Aeromagnetic reconnaissance over the Riiser-Larsen Ice Shelf, east Antarctica*

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Kristoffersen, Y. & Aalerud, J. 1988: Aeromagnetic reconnaissance over the Riiser-Larsen Ice Shelf, east Antarctica. *Polar Research 6*, 123–128.

A single 160 km long aeromagnetic profile across the Riiser-Larsen Ice Shelf from the coast to Vestfjella, indicates shallowing of the depth to the magnetic source from about 2 km below the sea floor at the ice front to a depth equivalent to ice thickness at the position of the grounding line about 80 km farther south. Adjoining marine multichannel seismic data and sonobuoy measurements suggest that the material below the ice shelf may be a prograding wedge of sediments of seismic velocity less than 3.5 km/s. Parallel northeast trending magnetic anomalies between the Plogen and Dagvola nunataks in Vestfjella can best be modelled as three large dyke swarms at depth.

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November 1986 (revised April 1988).

East Antarctica is rimmed by 50–100 km wide ice shelves along large parts of the eastern Weddell Sea margin, but the distance from the barrier to the shelf edge is no more than 50 km. This paper reports on a geophysical traverse across the southeastern Weddell Sea continental margin to the adjacent part of the Transantarctic Mountains made during the 1984/85 Norwegian Antarctic Research Expedition. The objective was to map the sub-ice continuation of the margin sediments. The geophysical traverse consists of a multi-channel seismic line (NARE 10–79), three sonobuoy measurements across the continental shelf and slope and aeromagnetic measurements from the barrier to Vestfjella (Fig. 1).

Geological setting

Vestfjella is a northeast trending group of nunataks situated at the westernmost end of the Transantarctic Mountain Range about 130 km from the edge of the Riiser-Larsen Ice Shelf. Basement is not exposed anywhere in Vestfjella, but biotite gneisses and amphibolites are exposed in Mannefallknausane and amphibolite facies paragneisses in Heimefrontfjella 100 and 150 km to the southeast, respectively (Juckes 1972). The nunataks in Vestfjella are Lower to Middle Jurassic predominantly tholeiitic subaerial basalt flows with insignificant volcanoclastics (Furnes & Mitchell 1978). Permian quartz rich sandstones and fossiliferous shales are present on Fossilryggen, a nunatak 30 km east of the main group (Hjelle & Winsnes 1972). These sediments were laid down in a shallow marine environment (Olausson 1985). The continental shelf in front of the Riiser-Larsen Ice Shelf is underlain by a several km thick section of sediments which shows strong progradation in the upper part (Hinz & Krause 1982).

* *Scientific results of the Norwegian Antarctic Research Expedition 1984/85. Publication no. 85.*

Aeromagnetic reconnaissance

250 km of aeromagnetic lines were flown with a helicopter using a Geometrics G 806 proton precession magnetometer with the sensor suspended 16 m below the aircraft. Navigation was by a Motorola Miniranger system with transponders at the barrier and in Vestfjella; a flight level of 150–300 m above the ice was maintained. Geomagnetic field variations as monitored at Halley during the survey interval were less than 20 nT. The magnetometer sample interval was about 200 m and the navigational accuracy was considered to be 10 m or better in the in-line direction, but unknown transverse to the flight

