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Gravity Mapping in the Southern Weddell Sea Region. (Explanatory note for free-air and Bouguer anomalies maps)

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Summary: New maps of free-air and the Bouguer gravity anomalies on the Weddell Sea sector (70-81 °S, 6-75 °W) of Antarctica are presented. These maps are based on the first computer compilation of available gravity data collected by "Sevmorgeologia" in 1976-89 in the southern Weddell Sea and adjacent coasts of western Dronning Maud Land (WDML) and Coats Land. The accomplished gravity studies comprise airborne observations with a line spacing of about 20 km and conventional measurements at over-the-ice points, which were spaced at 10-30 km and supplemented by seismic soundings. Hence, anomalies on the maps represent mainly large-scale and deep crustal features.

The dominant feature in free-air gravity map is a large dipolar gravity anomaly stretching along the continental margin. Following the major grain of seabed morphology this shelf-edge/slope anomaly (SESA) is clearly divided into three segments characterized by diverse anomaly amplitudes, wavelengths and trends. They are associated with continental margins of different geotectonic provinces of Antarctica surrounding the Weddell Sea. Apparent distinctions in the SESA signatures are interpreted as the gravity expression of tectonic, deep crustal structure segmentation of the continental margin. The prominent gravity highs (100-140 mGal) of the shelf edge anomaly mapped along WDML are assumed to represent high-density mantle injections intruded into the middle/lower crust during initial rifting of continental break-up. Enlarged wavelengths and diminished amplitudes of the gravity anomaly westwards, along the Weddell Sea embayment (WSE) margin, reflect a widening of the continental slope and a significant increase in thickness of underlying sediment strata.

Low amplitude, negative free-air anomalies in the Filchner-Ronne Ice Shelves (FRIS) contrast sharply with the dominating positive anomalies offshore. This indicates a greater sedimentary thickness of the basin in this area. Crustal response to the enlarged sediment load is impressed in mostly positive features of the Bouguer gravity field observed here. Two pronounced positive Bouguer anomalies of 50-70 mGal and an average widths of 200 km dominate the Weddell Sea embayment margins towards the Antarctic Peninsula and the East Antarctic craton. They correlate well with very deep seabed troughs (>1000 m below sea level). The gravity highs are most likely caused by a shallow upper mantle underneath graben-rift structures evolved at the margins of the WSE basin. A regional zone (>100 km in width) of the prominent Bouguer and free-air negative anomalies (-40 to -60 mGal) adjacent Coats Land to the north of the ice shelf edge may indicate the presence of the thick old cratonic crust far offshore beneath the Weddell Sea Embayment.

Zusammenfassung: Neue Freiluft- und Bouguerschwerekarten für den Weddellmeer-Sektor (70-81 °S, 6-75 °W) der Antarktis werden vorgestellt. Diese Karten beinhalten alle Gravimeter-Daten, die von Sevmorgeologia zwischen 1976 und 1989 im südlichen Weddellmeer, dem angrenzenden westlichen Dronning Maud Land (WDML) und Coats Land erhoben worden sind. Die Studie beinhaltet aerogravimetrische Daten mit einem Linienabstand von etwa 20 km als auch konventionelle Punktmessungen auf dem Schelfeis. Der Punktabstand auf dem Schelfeis betrug 10-30 km und wurde durch seismische Messungen ergänzt. In den Karten sind daher überwiegend großräumige Anomalien erfasst, die auf signifikante Dichteänderungen in der tieferen Kruste hinweisen.

Die markanteste Anomalie in der Freiluftschwere verläuft parallel zum Kontinentalrand der Ostantarktis. Die Anomalie markiert die wesentlichen Änderungen der Meeresbodentopographie. Das Schwerefeld macht diese Segmentierung des Kontinentalrandes sichtbar. Diese Schelfrand-Anomalie (SESA) kann in drei Segmente eingeteilt werden, die sich in den Amplituden, den Wellenlängen und ihrem Trend unterscheiden. Diese korreliert sehr gut mit den verschiedenen tektonischen Provinzen im südlichen Weddellmeer. Markante Schwerehochs (100-140 mGal) der SESA entlang des WDML repräsentieren vermutlich Intrusionen in die Mittel- bzw. Unterkruste, die beim initialen Rifting des Gondwana-Aufbruchs gebildet wurden. Nördlich des Filchner-Ronne-Schelfs nehmen die Wellenlängen zu und die Amplituden ab. Dies wird durch eine Verbreiterung des Kontinentalhanges und mit mächtigeren Sedimentablagerungen erklärt.

