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# APPLICATION OF RESISTIVITY AND MAGNETOMETRY GEOPHYSICAL TECHNIQUES FOR NEAR-SURFACE INVESTIGATIONS IN KARSTIC TERRANES IN IRELAND

P.J. Gibson
*Environmental Geophysics Unit, Department of Geography, National University of Ireland, Maynooth, Co. Kildare, Republic of Ireland*
P. Lyle
*School of the Built Environment, University of Ulster, Jordanstown, Co. Antrim, Northern Ireland*
D.M. George
*Environmental Geophysics Unit, Department of Geography, National University of Ireland, Maynooth, Co. Kildare, Republic of Ireland*

*Extensive glacial surficial deposits in Ireland prevent the identification of many karst features. Surface magnetic and resistivity geophysical measurements have been used to identify unknown karstic features. Two dimensional resistivity imaging has located an unknown 210-meter-long, 70-meter-wide and 25-meter-deep collapse feature in eastern Ireland beneath the surficial sediments. A resistivity survey over the Cloyne cave system in County Cork has identified the position of an unknown cave. A magnetic investigation of an infilled paleokarst collapse structure produced a 40 nanoTesla anomaly and illustrates that the technique can be employed in Ireland to locate unknown ones.*

Although most karstic regions are characterised by caves, collapse features or passageways, such features often do not have a surface expression, and their presence may go unrecorded. Approximately 35% of Ireland's land surface is underlain by Mississippian limestone, and karst landforms are known from Counties Roscommon, Fermanagh, Galway and the Burren in County Clare (Figure 1). However, most of the limestone is extensively covered by Quaternary glacial sediments, especially in the Irish midlands. It is believed that widespread karstification occurred in Ireland during the Tertiary, but the character of such karst landscapes is wholly unknown because of this surficial cover (Drew 1997). Geophysical surveying can, in certain circumstances, provide us with the means of locating karst features. A commonly employed geophysical technique employed in karst terranes is gravity surveying because the density contrast between air and rock is large. This has been employed to a limited extent in Ireland (Hickey & McGrath 2003), but a drawback of this technique is the large number of corrections — latitudinal, elevational, topographical, tidal and drift — that have to be applied to the data before they can be modeled. However, there are other geophysical techniques which can be used in karst terranes, two of which are considered here: magnetometry and resistivity (Gibson *et al*. 1996; El-Behiry & Hanafy 2000). The former technique is used to investigate a paleokarst structure and the latter technique employed to discover an unknown collapse structure and cave in Ireland. The resistivity data were collected and modeled in the field on a laptop computer in less than one hour. The magnetometry study took less than 20 minutes, providing near real-time acquisition of subsurface information which can be acted on while still in the field.

