Proc. NIPR Symp. Antarct. Geosci., 9, 24–39, 1996

MAGNETIC ANOMALIES OF PRECAMBRIAN TERRANES OF THE EAST ANTARCTIC SHIELD COASTAL REGION (20°E–50°E)

Alexander V. GOLYNSKY[1], Valery N. MASOLOV[2], Yoshifumi NOGI[3], Kazuo SHIBUYA[3], Chris TARLOWSKY[4] and Peter WELLMAN[4]

[1]*VNIIOkeangeologia, 1, Angliysky Avenue, 190121, St. Petersburg, Russia*
[2]*Polar Marine Geological Research Expedition, 24, Pobeda St., 189510, Lomonosov, Russia*
[3]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*
[4]*Australian Geological Survey Organisation, P.O. Box 378, Canberra 2601, Australia*

Abstract: Extensive regional magnetic survey flights with a line-spacing of about 20 km were conducted by Polar Marine Geological Research Expedition (PMGRE) in 1972, 1986, 1988 and 1990 over the 20°E–50°E coastal region of East Antarctica. The flights total more than 34000 line-km of total magnetic intensity data acquired along north-south trending profiles. Magnetic anomaly maps compiled from digital data provide a synoptic view of major magnetic anomalies and the corresponding tectonic/geologic features of the Eastern Dronning Maud Land nd the Western Enderby Land. Availability of digital data allowed an application of various enhancement techniques and provided new interpretative information from the magnetic anomalies. The filtered and shaded relief maps have characteristic anomaly patterns (trends, amplitudes and wavelengths) which correlate with Precambrian tectonic features of the extensive Late Proterozoic area, and of the Archaean cratonic block of Enderby Land (Napier Complex). Of particular interest is the linear magnetic anomaly observed along the continental slope and shelf area; the Antarctic Continental Margin Magnetic Anomaly, ACMMA. This is a continental-scale crustal discontinuity formed during the Gondwana breakup.

The archived aeromagnetic data will serve as the database for future production of the 'Digital Magnetic Anomaly Map of Antarctica' in the framework of the Scientific Committee on Antarctic Research/International Association of Geomagnetism and Aeronomy (SCAR/IAGA) compilation.

key words: magnetic anomaly, 20°E–50°E, 1:10000000 map, ACMMA, Precambrian terrane

1. Introduction

Analyses of magnetic anomaly maps must play an essential role in interpreting the tectonic evolution of the Precambrian East Antarctic Shield (EAS), because the magnetic anomalies and inferred distribution of upper crustal magnetized rock units convey new information on geological structures. The magnetic anomaly map, together with other geophysical maps and geological data, allow us to identify the main tectonic elements of the EAS. The aeromagnetic survey is especially useful over regions such as East Antarctica where basement outcrops are sparse and covered by thick ice or buried under sediments.

Extensive regional magnetic survey flights over the coastal region of East

Antarctica were conducted by Polar Marine Geological Research Expedition (PMGRE), Lomonosov, Russia in 1972, 1986, 1988 and 1990. Because these airborne surveys were carried out at different elevations, with different type of the aircraft, over a period of 18 years, sophisticated reduction methods were used to compile a consistent data set. The reduction procedure is described below.

The surveys covered the coastal regions up to 400 km inland along with adjacent shelf area from 0° as far as 90°E. This report summarizes the magnetic anomalies over the portion of 20°E–50°E region. All of the Russian aeromagnetic data were compiled in a digital form and were processed at the Australian Geological Survey Organisation (AGSO), Canberra, Australia. The magnetic anomaly maps produced by joint effort of VNIIOkeangeologia (St. Petersburg, Russia), PMGRE and AGSO can be used not only as an useful tool for interpretation and enhancement of the geological/tectonic structures, but can serve as the database for future production of the 'Digital Magnetic Anomaly Map of Antarctica' in the framework of the Scientific Committee on Antarctic Research/International Association of Geomagnetism and Aeronomy (SCAR/IAGA) compilation.

2. Aeromagnetic Surveys

The research region consists of three areas. It was covered by the four regional aeromagnetic surveys as illustrated in Fig. 1. The flight profiles were designed and flown by PMGRE. Area 1 spreads over the western part of Enderby Land and was flown in 1972 by Soviet Antarctic Expedition 17 (SAE-17). This area was overflown almost in the same scale in 1986 (SAE-31) when aeromagnetic survey was

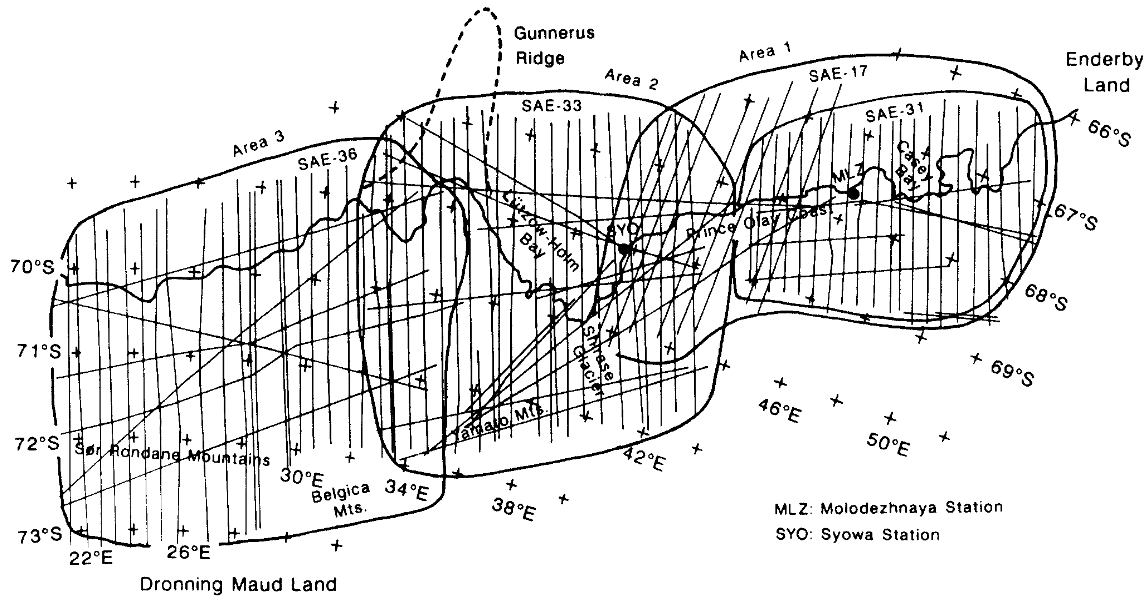


Fig. 1. Aeromagnetic survey flights by the former Soviet Antarctic Expeditions between 20°E and 50°E. A total of 110 profiles covered the three sub areas of the coastal region: Area 1, Western Enderby Land, by SAE-17 and SAE-31; Area 2, Prince Olav Coast, Shirase Glacier and Yamato Mountains, by SAE-33; and Area 3, Eastern Dronning Maud Land, by SAE-36.

accomplished simultaneously with gravity and radio-echo sounding measurements. The survey flights completed by SAE-33 in 1988 (Area 2) covers the Prince Olav Coast and the Shirase Glacier areas including Yamato Mountains. Area 3 corresponds to the eastern part of Dronning Maud Land and was covered by the SAE-36 (1990) flights.