Auf dem Filchner-Ronne-Schelf finden sich ausschließlich negative Schwereanomalien mit geringer Amplitude. Dies steht in deutlichem Kontrast zu den überwiegend positiven Anomalien entlang des Kontinentalrandes und wird durch eine größere Sedimentmächtigkeit im Becken erklärt. An den westlichen und östlichen Rändern des Beckens zeigt die Bouguer-Schwerekarte deutliche Variationen in der Krustenmächtigkeit an. Zwei markante, positive Bouguer-Anomalien mit 50-70 mGal und einer mittleren Breite von 200 km dominieren den Filchner-Ronne-Schelf von der Antarktischen Halbinsel im Westen bis zum ostantarktischen Kraton im Osten. Die Anomalien korrelieren sehr gut mit markanten Meeresbodendepressionen von mehr als 1000 m Wassertiefe. Diese positiven Schwereanomalien werden wahrscheinlich durch einen flacheren Mantel unterhalb der Riftgräben verursacht. Nördlich der Küste zeigt eine markante, negative Freiluft- und Bouguer-Anomalie (-40 bis -60 mGal) vor Coats Land die Existenz von mächtiger, kratonischer Kruste an.

INTRODUCTION.

Though the concept of Antarctica as a part of Gondwanaland is generally accepted, the exact original configuration of Antarctica in relation to other southern continents remains uncertain and speculative. In this context the Weddell Sea, being a part of the present-day Antarctic plate, represents a key structural area to understand the early evolution of the southern oceans and Gondwana break-up. The basic knowledge about crustal features and break-up related tectonics in the southern Weddell Sea region have been gathered during more than two decades of international geophysical studies including magnetic, gravity and seismic surveying (BROZENA et al. 1991, GRIKUROV et al. 1991a, HINZ & KRAUSE 1982, JOHNSON et al. 1992, JOKAT et al. 1996, LABRECQUE et al. 1989, MASLANYJ et al. 1991). Geophysical data acquired in the Weddell Sea and interpreted in terms of its geodynamic evolution are presented and discussed in numerous scientific publications (BELL et al. 1990, HINZ & KRISTOFFERSEN 1987, GHIDELLA & LABRECQUE 1997, HÜBSCHER et al. 1996 a, b, HUNTER et al. 1996, JOKAT et al. 1996, KRISTOFFERSEN & HINZ 1991, LABRECQUE & GHIDELLA 1997, LEITCHENKOV et al. 1996, LIVERMORE & HUNTER 1996). A substantial contribution to earth science research in the region was provided by the Russian (Soviet) Antarctic Expedition but the results of these investigations are still mainly unpublished.

The purpose of this paper is to represent the new gravity field maps on the Weddell Sea sector (70-81 °S, 6-75 °W) compiled on the basis of the Russian data, which constitute a major component of the existing in the area marine and airborne gravity coverage (JOKAT et al. 1996, LABRECQUE & GHIDELLA 1997) as well essentially complement ERS-1 altimetry

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evidence recently obtained for the southernmost Weddell Sea up to 78 °S (McAdoo & Laxon 1996). Systematic airborne and over-the-ice gravity surveys were performed by "Sevmorgeologia" in the Weddell Sea region in 1976-1989 as a part of the extensive earth science program carried out by Ministry of Geology of the USSR under the auspices of the Soviet Antarctic expedition. The total amount of acquired gravity data comprises about 70 000 km of aerogravity profiles and 1850 land (over-the-ice) stations collected over a vast area of 1 500 000 km^2 both offshore and onshore (Figs.1, 2). Until now, the results of gravity surveying accumulated during successive field seasons have never been summarized and remained unpublished in annual "Sevmorgeologia" archive reports as hand-drawn maps of individual surveyed areas accompanied by brief descriptions.