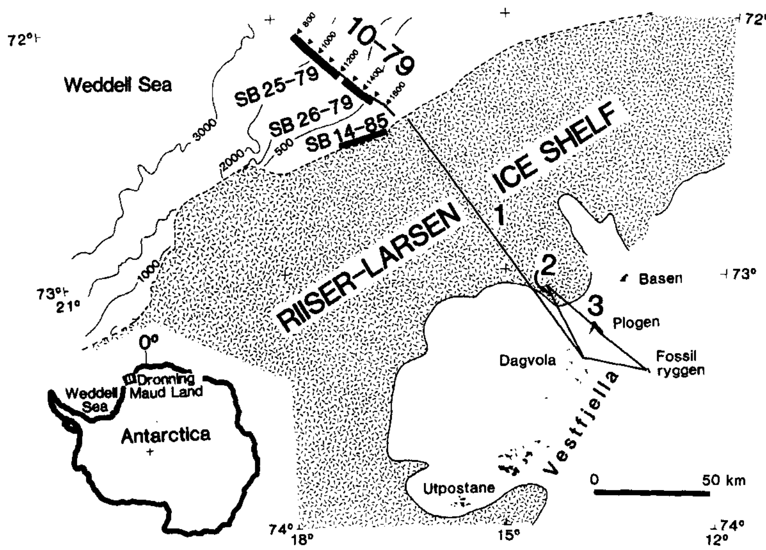

Fig. 1. Location of multichannel seismic line 10–79 and sonobuoy measurements (heavy lines) on the continental shelf, southeastern Weddell Sea, together with aeromagnetic flight tracks (1, 2 and 3) across Riiser-Larsen Ice Shelf. Position of ice front after Lange (1984) and grounding line after Drewry (1983).

line. The data were smoothed by a three point triangular filter and a linear gradient removed (Fig. 2). The magnetic total field intensity is characterized by a 400 nT anomaly at 35–55 km from the barrier and short wavelength linear anomalies of max. amplitude 150 nT associated with the Vestfjella nunataks.

Depth to magnetic source

Assuming that the observed magnetic field is due to two-dimensional magnetic source bodies, we have used Werner deconvolution (Hartman et al. 1971; Werner 1953) and interpretation by characteristic curves (Åm 1972) to estimate depth to magnetic source. This assumption is clearly valid in Vestfjella, but across the Riiser-Larsen Ice Shelf estimates will yield maximum depths as the horizontal extent of the anomalies and angle of crossing are unknown. The estimated depths to magnetic source show a consistent trend with values of +2 km landward of the barrier and a gradual shallowing towards the grounding line (Fig. 2).

Assuming that magnetic basement is overlain by relatively unmagnetic sediment, we may try to extrapolate the seismic stratigraphy of the continental margin sediments landward along the aeromagnetic profile (Fig. 2). Below the upper continental slope an upper 1.5 km thick section of sediments with velocity <3 km/s rests with a distinct unconformity – the Weddell Sea Unconformity on higher velocity (>4.5 km/s) strata representing a seaward dipping wedge of volcanic material (Hinz & Krause 1982).

Apart from a higher seismic velocity at the seafloor (2.65 km/s), a feature also observed on other parts of the Antarctic shelf exposed to ice loading (Haugland et al. 1985), the velocity-depth relationship on the shelf bears great similarity to that on the slope, and the unconformity in the sedimentary section may extend landward at least to the front of the ice shelf. Here its level appears to merge with the level of magnetic basement. The upper strongly prograding seismic sequences attain a thickness of 2 km below the shelf edge, and could possibly constitute the bulk of the section below the Riiser-Larsen Ice Shelf. These sequences have been interpreted as late Cenozoic glacial deposits by Hinz & Krause (1982).

Depths to magnetic basement range from 0.8–1.4 km on either side of Vestfjella and accentuate the nunataks as representing a horst block. Although depth estimates east of Vestfjella are uncertain because of low amplitude anomalies, we note the possibility of a more than 0.5 km thick pre-Permian section above basement near Fossilryggen (Fig. 2).

The subsurface structure of Vestfjella

Vestfjella, between the Dagvola and Plogen nunataks are associated with three linear NE-