The most significant differences between the above regional surveys are in the type of the aircraft, measuring equipment, navigation systems and recording techniques. During the first three expeditions the total intensity values of the magnetic field were measured using a proton precession magnetometer (resolution 1 nT) installed in an Ilyushin Il-14 ski-equipped aircraft with a sensor mounted in a 5 m tail stinger; the aircraft was partly magnetically compensated. Positioning was controlled by the combined use of DISS Doppler radar and flight-path camera which was electronically synchronized with the enforcing current of the magnetometer. Position uncertainty is generally of the order of 1–2 km, but sometimes as much as 3–5 km especially over the featureless terrain during the SAE-17 flights.

Surveys were carried out along north-south (NS) trending flight-lines at an average spacing of 20 km and made at an altitude of 2000–2500 m above sea level. The recording equipment throughout the period of the SAE-17 surveys comprised only an analog chart recorder, while digital recording of the total magnetic intensity and navigation data for SAE-31 and SAE-33 surveys was based on the Graviton digital data acquisition system, which was specially developed for scientific installation in the aircraft. The total intensity data were sampled at an interval of 1 s with a flight speed of 4 km/min, which approximated spatial sampling of every 60–70 m along the profiles.

The SAE-36 aeromagnetic data were collected from a long-range IL-18 aircraft fitted with cabin-mounted proton magnetometer sensors, which were integrated to a personal computer (PC)-based data acquisition system. Standard pseudo-range Global Positioning System (GPS) navigation was applied. A digital pressure

Table 1. A summary of SAE survey flights.

Item\expedition	SAE-17	SAE-31	SAE-33	SAE-36
Area	West Enderby Land	Enderby Land	Yamato Mountains	Sør Rondane Mountains
	Prince Olav Coast	Prince Olav Coast	East Dronning Maud Land	East Dronning Maud Land
Survey epoch	1972	1986	1988	1990
Aircraft	IL-14	IL-14	IL-14	IL-18
Sensor	Proton magnetometer	Proton magnetometer	Proton magnetometer	Proton magnetometer
Recorder	Analog chart	Digital cassette	Digital cassette	Digital cartridge
Flight speed	~4 km/min	~4 km/min	~4 km/min	~7 km/min
Flight hight	2000–2500 m	2000–2500 m	2000–2500 m	4000–4500 m
Footprint distance	60–70 m	60–70 m	60–70 m	110–120 m
Position control	Flight-path camera & DISS Doppler	Flight-path camera & DISS Doppler	Flight-path camera & DISS Doppler	GPS

transducer and a radar altimeter were used for altitude determination. The data acquisition was made at an interval of 1 s with a flight speed of about 7 km/min, which translated to an average spacing of 110–120 m between sampled data. The survey flights were conducted along NS trending flight-lines at an average spacing of 20 km between profiles with an elevation of roughly 4000 m above sea level.

A base station magnetometer was installed at Molodezhnaya Station (Fig. 1) to monitor diurnal variations during the survey flights. Flights were restricted to epochs of low external magnetic activity when possible.

Total flight distance within the whole region was 34000 km. An area 300–450 km (north-south) by 1300 km (east-west) was covered by a total of 110 profiles. A summary of survey flights is presented in Table 1.

3. Data Processing

The compiled aeromagnetic data consist of digitally recorded total intensity values (SAE-31, SAE-33, SAE-36) and digitized intensity values from the analog profiles obtained by SAE-17. The flight-path-recovery procedure and primary reduction of the profile data was carried out by PMGRE for each survey data set. The magnetic profiles were filtered to remove high-frequency noises due to interference from aircraft electrical systems. The profiles were corrected for diurnal variations of the external magnetic field using the temporal variation data collected with a ground-based magnetometer at Molodezhnaya Station (see Fig. 1).

Profiles and tie-lines were subjected to a leveling procedure in which the differences among the intersection points were minimized using a least squares fit. After assignment of the geodetic (latitude and longitude) coordinates to all point data, time-extrapolated International Geomagnetic Reference Field 1985 (IGRF 1985) model values (BARRACLOUGH, 1985) at the observation epoch were computed and subtracted from the total intensity data.

The core field for the SAE-17 (1972) data set was calculated by averaging of the total-intensity magnetic field measured during the surveying. It is obvious that this reference field can not completely account for the secular variation over the time elapse of 18 years. Because of this, there are large mis-ties between this survey and later surveys. Thus the data acquired after 1986 were chosen as a base level for controlling the compilation.

As an independent check of the compilation, the reduced data on the west-east (WE) running tie-traverse profiles (Fig. 1) flown specially in 1988 were compared over the overlapping SAE-31, SAE-33 and SAE-17 areas. After adjustment to these traverses, the compiled digital magnetic anomaly data on the profiles over the three survey areas is considered consistent to within 15–25 nT.

4. Gridding and Image Processing

The geodetic coordinates of the profile data were converted to the rectangular (x-y) coordinates, using a polar stereographic projection with a central meridian of 60°E longitude and standard parallels of 71°S and 90°S latitudes. This projection is the same as that used for the other Russian magnetic anomaly maps of East Antarctica (*e.g.*, GOLYNSKY *et al.*, 1995).

Data processing was made by applying the Intrepid geophysical image processing and visualization tool package (DESMOND FITZGERALD & ASSOCIATES PTY LTD., 1995) on a SUN-4 workstation at AGSO. The magnetic anomaly data were averaged to an equally spaced grid value by using a program based on a minimum-curvature algorithm (BRIGGS, 1974). This procedure takes into account randomly distributed values and generates a smooth surface, especially in areas of sparse data. The grid interval was selected as 5 km at one quarter of the flight line spacing.

An examination of the preliminary pseudo-color contoured maps (50 nT intervals) revealed residual errors in the form of spurious elongated anomalies (SEAs), which may be attributed to errors in tie-line unleveling, or to inadequately corrected diurnal variations. The Intrepid's SEA Decorrugation tool (DESMOND FITZGERALD & ASSOCIATES PTY LTD., 1995) was used for eliminating these errors from the grid, and the Microleveling tool was applied to correct the profile dataset. The data from the SAE-17 set were excluded for further processing when the corresponding overlapping data from the SAE-31 and SAE-33 sets were available, because the data quality of the SAE-17 set is comparatively poorer than the other three expedition data sets.

In the process of merging grids to obtain the final data set, contour maps from each data set were overlain in order that the dividing line drawn between data sets could pass through areas of the lowest gradient. The first-order fit along the boundary was calculated, and this surface was subtracted from one data set. The remained discrepancies were removed by applying a Laplacian differential equation to the residual errors in order that the smoothest surface consistent with the boundary differences can be achieved.

Various filtering techniques were employed to enhance the characteristic features of the obtained anomalies. These included reduction to the pole, upward continuation, vertical derivatives, wave-number filtering, etc. The obtained final grid set was transferred into the ER Mapper software system (EARTH RESOURCE MAPPING PTY LTD., 1993) at AGSO where all image processing was carried out.

The magnetic anomaly map with a contour interval of 50 nT is shown in Fig. 2 (scale 1:10000000). This map presents the primary information, though details can not be detected. Shaded relief image (Fig. 3) was produced by using a sun-angle routine with artificial illumination from northwest (315°) and an inclination of 45°, by applying a two-dimensional gradient transform to the gray-scale image. The color-coded magnetic anomaly map (Fig. 4) was created by applying a blue-red color table. As for Fig. 5 of the reduced-to-the-pole magnetic anomaly map, the grid values were scaled to a range of 256 using histogram-equalization and the values were converted into a 3-band pseudo-colored image by using the RGB (Red, Green, Blue) combinations. In the process of reducing the magnetic anomalies to the pole, we assumed that the observed anomalies are induced by a magnetic field with an inclination of $-64°$ and a declination of $-40°$.