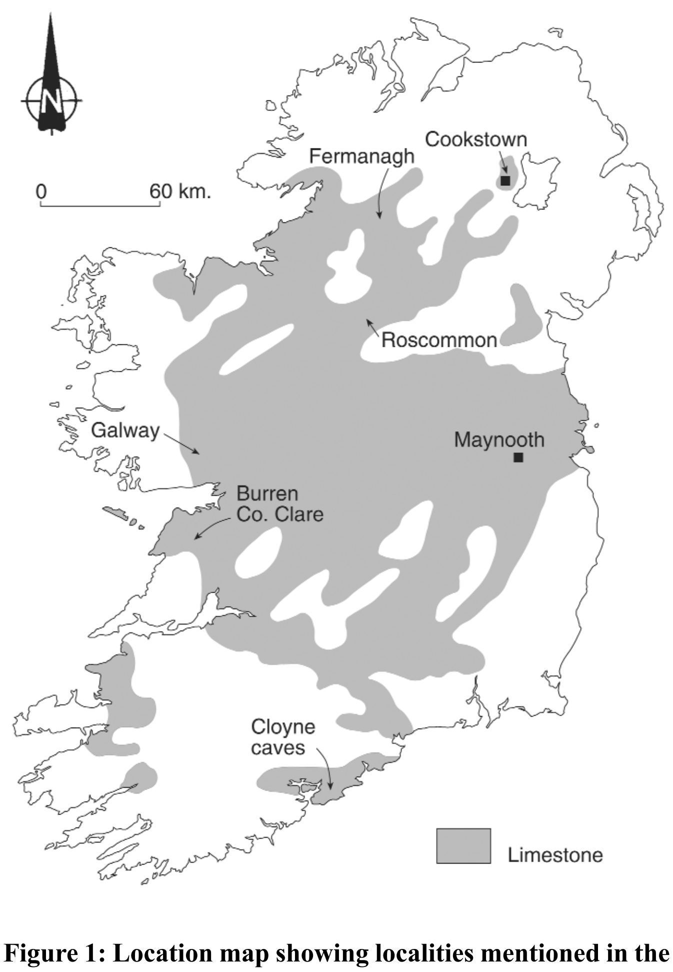


**Figure 1: Location map showing localities mentioned in the text.**

**Figure 2: Paleokarst collapse feature in the Carboniferous limestone in County Tyrone, northern Ireland.**

MAGNETIC CASE STUDY

A proton precession magnetometer was used to measure the Earth's total magnetic field which varies with latitude, from about 30,000 nanoTesla (nT) near the equator increasing to around 65,000 nT near the poles. The theoretical principles regarding such magnetometers can be found in standard geophysical texts (Sharma 1997; Gibson & George 2003).

Magnetic susceptibility is a property of a body and is a measure of how easily it can be magnetized. Limestone has an extremely low susceptibility, thus a collapse feature infilled by sediment with a higher susceptibility will be associated with higher magnetic readings. Collapse features are known to exist near Cookstown, northern Ireland, but other unknown ones, which pose a potential risk of collapse, are suspected. A magnetic study was made of a known one to ascertain if this approach could be adopted in the search for unknown ones. Figure 2 shows a funnel-shaped 15m-deep paleokarst collapse feature. The structure is 8 meters across nearest the surface and is capped by a 1.5 meter thick grainstone which indicates a return to marine conditions after the sub-aerial erosion phase during which the structure formed. The collapse feature is infilled by fine-grained unstratified red-brown sediment which is possibly of aeolian origin. The mass specific susceptibility ($\chi$) and percentage frequency dependent susceptibility ($\chi$fd%) of the infill and the limestone were obtained using an MS2 Bartington laboratory magnetic susceptibility system. A plot of $\chi$fd% against $\chi$ shows that the limestone is virtually non-magnetic but the infilled sediment has a mass specific susceptibility that is considerably higher (Figure 3a). A magnetic traverse taken across the feature shows a conspicuous positive 40 nT anomaly (Figure 3b) illustrating that the technique can be successfully employed in such Irish terranes.

