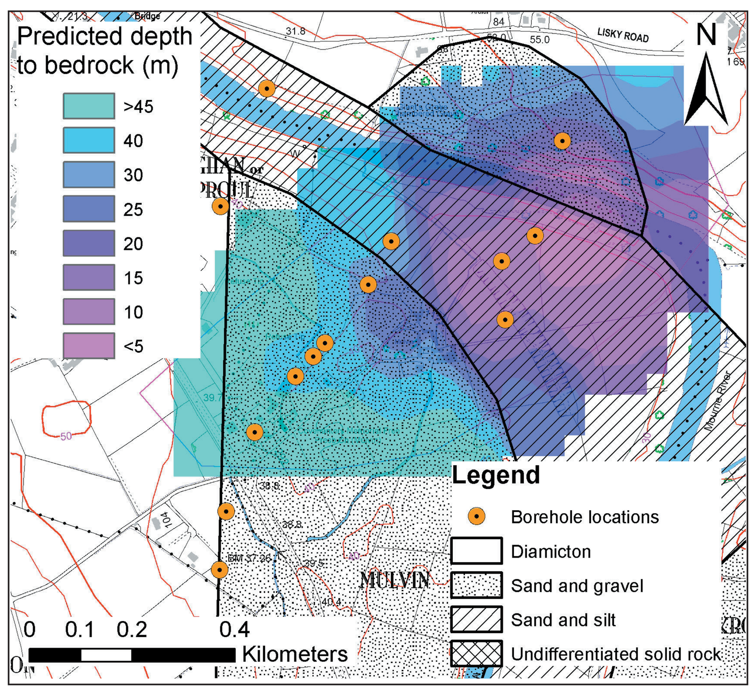
The scatter plot below shows a good correlation between depth-to-bedrock and apparent resistivity within a localised area across a typical valley transect as shown opposite.





Therefore, where such a good correlation has been demonstrated, the relationship may be used to provide estimates of the thickness of superficial cover in the local area around the transect and to generate simple depth-to bedrock maps. An example is shown opposite.

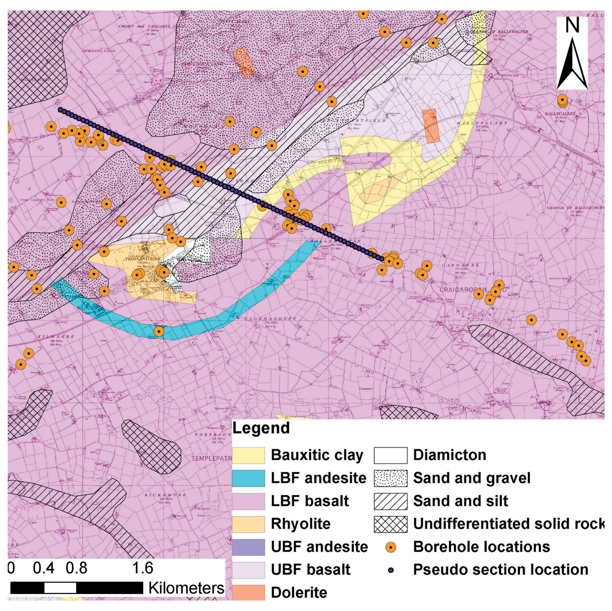
Useful predicted values are restricted to the target area where geology is constant. By nature, some detail is lost during the gridding process.

