ANALYSIS AND INTERPRETATION OF MAJOR MAGNETIC ANOMALIES WITHIN THE TERTIARY BASALTS OF NORTH-EAST IRELAND

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Abstract

Ground magnetometer traverses over drift-covered Tertiary basalt areas in north-east Ireland have revealed large-amplitude anomalies (>2000nT). Fault zones produce characteristic wide-zoned, large-variance, high-frequency anomalies, while faults that juxtapose basalts with different magnetic properties, or basalt against a non-magnetic lithology, can be identified. Plugs and relict fissures both produce large magnetic anomalies (up to 4000nT). Dykes associated with the basalts generally give anomalies of <500nT, with the largest dykes giving a maximum anomaly of ~ 2000nT. This magnetic profiling technique can be used to identify and interpret geological structures present in the basalts in drift-covered areas with little or no exposure.

Introduction

The Tertiary lavas of north-east Ireland form a major remnant of the Tertiary Volcanic Province in Britain and Ireland and their volcanology and geochemistry have been extensively studied, most recently by Lyle (1985; 1988) and Lyle and Preston (1993). Associated with the lavas is a generally north-west–south-east-trending dyke swarm which occurs over the whole of Northern Ireland, with a number of large examples recorded in County Fermanagh, some 50km to the west of the main basalt outcrops (Preston 1967). The basalts are reversely magnetised and their high remanent magnetism makes them suitable for ground surveys using a total field proton precession magnetometer, even in areas with a thick drift cover and where conventional geological mapping techniques are inappropriate. Ground magnetometer traverses over the drift-covered basalts have revealed large-amplitude anomalies (>2000nT) which do not coincide with any previously recognised geological structure. By comparing them with the profiles of known geological features such as dykes, plugs and faults, it has been possible to use magnetic profiling for the detection of previously unsuspected geological structures in unexposed areas. Since approximately 90% of the area of the Antrim basalts is drift-covered, such a technique, if successfully developed, could lead to the first fully comprehensive study of structures within the lava plateau.

Details of the geophysical method

The background readings for the basalts in

Antrim are around 49,000nT, with an associated variance of about 200–400nT, producing a characteristically irregular signature. This variation is probably due to primary variation of the magnetite content. Readings were taken every 20m, though close to an anomaly the spacing of the stations was reduced to 5m. During the course of the study a total of 80km were traversed. A significant magnetic anomaly within the basalt area was considered to be a difference greater than about 2000nT.

Magnetometer profiles of known geological features

(a) Faults

Figure 1a shows basalt (B) faulted (F) against non-magnetic Dalradian metasediments (D), with a typically smooth magnetic profile for the latter. Higher readings occur over the Dalradian because of the reversed magnetism of the basalts. Figure 1b shows a simple fault (F) juxtaposing basalt (B) against Cretaceous Chalk (C). The small negative anomaly in the Chalk is due to a narrow, reversely magnetised Tertiary dyke (Dy).

The Tow Valley Fault (TVF) is a major Caledonian-trending lineament in north-east Ireland. It is associated with a sharply defined 1km-wide zone of fractured basalts producing large-variance high-frequency magnetic anomalies of >2000nT (TVF, Fig. 2a), which are very different from unfractured basalt (B) or post-basaltic sediments (S).

A traverse across the TVF at a different locality shows a similar large-amplitude/high-frequency signature for the fault zone (Fig. 2b). This type of signature (wide-zone, large-variance, high-frequency anomalies) appears to be unique to major fault zones in the basalts. Flows away from the fault show much smaller magnetic variance than those in the fault zone.