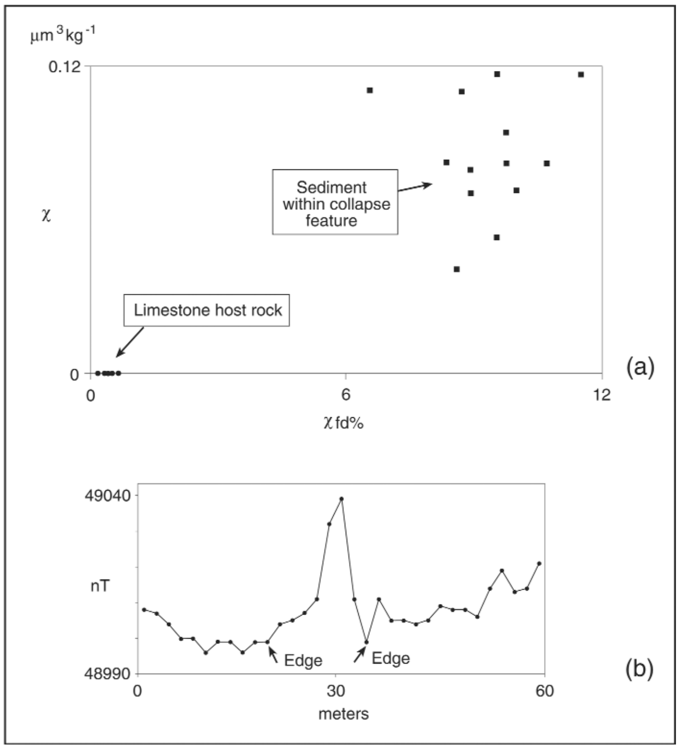


**Figure 3: (a) Magnetic susceptibility plot of limestone and infilled sediment for paleokarst collapse feature near Cookstown, County Tyrone, northern Ireland. (b) Results of magnetometer traverse across the same feature.**

RESISTIVITY CASE STUDIES

Electrical resistivity techniques involve inputting current into the ground via two source electrodes and measuring the potential difference between two sink electrodes — see Gibson & George (2003) for further details. In this study the process was automated using a multi-core cable and 25 electrodes and a two-dimensional apparent resistivity pseudosection was produced. The pseudosection was modeled using RES2DINV program which utilizes a least-squares optimization approach in order to determine how the true resistivity varies with depth (Loke & Barker 1995; 1996). In the examples shown here, errors are of the order of 5 per cent.

COLLAPSE FEATURE

Figure 4a shows the results of a resistivity traverse across a flat football pitch in the town of Maynooth, eastern Ireland (see Figure 1 for location). The limestone in this region is covered by 10m of Quaternary glacial sediments and there are no known karstic features. Other resistivity traverses in this locality have shown that the resistivity of the limestone is typically 500–1000 ohm meters. The acquired data indicate the presence of an unknown collapse feature in the underlying limestone. Bedrock is quite near the surface at the beginning (0–50) and end (170–220) of the traverse and is shown as a red-pink color (Fig. 4a). The central portion of the image is characterized by