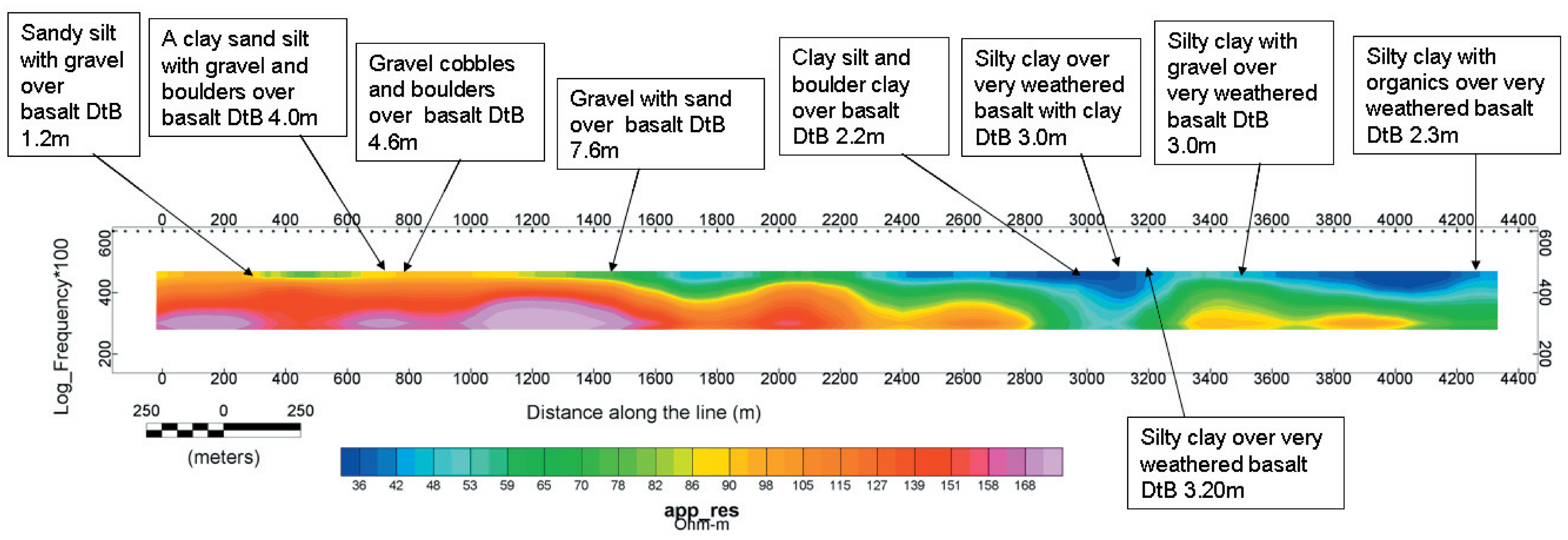


3. Co. Antrim - relating resistivity and superficial deposits

In this test area of Co. Antrim, conductive fluvio-glacial materials overlie Palaeogene basalts. A pseudosection (below) was created from gridded three-frequency data across an area of basalt overlain by diamicton to the SE and a sand and gravel and sand and silt sequence to the NW. The mapped extent of superficial deposits are shown on the map (right). Additional geological information from adjacent boreholes is shown on the pseudo section.

Areas of main sand and gravel deposition correlate with the more resistive shallow portions of the pseudosection.





Conclusions and further work

The correlation of apparent resistivity with depth-to-bedrock has been examined in three areas of Northern Ireland with adequate borehole control. In these areas, the apparent resistivity of bedrock contrasts with that of the overburden.

Results indicate that high frequency apparent resistivity correlates semi-quantitatively with depth to bedrock where bedrock and overburden are reasonably homogenous. Such correlations can be extrapolated to estimate depth-to-bedrock in the immediate vicinity where the geology remains consistent.

Pseudosections provide a useful qualitative method of illustrating resistivity laterally and with depth and are useful for initial comparisons with borehole control.

Limitations on application include:

•Apparent resistivity is a function of several physical variables rather than rock type and may not reflect mapped lithologies.

•Borehole control is necessary to constrain depth-to bedrock estimates

•Airborne apparent resistivity is unreliable over urban areas where the height of the aircraft increased.

•Buildings and infrastructure may also adversely affect the data.

Additional methods of investigation include analysis of apparent resistivity ratios and other inversion models.

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Geological Survey of Northern Ireland

British Geological Survey

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