(b) Dykes

The Tertiary basalts in north-east Ireland have an associated dyke swarm with dykes most commonly 2–3m wide and rarely greater than 5m. To assess the magnetic characteristics of such dykes, profiles were taken across dykes intruded into non-magnetic country rock outside the outcrop of the basalts. A 5m-wide dolerite dyke intruded into Triassic sandstones produced a negative anomaly of <500nT (Fig. 3a), while dykes intruded into Cretaceous Chalk gave anomalies of <300nT (Fig. 3b). A number of much larger Tertiary dykes, up to 90m wide, have been recorded in County Fermanagh, to the west of the basalt plateau (Preston 1967). They occur as discontinuous ridges for several kilometres and are intruded into Devonian or Carboniferous sediments. Profiles across one of the largest of these dykes (Fig. 4a, b), with an exposed width of 80m, gave reversed anomalies of 1000–2000nT (Gibson and Lyle 1993).

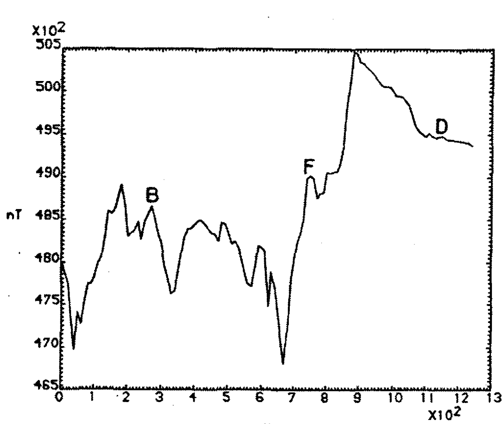


Fig. 1a — Magnetometer profile showing Tertiary basalt (B) faulted (F) against non-magnetic Dalradian meta-sediments (D).

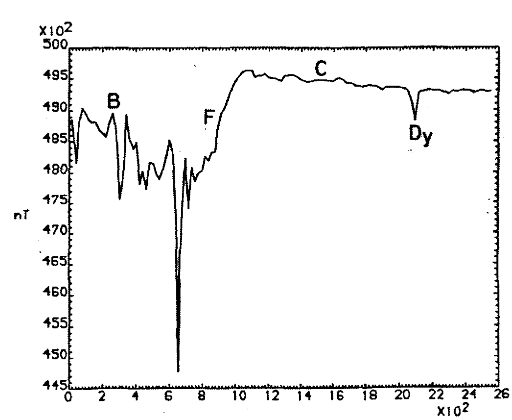


Fig. 1b — Magnetometer profile showing a simple fault (F) juxtaposing Tertiary basalt (B) against Cretaceous Chalk (C). A Tertiary dyke intruded into the Chalk is shown at Dy.

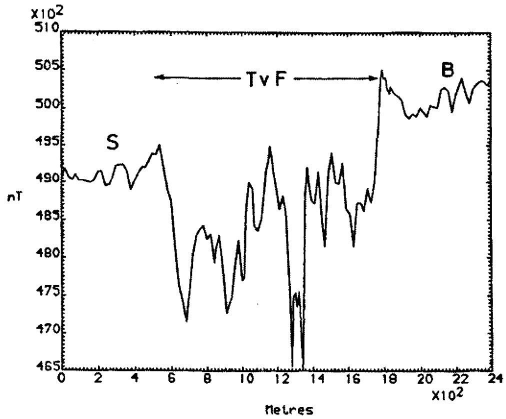


Fig. 2a — Magnetometer profile across the Tow Valley Fault (TVF) between post-basaltic sediments (S) and Tertiary basalts (B).

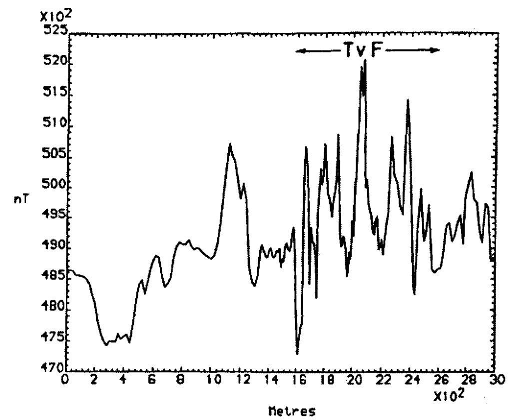


Fig. 2b — Magnetometer profile across the Tow Valley Fault (TVF) showing the typical large-amplitude/high-frequency signature for the fault zone.