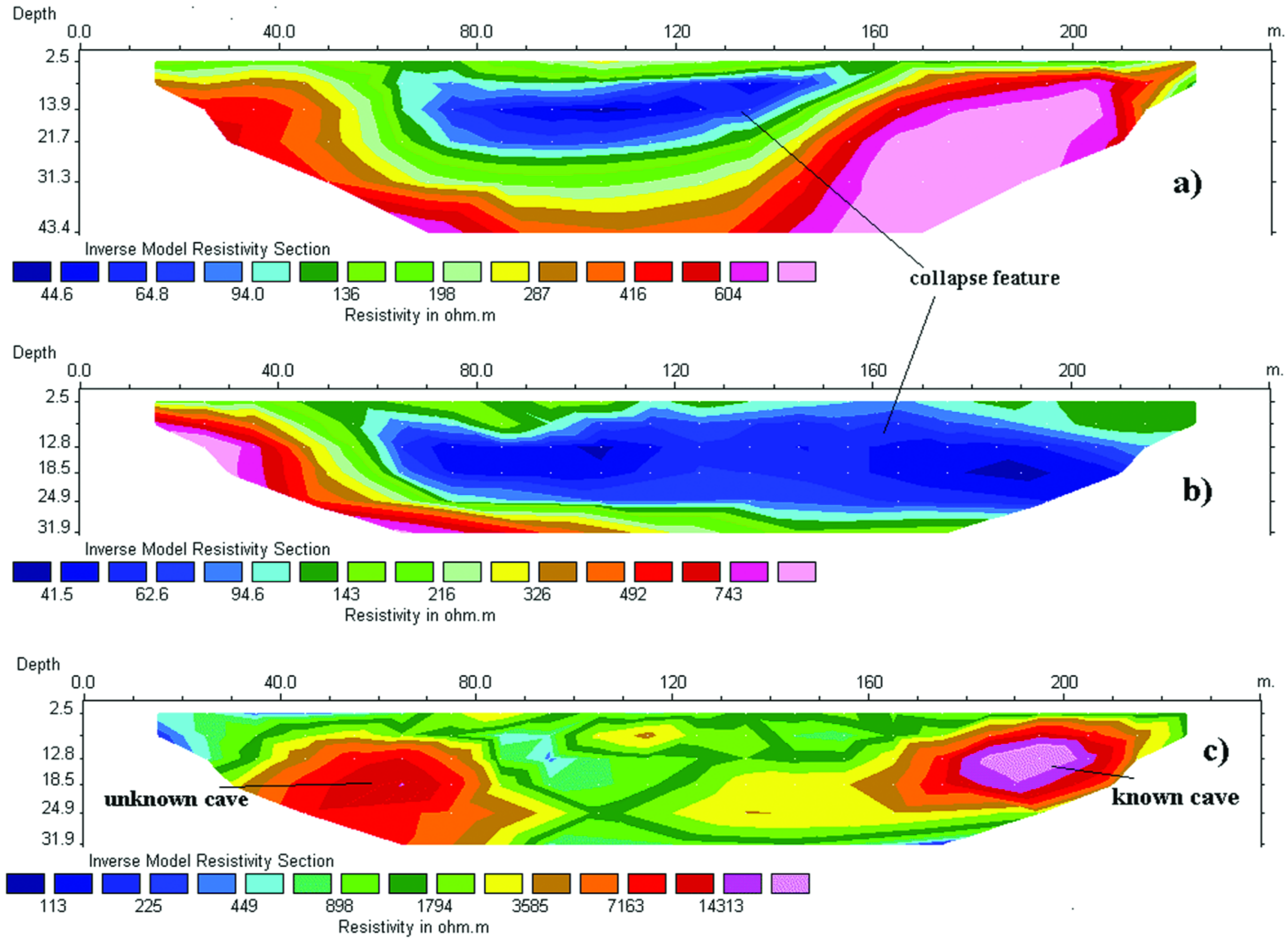


**Figure 4: (a) Resistivity traverse across unknown collapse feature in Maynooth, County Kildare, eastern Ireland. (b) Resistivity traverse across same feature at right angles to (a). (c) Resistivity traverse across a known and unmapped cave.**

resistivity values an order of magnitude less than those expected for the limestone and are shown in blue. These low values are similar to those obtained for glacial sediments in the vicinity, and the observed pattern is interpreted as an unknown infilled collapse feature approximately 70 meters wide and 25–30 meters deep. A second traverse was taken at right angles to Figure 4a in order to determine its extent. The results show that in this direction the feature is considerably longer (Fig. 4b). A number of such traverses were undertaken and they indicate that the feature is about 25 meters deep, with a 210-meter-long axis oriented NW/SE, and a 70 meter shorter axis oriented approximately at right angles to the long axis.

### CAVE SYSTEM

One of the largest subsurface resistivity contrasts is that between solid rock and air such as can occur in a cave system (Morgan *et al*. 1999; Roth *et al*. 1999, 2000). In practice, air-filled caves are typically associated with resistivity values greater than about 15,000 ohm meters, the actual resistivity obtained depending on the size of the caves. Figure 4c shows a 2D resistivity image taken over the Cloyne cave system in Co. Cork, Ireland. The very high resistivity values of over 30,000 ohm meters between 180–210 meters were acquired over a mapped region in which caves are known to exist. However, a similar anomaly associated with high resistivity values can be observed in the 40–70 meter range at a depth of about 20 meters. This area has not been explored and the anomaly is interpreted as an unmapped cave.

## CONCLUSION

Magnetometry and resistivity are geophysical techniques that can provide useful subsurface information in karst regions. The resistivity of air-filled caves is always significantly higher than the bulk rock and, because limestone is virtually non-magnetic, even infill with a low magnetic susceptibility will often yield a magnetic contrast. The techniques have been employed in Ireland to show that karst features can be located by such means and to discover an unknown cave and a large unknown collapse feature below the glacial deposits.

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