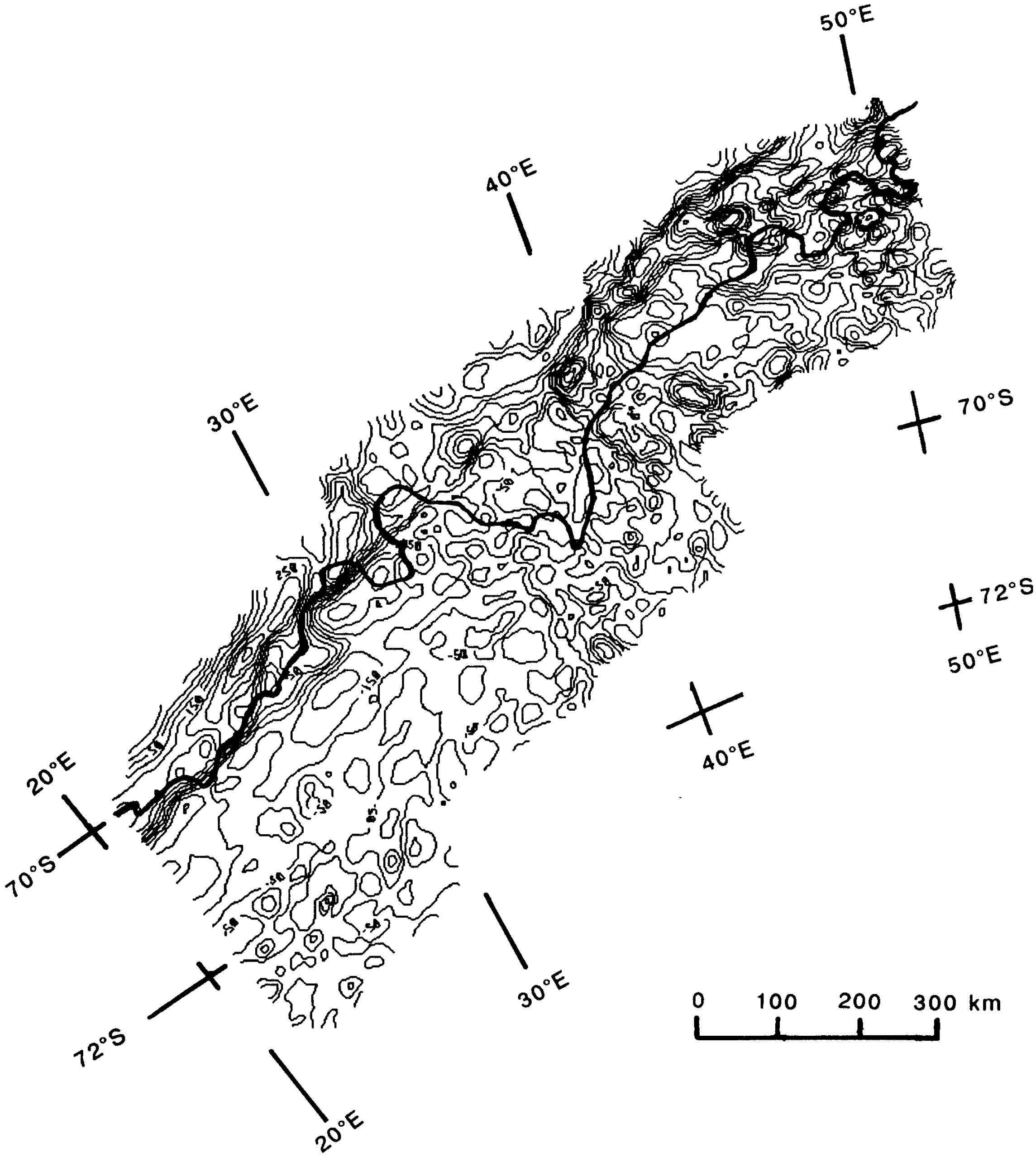


Fig. 2. Aeromagnetic anomalies over the coastal region of East Antarctica in the sector 20°E–50°E (1:10000000). Contour interval is 50 nT.

5. Characteristic Features of the Magnetic Anomalies of Main Geologic Terranes

The magnetic anomaly map (Fig. 2) depicts rather complex crustal–magnetization pattern with an amplitude range of almost 7500 nT. The contour levels range from −250 nT to 1200 nT. Color and shaded-relief images shown on Figs. 3–5 convey information on both anomaly amplitude and anomaly gradient. They highlight structural trends, lineaments and textural contrasts which are not easily discernible on

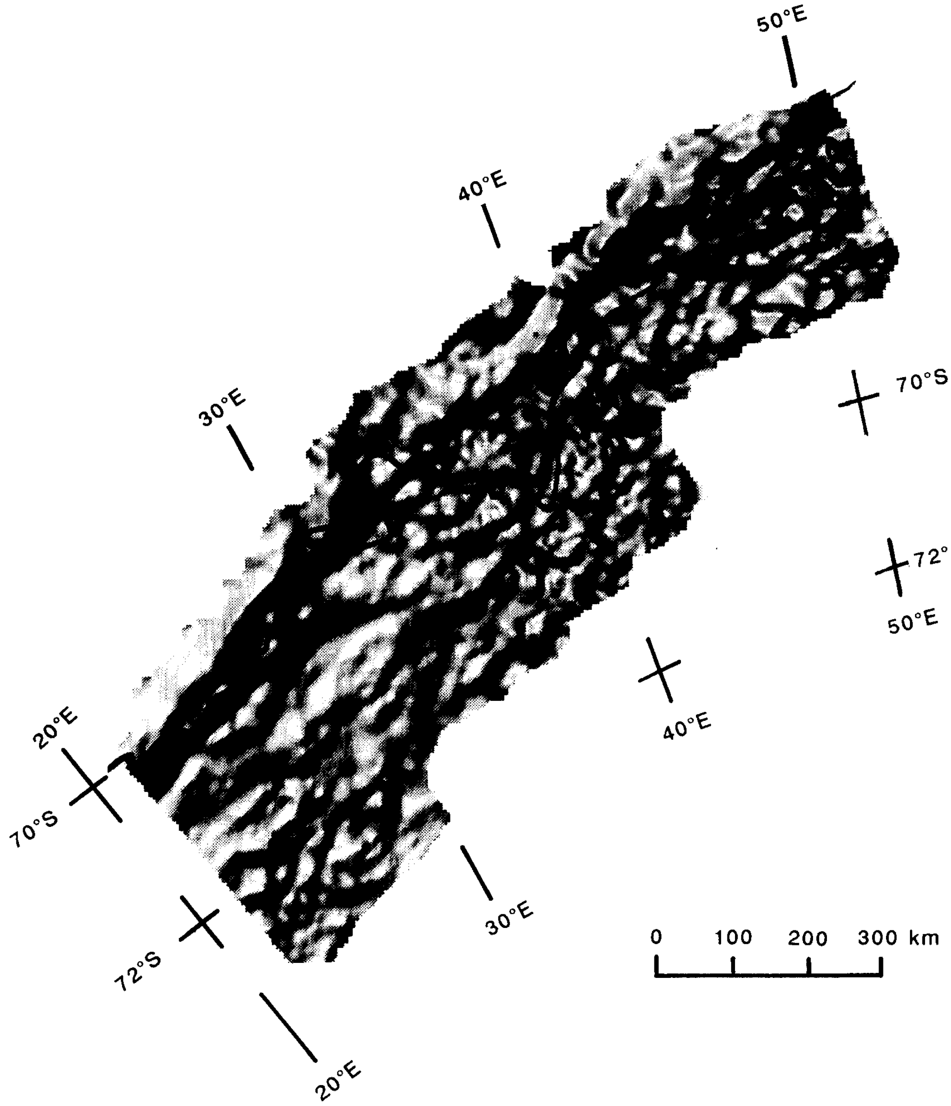


Fig. 3. Shaded-relief map of the magnetic anomalies over the coastal region of East Antarctica in the sector 20°E–50°E (1:10000000), which is illuminated from northwest (315°) with an inclination of 45°. For illustration, original map was reduced in scale to 84%.

standard contour map, and it is interesting to compare them with known geologic provinces or terranes.