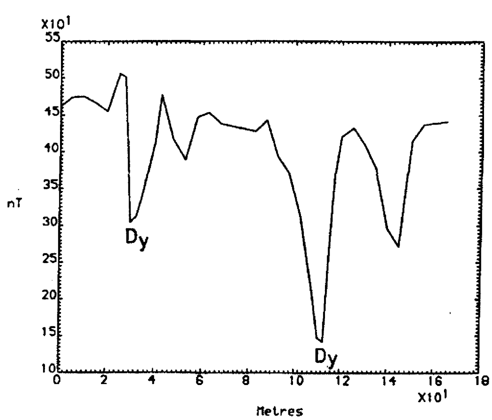


Fig. 3a — Magnetometer profile of a Tertiary dolerite dyke (Dy) intruded into Triassic sandstone.

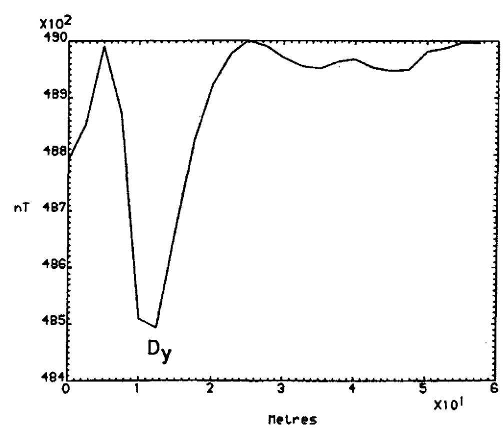
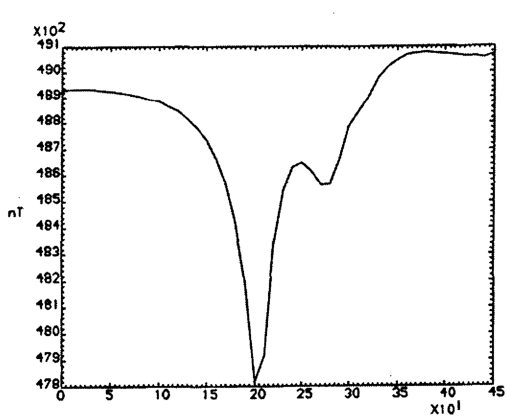
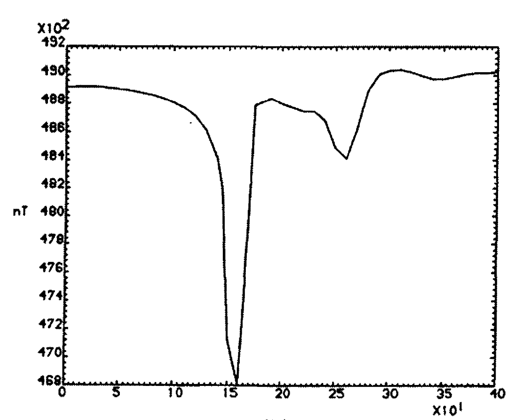


Fig. 3b — Magnetometer profile of Tertiary dolerite dykes (Dy) intruded into Cretaceous Chalk.





Figs 4a and 4b — Magnetometer profiles across large-scale Tertiary dolerite dykes intruded into Devonian sandstones in County Fermanagh.

Thus a dyke of normal width, i.e. 2–3m, will not normally be detected by magnetic profiling across the basalts because the magnetic signature of the dyke is within the variance range of the lavas.

(c) Plugs

A number of dolerite plugs are associated with the Antrim lavas, generally elongated in a north-west–south-east direction and often aligned in groups along a similar orientation. Slemish plug, the largest in north-east Ireland, has a complex internal structure involving several phases of intrusion (Preston 1963). This complexity is shown in its magnetic profile (Fig. 5a). The western edge of the plug has a marked negative anomaly, >3500nT (W), while the anomaly marking the eastern edge, (E), is much less (<1500nT). The high-variance, high-frequency magnetic signature in the surrounding basalt to the east (A in Fig. 5a) may be the result of fracturing in the lavas, while the anomalies shown to the west (B and C) may be associated minor feeders.

