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Regional Magnetic Anomalies of the Weddell Sea Region and Their Geological Significance

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Summary: On the basis of characteristic anomaly wavelength and amplitude a number of magnetic patterns attributed to different crustal units can be distinguished and combined into three major zones associated with the West and East Antarctic terranes and the Weddell Sea area. The East Antarctic magnetic zone can be subdivided into six distinct magnetic units. A magnetic low over the Princess Martha Coast and linear short-wavelength magnetic anomalies over the Ahlmannryggen-Borgmassivet area correspond to the Archean to Mid-Proterozoic Grunehogna Province. A broad linear belt of magnetic highs and lows observed over H.U. Sverdrupfjella and Kirwanveggen is associated with a Middle to Late Proterozoic metamorphic belt (Maudheim Province). It can continuously be traced through Vestfjella to the continental slope where the well-known Explora Anomaly cuts it abruptly. The discrete high-amplitude anomalies in Vestfjella (1900 nT) and H.U. Sverdrupfjella (800 nT) correspond to Jurassic intrusions of olivine gabbro and the Straumsvola-Tvora alkaline complexes respectively. The Coats Land magnetic unit exhibits a broken anomaly pattern with isolated short-wavelength highs. In the south it is bound by the prominent Shackleton Range magnetic anomaly and to the west by the Druzhnaya Anomaly.

The West Antarctic magnetic zone comprises the Palmer Land Unit and the Haag Nunataks Unit. The first one is dominated by the Pacific Margin Anomaly, Central Plateau Magnetic Anomaly and East Coast Magnetic Anomaly, which are caused by Cretaceous plutonic rocks. The aeromagnetic data provide additional information on the extent of the Haag Nunataks (HN) block. In accordance with our interpretation, the crystalline basement of the HN may also lie at least beneath the Ellsworth-Whitmore Mountains, the Ronne Ice Shelf up to 59 °W in the east and northward to the coastline and southern Palmer Land.

The magnetic field of the Weddell Sea zone is relatively smooth and of low amplitude, while there are some outstanding magnetic anomalies which provide clues to the nature of the underlying basement. The most conspicuous feature of the WS zone is a wide curvilinear belt of positive magnetic anomalies running parallel with the coast of western Dronning Maud Land and Coats Land southwards to Berkner Island. It includes the Explora Anomaly, the Druzhnaya Anomaly and the Berkner Island Anomaly and marks the transition between the WS and EA magnetic zones. We believe that these anomalies are caused by the sources originated from different tectonic events during the evolution of the Antarctic continental margin in this region. Another striking feature of the WS zone is a linear magnetic low with a minimum amplitude less then -300 nT and average width of about 100 km which runs southwards from the continental rise to the coast-line and is associated with the Weddell Sea "failed rift". Many additional anomalies and lineaments are observed within the Weddell Sea region that have yielded important clues to the tectonic framework, in characterizing the continental crust and interpreting its geological history.

Zusammenfassung: Basierend auf charakteristischen Wellenlängen und Amplituden der Anomalien, kann eine Anzahl von magnetischen Mustern verschiedenen Krusteneinheiten zugeordnet und zu drei größeren Zonen, die mit den west- und ostantarktischen Einheiten und dem Weddellmeer-Gebiet in Verbindung gebracht werden können, zusammengefasst werden. Die ostantarktische magnetische Zone kann in sechs eigenständige magnetische Einheiten aufgeteilt werden. Ein magnetisches Tief über der Princess Martha Coast und lineare kurzwellige magnetische Anomalien über dem Ahlmannryggen-Borgmassivet-Gebiet gehören zur archaischen bis mittelproterozoischen Grunehoga-Provinz. Ein breiter linearer Gürtel magnetischer Hochs und Tiefs, die über der H.U. Sverdrupfjella und Kirwanveggen beobachtet werden, ist mit einem mittel- bis spätproterozoischen metamorphen Gürtel assoziiert (Maudheim Provinz). Dieser kann kontinuierlich durch die Vestfjella bis zum Kontinentalhang, wo er von der bekannten Explora-Anomalie abrupt abgeschnitten wird, kartiert werden. Die isolierten Anomalien hoher Amplitude im Vestfjella (1900 nT) und H.U. Sverdrupfjella (800 nT) sind den jurassischen Intrusionen von Olivin-Gabbro und den alkalischen Komplexen Straumsvola-Tvora entsprechend zuzuordnen. Die magnetische Einheit von Coats Land stellt ein aufgebrochenes Anomaliemuster mit isolierten kurzwelligen Hochs dar. Im Süden ist es von der herausstehenden Magnetfeldanomalie der Shackleton Range und im Westen von der Druzhnaya-Anomalie begrenzt.

Die westantarktische magnetische Zone besteht aus der Palmer-Land-Einheit und der Haag-Nunataks-Einheit. Die erste wird dominiert von der Pacific Margin Anomaly, der Central Plateau Magnetic Anomaly und der East Coast Magnetic Anomaly, die durch kretazische Plutonite verursacht werden. Die flugmagnetischen Daten liefern zusätzliche Informationen über die Ausdehnung des Haag Nunataks (HN) Blocks. In Übereinstimmung mit unserer Interpretation könnte sich das kristalline Basement der HN zumindestens bis unterhalb der Ellsworth-Whitmore Mountains, dem Ronne-Eisschelf bis 59 °W im Osten und nördlich bis zur Küstenlinie und dem südlichen Palmer Land erstrecken.

Das Magnetfeld der Weddellmeer-Zone ist relativ geglättet und von niedriger Amplitude, aber mit einigen herausragenden magnetischen Anomalien, die einen Hinweis über die Natur des unterliegenden Basement liefern. Als die am deutlichsten in Erscheinung tretende Struktur verläuft ein weiter kurvilinearer Gürtel von positiven Anomalien parallel zur Küste des westlichen Dronning Maud Land und Coats Land südwärts zu Berkner Island. Er schließt die Explora-Anomalie, die Druzhnaya-Anomalie und die Berkner-Island-Anomalie mit ein und markiert den Übergang zwischen den magnetischen Zonen WS und EA. Wir glauben, dass diese Anomalien von Quellen, die durch verschiedene tektonische Ereignisse während der Entwicklung des antarktischen Kontinentalrandes in dieser Region erzeugt wurden, verursacht werden. Eine weitere, stark in Erscheinung tretende Struktur der WS-Zone ist ein lineares magnetisches Tief mit einer Minimalamplitude von weniger als –300 nT und einer durchschnittlichen Weite von ungefähr 100 km, die südwärts vom Kontinentalsockel zur Küstenlinie verläuft und mit dem "failed rift" des Weddellmeeres in Verbindung gebracht wird. Eine Anzahl weiterer Anomalien und Lineamente kann in der Weddellmeer-Region beobachtet werden, die wichtige Hinweise auf die tektonischen Rahmenbedingungen, die Charakterisierung der kontinentalen Kruste und die Interpretation der geologischen Geschichte liefern.

INTRODUCTION

Many of the aeromagnetic anomalies of the Weddell Sea (WS) region have been previously discussed and analyzed by others to investigate large scale crustal features, to delineate microplate boundaries and lineaments, and to model depth, size, shape and magnetic-property contrasts of the prominent anomalies (BEHRENDT et al. 1966, MASOLOV 1980, MASLANYJ & STOREY 1990, MASLANYJ et al. 1991, JOHNSON et al. 1992, HUNTER et al. 1996, GHIDELLA & LABRECQUE 1997). In this paper, based on the Russian aeromagnetic data acquired in this region, we further analyze the character of the distribution of magnetic anomalies, their relationship with known geology, and present results of magnetic anomaly field structural interpretation.

The new digitally produced 1 : 2 500 000 "Aeromagnetic Anomaly Map of the Weddell Sea Region" (GOLYNSKY et al.

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2000) and associated 5 km grid is extremely useful in the delineation of the boundaries of geologic provinces and in tectonic studies. The great wealth of geologic information contained within the new compilation is evident from Figure 1 which shows all data as a colour shaded-relief map. Additional products, such as shaded-relief maps of derivatives, pseudo-gravity map and analytic signal amplitude (Figs. 1 through 5) were used to present data in alternative forms that emphasize different geologic/tectonic features. The figures accompanying this report prepared at 1 : 10 000 000 scale and are admittedly inadequate to portray fully every feature being discussed. The larger and more detailed maps being referred to may be needed for comprehensive review of specific anomaly relationships. The procedure adopted for the present study was to identify separately on each image the most important lineaments, structural trends and characteristic anomaly patterns and then correlate this information on a single diagram (Fig. 6).

The images reveal considerably more information than can be discerned from standard contour maps, especially that relating to structural trends and lineaments. The origin of some is obvious, where they correspond to known exposures. Others relate to structures concealed under ice-cover or sedimentary sequences and their origin is more speculative. In these cases the images assist considerably in correlating known features and trends across large regions. By identifying and correlating features on the magnetic images, therefore, it was possible to distinguish three major magnetically distinct structural zones which can be further subdivided into a number of areas with outstanding magnetic grain. These zones are the East Antarctic magnetic zone, the West Antarctic magnetic zone and the Weddell Sea magnetic zone.

EAST ANTARCTIC MAGNETIC ZONE

Aeromagnetic studies have a profound impact on our knowledge of the Precambrian provinces of the East Antarctic Shield. The dominant sources of magnetic anomalies within the shield are the Precambrian basement rocks. These basement rocks are difficult to study by direct methods due to ice-cover and sparse outcrops. However, these regions of Precambrian crystalline-rock outcrop are critical because they provide benchmarks from which geological information can be extrapolated using regional magnetic anomaly data. The East Antarctic (EA) magnetic zone is outlined in the easternmost part of the map and covers the edge of the East Antarctic Shield. It can be subdivided into six magnetic units, two of them recognized over Dronning Maud Land (DML) and another four over Coats Land (CL).

Grunehogna Province Magnetic Unit

The part of DML, that includes Borgmassivet, Ahlmannryggen and the area between Annandagstoppane and Vestfjella (Fig. 9), is referred in this paper as the Grunehogna Unit magnetic unit (GU). It is associated in general with a broad, featureless magnetic low with a few circular short-wavelength anomalies of high amplitude (from 500 to 1700 nT), clipped on in the northern and southern parts by linear continuously traced magnetic highs, named in this paper as the Princess Martha Coast Magnetic Anomaly. The GU magnetic unit is characterized by the widespread presence of low-amplitude (25-50 nT) short-wavelength magnetic anomalies (3-5 km) which can be distinguished only on profile maps suggesting that the magnetic basement is shallow.

The western, southern and eastern boundaries of the GU unit are outlined by the appearance of a prominent positive magnetic anomaly, about 700 km long and averages 40 km in width, which we have named the Sverdrupfjella-Kirwanveggen Anomaly (SKA). It continuously extends in an arcuate and an en-echelon pattern, concave to the south from H.U. Sverdrupfjella, through Kirwanveggen and Vestfjella towards the Weddell Sea depression. Geologically, the GU unit corresponds to the cratonic Grunehogna Province (Groenewald et al. 1991), which consists of Archean granite basement cropping out at Annandagstoppane (Ravich & Soloviev 1969), overlain by relatively undeformed and unmetamorphosed, intracratonic-basin Proterozoic sediments of the Ritscherflya Supergroup (Wolmarans & Kent 1982) that was deposited in a proximal to distal braided river system (Knoper et al. 1995). These sediments are intruded by tholeiitic sills and dykes of the Borgmassivet Intrusions, which have been regarded to be probably Mid to Late Proterozoic in age (Moyes & Barton 1990).

The area of development of volcano-sedimentary assemblages can be outlined in the southernmost part of the GU as a linear zone of low-amplitude highs and lows. It is observed northward from the Kirwanveggen and to the northwest from the Jutulstraumen Glacier and Pencksökket, major physiografical divides of the discussed region. This zone labeled as the Borgmassivet-Ahlmannryggen sub-unit is clearly distinguishable on all presented maps/images although it is not pronounced on ordinary contour map which shows elongated magnetic high of low-amplitude (50-150 nT) accompanied by low from its south-eastern side. In contrast, much of the textural information seen on color shaded-relief image (Fig. 1) based on regional a 5 x 5 km grid indicates that the inner structure of this zone is more complex.