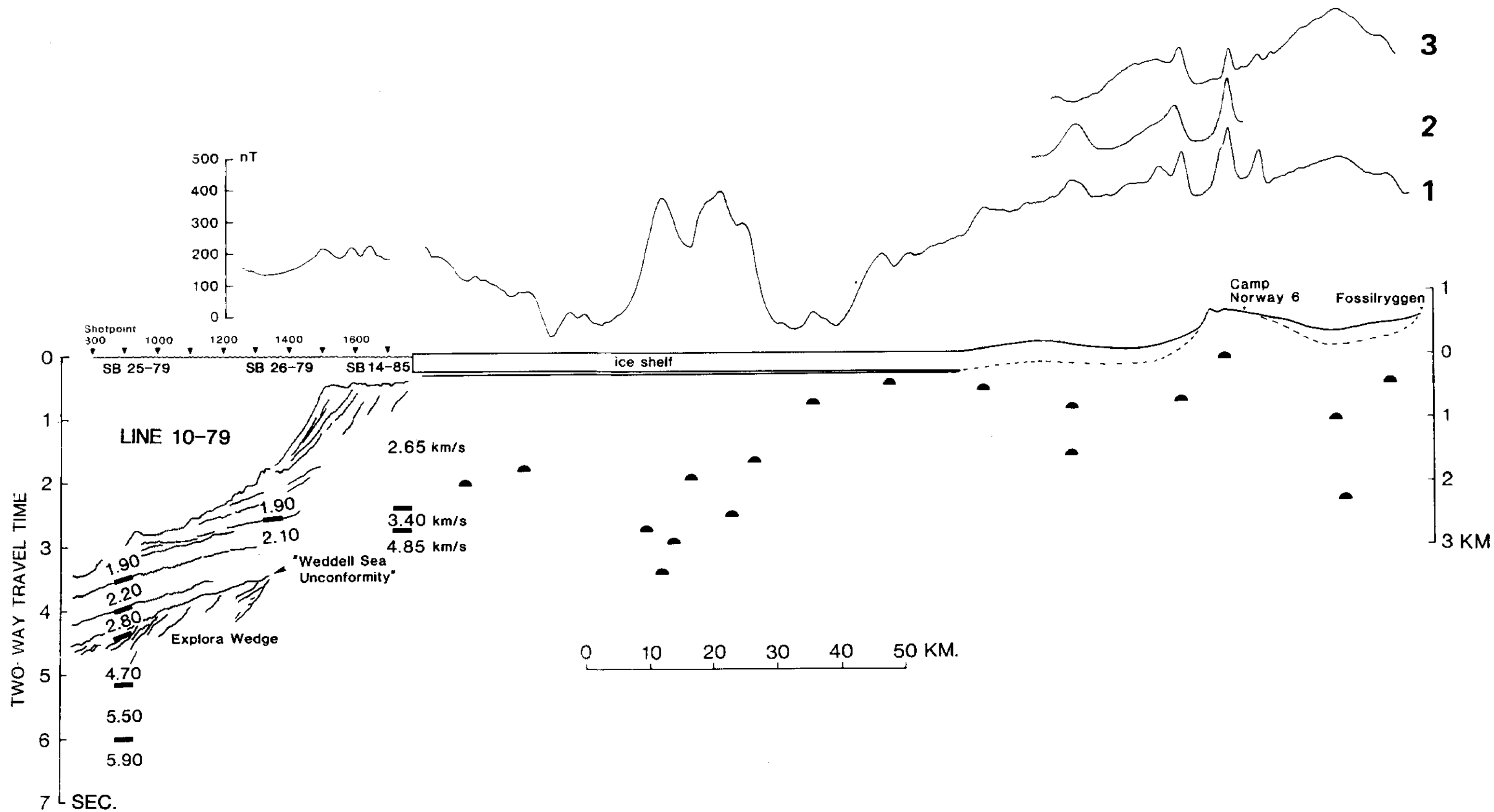

Fig. 2. Line drawing of seismic line 10–79 across the continental margin and residual total magnetic intensity across the Riiser-Larsen Ice Shelf after removing a constant value of 42 nT and linear gradient of 5.85 nT/km. Estimated depth to top of magnetic source shown by filled half circle. Location of profiles in Fig. 1.

SW trending magnetic anomalies parallel to the general trend of exposures (Fig. 3). Measurements on a large number of samples from Plogen (R. Løvlie pers. comm.) show that the dykes are strongly magnetized (2.10^{-3} emu.) relative to the lavas (5.10^{-5} emu.) and predominantly of normal polarity. The simple models shown in Fig. 4 demonstrate that the magnetic source is not a body approximating the horizontal extent of the lava pile from surface exposures (Fig. 4a), but rather three separate groupings of narrow vertical bodies with their upper surface at 0.5–1.0 km below the flight level (Fig. 4b).