A smaller plug in mid-Antrim at Craigcluggan (Lyle and Patton 1989) was also profiled. In contrast to Slemish this shows no field evidence for multiple intrusions and produces a simple magnetic profile (Fig. 5b). It is remarkably symmetrical, with very sharply defined anomalies of around 4500nT at both margins and in the centre of the intrusion. The anomalies are very steep and correlate closely with the outcrop of the plug.

(d) Relict volcanic fissures

Two elongate and parallel structures occur in Cam Quarry in the west of the Antrim plateau and have been interpreted by Lyle (1988) as spatter ramparts formed along the line of active fissures. Two parallel magnetic profiles were taken, across the exposures and to the north-west along the strike of the features, over ground with a thick peat cover.

Both exposed fissure structures, A and B (Fig. 6a), produce sharply defined anomalies of 3000–4000nT. Other anomalies occur on the profile at C and D, suggesting similar parallel features in the unexposed ground away from the main quarry.

The second traverse, parallel to the first and taken along the strike of the fissures (Fig. 6b), shows that fissure B continues to the north-west, but fissures A and C have died out, and anomaly D is significantly greater. The magnetic data appear to define an *en echelon* array of possible fissures, each fissure separated from the next by a distance of 100–300m.

Magnetometer profiles across unexposed ground

On a number of occasions magnetometer profiles across unexposed terrain showed

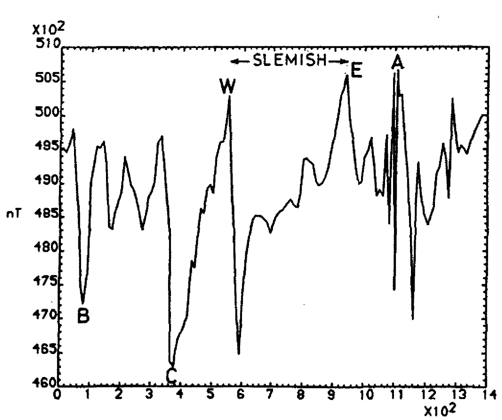


Fig. 5a — Magnetometer profile across the Slemish plug, mid-Antrim.

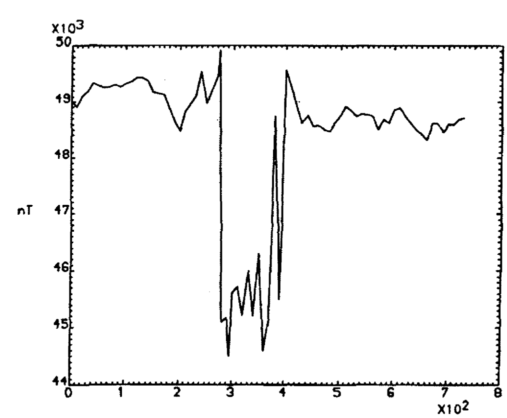


Fig. 5b — Magnetometer profile across the Craigcluggan plug, mid-Antrim.

significant anomalies where no geological features are shown on published geological maps. Figure 7a shows a complicated magnetic signature with several distinct zones: zone A, rising magnetic values, medium variance; zone B, decreasing values with very high-amplitude, high-frequency anomalies, some over 3000nT; zone C, sharply defined with declining values and low variance; zone D, similar to A.

The wide-zoned, large-variance, high-frequency anomalies in zone B are similar to the magnetic characteristics of known faults (Fig. 2a, b) and probably represent an 800m-wide fault zone. The different magnetic signatures shown by zones A, C and D on Fig. 7a can be explained by the juxtaposition by faulting of basalts of differing primary magnetic characteristics. In Fig. 7b the symmetrical signature of the Craigcluggan plug (Fig. 5b) is reproduced on a slightly reduced scale (2500nT and 200m wide) and suggests a previously unrecognised plug in mid-Antrim.