5.1. *Enderby Land*

GRIKUROV (1982), KAMENEV (1982), RAVICH and KAMENEV (1975), BLACK *et al.* (1987) and SHERATON *et al.* (1987) have subdivided the Precambrian Antarctic Shield on the basis of geology and radiometric ages. For example, the crustal boundary between the Archaean Napier Complex and the Late Proterozoic Rayner Complex is traditionally drawn from the Edward VIII Gulf region through the thick-ice covered central part of the Enderby Peninsula into Casey Bay (Fig. 6; modified from BLACK *et al.*, 1987). However, it should be noted that the study area has only a small region of

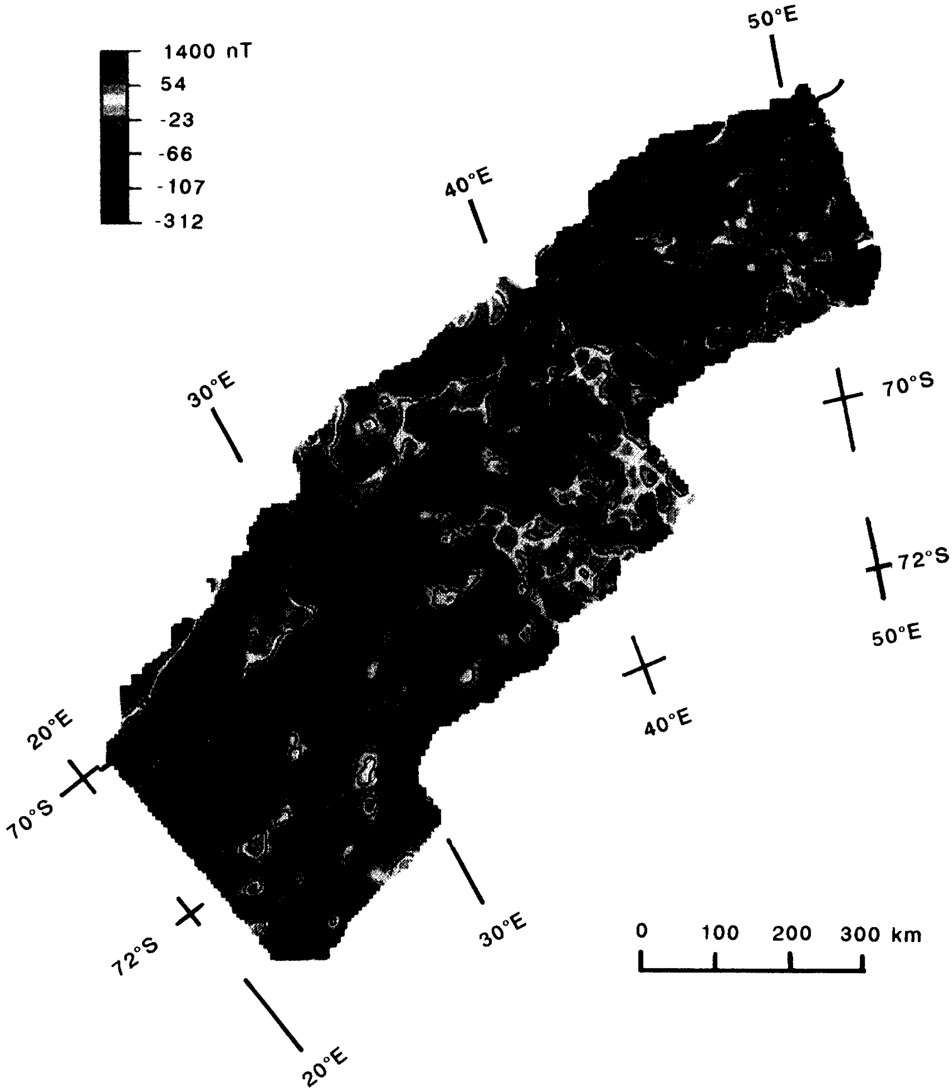


Fig. 4. Color-coded magnetic anomalies over the coastal region of East Antarctica in the sector 20°E–50°E (1 : 10000000). Note that the color legends are not linearly divided. For illustration, original map was reduced in scale to 84%.

exposed rocks, and these are mainly in the east. All aeromagnetic data acquired to date over Enderby Land and MacRobertson Land were used in the subsequent analysis to have a better view of the magnetic anomalies as shown in Fig. 7.

The magnetic anomalies over the Napier Complex region are generally higher than those over the adjacent Rayner Complex region. A band of even higher anomalies occurs over the boundary between the two complexes. Within the Napier Complex the amplitude and wavelength of the anomalies are thought to reflect lithology of the high-grade granulites. Granitic and meta-sedimentary rocks of the Tula and Napier Mountains (*e.g.*, RAVICH and KAMENEV, 1975) correlate with magnetic lows, while orthogneisses in the Scott Mountains correlate with elongated magnetic highs (100–500 nT). Localized iron-banded formations can give rise to maximum amplitude of 7500 nT.

