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The deep crustal magnetic structure of Britain

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ABSTRACT

The deep crustal magnetic structure of Britain has not previously been described in a uniform manner. We provide a new assessment of the deep crustal magnetic bodies responsible for the long wavelength magnetic features. The study area contains deep crustal relics of the destruction of early Palaeozoic oceanic lithosphere along the Thor-Tornquist Suture and primarily the Iapetus Suture separating Baltica and Avalonia from the Laurentian terranes. Spectral decomposition is applied to a merged onshore and offshore magnetic anomaly data set. Thirty idealised basement bodies are compared with a representation of the subsurface obtained by a coarse 3D inversion of the data. The central area separating Laurentia and Avalonia, is largely characterised by an absence of high susceptibilities throughout the whole crustal volume. We find that the idealised basement bodies are largely consistent with relatively high susceptibility zones at depths in excess of 10 km. The zones of higher relative susceptibility are referenced to the tectonic-terrane framework of the area and possible geological explanations for the contrasts are reviewed. In the north, the Laurentian terranes are diverse, comprising crust first created in the Archaean (Hebridean Terrane), Palaeoproterozoic (Rhinns Terrane), Mesoproterozoic? (Midland Valley Terrane), Neoproterozoic (sub-Southern Upland rocks) and Ordovician. Magnetic anomalies further record the assembly of the Gondwanan (Eastern Avalonian) part of the country through Neoproterozoic and Ordovician (Tornquist) arc magmatism and accretion. The convergence zones between Laurentia, Avalonia and Baltica have all left a magnetic imprint, as has Variscan convergence to the south.

1. Introduction

The tectonic framework of Britain and Ireland was presented in the map produced by Pharaoh et al. (1996). The map defines recognised major structures, divisions and sub-divisions at the crustal scale. Here we use as a reference the 15 terranes and 2 sub-terranes shown across the study area (700 × 1250 km) in Fig. 1. Table 1 provides details of the codes used. The study area, defined by available airborne and marine magnetic survey data, sits within the wider tectonic framework of western Europe. This more extensive setting is discussed by Pharaoh (1999) and more recently by Lyngsie et al. (2006). The most significant terrane boundaries are those associated with destruction of early Palaeozoic oceanic lithosphere such as the Thor-Tornquist Suture separating Baltica and Avalonia and the Iapetus Suture separating Baltica and Avalonia, from the Laurentian terranes to the NW. The triple junction between these three Ordovician palaeocontinents is inferred to lie beneath the North Sea, to the east of the study area (e.g. Soper et al., 1992; Lyngsie et al., 2006). Within the study area, the Laurentian and Avalonian terranes are separated by the Iapetus Suture Zone (Soper et al., 1992), which is concealed beneath the Carboniferous Solway-Northumberland Basin and inferred to dip northwards beneath the Southern Upland Terrane (SUT, Fig. 1). Accretion of Avalonia and related terranes was completed in early Palaeozoic time. The orogenic Variscan Front (the northern margin of the Variscide Rhenohercynian Zone or VRZ) represents a later displacement superimposed on the original accretionary mosaic.

The main method of characterising the magnetic character of the deep crust across Britain has traditionally been through 2.5D profile modelling. The modelling has typically used both magnetic and gravity anomaly variations alongside structural information provided by outcrop mapping and (where available) results from boreholes and seismic surveys. The joint modelling of magnetic and gravity variations is then further controlled by judgements of the geological-tectonic (i.e. 'terrane') framework along the profile.

