Magnetic susceptibility of West Antarctic rocks

D. J. Drewry[1] and E. J. Jankowski[2]

[1]Office of the Vice-Chancellor, The University of Hull, Kingston-upon-Hull, HU6 7RX. United Kingdom (david.drewry@hull.ac.uk)
[2]RPS Group, c/o 63 Hauxton Road, Little Shelford, Cambridge, United Kingdom (jankowskie@rpsgroup.com)

Summary An ensemble of geophysical techniques: airborne radio echo sounding combined with magnetic and gravity measurements as well as surface seismic refraction shooting provide high levels of resolution of the sub-ice surface and its material properties and hence geological inferences. Residual magnetic anomaly fields are produced by variations in the distribution of magnetised material in the uppermost crustal layers. In order to model possible structures and geological units from magnetic surveys magnetic susceptibilities are required. During long-range airborne geophysical missions in the later 1970s by the Scott Polar Research Institute in conjunction with National Science Foundation and Technical University of Denmark magnetic data were collected over West Antarctica and have been reported by Jankowski (1981). To assist their interpretation magnetic susceptibility measurements were made of rocks specimens from West Antarctic outcrops collected or assembled by Cam Craddock and examples of their use in the modelling the geophysical architecture of West Antarctica are outlined.

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Introduction

The elucidation of the tectonic history of Antarctica was tackled first in a systematic manner by Craddock (1972). His early synthesis of tectonic style and development led to an increasing volume of research to unfold the successive orogenic episodes that have shaped Antarctica. Such work on other continents would have revealed a rich pattern of geological evolution with identification of boundaries delimiting zones of progressive crustal development. In Antarctica, however, the masking effect of the substantial ice cap has been to isolate mountain ranges and small outcrops in nunataks that tantalise and frustrate the geologist in creating a regionally coherent picture. The pattern of landscape beneath the ice sheet and its geophysical characteristics has been advanced by several decades of airborne radio echo sounding combined with magnetic and gravity measurements as well as surface seismic refraction shooting. These are providing new levels of resolution of the sub-ice surface and its properties thus aiding geological interpretations (eg. Holt et al 2006).

In the 1970s the first airborne RES and magnetic soundings were undertaken in West Antarctica (Drewry, 1983). In order to both constrain and assist magnetic modelling and geological interpretation it was important to assemble a dataset of magnetic susceptibilities. At that time few measurements had been made and a small-scale programme of measurements was developed focused upon the only contemporary comprehensive collection of West Antarctic rocks- that assembled by Craddock at the University of Wisconsin at Madison. These had either been collected by Craddock himself, his students and co workers or derived from other Antarctic geoscientists.

Measurements

In 1980 the first author visited Craddock's laboratory and undertook the magnetic measurements. From the collections a total of 31 samples were taken. Cores of 24.5mm (1-inch) diameter were drilled out from the collection specimens. These were analysed using a Bison 3101 magnetic susceptibility meter. The Bison system was based on a using a three-coil induction balance. A particular feature of the instrument was that it measured susceptibility in a field approximately equal to that of the earth's magnetic field; magnetic susceptibility for ferri-magnetic materials is strongly dependent upon field strength. The results of the measurements are given in the Table 1.

Table 1. Susceptibility measurements of West Antarctic rocks from collection of Craddock

Sample Location	*Sample (Craddock Collection No.)*	*Description (as labelled)*	*Susceptibility (cgs x10^{-5})*
THIEL MTS.	60-H-1	Basement ‘monzonite’	205-236
	60-H-2	Altered ‘Beacon’?	15-20
	60-H-46	Basement ‘monzonite’	50
	60-H-52	‘Beacon’	50
STEWART HILLS	60-6-17	Quartzite	5
	60-6-30	Quartzite	5
PIRRIT HILLS	60-8-27	Granite	10
HART HILLS	W-65-35	Quartzite	2-3
	W-65-8	Gabbro	7-8
PAGANO NUNATAK	W-64-3	Granite	2-4
	W-64-6	Granite	2-4
WHITMORE MTS.	W-65-53	Phyllite quartzite	3-4
Mt Seelig	W-65-48	Pegmatite Gneiss-granite	4-5
Linck Nunatak	W65-75	Granite	3-4
ELLSWORTH MTS.			
Polarstar Point	TB-64-68	Polarstar Formation	4
Mucks Hills	64-TB-51F	Crashsite Quartzite?	7
Heritage Range	62-A-1	Crashsite Quartzite	1
Heritage Range	64-HH-61C	Crashsite Quartzite	3
(Marble hills)	TB-64-47	Minaret group	0
HUDSON MTS.	68-10-2	Vesicular basalt	25
	60-12-19	Vesicular basalt	10
RUPPERT COAST			
Kinsey Ridge	67-C-12	‘Felsic intrusive’	80-100
Lambert Nunatak	67-C-119		150-320
Mt. Vance	67-C-23A	Metavolcanic	375-315
THURSTON ISLAND	60-9-14	Granite-gneiss	300+
	60-9-6	Granite-gneiss	220+
JONES MTS.	61-13-9	Dark green serpentenized basalt dyke	5
	61-203	Porphyritic olivine basalt	140-150+
	61-7-14?	Olivine basalt	11
Runner Ridge	61-11-37	Porphyritic basalt	140-150+
N-Dome E Peak	61-12-44	Porphyritic basalt	20-25