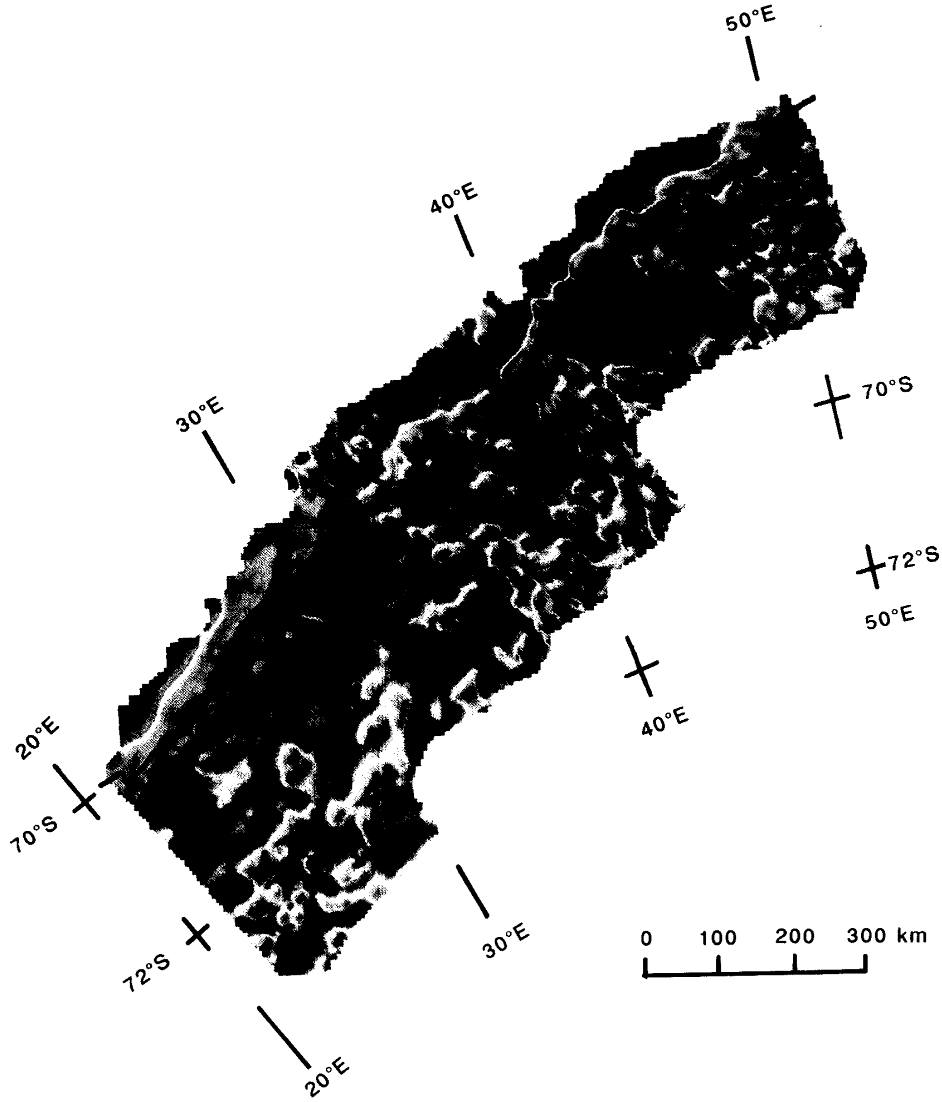
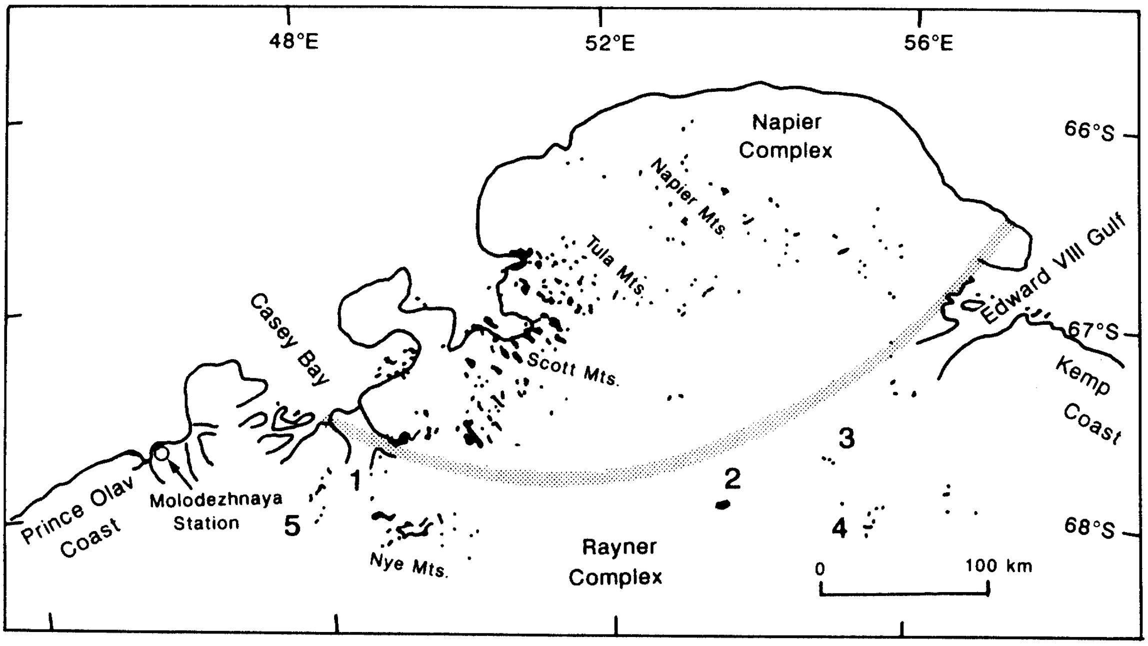


Fig. 5. Similar color-coded reduced-to-pole magnetic anomalies with the range of 256 after the scaled histogram equalization method. We assumed that the observed anomalies are induced by the magnetic field with an inclination of −64° and declination of −40°. For illustration, original map was reduced in scale to 84%.

North of Knackey Peaks and Doggers Nunataks is an area of no exposure, and extremely complicated, high-amplitude (500–2800 nT) anomalies. The anomalies trend east-west, and form a huge magnetic block (150–350 km) of irregular shape (see Fig. 7). This block consists of two units and two offsets trending northeast. The northern unit is characterized by moderate-amplitude anomalies, whereas southern unit displays high-intensity anomaly with strong magnetic gradient associated with the Knackey Peaks–Doggers Nunataks line (see Figs. 6 and 7). The boundary between the two units is outlined by relative low and may correspond to the boundary between the Napier and Rayner Complexes. Geologically the southern offset of this block is related to meta-igneous rocks, while the northern offset (no outcrops) may be



1. Condon Hills 2. Knackey Peaks 3. Doggers Nunataks 4. Dismal Mountains 5. Mount Christensen

Fig. 6. Sketch of the Enderby Land area for comparison with the obtained magnetic anomalies over the region concerned. Modified from BLACK *et al. (1987).*

associated with meta-sedimentary rocks with iron formation (KAMENEV, 1975). Moreover, the broad magnetic low between the above two offsets is related with the Tula metasediments according to RAVICH and KAMENEV (1975). Therefore the whole magnetic block must be associated with Archaean granulites, or at least, can be interpreted as reworked zone of ancient protocraton.

The magnetic expression is generally low over areas of upper amphibolite to lower granulite facies rocks of the Rayner Complex. Magnetic highs of moderate amplitude (100–300 nT) are observed only around Molodezhnaya Station, Mount Christensen, Nye Mountains and Condon Hills (Figs. 6 and 7). These magnetic highs are apparently associated with tonalitic to granitic orthogneisses (RAVICH and KAMENEV, 1975; KAMENEV, 1975). The chain of irregular magnetic anomalies with amplitudes of 400 nT, between the southern extremity of Nye Mountains and Prince Olav Coast, may also be related to similar rocks of similar age.

Recent aeromagnetic data (see Fig. 7) indicate that magnetic features can be traced from eastern Nye Mountains, east to the Dismal Mountains area, then northeast to Kemp Coast, and then further east into MacRobertson Land following Precambrian structures. These magnetic anomalies form a broad negative belt with more than 200 km width, and group into linear zones of lows and abundant low-intensity linear zones of highs. It is most plausible that magnetic anomalies are mainly caused by supracrustal rocks (Condon Seria by RAVICH and KAMENEV, 1975), which are distributed widely throughout Enderby Land.