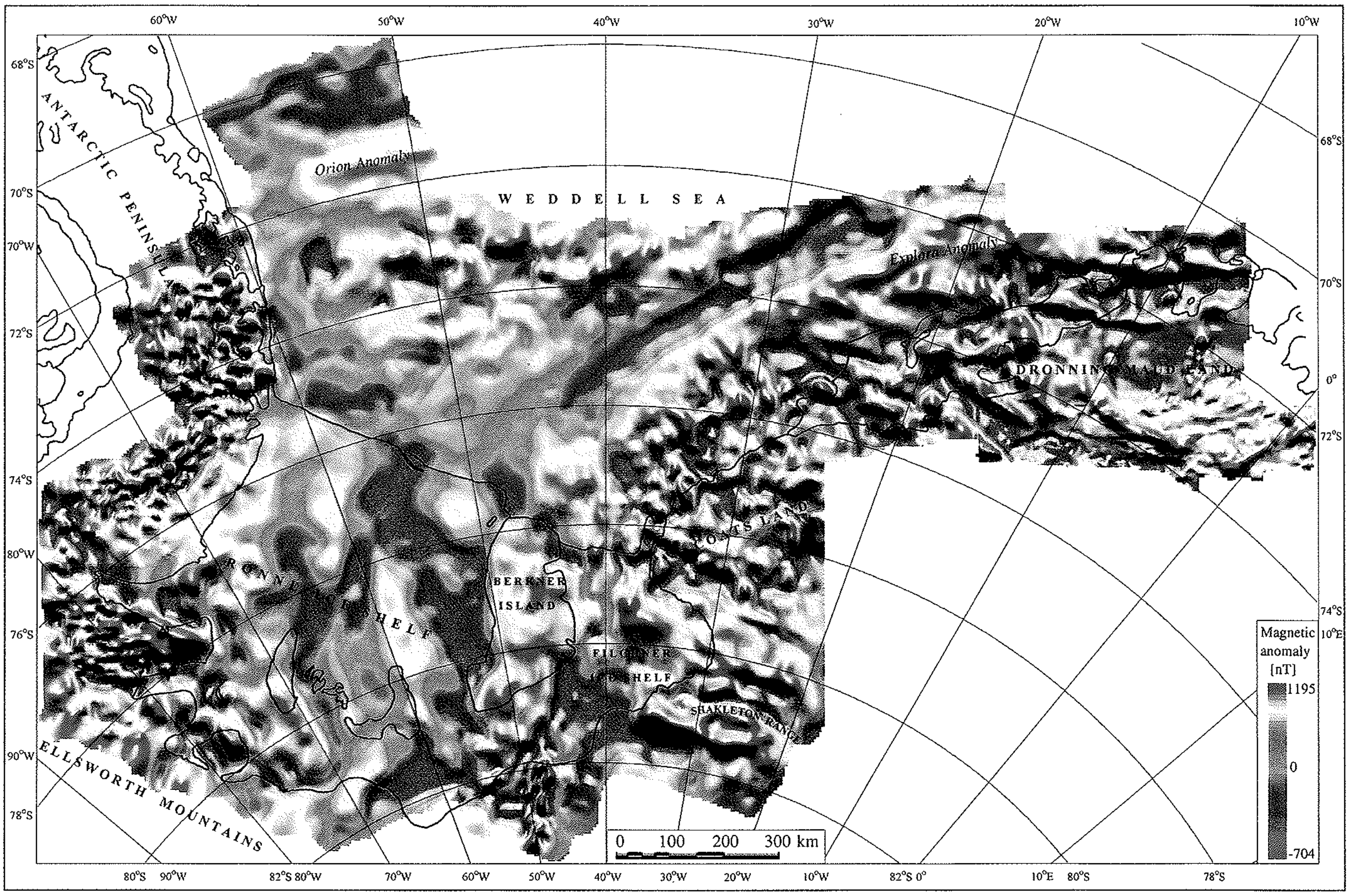
A northeast structural grain of magnetic anomalies is also clearly visible on the north-illuminated shaded-relief map of first vertical derivative (Fig. 2). More precisely this zone can

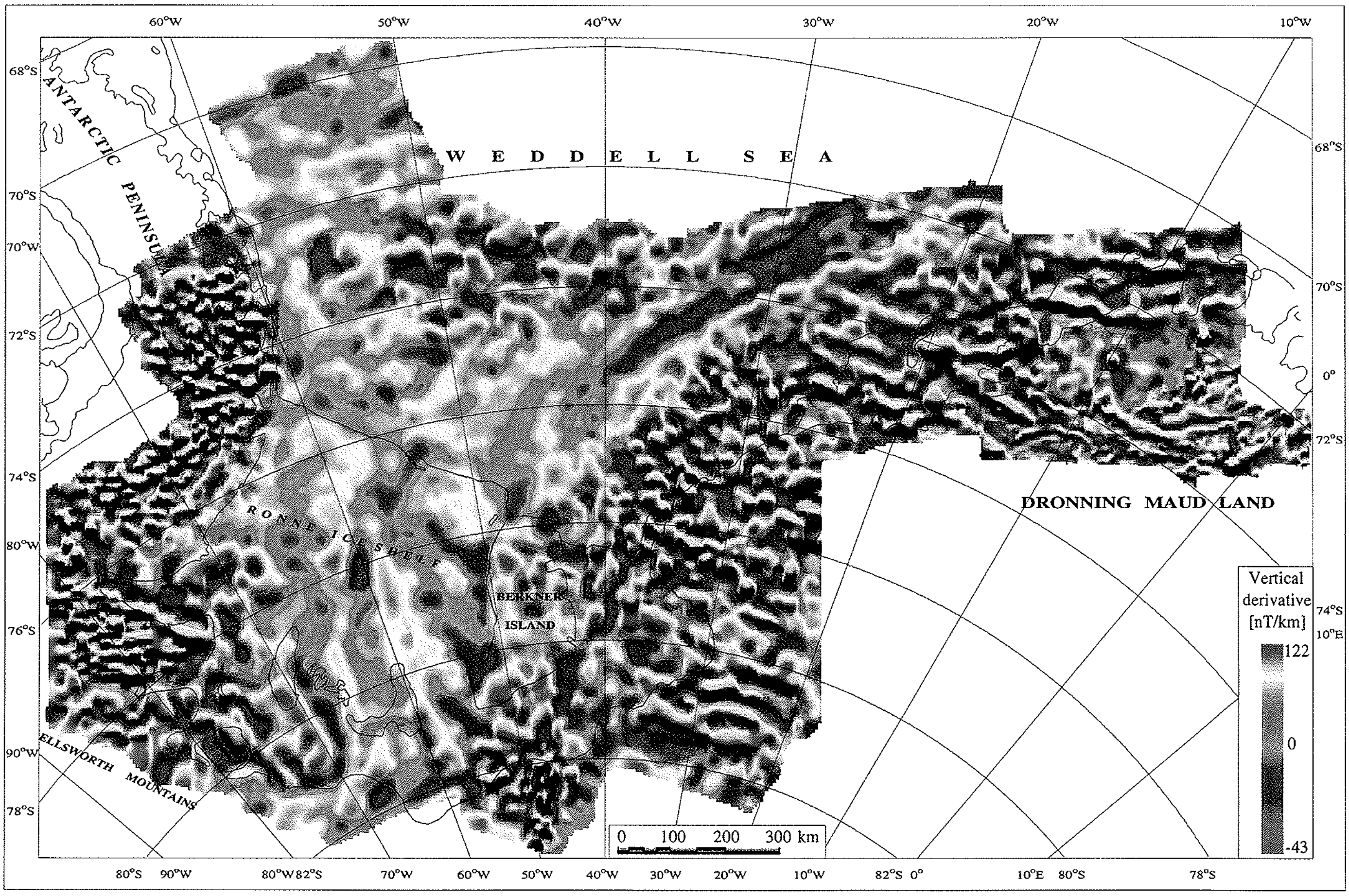
Fig. 1: Shaded-relief aeromagnetic map of the Weddell Sea region. Illumination is from the North at an inclination of 45°.

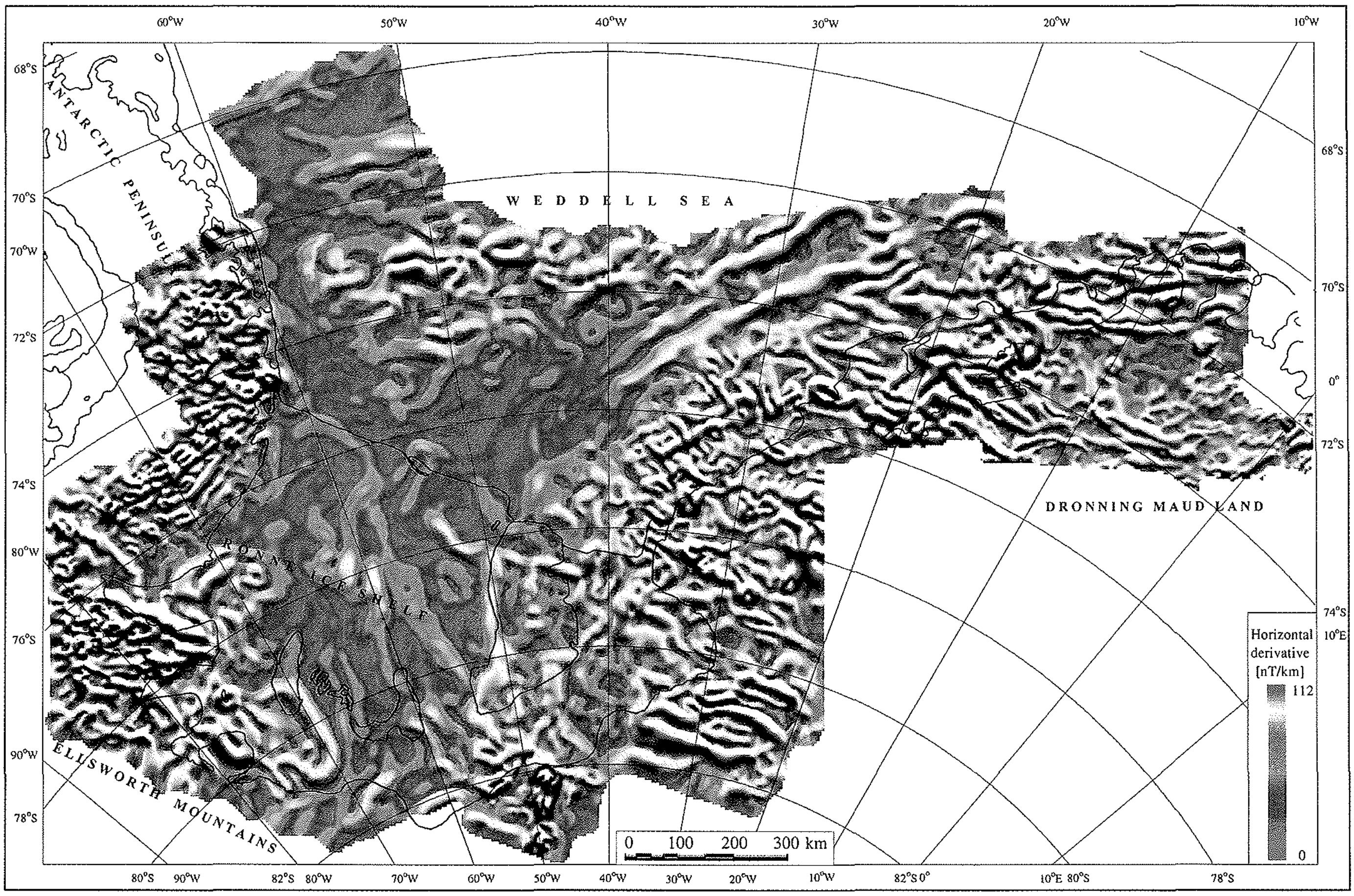
Abb. 1: Flugmagnetische Karte der Weddellmeer-Region mit schattiertem Relief. Beleuchtung von Norden mit einer Inklination von 45°.

Fig. 2: Shaded-relief map of first vertical derivative of the Weddell Sea region aeromagnetic data. Illumination is from the North at an inclination of 45°.