Discussion

The Early to Middle Jurassic volcanism along the length of the Transantarctic Mountains is evidence of a tensional regime with crustal extension (Elliot 1985). The lava pile at Vestfjella is cut by a large number of near vertical dykes of thickness 0.5–10 meter of predominantly NE-SW strike (Spaeth 1986; Furnes & Mitchell 1978). Spaeth (1986) estimates the aggregate dyke thickness to be 275 m along the 6 km long northeastern cliff of Plogen, which amounts to 5% of crustal extension. The magnetic models indicate that dykes must be abundant at depth and concentrated in at least three large swarms (Fig. 4). A total width of 3.2 km of the magnetic source bodies implies a maximum extension of 25%. The dykes are observed to cut the lavas at the surface, but their greater width at depth suggests that a major part of the crustal extension must have taken place prior to extrusion of the exposed part of the lava pile. Also, two of the dyke swarms coincide with major topographic breaks, and the nunataks of Vestfjella may therefore be a complex of fault blocks bounded by dyke swarms along major faults.

The cross-line extension of the large 400 nT magnetic anomaly present over the central part of the Riiser-Larsen Ice Shelf is not known (Fig. 2). As there is no associated rise in depth to the magnetic sources, the anomaly may be caused by an old intra-basement contrast in magnetization rather than a young Jurassic mafic intrusion. Below the continental slope at a distance of 250 km from Vestfjella there is seismic evidence of an extinct rift axis flanked by wedges of inward dipping seismic sequences (Hinz & Kristoffersen 1986). The wedges of seaward dipping reflectors are interpreted as volcanogenic material extruded from a central rift and progressively loading the continental crust (Hinz 1981). Unfortunately, the

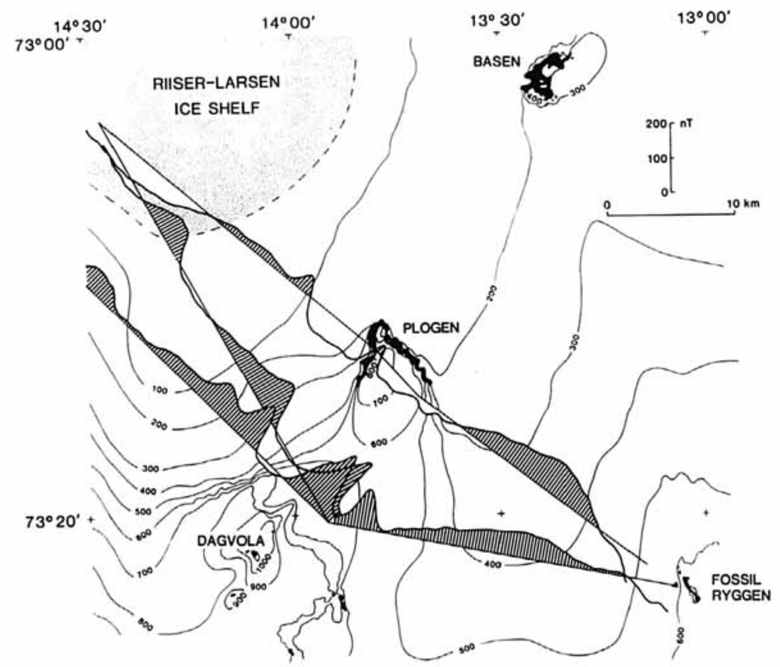

Fig. 3. Residual total magnetic intensity (positive values shaded) along flight tracks across Vestfjella. Ice surface topography from map sheet C7, Norsk Polarinstitutt (1972).