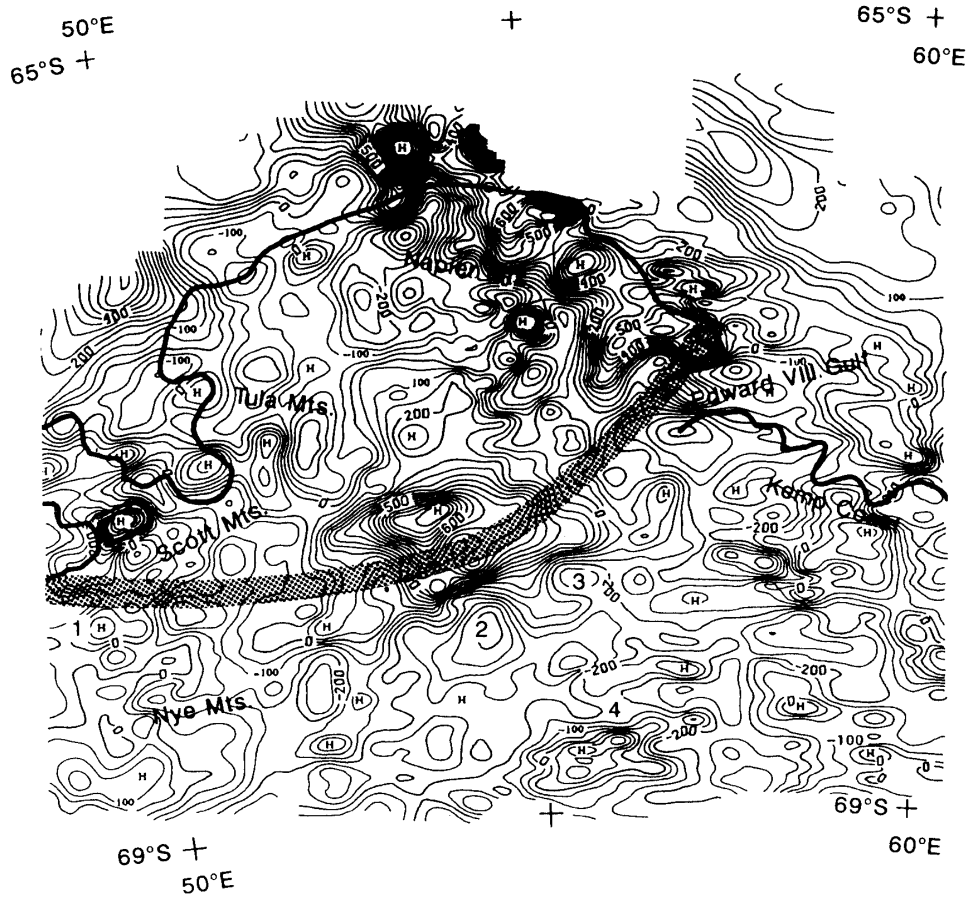


Fig. 7. Detailed magnetic anomaly map over the Napier and Rayner Complexes, Enderby Land. Contour interval is 50 nT.

5.2. *Prince Olav Coast*

The magnetic anomalies over Prince Olav Coast are strongly negative and they are parallel to the general east-west strike of the metamorphic sequences (YOSHIDA and VITANAGE, 1993; YOSHIDA, 1994; see Figs. 2–5). Broadened and subdued anomalies within the lows may be related with psammitic and granitic rocks of the Prince Olav Coast (YOSHIDA, 1994), comprising the Okuiwa Group (YOSHIDA and VITANAGE, 1993), and Hinode and Olav Series (RAVICH and KAMENEV, 1975). The similarity between the magnetic anomaly pattern of the Prince Olav Coast area on the west and the Kemp Coast area on the east allows us to regard these two prominent units as an indivisible magnetic belt. This must align with structural grain of the Rayner Complex originating during the 1100 Ma event (BLACK *et al.*, 1987).

Thus our interpretation on the Prince Olav Coast area is not consistent with a Cambrian orogenic belt striking from Yamato Mountains to Molodezhnaya Station (SHIRAISHI *et al.*, 1994), or a Late Proterozoic Prince Olav Complex (YOSHIDA, 1994). The boundary between the Rayner and Lützow-Holm terrane (Fig. 8) can clearly be identified from appearance of 350 nT amplitude anomaly block (40°E–42°E in Fig. 2) over the offshore and the ice-covered interior of the Prince Olav Coast and from difference of anomaly trends on both sides of the above block.

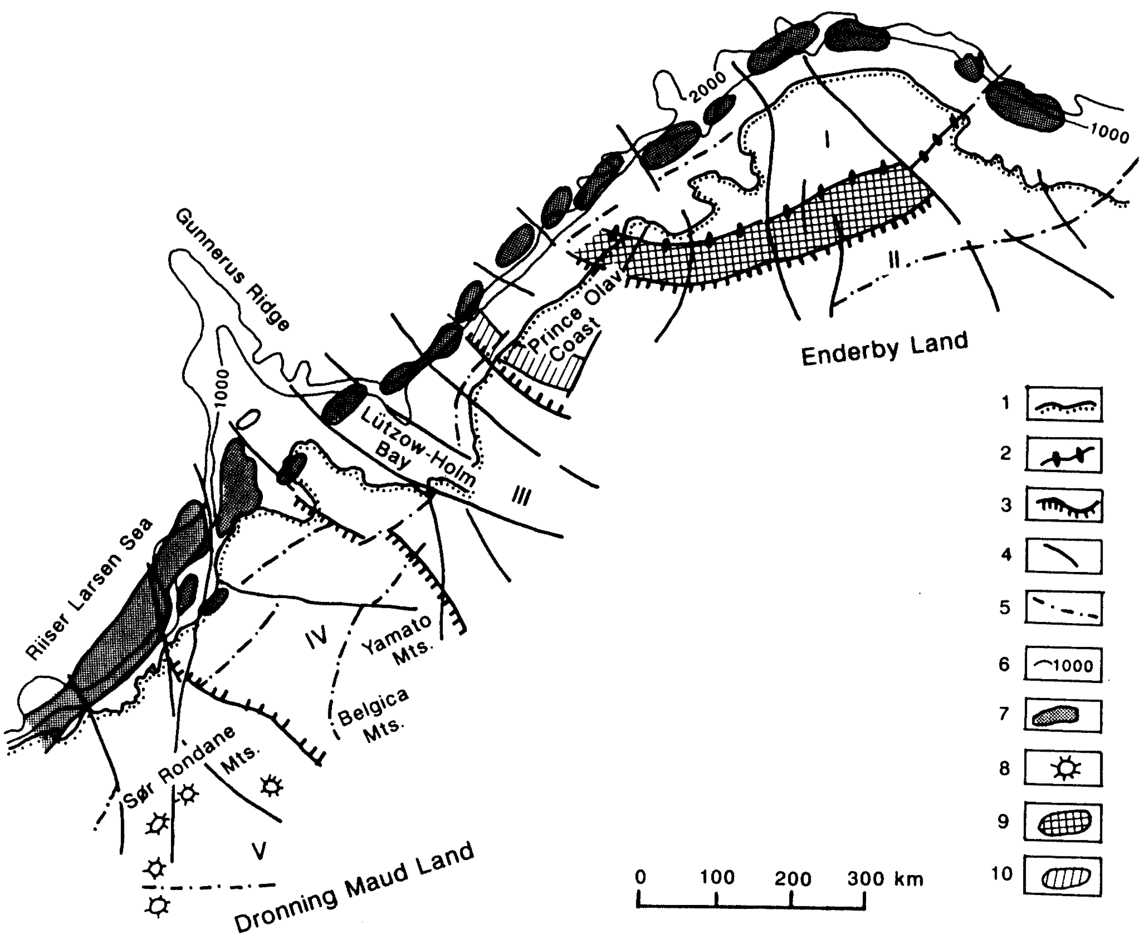


Fig. 8. Summary of the magnetic anomaly features of the studied area. Legends are: 1, Coastline; 2, Geological boundary between the Napier and Rayner Complexes; 3, Boundary between magnetic terranes; 4, Normal faults; 5, Lineaments; 6, Bathymetric contours in meters; 7, ACMMA-Antarctic Continental Margin Magnetic Anomaly; 8, Short-wavelength magnetic anomalies within the Sør Rondane terrane; 9, Oval band of high-intensity magnetic anomalies associated with transition zone between the Napier and Rayner Complexes (reworked zone of Napier Complex); 10, Area of moderate-amplitude anomalies associated with transition zone between the Rayner and Lützow-Holm Complexes. Roman numbers are: I, Napier terrane; II, Rayner terrane; III, Lützow-Holm terrane; IV, Yamato-Belgica terrane; and V, Sør Rondane terrane.