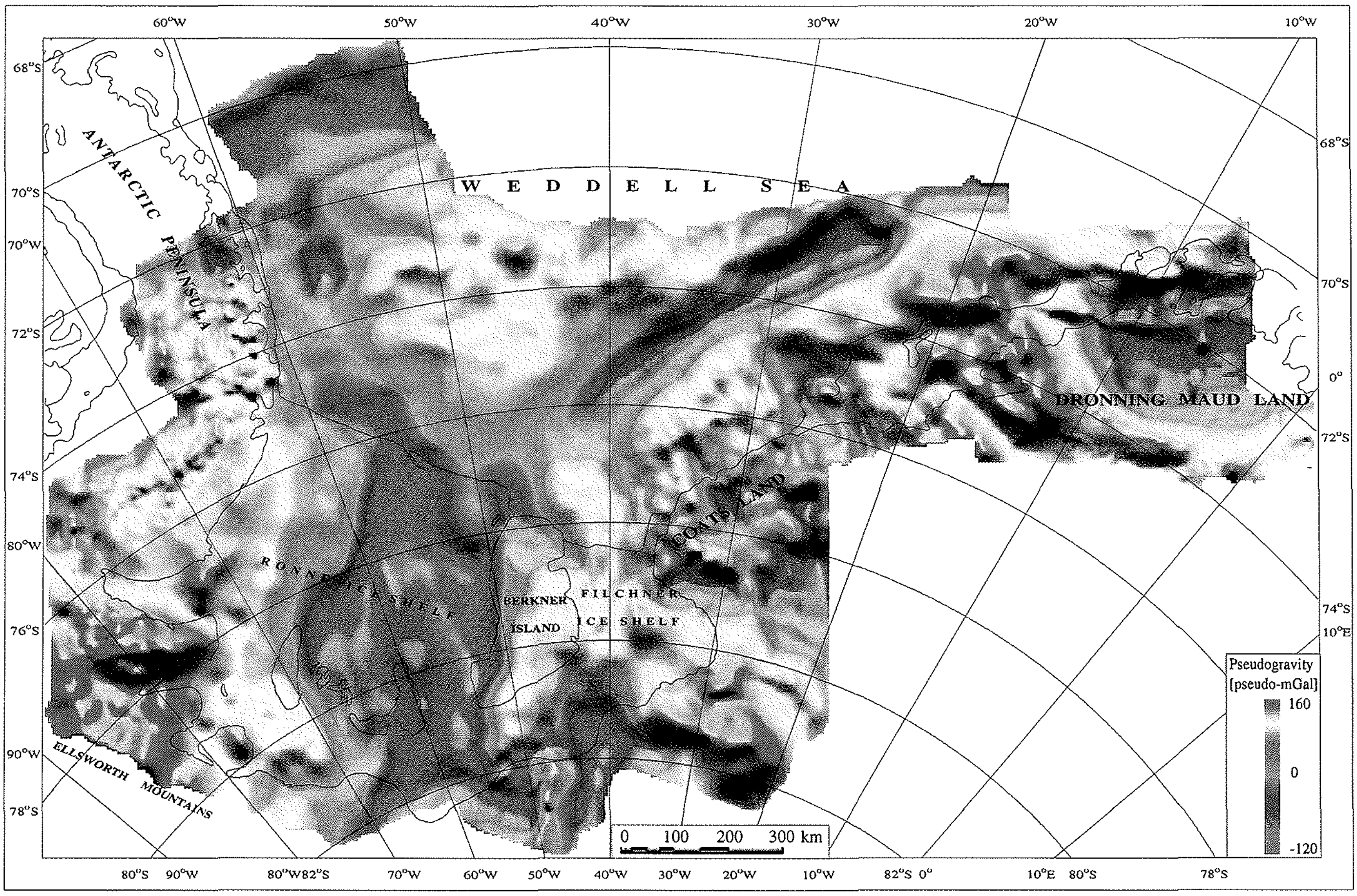
Abb. 2: Karte der ersten vertikalen Ableitung der flugmagnetischen Daten der Weddellmeer-Region mit schattiertem Relief. Beleuchtung von Norden mit einer Inklination von 45°.


60°W
50°W
40°W
30°W
20°W
10°W
68°S
70°S
72°S
74°S
76°S
78°S
70°W
80°W
90°W
0°
10°E
ANTARCTIC PENINSULA
Orion Anomaly
WEDDELL SEA
Explora Anomaly
DRONNING MAUD LAND
BERKNER ISLAND
ELLSWORTH MOUNTAINS
0 100 200 300 km
Magnetic anomaly [nT]
1195
0
-704
80°S
82°S


60°W
50°W
40°W
30°W
20°W
10°W
68°S
70°S
72°S
74°S
76°S
78°S
70°W
80°W
90°W
0°
10°E
ANTARCTIC PENINSULA
WEDDELL SEA
RONNE ICE SHELF
BERKNER ISLAND
ELLSWORTH MOUNTAINS
DRONNING MAUD LAND
0 100 200 300 km
Vertical derivative [nT/km]
122
0
-43
80°S
82°S



WEDDELL SEA
ANTARCTIC PENINSULA
RONNE ICE SHELF
ELLSWORTH MOUNTAINS
DRONNING MAUD LAND
Horizontal derivative [nT/km]
112
0
0 100 200 300 km



WEDDELL SEA
ANTARCTIC PENINSULA
RONNE ICE SHELF
BERKNER ISLAND
FILCHNER ICE SHELF
COATS LAND
ELLSWORTH MOUNTAINS
DRONNING MAUD LAND
Pseudogravity [pseudo-mGal]
160
0
-120
0 100 200 300 km

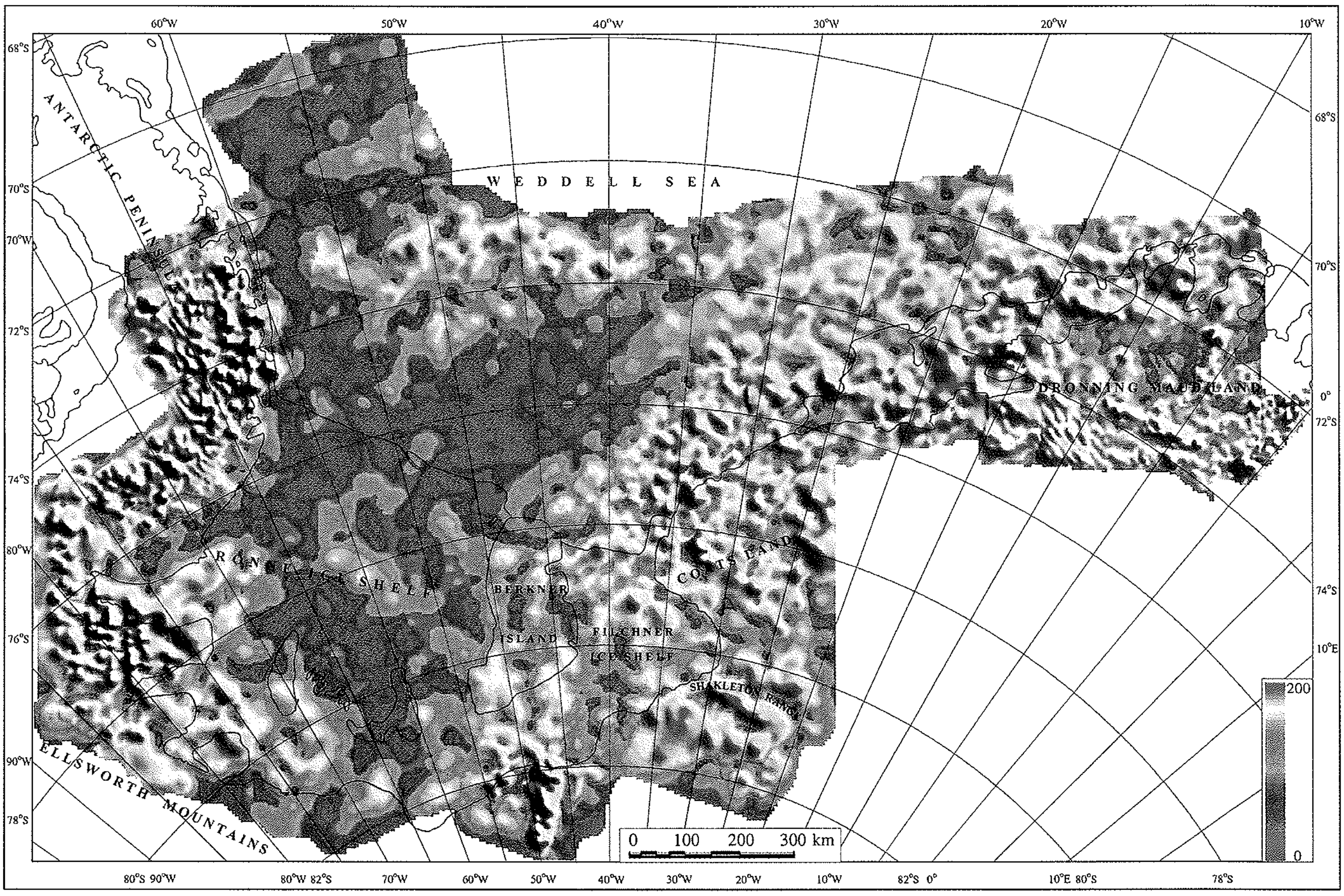


Fig. 5: Analytical signal of the Weddell Sea aeromagnetic data. Shaded-relief image with illumination from the North at 45°.

Abb. 5: Karte des analytischen Signals der flugmagnetischen Daten der Weddellsmeer-Region mit schattiertem Relief. Beleuchtung von Norden mit einer Inklination von 45°.

be outlined by using the colour shaded-relief map (Fig. 7) based on detailed data with flight-line spacing of 5 km. It displays a linear belt of highs and lows that correspond to the Pencksökket-Jutulstraumen (P-J) suggesting a tectonic cause of the anomalies. A more irregular pattern is observed over the Borgmassivet-Ahlmannryggen area. They may reflect NE-SW trending faults, or horsts and grabens within the P-J which separates H.U. Sverdrupfjella from the relatively undeformed and unmetamorphosed Ahlmannryggen to the west. According to ALLEN (1991), this discontinuity is exposed on Midbresrabben in Pencksökket where a network of anastomosing mylonitic shear zones and cataclastic zones cut banded gneisses, similar to those of the basement of H.U. Sverdrupfjella. It should be noted that the magnetic low with amplitude of (-50-100) nT associated with Midbresrabben discontinuity is marginal within a linear belt of highs and lows of Pencksökket and corresponds to a boundary between two basement terranes or provinces (Grunehogna and Maudheim) (GROENEWALD et al. 1991) with contrasting lithologic and magnetic characteristics.

The rocks responsible for the magnetic anomalies observed over the Borgmassivet-Ahlmannryggen area are dolerites of the Borgmassivet intrusions formation with mean magnetic susceptibility of 0.014 SI units (Sergeev, unpubl. data), other widespread formations are represented by low-magnetic rocks (<0.0005 SI units for all groups), metasediments of Ahlmannryggen Group, sandstones of Jutulstraumen and andesites-basalts of Straumsnutane Formation.