Conclusions

(a) The similarity between the magnetic anomalies produced by known geological structures and those found over non-exposed

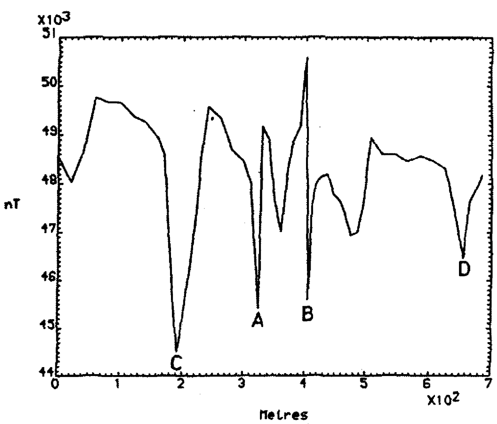


Fig. 6a — Magnetometer profiles across exposed relict fissure structures in Tertiary basalts, Cam Quarry, Co. Londonderry.

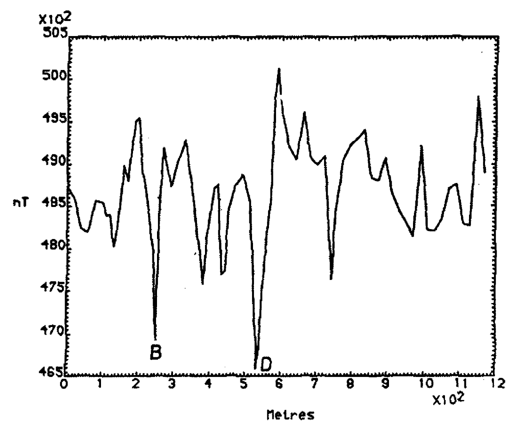


Fig. 6b — Magnetometer profile, parallel to Fig. 6a, across unexposed areas in Cam Quarry, Co. Londonderry.

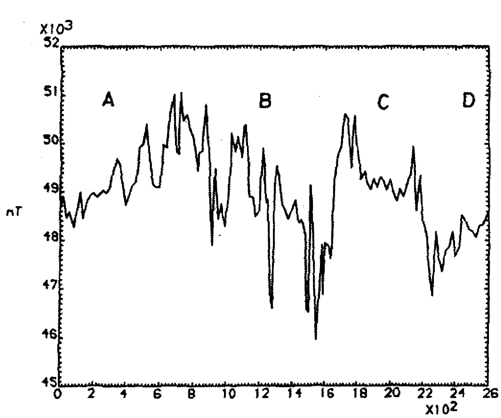


Fig. 7a — Magnetometer profile across unexposed basalts in Antrim, showing the complex signature typical of the magnetic characteristics of known fault zones (compare Fig. 2a, b).

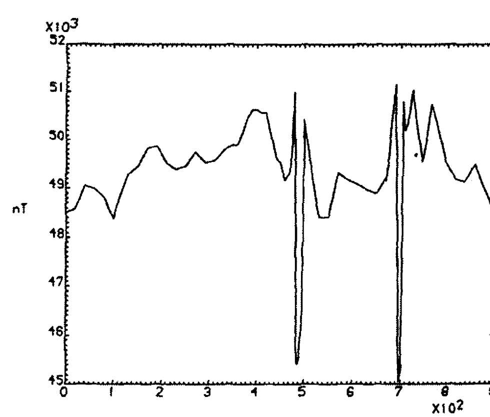


Fig. 7b — Magnetometer profile across unexposed basalts in Antrim, showing the magnetic signature typical of a simple plug intrusion (compare Fig. 5b).

basaltic terrain shows that magnetometer profiling could be a powerful technique for detecting and investigating unexposed geological features. Based on random profiles, some form of structure has been detected on average every 1.5km.

(b) Fault zones produce characteristic wide-zoned high-variance anomalies, while simple faults can be recognised by the juxtaposition of basalts with different magnetic characteristics, or basalts with non-magnetic lithologies.

(c) Relict fissure structures produce large, sharply defined anomalies that are substantially greater than those produced by even the largest dykes associated with the Tertiary basalts in north-east Ireland.

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