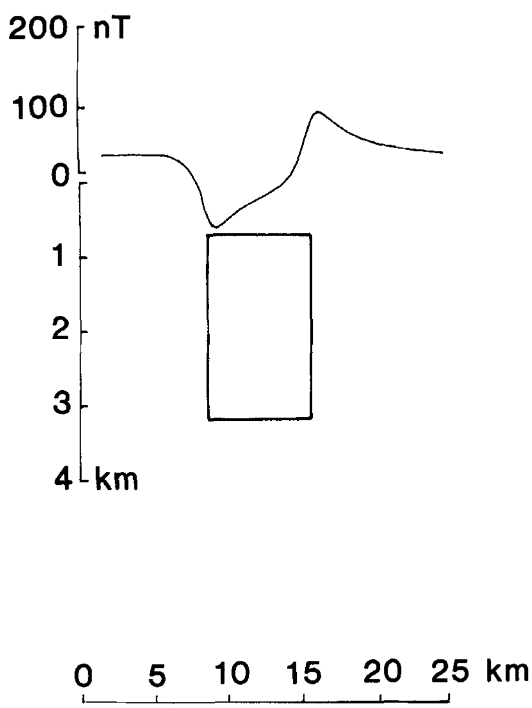

Fig. 4a. Calculated magnetic effect of a reversely (declin. = 220 degrees, incl. = 50 degrees) magnetized lava pile of intensity 5.10^{-4} emu.

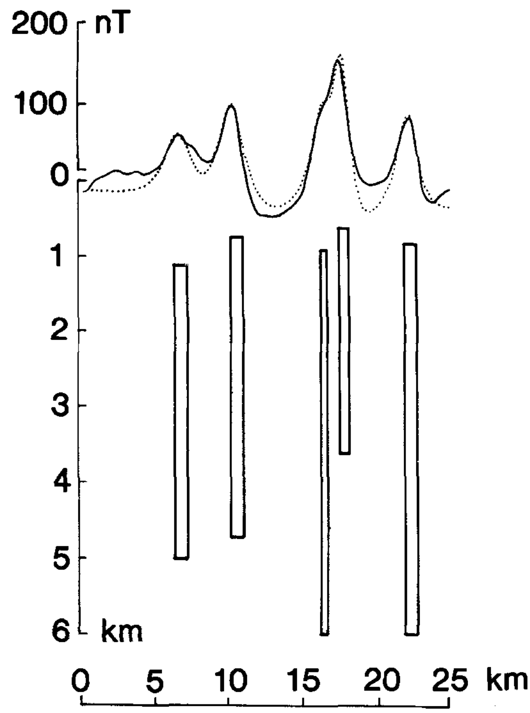

Fig. 4b. Observed magnetic total intensity anomaly (solid line) along flight track across Vestfjella and calculated magnetic effect (dotted line) of normally (declin. = 40 degrees, incl. = −60 degrees) magnetized dyke swarm of intensity 10^{-3} emu.

limited magnetic data available allow no inferences to be made about further presence of early Jurassic volcanics within magnetic basement between Vestfjella and the front of the ice shelf. The Explora Wedge appears to pinch out towards the southeast near the present position of the ice front (Fig. 2). Thus, the volcanism in Vestfjella may have related to spatially separate, but probably contemporaneous rifting which aborted during its early stage. Post-rift thermal subsidence of the crust below the Riiser–Larsen Ice Shelf is small and the major part of the overlying sediments is probably late-Cenozoic.

Summary and conclusions

Aeromagnetic measurements across the Riiser-Larsen Ice Shelf and the adjacent nunataks of Vestfjella show that magnetic basement shallows from the front of the ice shelf (2 km) to the grounding line. The bulk of the sediments underlying the ice shelf is part of the late Cenozoic prograding sequences observed on the shelf. The magnetic field associated with the area between the Plogen and Dagvola nunataks in Vestfjella can be modelled as three parallel dyke swarms at 0.3–0.8 km depth, two of which appear to bound the Vestfjella complex of fault blocks. Therefore, dyke intrusion at depth is apparently more important than that observed in outcrops, and a crustal extension of about 3 km may have taken place below Vestfjella. Magnetic basement may be more than 0.5 km below the outcrop of Permian shallow marine sediments at the Fossilryggen nunatak.

Acknowledgements. – We are indebted to the pilot P. Ellingsen and colleagues A. Solheim and R. Løvlie for their assistance in the field. K. Haugland and F. Veim acquired the multi-channel seismic and sonobuoy data in 1979.

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