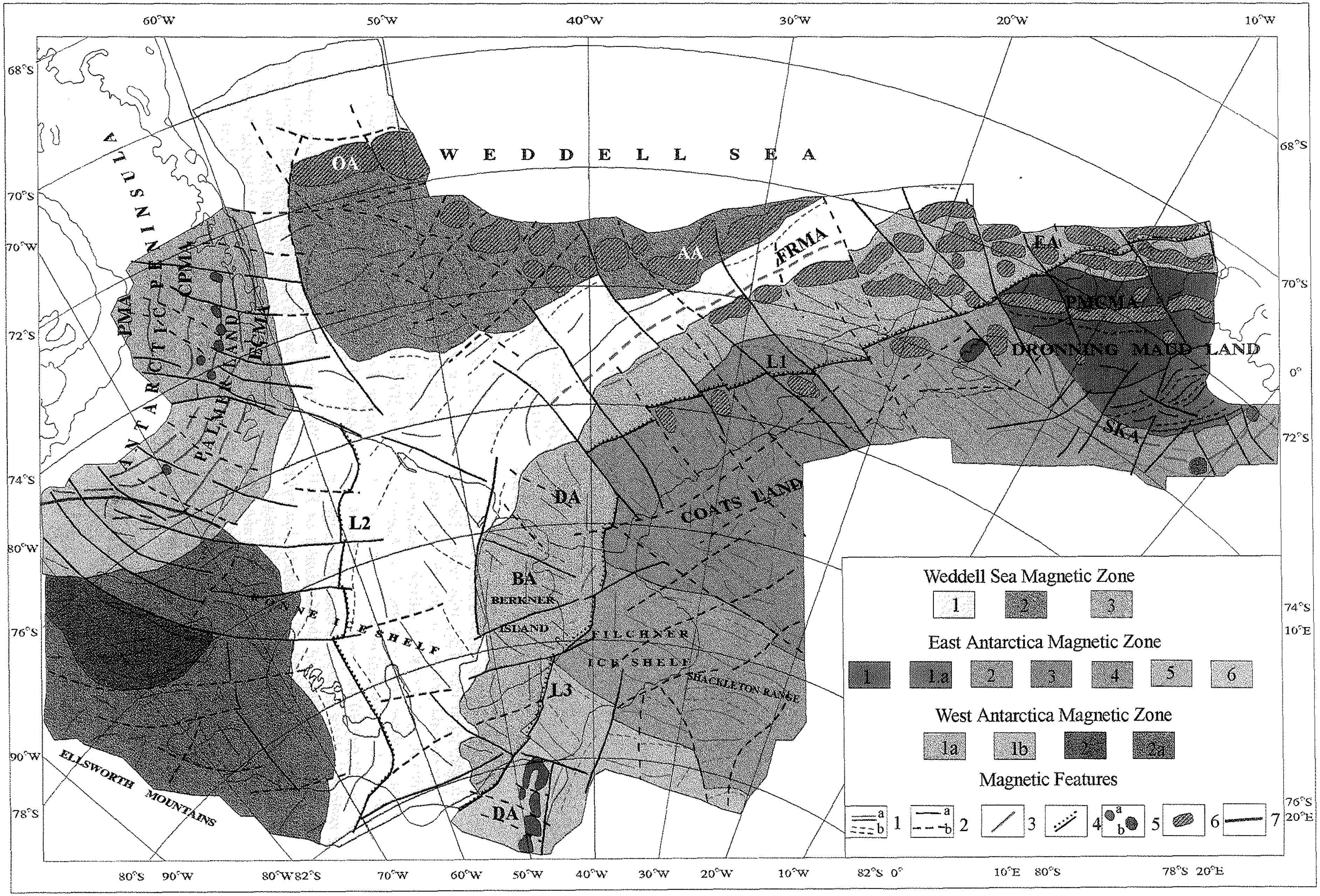
The Grunehogna Unit comprises some prominent magnetic anomalies which required additional consideration. It was mentioned above that the central part of the unit is transected by the Princess Martha Coast Magnetic Anomaly (PMCMA) that extends for more than 400 km and can be traced westward on the Weddell Sea shelf and continental slope area. It is linear

Fig. 3: Shaded-relief map of horizontal gradient of the Weddell Sea aeromagnetic data. Illumination is from the North at an inclination of 45°.

Abb. 3: Karte des horizontalen Gradienten der flugmagnetischen Daten der Weddellmeer-Region mit schattiertem Relief. Beleuchtung von Norden mit einer Inklination von 45°.

Fig. 4: Pseudogravity of the reduced-to-pole Weddell Sea aeromagnetic data. Shaded-relief image with illumination from the North at 45°.

Abb. 4: Karte der Pseudoschwere aus polreduzierten flugmagnetischen Daten der Weddellmeer-Region mit schattiertem Relief. Beleuchtung von Norden mit einer Inklination von 45°.



60°W
50°W
40°W
30°W
20°W
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68°S
70°S
70°W
72°S
74°S
80°W
76°S
90°W
78°S
10°E
20°E
0°
WEDDELL SEA
ANTARCTIC PENINSULA
PALMER LAND
OA
AA
FRMA
EA
PMCMA
DRONNING MAUD LAND
SKA
L1
L2
L3
PMA
CPMA
ECMA
DA
BA
BERKNER ISLAND
COATS LAND
FILCHNER ICE SHELF
SHACKLETON RANGE
RONNE ICE SHELF
ELLSWORTH MOUNTAINS
Weddell Sea Magnetic Zone
1
2
3
East Antarctica Magnetic Zone
1
1a
2
3
4
5
6
West Antarctica Magnetic Zone
1a
1b
2
2a
Magnetic Features
a
b
1
2
3
4
5
6
7
80°S
90°W
80°W
82°S
70°W
60°W
50°W
40°W
30°W
20°W
10°W
82°S
0°
10°E
80°S
78°S
20°E

in shape and consists of four major anomaly segments with local short- to moderate-wavelength (15-30 km) maxima on the profile of 50-500 nT. The gravity expression of this feature (ALESHKOVA et al. 2000) is minimal, while two local gravity highs over the Riiser-Larsen Ice Shelf and over the Halvfarryggen Ridge roughly coincide with magnetic positive anomalies which can be interpreted as being due to mafic intrusions. Correlative circular gravity and magnetic anomalies observed in the westernmost Vestfjella provides additional support for this interpretation. Both, magnetic (1300 nT) and gravity extensive highs may be associated with the northern continuation of olivine gabbro intrusion outcropping on Utpostane and Muren (HJELLE & WINSNES 1972, LUTTINEN et al. 1994). South of the PMCMA the magnetic anomalies have an overall Grunehogna signature, north of it they are mainly negative and have broader wavelengths that parallel deep crustal structures associated with igneous intrusives during the early stages of continental breakup. From these observations, the PMCMA may delineate a zone of structural weakness that initially developed during or prior to the Gondwana separation. Two circular magnetic anomalies with amplitude approximately 800 nT and 1700 nT lie near the PMCMA and supposedly reflected by mafic intrusions, probably similar to the exposed Jurassic olivine gabbro in Utpostane or the syenite bodies near Straumsvola (RAVICH & SOLOVIEV 1969).

Maudheim Province Magnetic Unit

The Maudheim Province magnetic unit with an estimated width of about 350 km consists of the pronounced H.U. Sverdrupfjella-Kirwanveggen Anomaly and alternating bands of elongated positive and negative anomalies to the southwest. The regional bands of alternating-sign anomaly trends, which are discernible from Heimefrontfjella northwestward, are disrupted by the south-eastern Weddell Sea hinge-zone magnetic lineament (HZL), one of the more interesting features on the map. The sudden change in magnetic character across this lineament is observed in the vicinity of the coastline where the strike of the magnetic anomalies turns from west-northwest to roughly west-east, and they are terminated by the Explora Anomaly.

The Sverdrupfjella-Kirwanveggen Anomaly consists of three major segments that corresponds to H.U. Sverdrupfjella, Kirwanveggen and Vestfjella areas. At that time, it is obvious that this anomaly may continue onto the Weddell Sea shelf where it is overprinted by the western continuation of the PMCMA and the Explora Anomaly. The north-western continuation of the SKA is recognized on the shaded-relief map (information derived from other images also support such interpretation) due to the appearance of subtle bordering minimum which is coherently running with an anomaly zone through Vestfjella onto the shelf area (Fig. 1). The amplitude and wavelength of the SKA vary along its lengths and may be attributed to crustal blocks uplifted by varying degrees along the strike-length of the anomaly. The most outstanding areas of the sharp change in anomaly character occur at Vestfjella, Heimefrontfjella and Neumayerskarvet.

The H.U. Sverdrupfjella segment itself consists of two distinctive parts, divided by a structural disruption which occurs south of the major exposures of the H.U. Sverdrupfjella (~70° 40'S). Within the southern part of the segment which stretches N-S and is outlined over the western shoulder of the Jutulstraumen Glacier, a high-intensity magnetic anomaly is observed (1500 nT). It corresponds to Mount Sistenup which consists of a sheet of massive trachytic basalt lava intruded by Jurassic (173 ±2 Ma) syenite (KNOPER et al. 1997), like those in the Sverdrupfjella (RAVICH & SOLOVIEV 1969).

Fig. 6: Structural map of the Weddell Sea region based on aeromagnetic data.
Weddell Sea Magnetic Zone: (1) = Ronne Ice Shelf magnetic unit. (2) = Southern Weddell Sea margin magnetic unit. (3) = East Antarctica margin magnetic unit.
East Antarctic Magnetic Zone: (1) = Grunehogna Province magnetic unit. (1a) =. Borgmassivt-Ahlmanryggen magnetic sub-unit. (2) = Maudheim Province magnetic unit. (3) = Coats Land magnetic unit. (4) = Shackleton Range magnetic unit. (5) = Argentina Range magnetic unit. (6) = Pensacola Mountains magnetic unit.
West Antarctic Magnetic Zone: (1) = Palmer Land magnetic unit. (1a) = Lassiter Coast magnetic sub-unit. (1b) = Orville Coast magnetic sub-unit. (2) = Haag Nunataks magnetic unit. (2a) = Fowler Peninsula magnetic sub-unit.
Magnetic features: (1a) = Axis of magnetic high. (1b) = Axis of magnetic low. (2) = Transverse discontinuities of magnetic pattern: a. major; b. minor. (3) = Magnetic features comformable to regional grain. (4) = Lineaments: L1 - Hinge Zone Lineament. L2 – Inferred structural suture between West and East Antarctica. L3 – Filchner Lineament. (5) = Intensive magnetic high associated with exposed intrusions: a. mafic; b. alkaline. (6) = Magnetic anomalies of high to moderate amplitudes associated with magmatic complex related to Gondwana break-up. (7) = Northern inferred boundary of the Haag Nunataks crustal block associated with Bouguer gravity gradient (McGibbon & Smith 1991).
Prominent magnetic anomalies: AA = Andenes Anomaly; BA = Berkner Anomaly; CPMA = Central Plateau Magnetic Anomaly; DA = Druzhnaya Anomaly; EA = Explora Anomaly; ECMA = East Coast Magnetic Anomaly; OA = Orion Anomaly; PMA Pacific Margin Anomaly; PMCMA = Princess Martha Coast Magnetic Anomaly; SKA – Sverdrupfjella-Kirwanveggen Anomaly.

Abb. 6: Strukturkarte der Weddellsmeer-Region, basierend auf flugmagnetischen Daten.
Weddellmeer Magnetische Zone: (1) = Ronne Eisschelf Magnetikeinheit. (2) = Südlicher Weddellmeerrand Magnetikeinheit. (3) = Ostantarktische Magnetikeinheit.
Ostantarktische Magnetische Zone: (1) = Grunehogna-Provinz Magnetikeinheit. (1a) = Borgmasivt-Ahlmanryggen magnetische Untereinheit. (2) = Maudheim-Provinz Magnetikeinheit. (3) = Coats Land Magnetikeinheit. (4) = Shackleton Range Magnetikeinheit. (5) = Argentina Range Magnetikeinheit. (6) = Pensacola Mountains Magnetikeinheit.
Westantarktische Magnetische Zone: (1) = Palmer Land Magnetikeinheit. (1a) = Lassiter Coast magnetische Untereinheit. (1b) = Orville Coast magnetische Untereinheit. (2) = Haag Nunataks Magnetikeinheit. (2a) = Fowler Peninsula magnetische Untereinheit.
Magnetische Strukturen: (1a) = Achse des magnetischen Hochs. (1b) = Achse des magnetischen Tiefs. (2) = transversale Diskontinuitäten der magnetischen Muster: a. groß; b. klein. (3) = magnetische Strukturen konform mit regionalem Muster. (4) = Lineamente: L1 - Hinge Zone Lineament. L2 - vermutete strukturelle Sutur zwischen West- und Ostantarktis. L3 - Filchner Lineament. (5) = intensives magnetisches Hoch, assoziiert mit aufgeschlosenen Intrusionen: a. mafisch; b. alkalisch. (6) = magnetische Anomalien hoher bis moderater Amplituden, assoziiert mit magmatischen Komplexen in Zusammenhang mit Gondwana-Aufbruch. (7) = vermutete nördlich Begrenzung des Haag-Nunataks-Krustenblocks, assoziiert mit dem Bouguer-Schweregradient (McGibbon & Smith 1991).
Herausragende magnetische Anomalien: AA = Andenes-Anomalie; BA = Berkner-Anomalie; CPMA = Central Plateau Magnetische Anomalie; DA = Druzhnaya-Anomalie; EA = Explora-Anomalie; ECMA = East Coast Magnetische Anomalie; OA = Orion-Anomalie; PMA = Pacific-Margin-Anomalie; PMCMA = Princess Martha Coast Magnetische Anomalie; SKA = Sverdrupfjella-Kirwanveggen-Anomalie.