5.3. *Lützow-Holm Bay*

The Lützow-Holm terrane has few exposures, but it can be defined on the magnetic anomaly maps. It has a width of about 250 km. The terrane has elongated/fragmented magnetic highs and intervening lows with north to northwest trends, except for west trends in the extreme south region (Fig. 4). The magnetic anomalies are terminated in the offshore area by the continental margin magnetic anomaly which roughly coincides with the continental slope. The shaded-relief map (Fig. 3) is particularly effective for delineating low-amplitude features which can not clearly be identified on the ordinary contour map (Fig. 2). It reveals numerous short-wavelength magnetic patterns which indicate shallow basement origin underlying Lützow-Holm Bay and Gunnerus Ridge (Fig. 1).

Several crosscutting lineaments appear in Figs. 4 and 5. The most outstanding one corresponds to the fault system of the Shirace Glacier graben and its continuation into the eastern margin of Gunnerus Ridge. Although little is known on sources of magnetic anomalies, ground magnetic measurements over Ongul Islands around Syowa Station (Fig. 1) showed that only orthogneisses can produce magnetic highs of 600–900 nT amplitude (NIKKI *et al.*, 1981). Pink granites are also associated with magnetic highs, but they are sparse, and their horizontal extent is very limited (NIKKI *et al.*, 1981).

Magnetic anomaly pattern of the Lützow-Holm Bay area is very similar to that observed over the Northern Prince Charles Mountains area (GOLYNSKY *et al.*, 1995). Both areas are formed of the Late Proterozoic rock (Beaver Belt of KAMENEV *et al.*, 1993). They may form one geological unit that is continuous under ice-covered interior of East Antarctica.

The western boundary of the Lützow-Holm terrane also stands out by the abrupt change of the magnetic anomaly pattern. This boundary can be outlined eastward to the Yamato Mountains along 36.5°E with break at 70°S and then continues with north-northwest turn to the western margin of Gunnerus Ridge (see also Fig. 8).

5.4. *Yamato-Belgica Mountains*

The magnetic-low area with a few subdued highs over the Yamato-Belgica terrane corresponds mainly to meta-sedimentary gneisses and granitoids of amphibolite facies grade (YOSHIDA and VITANAGE, 1993). It is noted that metamorphic rock samples from some locations of the Yamato Mountains have no measurable magnetic susceptibility (SHIBUYA *et al.*, 1987). Aeromagnetic surveys by the Japanese Antarctic Research Expedition with flight-line spacing of 5–10 km over the Yamato Mountains (SHIBUYA *et al.*, 1987) indicate that magnetic features trending north-south follow geological structures.

There is no consensus to the tectonic interpretation of the Yamato-Belgica terrane and the Lützow-Holm Bay–Prince Olav Coast area. For instance, HIROI *et al.* (1991) thought that the Lützow-Holm Complex comprised a suture-zone with southward subduction between the Yamato-Belgica Complex to the southwest and the Rayner Complex to the northeast, while YOSHIDA (1994) thought that the vergency analysis of the Ongul-Skallen Groups was inconsistent with the southward subduction model. The concept of southward subduction in single continental block is, we believe, not in agreement with the magnetic trends.

The western boundary of the Yamato-Belgica terrane is not sharply defined by the magnetic anomalies. It is defined by unpublished Russian gravity and radio-echo sounding data.

5.5. *Sør Rondane Mountains*

The anomaly pattern of the Sør Rondane Mountains is relatively subdued. Anomalies are low-amplitude and short-wavelength (Fig. 3). The structural grain is generally not well defined. However, the more prominent highs form an arc with concave southward configuration; these highs can be attributed to metamorphic rocks of amphibolite facies grade (VAN AUTENBOER, 1969). The metamorphic rocks of greenschist facies grade (KAMENEV, 1982; SHIRAISHI *et al.*, 1991) are mainly associated with low-amplitude negative anomalies.

The two neighboring terranes (Sør Rondane and Yamato-Belgica Mountains) have different structural features. The difference is clearly seen in the outcrop geology and is less clear in aeromagnetic anomalies. The structural grain of the Sør Rondane terrane trends east, turning southeast at its eastern extremity, while the structural grain of the Yamato-Belgica terrane trends northerly (IVANOV and KAMENEV, 1990; OSANAI *et al.*, 1992; YOSHIDA, 1994).

5.6. *Antarctic continental margin*

The most important structural discontinuity of the offshore area occurs at the Antarctic continental margin. Overlying the margin is a prominent positive magnetic anomaly belt (Antarctic Continental Margin Magnetic Anomaly; ACMMA). This extends from Enderby Land to Dronning Maud Land, and westward towards the Weddell Sea (JOHNSON *et al.*, 1992). The anomaly is due to continental crustal discontinuities, that were formed during the Gondwana breakup. The ACMMA has a width of 120 km, with maxima of moderate- to short-wavelength anomalies of 150–600 nT. It is broadly curvilinear in shape and shows several changes in amplitude and pattern. Three segments can clearly be identified on the maps.

The western segment extends along coastal region of Dronning Maud Land from western extremity of the map (Fig. 4) to western margin of Gunnerus Ridge, where it bifurcates. In this part of the map the ACMMA is adjacent to large negative anomalies over onshore coastal area. The central segment corresponds to the Lützow-Holm Bay and Prince Olav Coast areas. In this sector the anomaly consists of a low to the north, and a less prominent low to the south. The eastern segment has large amplitudes (500–600 nT) and extends from Casey Bay to Edward VIII Gulf region, where it terminates. The differences among segments of the ACMMA suggest that rifting of the Antarctic continental margin resulted in different structures in the margin.

6. Summary

The magnetic anomaly map of the Eastern Dronning Maud Land and the Western Enderby Land has numerous basement anomalies that must correlate with major geologic features. The amplitudes and wavelengths of these anomalies vary considerably reflecting a complex history of lithologies and structures. The boundaries of the East Antarctic Shield terranes of various ages are distinguished from the change of magnetic anomaly pattern as summarized in Fig. 8.

The boundary between the Napier terrane and the Rayner terrane is delineated by the oval band of high-intensity magnetic anomalies. The Napier terrane displays a complex magnetic trends which reflect the lithology of granulites. Meta-sedimentary rocks and granitoids are associated with magnetic lows, whereas orthogneisses correlate with magnetic highs.

A broad magnetic-low belt extends from Prince Olav Coast (western side) towards MacRobertson Land (eastern side). It has at least 100 km width at the boundary between the Napier and the Rayner terranes. From the similarity of magnetic anomaly patterns of both the western and eastern sides, these two prominent units are thought to be an indivisible belt. It must align with the meta-sedimentary rocks of the Rayner Complex. The difference of the anomalies within the belt can be explained by the difference of metamorphic grade and lithology.