Magnetic modelling

Susceptibility measurements were used to assist in the modelling and interpretation of magnetic data collection in West Antarctic during field campaigns in the late 1970s, based on a program developed by Cady (1977). An example is given in Figure 1 of a cross section of the elevated terrain found in the Byrd Sub-glacial basin. Jankowski and Drewry (1981) considered this zone to be of volcanic origin and this interpretation was supported by modelling as reported by Jankowski et al. (1982). The susceptibilities required to fit the observed anomalies are relatively low, between 0.002 and 0.005cgs. Normal and reversed magnetisations were required with amplitudes of 0.0001 to 0.003 gauss. Calculations of the maximum depth to magnetic basement (Ibid. and Jankowski, 1983) allowed the model to be refined and this increased the maximum susceptibility to 0.0133cgs and the remnant magnetisation to 0.012 gauss. It can be observed that none of the volcanics samples in the Table possess susceptibilities this high, but are within the value estimated by Bentley and Chang (1971) for the volcanics near Crary Mountains (0.05cgs).

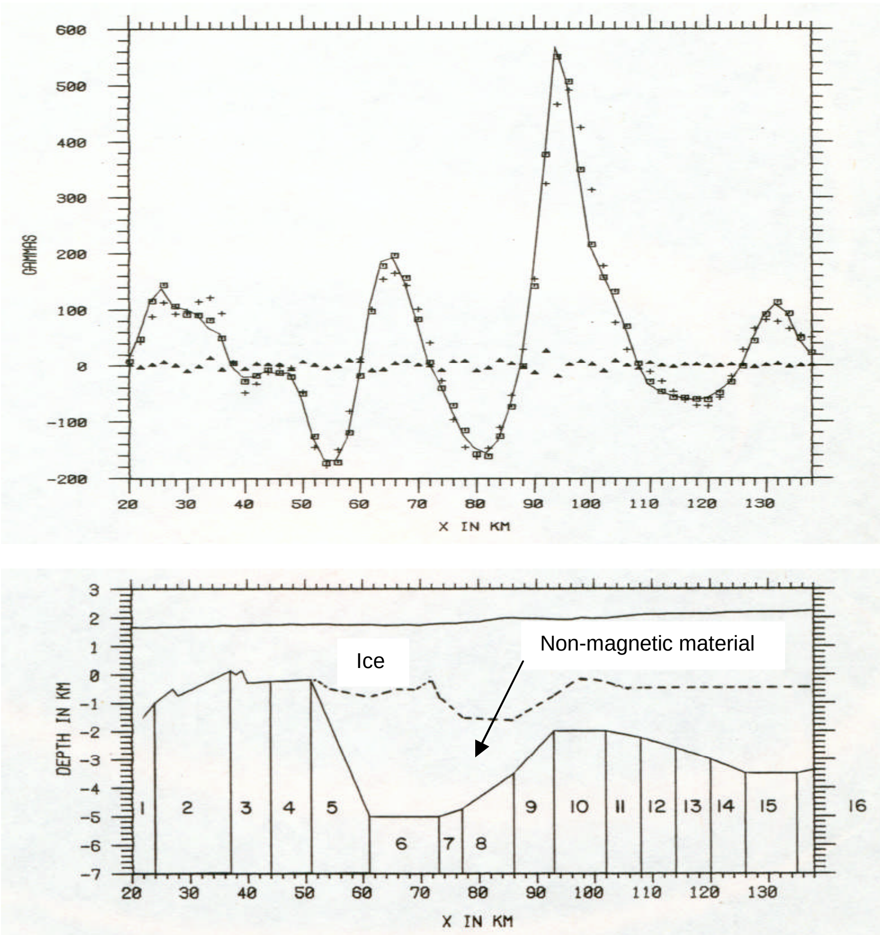

Figure 1. Modelled magnetic anomalies over elevated ridge (upper) as continuous line. Inverse solutions shown as crosses, remanent magnetisation open squares. Residual between observed and latter as triangles. Lower: 2-D model shown as vertical blocks. From Jankowski (1981).

Table 2 Table of results of the modelling given in Figure 1. NB. Error for susceptibility 2.13±30.5, for amplitude -0.025±6.97 (from Jankowski, 1981).

Bodies/ Blocks	*Susceptibility (cgs x10^{-5})*	*Remanent magnetisation*		
		Amplitude (Gauss)	*Inclination*	*Declination*
1	311	169	-84.4	45
2	308	192	-77.3	45
3	240	168	-89	45
4	237	157	-87.3	45
5	171	139	-78.3	225
6	1330	1080	-84.1	225
7	1020	1160	-23.7	225
8	291	296	38.2	225
9	290	290	71.9	45
10	811	586	-40.4	45
11	523	671	-65.3	45
12	509	595	-83.5	45
13	456	603	-81.7	45
14	382	626	-63.8	45
15	668	658	-49.5	225
16	554	344	-30.7	225

Summary

Magnetic susceptibility measurements are presented on rock specimens collected from West Antarctic outcrops. These have been used to assist in the modelling of airborne magnetic measurements and the interpretation of the geophysical characteristics of the region.

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