It can readily be seen from Figures 1-3 that NS-trending magnetic anomalies of the northern part of the H.U. Sverdrupfjella segment extend as far north as the border of the survey area. The causative sources of this anomaly belt are not immediately evident, and they may be caused by infra-structural variations in the crust. However, its central part corresponds to the Roerkulten granite of Grenville orogenic event (1100 Ma) and is located westward from the main axis of the mountain range.

The Sverdrupfjella segment is characterized by low-amplitude magnetic anomalies (100-250 nT) with two offsets of moderate anomalies located on both western and eastern sides of the segment. The western circular high with amplitude 350 nT and with a 25 km diameter is related to the Straumsvola nepheline syenite and the Tvora syenite complexes (RAVICH & SOLOVIEV 1969). These two Jurassic intrusions (170 ±4 Ma, Allen 1991) are exposed in the area adjacent to the Jutulstraumen-Pencksökket structure. Two outcrops of the Straumsvola nepheline syenite complex were sampled by Russian geologists in 1989. The sampling was not fully representative but suggests that susceptibility for this complex is high with an average of about 26 10^{-3} SI units (SERGEEV 2000). Other susceptibility measurements for basement gneiss sequences of the Sverdrupfjella Group (only 14 samples were measured) evidenced that ortho- and paragneisses have a range of ~(0.2-4.0) 10^{-3} SI units, although orthogneisses show higher susceptibilities. The eastern elongated high with an amplitude of 500 nT is probably caused by the relatively un-deformed thrust-related Brattskarvet granitoid suite with an intrusive age of approx. 519 Ma (MOYES et al. 1993).

A significant change in strike direction of the SKA occurs in the Neumayerskarvet area, i.e. westward of Halgrenskarvet the strike direction of this anomaly is predominantly east-west, whereas eastwards it is NNE coinciding with the H.U. Sverdrupfjella. This area is characterized by weaker and more irregular anomalies of less than 150 nT amplitude and 10-20 km wavelength. Two NS faults are recognized from the magnetic anomaly pattern to bound this magnetically smooth block. The difference in magnetization intensity as compared with adjacent terranes is due to a change in crustal level or by lithology of high-grade metamorphic sequences.

A prominent anomaly feature of the SKA is a strong (up to 500 nT), WE trending, arcuate positive anomaly, about 220 km long, the eastern limit of which corresponds to northern and central Kirwanveggen consists almost entirely of high-grade gneisses associated with the 1200-1000 Ma Grenvillian orogeny. In accordance with FERRAR et al. (1995), the Meso-Neoproterozoic gneisses of Kirwanveggen are interpreted to represent predominantly meta-igneous rocks. The magnetic anomaly data in Figure 1 show a subdued expression over much of southern Kirwanveggen and might be explained by the development of the Neoproterozoic-Cambrian sedimentary sequence of the Urfjell Group.

The individual short-wavelength magnetic anomalies in the Kirwanveggen and adjacent areas may represent numerous thrusts or shear zones directed towards the Grunehogna Province to the northwest. A detailed analysis of the detailed magnetic data is not possible at the present scale but the presence of the subtle structural grain probably associated with thrust /shear zones suggest that a more detailed study of the magnetic anomalies in the western Dronning Maud Land might shed further light on the Mesoproterozoic to Mesozoic evolution of the area.

The most important feature that the images (Figs. 1, 2, 7) bring out is that the Kirwanveggen segment does not form an un-interrupted band stretching from the Kirwanveggen to Vestfjella, as suggested by the contour map, but indicate the intersection of two trends. The cross-cutting, NE trending lineaments define the Vestfjella segment of the SKA and also mark the junction of areas of contrasting magnetic character. To the east of the SKA interruption observed at 10 °W longitude is the zone of relatively high frequency magnetic anomalies, indicating relatively near surface magnetic basement, while to the west longer wavelength anomalies indicate deeper magnetic basement.

The images also suggest (see Figs. 1, 2) that the Vestfjella segment is much broader than in Kirwanveggen and H.U. Sverdrupfjella areas and formed by two strands of magnetic anomalies which interrupted by NE-SW-trending low-amplitude magnetic minima close to the major outcrops of Vestfjella consist of Permian sediments and Lower to Middle Jurassic predominantly tholeiitic subaerial basalt flows (FURNES & MITCHELL 1978).

Other pattern changes also occur within the Maudheim Province magnetic unit itself. The negative magnetic anomaly flanking the Kirwanveggen segment of the SKA is outlined over Heimefrontfjella and the southern part of Kirwanveggen. It is likely that the magnetic low over Heimefrontfjella is associated with Precambrian rocks, in which paragneisses appear to be predominant (GRANTHAM et al. 1988, TINGEY 1991). On the other hand, this low may be explained by pervasively Pan-African overprint of Mesoproterozoic crust (JACOBS et al. 1996).

Short wavelength low-amplitude magnetic anomalies (less than 50 nT) superimposed on a negative background are widely distributed through Heimefrontfjella and may be caused by lithologic variations of metamorphic rocks. A second possible explanation of these anomalies is that they may be associated with Mesozoic volcanic rocks which are conformable with Lower Permian sedimentary rocks (JUCKES 1972). However, such inferences should be made with extreme caution due to the absence of magnetic properties for the basalt flows. On the other hand, it is noted that volcanic rock samples (basalts) from Vestfjella have no distinct magnetic susceptibility values at all (KRISTOFFERSEN & AALERUD 1988, RUOTOISTENMÄKI & LENTIMÄKI 1997). In case that magnetic properties of the Heimefrontfjella volcanics have a higher level in comparison with basaltic rocks in Vestfjella, it will not be suggested that associated magnetic anomalies could reach higher amplitude and extent because the measured thickness of lava flows are rather limited and do not exceed 300 m, whereas individual flows are between 3-20 m thick and of varied appearance along outcrop (JUCKES 1972).

Weak narrow curvilinear maxima over the northern part of Heimefrontfjella is enhanced by the first-derivative filter, and some of the better defined patterns are presented in Figure 2. They follow NE trends similar to those observed in H.U.

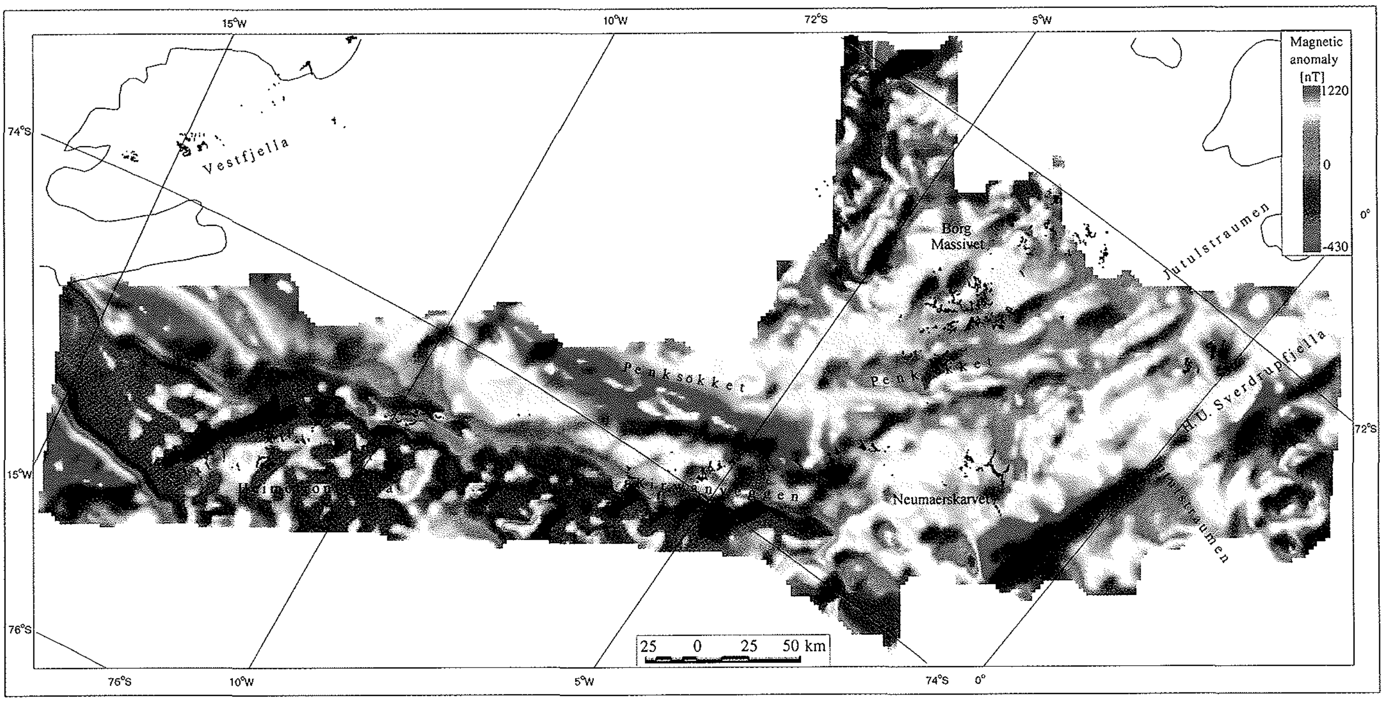

Fig. 7: Shaded-relief aeromagnetic map of Western Dronning Maud Land based on detail data with flight-line spacing of 5 km. Illumination is from the northwest at an inclination of 45°.

Abb. 7: Flugmagnetische Karte des westlichen Dronning Maud Land mit schattiertem Relief, basierend auf detaillierten Daten mit einem Fluglinienabstand von 5 km. Beleuchtung von Nordwesten mit einer Inklination von 45°.

Sverdrupfjella. As was mentioned above, these subtle magnetic anomalies occur over the Maudheim Province, and the nature of their sources is as yet unknown. Two possibilities are that the magnetic anomalies represent either (a) zones of metamorphic rocks with a higher primary magnetic content, or (b) thrust zones in which the movement of metasomatic fluids causing iron in the protoliths to recrystallise to magnetite. Whatever the cause is, the geophysical feature is largely associated with a crustal discontinuity that is expressed as a magnetic lineament or arcuate feature. The latter assumption appears to be more reasonable and is in agreement with field observation in the area. WEBER et al. (1987) report that the major thrust in the northeastern Heimefrontfjella is an ultramylonitic shear zone related to a younger northwest vergent tectonism. Furthermore, JACOBS (1991), JACOBS et al. (1996) and JACOBS et al. (1997) provide additional evidences that the Grenville-aged Heimefront Shear Zone separates the Vardeklettane granulite terrane from the amphibolite facies Sivorg terrane and shows a consistent dextral sense of shear and has a significant transpressional component. Clearly, that a more comprehensive analysis of the images based on the detailed data might help resolve some of the outstanding problems.

It was mentioned above that the Maudheim Province magnetic unit corresponds to a Mid to Late orogenic belt and is characterized by alternating bands of positive and negative anomalies. Two positive magnetic anomalies are located in the westernmost part of the Dronning Maud Land and their origins are unknown due to the lack of geological control. However, an elongated magnetic structure up to 170 km in length is partly observed over the Mannefalknausane outcrops consisting largely of gneissic and possibly plutonic rocks of the basement complex which appear to be mostly orthogneisses associated with Grenvillian/Kibaran orogenic event (TINGEY 1991), whereas negative anomalies mainly observed over the areas where metasedimentary rocks are largely recognized. Apparently, two positive magnetic anomalies observed close to the boundary between the Maudheim Province and the Coats Land magnetic units might also be interpreted by orthogneisses.

Coats Land Magnetic Unit

The Coats Land magnetic unit is clearly differentiated from the adjacent terranes by an intricate or broken anomaly pattern and is characterized by short wavelength (20-50 km) circular, elongated and irregular anomalies with amplitudes reaching to 500 nT on the grid and up to 800 nT on the profile data. The trend of anomalies is rather complicated. The unit does not show any predominant trends and they vary widely from roughly W-E in the southern part to NW-SE in the offshore area. Some of them are formed by grouped, slightly elongated anomalies with a NW-SE appearance. It is interesting to see that the negative anomalies are observed along the boundary of the unit in the north-west, west and south form a round-shaped crustal block with long axis stretched in NW-SE direction. This observation is rather speculative and requires additional confirmation because the eastern part of the block is not covered by aeromagnetic survey, whereas its north-western part is overprinted by NE-SW-trending magnetic anomalies related to a formation of the continental margin. A complete analysis of the Coasts Land crustal block requires an extension of the present study area to the east and the incorporation of the AWI aeromagnetic data, gathered in this area in 1994-95 field season (W. Jokat, pers. comm.).