The Lützow-Holm terrane extends from the eastern side of the Lützow-Holm Bay to the eastern margin of the Yamato Mountains. It has elongated and fragmented magnetic highs and intervening lows which correlate with the rocks metamorphosed under granulite facies conditions. The boundary between the Lützow-Holm terrane and the Yamato-Belgica terrane stands out by an abrupt change of the magnetic fabric.

Magnetic-low area with subdued highs on the Yamato-Belgica terrane corresponds with meta-sedimentary gneisses and granitoids of amphibolite facies grade. The boundary between the Sør Rondane terrane and Yamato-Belgica terrane is not obvious in the aeromagnetic data.

There is a prominent positive magnetic anomaly belt along the continental slope and shelf area, which we call the Antarctic Continental Margin Magnetic Anomaly (ACMMA). The ACMMA extends from Enderby Land to Dronning Maud Land, and further westward towards the Weddell Sea. The ACMMA is due to continental crustal discontinuities that were formed during the Gondwana breakup.

Acknowledgments

The authors express their deep appreciation to the flight crews and ground staffs of the former Soviet Antarctic Expeditions for accomplishing extensive survey flights. We particularly thank I. Z. Balashov, N. I. Khlyupin, and A. S. Tscherinov. Our special thanks go to G. E. Grikurov (VNIIOkeangeologia, Russia), D. Denham (AGSO, Australia), P. G. Quilty (ANARE, Australia) and K. Kaminuma (NIPR, Japan) for initiating our international collaborative study. This work was partially supported by the Australian Antarctic Foundation and the Japan Science Promotion Society.

References

Barraclough, D. R. (1985): International geomagnetic reference field revision. Nature, **318**, 316.

Black, L. P., Harley, S. L., Sun, S. S. and McCulloch, M. T. (1987): The Rayner Complex of East Antarctica: Complex isotopic systematics within a Proterozoic mobile belt. J. Metamorph. Geol., **5**, 1–26.

Briggs, I. C. (1974): Machine contouring using minimum curvature. Geophysics, **39**, 39–48.

Desmond FitzGerald & Associates Pty Ltd. (1995): Intrepid Image Processing and Visualisation Tools Reference Manual.

Earth Resource Mapping Pty Ltd. (1993): ER Mapper and ER Storage software and documentation.

Golynsky, A. V., Aleshkova, N. D., Grikurov, G. E., Kamenev, E. N., Kurinin, R. G., Masolov, V. N. and Volnukhin, V. S. (1995): Main tectonic provinces of the Lambert Graben region of East

Antarctica, based on airborne magnetic data. Abstracts: 7th Int. Symp. Antarct. Earth Sci., Siena, Italy, 160.

GRIKUROV, G. E. (1982): Structure of Antarctica and outline of its evolution. Antarctic Geoscience, ed. by C. CRADDOCK. Madison, Univ. Wisconsin Press, 791–804.

HIROI, Y., SHIRAISHI, K. and MOTOYOSHI, Y. (1991): Late Proterozoic paired metamorphic complexes in East Antarctica, with special reference to the tectonic significance of ultramafic rocks. Geological Evolution of Antarctica, ed. by M.R.A. THOMSON *et al.* Cambridge, Cambridge Univ. Press, 83–87.

IVANOV, V. L. and KAMENEV, E. N., ed. (1990): Geology and Mineral Resources of Antarctica. Moscow, Nedra, 232 p. (in Russian)

JOHNSON, A. C., ALESHKOVA, N. D., BARKER, P. F., GOLYNSKY, A. V., MASOLOV, V. N. and SMITH, A. M. (1992): A preliminary aeromagnetic anomaly compilation map for the Weddell province of Antarctica. Recent Progress in Antarctic Earth Science, ed. by Y. YOSHIDA *et al.* Tokyo, Terra Sci. Publ., 545–553.

KAMENEV, E. N. (1975): The geology of Enderby Land. Acad. Sci. USSR, Comm. Antarct. Res. Rep., **14**, 34–38 (in Russian).

KAMENEV, E. N. (1982): Regional metamorphism in Antarctica. Antarctic Geoscience, ed. by C. CRADDOCK. Madison, Univ. Wisconsin Press, 429–433.

KAMENEV, E. N., ANDRONIKOV, A. V., MIKHALSKY, E. V., KRASNIKOV, N. N. and STUVE, K. (1993): Soviet geological maps of the Prince Charles Mountains, East Antarctic Shield. Aust. J. Earth Sci., **40**, 501–517.

NIKKI, K., YOSHINO, T. and FUKUNISHI, H. (1981): Contour maps of geomagnetic field intensity in the vicinity of Syowa Station, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **71**, 64–75.

OSANAI, Y., SHIRAISHI, K., TAKAHASHI, Y., ISHIZUKA, H., TAINOSHO, Y., TSUCHIYA, N., SAKIYAMA, T. and KADOMA, S. (1992): Geochemical characteristics of metamorphic rocks from the central Sør Rondane Mountains, East Antarctica. Recent Progress in Antarctic Earth Science, ed. by Y. YOSHIDA *et al.* Tokyo, Terra Sci. Publ., 17–27.

RAVICH, M. G. and KAMENEV, E. N. (1975): Crystalline Basement of the Antarctic Platform. New York, Halsfed Press, 582 p.

SHERATON, J. W., TINGEY, R. J., BLACK, L. P., OFFE, L. A. and ELLIS, D. J. (1987): Geology of unusual Precambrian high-grade metamorphic terrane—Enderby Land and Western Kemp Land, Antarctica. BMR Bull., **223**, 51 p.

SHIBUYA, K., TANAKA, A. and MANABE, M. (1987): Aeromagnetic surveys over the Yamato Mountains and the Yamato Meteorite Ice Field, East Antarctica. Nankyoku Shiryô (Antarct. Rec.), **31**, 1–10.

SHIRAISHI, K., ASAMI, M., ISHIZUKA, H., KOJIMA, H., KOJIMA, S., OSANAI, Y., SAKIYAMA, T., TAKAHASHI, Y., YAMAZAKI, M. and YOSHIKURA, S. (1991): Geology and metamorphism of the Sør Rondane Mountains, East Antarctica. Geological Evolution of Antarctica, ed. by M. R. A. THOMSON *et al.* Cambridge, Cambridge Univ. Press, 77–82.

SHIRAISHI, K., ELLIS, D. J., HIROI, Y., FANNING, C. M., MOTOYOSHI, Y. and NAKAI, Y. (1994): Cambrian orogenic belt in East Antarctica and Sri Lanka: Implications for Gondwana assembly. J. Geol., **102**, 47–65.

VAN AUTENBOER, T. (1969): Geology of the Sør Rondane Mountains, Sheet 8, Sør Rondane Mountains. Geologic Maps of Antarctica, ed. by V. C. BUSHNELL and C. CRADDOCK. New York, Am. Geogr. Soc. (Antarct. Map Folio Ser., 12).

YOSHIDA, M. (1994): Tectonothermal history and tectonics of Lützow-Holm Bay area, East Antarctica: A re-interpretation. J. Geol. Soc. Sri-Lanka, **5**, 81–93.

YOSHIDA, M. and VITANAGE, P. W. (1993): A review of the Precambrian geology of Sri Lanka and its comparison with Antarctica. Gondwana Eight: Assembly, Evolution and Dispersal, ed. by R. H. FINDLAY *et al.* Rotterdam, Balkema, 97–110.

(Received April 25, 1996; Revised manuscript accepted July 18, 1996)