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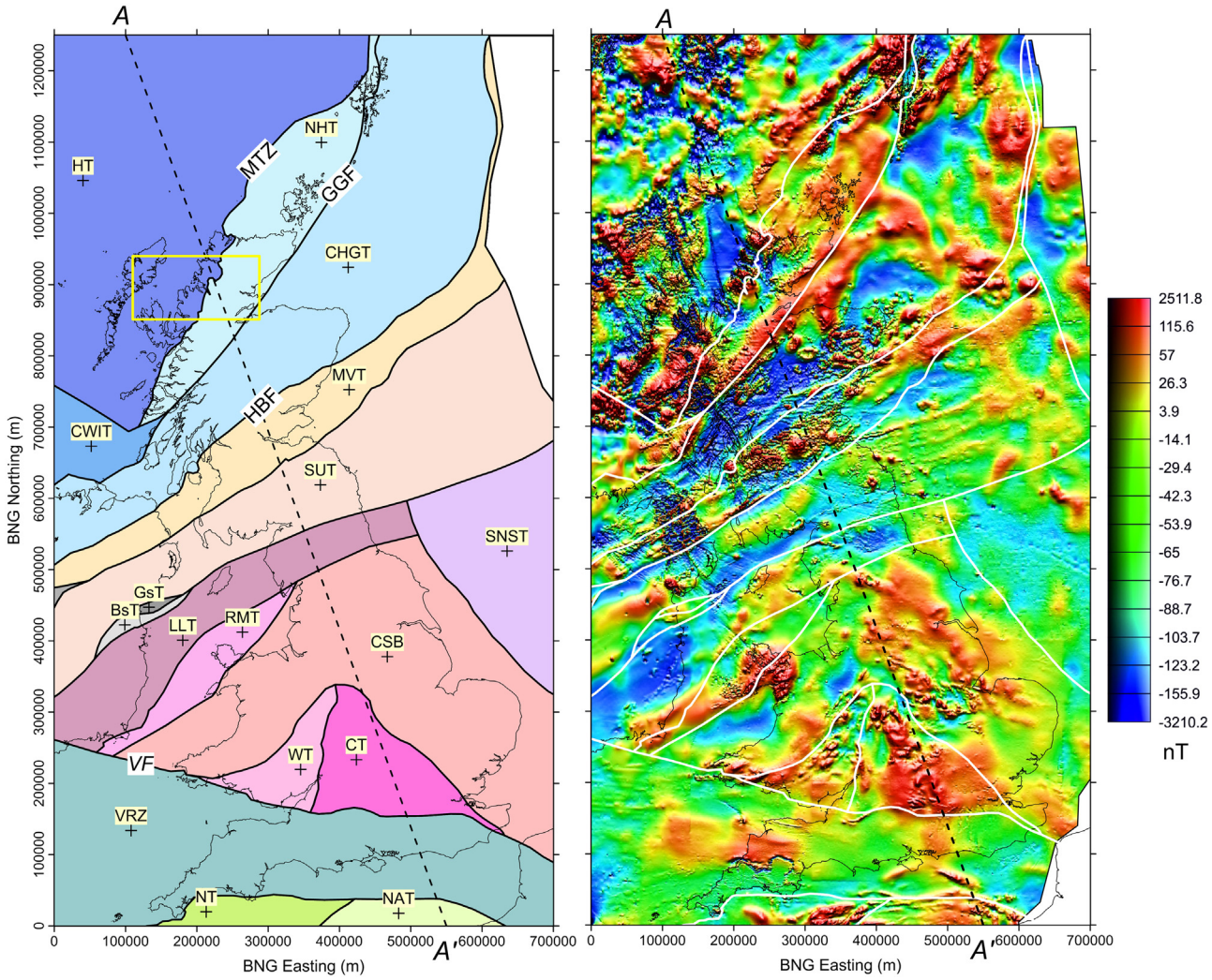

Fig. 1. The study area (700 × 1250 km) with a profile line A–A′ identified. Labelled and coloured tectonic terranes (see Table 1) with 4 boundaries identified as MTZ (Moine Thrust Zone), GGF (Great Glen Fault), HBF (Highland Boundary Fault) and VF (Variscan Front). BNG refers to British National Grid coordinates which are used throughout this study. The yellow box shows the Hebridean study area (178 × 89 km) discussed in the text and shown in Fig. 2.

This understanding guides the geometries of the polygons of juxtaposed geophysical properties. The framework is required to reduce inherent ambiguities of non-uniqueness. These methods have been widely applied to the UK aeromagnetic and land-based gravity data within 3 large and overlapping regional areas of South East England, Southern Scotland & Northern England and Northern Scotland (Busby et al., 2006; Kimbell et al., 2006; Rollin, 2009; respectively). Further examples are provided by Trewin and Rollin

Table 1
The 15 terranes and 2 subterranes that define the tectonic framework of Britain and eastern Ireland.

LABEL	Terrane	Age of crustal formation
BsT	Bellewstown Sub-terrane	?Ordovician
CHGT	Central Highlands Terrane (Grampian Terrane)	Proterozoic
CSB	Caledonides of Southern Britain	Neoproterozoic
SUT	Southern Uplands Terrane	Ordovician
CT	Charnwood Terrane	Neoproterozoic
CWIT	Colonsay—W Islay—Inishtrahull Terrane (Rhinns Terrane)	Palaeoproterozoic
GsT	Grangegeeth Sub-terrane	?Ordovician
HT	Hebridean Terrane	Archaean
LLT	Leinster-Lakesman Terrane	Ordovician
MVT	Midland Valley Terrane	?Mesoproterozoic
NAT	North Armorican Composite Terrane (east)	Archaean-Proterozoic
NHT	Northern Highlands Terrane	Archaean
NT	Normannian Terrane	Neoproterozoic
RMT	Rosslare-Monian Terranes	Neoproterozoic
SNST	Southern North Sea Terrane	?Ordovician
VRZ	Variscide Rhenohercynian Zone	Neoproterozoic
WT	Wrekin Terrane	Neoproterozoic

The question marks in Table 1 (used as a prefix) denote that the assigned geological age might be debated by some authors. The assigned geological age is our interpretation.