It is necessary to note that the observed magnetic anomaly pattern corresponds to the Coats Land area that is characterized by limited outcrops of the Touchdown Hills nunataks and the Theron Mountains. The Theron Mountains form an approximately 120 km long NE-trending escarpment and is composed of Lower Permian sedimentary rocks intruded by Jurassic doleritic dykes and sills (KAMENEV & IVANOV 1983, BREWER et al. 1996). The last ones have a greater thickness varying from <1 to >200 m, in contrast the dykes range from 1 to 6 m in width. The Theron Mountains escarpment as a elongated fault-bounded tectonic structure has no clear magnetic signature. Magnetic anomalies are mainly negative and vary from 0 nT to -200 nT. Only one profile-intersection in the north-eastern part of the escarpment displays moderate magnetic anomaly with amplitude of 300 nT, probably reflecting a thick sill of dolerites. However, filtered maps (Figs. 2, 3) attenuate a weak linear northeast-running feature which is parallel to the present topography. The change in magnetic anomaly character along this feature implies a possible fault.

The hand-sample susceptibility measurements of rhyolites from the Bertrab and Littlewood Nunataks were made by Sergeev (2000). These samples yielded susceptibility values with an average of about 17.3 10^{-3} SI units for the Bertrab Nunatak (9 samples), whereas the level of susceptibility for rhyolites from the Littlewood Nunataks (3 samples) is rather low and does not exceed 0.25 10^{-3} SI units. This sampling is not representative, but suggests that felsic volcanics have a bimodal distribution. It is therefore likely that they could produce positive as well as negative magnetic anomalies. Due to relatively sparse flight-line network the outcrops were not crossed during an aeromagnetic surveying. The nearest short wavelength positive magnetic anomaly (~200 nT) is outlined within 5-7 km from the nunataks. Clearly, the problem of this not very prominent anomaly and its probably source should be further investigated. Other features of the magnetic field in conjunction with gravity data are discussed by ALESHKOVA et al. (2000).

Shackleton Range Magnetic Unit

The Shackleton Range magnetic unit is outlined in the south-eastern part of the study area and is associated mainly with positive anomalies of up to 500 nT amplitude. It covers a 250 km by 300 km area over the Shackleton Range including two accompanying glaciers (Slessor and Recovery) and a large part of the Filchner Ice Shelf. The east-west structural grain of the unit is clearly seen on an ordinary counter map that shows that two broad E-W-trending positive anomalies (belts) are divided by paired relative lows with the pronounced oval (30 x 70 km) high of 500 nT amplitude located between them. This high is situated between the southern part of the Haskard Highlands and the western part of the Fuchs Dome. It was named by MEYER et al. (in press) as the Haskard-Fuchs Anomaly (HFA). The Pointer Gneiss formation, subdivision of the Early Proterozoic Stratton Group (CLARKSON et al. 1995), represented by leucocratic biotite and biotite-amphibolite gneisses with high concentration of magnetite is responsible for the HFA. The mean-weighted value of magnetic susceptibility of the Pointer Gneiss rocks is 29.0 10^{-3} SI units. The other widespread sequences of the Stratton Group and Pioneers Group considered by many workers as infracrustal and supracrustal units of the non-cratonic northern belt of the Shackleton Range (KLEINSCHMIDT et al. 1995), as well as Wyeth Heights Formations and Blaiklock Glacier Group (CLARKSON et al. 1995) are generally low-magnetic with average susceptibility value about 0.2 10^{-3} SI units (MEYER et al. in press).

The colour shaded-relief map of the magnetic field and other images (first vertical derivative and horizontal gradient of magnetic anomaly data) reveal considerably more information than can be discerned from standard contour map, especially that relating to structural trends, lineaments and other features some of which are subtle to the extent that they are visible only by illumination from a particular direction. A major feature, seen most clearly on the first derivative and horizontal gradient of the magnetic data is the arcuate grain of structural trends with concave south configuration. This grain is surprisingly in good agreement with structural fabric of known geological subdivisions of the northern as well southern Shackleton Range. It is interesting to note that major outcrops have a similar appearance (CLARKSON et al. 1995). At that time, the southernmost feature lies approximately along the Recovery Glacier is linear in form, delineating a southern boundary of the Shackleton Range magnetic unit. The effect of several crosscutting structures has also been significantly enhanced by the filtering maps/images.

The origin of some above-mentioned features is more or less obvious, where they correspond to known basement structures. The images show that the Pointer Gneiss formation can be continued to the east due to existence a week curvilinear trend as far as 20 °W. The sparse outcrops of the Stratton Group infracrustal rocks located in northern extremity of the Shackleton Range have even more pronounced magnetic response.

The origin of positive magnetic anomalies associated with the southern cratonic belt of the Shackleton Range is not clarified at the moment. MEYER et al. (in press) reported that only biotite and biotite-amphibolite gneisses of Beche Blade in the Read Mountains are strongly magnetized (26.7 10^{-3} SI units) relative to other gneiss sequences and intrusive rocks which are characterized by low magnetic susceptibility (less than 0.5 10^{-3} SI units). Thus, it is possible to suggest, that these high magnetic gneisses are responsible for the southern magnetic belt of the Shackleton Range, at that time its possible sources might originate deep in the crust.

Magnetic images clearly show that not only the northern magnetic belt continuously stretched in northwestern direction towards the Druzhnaya Anomaly but the southern magnetic belt has also approximately the same trend towards the Berkner Island where the broad NS-trending Berkner Anomaly is recognized. Both belts are interrupted by the sharply defined NE-SW-trending Filchner Lineament (FL). This lineament corresponds to the axial part of a deep trough with depths up to 1400 m bellow msl as outlined by land-based seismic observation (POZDEEV & KURININ 1987). It lies under the Filchner Ice Shelf from the ice-front in the north to the Foundation Ice Stream westwards of the Pensacola Mountains with the branch into the Support Force Glacier area. The bathymetry data show that this through known, as

Crary or Thiel Trough is continued along the Coats Land coast up to 31 °W where it terminates. The Filchner Lineament is also well defined by the gravity images and associated with axial part of pronounced Bouguer anomalies of up to 90 mGal (ALESHKOVA et al. 2000).

Argentina Range Magnetic Unit

The Argentina Range Magnetic Unit (ARMU) is distinguished in the south-eastern corner of the map southward from the Shackleton Range and eastward from the Pensacola Mountains. The northern and western boundaries of the unit are sharply defined by abrupt change in the magnetic anomaly pattern. In comparison to the neighboring terranes the ARMU is characterized by surprisingly smooth and uncomplicated magnetic anomalies, the negative anomalies are predominant, although flight-line terminations in this remote area make refined interpretations difficult. Magnetic anomalies trend predominantly E-W, parallel or coherently with anomalies observed over the Shackleton Range. They run through the Filchner Ice Shelf to the coast of Berkner Island where they terminate by the N-S trending the Berkner Anomaly. Narrow N-S running minimum with a gridded amplitude 100-150 nT over the Argentina Range is apparently reflected by the Cambrian carbonate platform rocks (ROWELL & REES 1991).

Pensacola Mountains Magnetic Unit

The Pensacola Mountains Magnetic Unit is outlined in the northern part of the Pensacola Mountains and characterized by short-wavelength magnetic anomalies of different amplitudes (from several nTs up to 1700 nT). Two major linear highs of the unit correspond to the Forrestal Range and to the northern ice-covered continuation of the Dufek Massif. Their predominant trend is NNE-SSW, whereas some local features, apparently including magnetic anomalies over the Dufek Massif, are characterized by ENE trend. It is rather clear seen on the shaded-relief map (Fig. 1) and other images (Figs. 2, 3) that NNW-SSE crosscutting lineaments offset all features of the unit implying that they may represent the youngest structural event (possibly an extensional episode associated with Thiel Trough formation).

The unit is largely corresponded to the Middle Jurassic Dufek intrusion which was emplaced just prior to Gondwana break-up and considered as one of the largest layered intrusion in the world with a minimum estimated size of about 50 000 km^2 (BEHRENDT et al. 1966). However, recent analysis of aeromagnetic data allowed FERRIS et al. (1998) to reduce the total extent of the intrusion from 50 000 to 6600 km^2. They reported that the reduced size of the Dufek intrusion is mainly due to reinterpretation of an anomaly over Berkner Island which is related to uplifted basement rocks rather than a continuation of the intrusion. The total extent of the Dufek intrusion in accordance with our interpretation is approximately 10 000 km^2.

It is rather obvious from magnetic images (Figs. 1 through 5) that N-S trending magnetic anomalies over Berkner Island are superimposed with NW-SE-running features. Therefore, it is believed that apparently some N-S-running anomalies may be associated with deep-buried intrusions similar to the Dufek intrusion and related to Gondwana break-up.

WEST ANTARCTIC MAGNETIC ZONE

The West Antarctic magnetic zone comprises the Palmer Land Unit and the Haag Nunataks Unit. Both units are mainly characterized by short-wavelength magnetic anomalies (<50 km) whereas their trends are discordant to each other. The outstanding feature of magnetic anomaly pattern of the Palmer Land is arcuate appearance of linear chains along the length of the Antarctic Peninsula. The magnetic anomaly grain of the Haag Nunataks unit is more complex and associated with zone of concentration of high-intensity magnetic anomalies around the Haag Nunataks.

The Palmer Land Magnetic Unit

The Palmer Land magnetic unit is dominated by the Pacific Margin Anomaly (PMA) (MASLANYJ et al. 1991) the Central Plateau Magnetic Anomaly (CPMA) and the East Coast Magnetic Anomaly (ECMA) (GOLYNSKY & MASOLOV 1999). The PMA, a belt of anomalies in excess of 1000 nT is interpreted as an expression of a linear plutonic complex associated with arc magmatism (GARRET 1990), however, the anomaly does not correspond well to known outcrops of intrusive rocks in any particular age range (LEAT et al. 1995). The magnetic anomalies along the eastern side of the Antarctic Peninsula (CPA and ECMA) are thought to be due to large isolated mafic intrusions (MCGIBBON & GARRET 1987).

In general, magnetic features over the Palmer Land trend roughly parallel to the curvature of the southern Antarctic Peninsula. The magnetic anomaly pattern allows us to subdivide the survey area into two sub-units named in accordance with their geographical position, the Lassiter Coast sub-unit and the Orville Coast sub-unit. The boundary or transitional zone between two sub-units lies along the Wetmore-Irvine Glaciers which are determined by NW-SE trending negative anomalies. The remarkable linearity of this feature is presumably associated with substantial strike-slip displacements of the Lassiter Coast crustal segment relatively to the Orville Coast segment.

Lassiter Coast magnetic sub-unit

Within the Lassiter Coast sub-unit a fragment of the PMA (MASLANYJ et al. 1991), the CPMA and the ECMA are recognized. The sources of the PMA in the survey area are unknown due to sparse outcrops. We suggest that there are not obvious correlations between magnetic anomalies and rock outcrops. Low-amplitude magnetic anomalies (-100 to -300 nT) are observed in vicinity of Mount Vang, Gunn Peaks, Galkin Nunatak composed by rocks of the Antarctic Peninsula Volcanic group (ROWLEY et al. 1992) that characterized by low values of magnetic properties. The granodiorite-tonalite rocks of the Seward Mountains also are reflected by similar magnetic anomalies.

One of the most pronounced north-south-trending anomalies of the Lassiter Coast unit is the CPMA, a complex high-amplitude (500-1300 nT) anomaly with wavelength 10-30 km. These highs are abruptly truncated on their south edge by the NW-SE system of the Wetmore-Irvine magnetic lineament and on their northern edge by the Mosby Glacier magnetic lineament (Fig. 1). The northern continuation of the CPMA is not clearly evident, possibly it might coincide with any of a group of north-south-trending anomalies. Two intense magnetic highs of the CPMA appear to be offset by faults which coincide with a gabbro intrusion exposed at Mount Coman and a diorite intrusion which lies west of Galan Ridge (ROWLEY et al. 1992).

The East Coast Magnetic Anomaly (anomaly 3 after JONES & MASLANYJ 1991) is a group of discrete high-amplitude anomalies (600-5000 nT) that form a broadly linear belt trending parallel to and inland of the Lassiter and Black Coasts. The width of the ECMA is about 75-100 km. Comparison of the aeromagnetic anomaly map with the outcrop geology shows that bulk of the positive anomalies occurs over areas of development of the Lassiter Coast Intrusive Suite. Broad, irregular anomalies (100-500 nT amplitude) are related with the Cretaceous plutons of granite-granodiorite composition, whereas small (10-20 km) circular anomalies of 800-1900 nT amplitude are corresponded to dioritic or gabbroic intrusions of similar age (PANKHURST & ROWLEY 1991). However, in some parts, such as the Playfair Mountains and over intrusion to the west from the Werner Mountains (close to Barkov Mount) dioritic rocks are associated with the negative anomalies. As a rule they are located to the SSW of the intrusions characterized by intensive magnetic anomalies. Magnetic properties of plutonic rocks vary considerably and central parts of gabbroic plutons mostly yield higher susceptibilities than contacts. It is highly likely that, in some cases, negative anomalies are associated with such outer parts of plutons (e.g. Playfair Mountains) or alternatively due to the less mafic composition and dominance of ilmenite over magnetite (MOYES & STOREY 1986).

Orville Coast magnetic sub-unit

The structural grain of the magnetic anomalies within the Orville Coast sub-unit (OCSU) has obvious similarity with the Lassiter Coast sub-unit. The anomalies are elongated subparallel to the axis of the Antarctic Peninsula, and their form, amplitude and wavelength vary considerably reflecting lithology and spatial distribution of intrusions and metasedimentary rocks. The high-intensity anomalies within the Orville Coast sub-unit are rather rare and generally elongate. One of the most pronounced peculiarities of the OCSU is decreasing of the amplitude of magnetic anomalies in westward direction where they are subdued and reduced in value (the extreme western region of the Behrendt Mountains), probably indicating the area in which the volume of magmatic rocks is limited due to modification of crustal structure of the Antarctic Peninsula. The magnetic images in particular give the impression that the magmatic front associated with mafic-intermediate plutons intruded along the spine of the arc stops in vicinity or is turned away from the northern flank of the Haag Nunataks crustal block which acted as rigid indenter during the Mesozoic evolution of the Antarctic Peninsula.

The magnetic grain of the OCSU allows identification of two major linear belts or lineaments. One of them continuously stretches from the Merrick Mountains through the Sweeney Mountains towards the Latady Mountains and is associated with gabbro-diorite rocks and accompanying plutons intruded near by border of the Mount Poster Formation and the Latady Formation (KELLOGG & ROWLEY 1991). The Merrick-Sweeney-Latady lineament may be considered as a paired feature that is outlined by two subparallel chains of positive anomalies with amplitudes up to 1900 nT and divided by coherently stretched negative anomalies.

The second magnetic lineament extends for at least 400 km from the southern Behrendt Mountains across the Hauberg Mountains and Peterson Hills, across the Wilkins and Scaife Mountains to the southern Latady Mountains and is named the Behrendt-Hauberg-Scaife lineament. It is arcuate in form and associated with subdued low-amplitude anomalies, indicating an increase in depth to causative bodies. To the south-east the lineament is flanked by a narrow belt (15-25 km) of negative anomalies of 50-100 nT amplitude. Isolated magnetic anomalies with amplitude up to 500 nT located in apposite parts of this linear magnetic belt (close to Mount Hassage, Quilty Nunataks and over Janke Nunatak in the west; over Mount Terwileger, Mount Brundage and other localities in the Latady Mountains in the north-east) correspond to known intrusions of different composition (PANKHURST & ROWLEY 1991). This observation suggests that the linear plutonic complex may be found under sediments of the Latady Formation through whole length of the lineament.

Broad, subdued magnetic anomalies with amplitudes of about 100 nT in a similar manner run parallel to other anomaly-belts within the OCSU from the northern tip of the Dodson Peninsula towards the Evans Ice Stream. They are located close to the grounded-line of the Ronne Ice Shelf and may be considered as transition zone between the Palmer Land magnetic unit and the Weddell Sea magnetic zone or transition zone between structures of the Antarctic Peninsula and Weddell Sea Embayment crustal blocks. The causative sources of magnetic anomalies buried at 4-8 km (Fig. 8) under sediments presumably interpreted as plutonic bodies of Antarctic Peninsula batholith intruded into nonmagnetic sedimentary rocks of the Latady Formation.

Haag Nunataks Magnetic Unit

The Haag Nunataks (HN) magnetic unit is outlined in the south-western part of the study area and is associated with the magnetic anomalies of different amplitudes and wavelengths which surrounds exposures of Precambrian rocks at the Haag Nunataks. Extensive, short-wavelength (10-20 km) magnetic anomalies with amplitudes up to 1050 nT with NW-SE dominant grains parallel to the ice streams are observed over the topographic block of the Fowler Peninsula (Fowler Peninsula sub-unit), the outcrops being the site of 300 nT anomalies. In the NE, the unit is delimited by a continuous negative linear anomaly that runs parallel to the Evans Ice Stream for more than 300 km. This linear magnetic anomaly appears to be due to a fault which lies under central Evans Ice Stream marking the northeasterly limit of subglacial outcrop of the basement. The Carlson Inlet is marked by a negative magnetic anomaly of -200 nT amplitude.

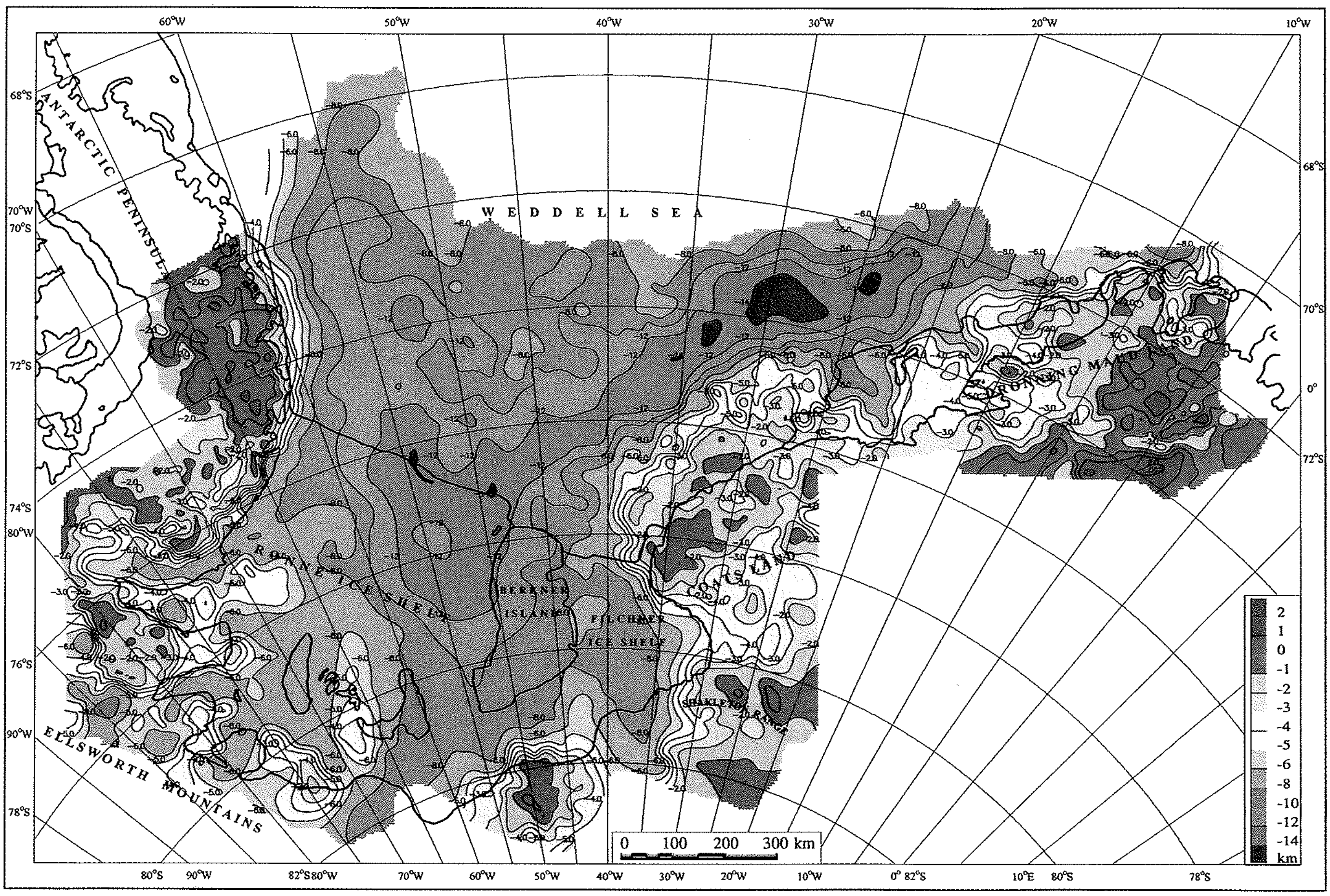

Fig. 8: The relief of the magnetic basement in the Weddell Sea survey area.

Abb. 8: Das Relief des magnetischen Basement im Messgebiet des Weddellmeeres.

In the south-western extremity of the unit, anomalies of up to 400 nT amplitude and 50-70 km wavelength, complemented by weaker anomalies and 10-20 km wavelengths extend 300 km along strike over the Rutford Ice Stream. Similar magnetic anomalies are located over the Fletcher Promontory, Skytrain Ice Rise and close to Kershaw Ice Rumples. The eastern boundary of the unit is outlined in the area between the Korff Ice Rise in the East and the Fowler Peninsula in the West. It is corresponded to deep topography through with depth more than 1300 m bellow sea level (Pozdeev & Kurinin 1987, Aleshkova et al. 2000), suggesting normal-fault displacements of the Precambrian HN magnetic basement.

There is a conspicuous long-wavelength magnetic anomaly of 700 nT amplitude in the southernmost Antarctic Peninsula (close to Cape Zumberge, composed of sedimentary rocks of Latady Formation) and a complex long-wavelength low-amplitude magnetic anomaly (150 nT) located south of the Korff Ice Rise. Magnetic images (Figs. 1-3) strongly suggest that, despite their trends being inconsistent with those within the HN unit, causative sources might be related with the basement of the HN crustal block. This suggests that basement of HN may extend beneath the Ronne Ice Shelf as was inferred previously by many authors (Kadmina et al. 1983, Garret et al. 1987, Maslanyj & Storey 1990) and the Antarctic Peninsula. It should be noted that in accordance with interpretation of British aeromagnetic data given by Maslanyj & Storey (1990, see Fig. 9) the area covered by the Cape Zumberge magnetic anomaly was also included in the HN crustal block. However, any conclusions were not inferred from this observation.

Much of the complexity of the magnetic anomalies within the HN unit results from crosscutting and normal faults that dissected and stepped the magnetic basement. This is consistent with bedrock topography data and with depth estimations to magnetic basement (Fig. 8). Additional complexity may result from non-outcropped rocks at exposures since magnetic properties of Precambrian rocks (orthogneisses show volume susceptibilities in the range of 11-20 10^{-3} SI units (Garret et al. 1990}, amphibolitic gneisses have susceptibilities of 0.2-1.0 10^{-3} SI units and intermediate dykes show susceptibilities of up to 50 10^{-3} SI units) could be partly responsible for observed magnetic anomalies. In this respect Maslanyj & Storey (1990) pointed out that low magnetizations of rocks may reflect very superficial sources and larger magnetizations may be encountered at quite shallow depths.

WEDDELL SEA MAGNETIC ZONE

The magnetic field of the Weddell Sea (WS) zone in contrast to the adjacent provinces, is relatively smooth and uncompli-

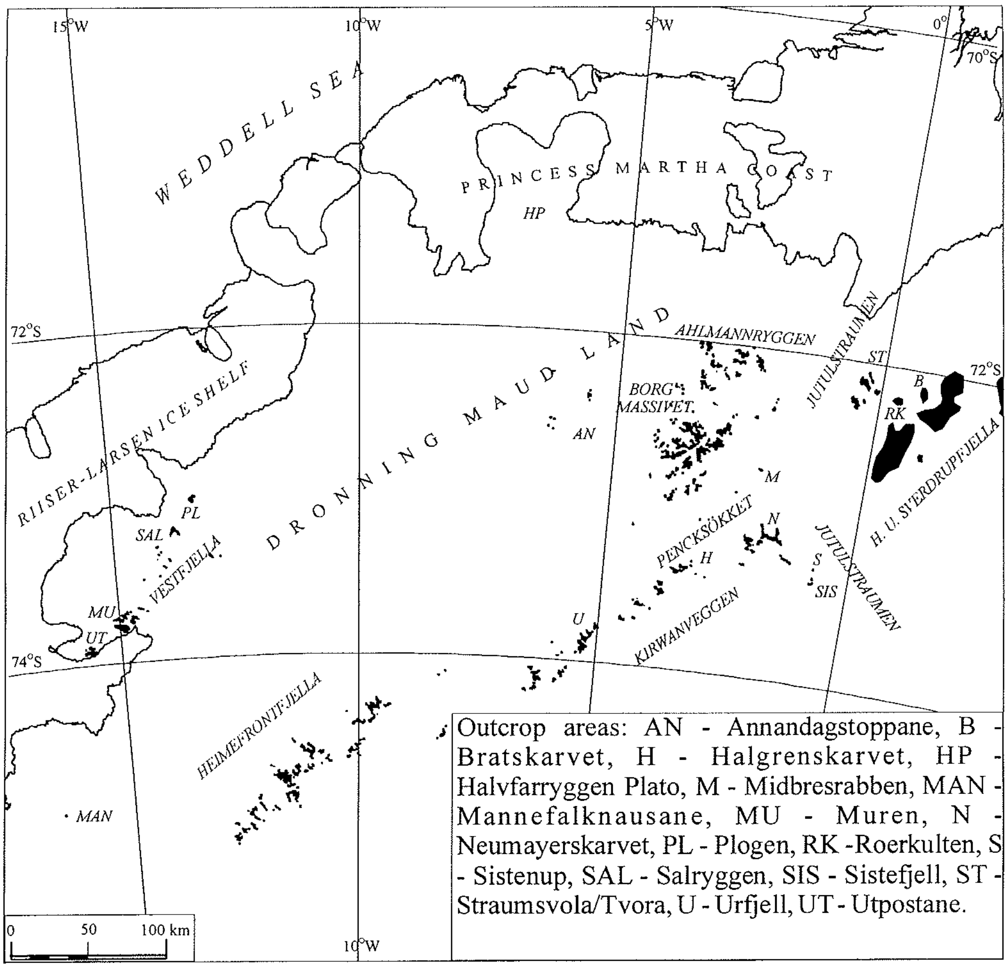

Fig. 9: Location of major outcrop areas in Western Dronning Maud Land.

Abb. 9: Lokation der größten Aufschlussgebiete im westlichen Dronning Maud Land.

cated with a poorly differentiated magnetic pattern of low gradients (<5 nT/km) and low amplitude with dominantly long-wavelengths (100-150 km). The contour levels within the WS zone range from -250-350 nT. This picture, well corresponding to the typical "basin anomaly" pattern, is mostly due to the large thickness of sediment strata reaching 15 km in the central part of the Weddell Sea Embayment (WSE) (KUDRYAVTZEV et al. 1987). Thick sedimentary successions of the WSE basin rest on the down-faulted and substantially reduced upper crust complexes presumably represented by crystalline rocks of the Precambrian and Early Paleozoic age. From the magnetic anomaly pattern the WS zone can be subdivided into three main parts, hereinafter referred to as: Ronne Ice Shelf unit, southern Weddell Sea margin unit and East Antarctica margin unit. It is necessary to note that the northern boundary of the RIS unit is not shown on the interpretation scheme (Fig. 6), two faults running parallel with the shelf-ice break may approximately delineate this boundary.

Ronne Ice Shelf Magnetic Unit

The Ronne Ice Shelf (RIS) magnetic unit is characterized by a relatively smooth magnetic field consisting mainly of long wavelength, low-amplitude anomalies. It was mentioned above that the major grain of magnetic anomalies within the south-western part of the RIS including the Korff Ice Rise indicates that the Haag Nunataks type basement underlies the Ronne Ice Shelf. The rest of the unit is associated with linear lows and highs which run S-N from southern extremity of the map towards outer shelf of the WSE. They terminate close to the northern edge of the ice front and apparently indicate the prominent structural boundary between southern end of the Weddell Sea and the RIS. Two isolated linear positive long-wavelength (~100 km) anomalies with amplitudes up to 150 nT may also suggest possible fault control in the inferred crystalline basement underlying the thick sedimentary sequences.

The dominant feature of the RIS magnetic unit, as well as of the whole WSE, is a broad, up to 250 km in width, depression in magnetic field pattern, which is located just westward from Berkner Island (Fig. 1). This broad low is spatially coincident with deepest part of the WSE basin underlain by highly modified, stretched and subsided continental crust with 15 km sediment fill (KUDRYAVTZEV et al. 1987) due to a period of thermal subsidence following a multiphase rifting, which supposedly occurred since at least early Paleozoic time. The locus of crustal thinning in the upper crust appears to be controlled by preexisting structures.

Southern Weddell Sea Margin Magnetic Unit

The southern Weddell Sea magnetic unit covers the continental rise and the southern part of the Weddell Sea shelf. The structural grain within the unit is not strongly defined in the magnetic field. It is characterized by linear chains of highs and lows, as well as by irregular-shaped or elongated magnetic anomalies. The magnetic anomaly pattern of this unit allows to divide it into two parts - northern and southern. In the northern part of the unit, low-amplitude magnetic anomalies run E-W, however in the eastern extremity the dominant trend of anomalies is NE-SW. The most intensive anomalies with amplitudes up to 350 nT are observed over the shelf edge to continental slope/rise area. The dominant trend of magnetic anomalies of the southern part of the unit is sublatitudial.

The magnetic signature of the southern part of the unit is associated with weak to moderate groups of positive magnetic anomalies which are concentrated around negative background and surrounded also by negative anomalies. This grain is observed over the shelf area southward from the General Belgrano Bank. From the east this grain is superimposed with a linear belt of low-amplitude magnetic anomalies (<50 nT) running NE-SW. It is outlined roughly over the NE-SW striking morphological plateau (Litchner Bank) which bounds by northern continuation of the Filchner Trough. This plateau together with similar one located under Berkner Island forms a continuous sinuous morphological structure with an approximate length of about 850 km. It is worth nothing that this structure along its length is accompanied by positive anomalies of different amplitude and wavelength.

The origin of the magnetic anomalies of the southern Weddell Sea unit is not immediately evident and they may be caused either by infrastructural variations in the crust or by large volumes of magma intruded or extruded during early stages of rifting. While our present knowledge of the discussed area is inadequate to draw any definite conclusions about the processes active at the southern Weddell Sea shelf and margin. We attribute the round-shaped geometry of the magnetic features outlined over the southern Weddell Sea to rifted and/or down-faulted crustal blocks of possibly Late Proterozoic to Early Paleozoic age.

There are some outstanding magnetic anomalies which provide clues to the nature of the underlying basement. Russian aeromagnetic mapping and subsequently the USAC flights along the southern Weddell Sea margins reveal a continuous magnetic anomaly named the Orion Anomaly (OA) by LaBrecque et al. (1986), as a dominant feature along the margin (Ghidella & LaBrecque 1997, LaBrecque & Ghidella 1997). This broad E-W-running low-amplitude anomaly (<200 nT) of 120 km wavelength extends for more than 1100 km from the continental slope area near by the Lassiter Coast towards a region where magnetic anomalies associated with the Andenes plateau were recognized. Changes in trend and form naturally break the OA into four or five 200-250 km segments, one of them associated with the Andenes plateau. The major break in trend of the OA is observed between 40 °W and 35 °W where the anomaly runs NWSE. Further east the anomaly is discontinues and has several significant gaps plausibly to a sparse network of profiles used in compilation. We do not have a definitive explanation for the observed features. A possible explanation is that the segments are caused by large amount of igneous rocks that originated at the time of initial rifting of the Weddell Sea.

East Antarctica Margin Magnetic Unit

One of the most prominent feature of the WS zone is a wide curvilinear belt of positive magnetic anomalies running parallel with the coast of western Dronning Maud Land and Coats Land southwards to Berkner Island. It includes the Explora Anomaly, unnamed magnetic anomalies over adjacent shelf of Coats Land, Druzhnaya Anomaly and the Berkner Island Anomaly and marks the transition between the WS and EA magnetic zones. Magnetic anomalies within the belt reach amplitudes in excess of 300 nT and have an average width of approximately 75-100 km. Four major segments of the belt are characterized by their own distinct set of signs such as wavelength, intensity and structural fabric. This is rather clearly discernible on the shaded-relief map (Fig. 1). More advanced information about the structural pattern of the magnetic field derived from other images including first vertical derivation, horizontal derivation and analytic signal allow (Figs. 2, 3, 5) to suggest that some magnetic features distinguished within the belt may be attributed with geological structures developed in onshore areas. This is obvious for the Coats Land crustal block and the Maudheim Province and to lesser degree for the Shackleton Range and the Grunehogna Province. Nevertheless, we believe that despite the overprinted character of the entire belt regarding to surrounding anomaly grain, its components are caused by the sources originated from different tectonic events during the evolution of the Antarctic continental margin in this region.

Another striking feature of the WS zone is a linear magnetic low with minimum amplitudes less then -300 nT and an average width about 80 km runs southwards from the continental rise to the coast-line. The approximate length of the low is about 900 km. It is associated with the Weddell Sea failed rift of Hinz & Kristoffersen (1987). Three major segments are recognized within this low. The eastern segment can be supposedly outlined eastward from the PSB, although its continuation along WDML margin is not obvious at the moment due to absence of the data. The central segment is observed between the PSB and the continental slope at 32 °W, 74 °S. In comparison with others, this segment is characterized by the largest amplitude (~-300 nT) and width (~90 km). The western segment continues to approximately ice-front where it terminates.

In accordance with our results of depth estimation to the magnetic sources (Fig. 8), the above-mentioned low roughly corresponds to a broad linear depression divided by high-lying basement structures over Coats Land from low-lying over the southern shelf of the Weddell Sea. The depth to the magnetic basement reaches more than 14 km along the axis of the depression. This is in conflict with multichannel seismic data that shows approximately 9 km to the acoustic basement (Jokat et al. 1996).

CONCLUSIONS

The regional magnetic data analyzed in this study reveal the presence of numerous basement anomalies that may reflect major geologic features and provide considerable insight into the complex structural relations of the Weddell Sea region. In general, the aeromagnetic anomaly map shows the form and extent of magnetically distinct structural zones, imaging deep geological crustal sources.

Six magnetic units are clearly recognized within East Antarctica and are characterized by a wide variety of magnetic anomaly patterns. A rather distinct boundary exists between the northern Grunehogna unit associated with a broad, featureless magnetic low and the southern Maudheim Province unit, whose magnetic signature is a series of alternating bands of elongated positive and negative anomalies. The southern boundary of the Maudheim Province is also sharply defined by steep horizontal gradients.

Geologically, the GU unit corresponds to the cratonic Grunehogna Province which consists of Archean granite basement and bounded from the south and east by the highly deformed Mesoproterozoic orogenic belt. Our observation evidenced that bulk of positive magnetic anomalies coherently running with geologic structures of the mobile belt is apparently corresponded to orthogneisses, whereas negative anomalies mainly observed over the areas where metasedimentary rocks are largely recognized. The pattern of magnetic anomalies over Coats Land seems to define the extent of the Coats Land crustal block and delineates structural elements and characteristic trends of the Shackleton Range.

The West Antarctic magnetic zone comprises the Palmer Land and Haag Nunataks units; both are mainly characterized by short-wavelength magnetic anomalies (<50 km) whereas their trends are discordant to each other.

Magnetic anomalies of the Weddell Sea Embayment are smooth and uncomplicated because of the thick sedimentary cover. Three major magnetic units are recognized within it. The most pronounced feature of the WS zone is a wide curvilinear belt of positive magnetic anomalies running parallel with the coast of western Dronning Maud Land and Coats Land southwards to Berkner Island. It includes the Explora Anomaly, the Druzhnaya Anomaly and the Berkner Island Anomaly and marks the transition between the WS and EA magnetic zones. We believe that these anomalies are caused by the sources originated from different tectonic events during the evolution of the Antarctic continental margin in this region. Many additional anomalies and lineaments are observed within the Weddell Sea region that have yielded important clues to the tectonic framework, in characterizing the continental crust and interpreting its geological history.

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