In 1995-1997 the German Federal Ministry for Research and Technology and the Russian Ministry of Science jointly supported a cooperative research project between the Alfred Wegener Institute and VNIIOkeangeologia / Polar Marine Geological Research Expedition (PMRG; both currently representing the former "Sevmorgeologia"). The objective was to process the numerous Russian geophysical data collected in the Weddell Sea area and make them available in digital form. The project enabled digitizing of gravity data, their mutual adjusting and merging into a comprehensive data set, which

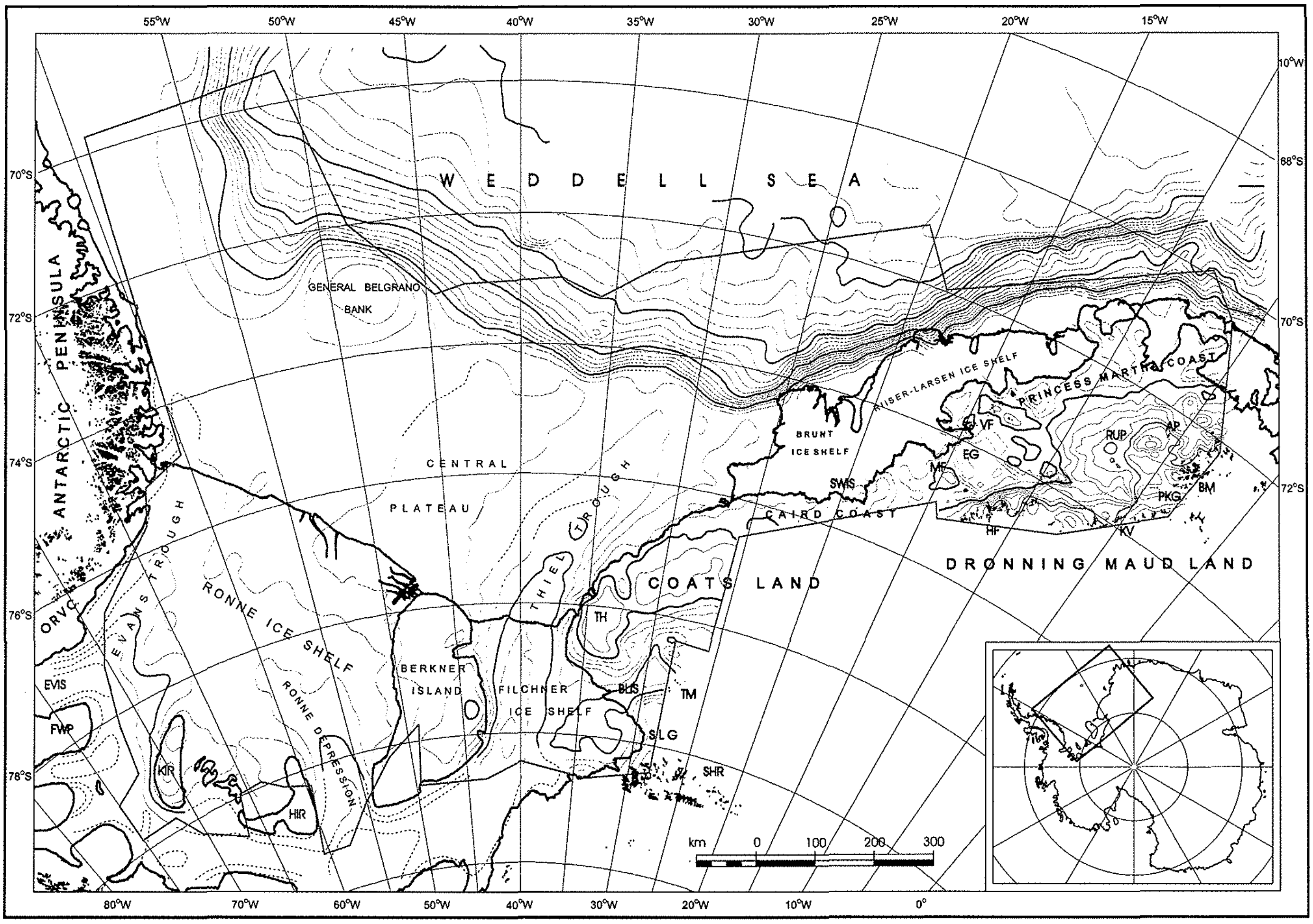

Fig. 1: Map of smoothed subglacial and seabed topography with rock outcrop distribution showing location of the gravity study area (outlined in magenta) in the southern Weddell Sea region and place names referred to in the text. Contours are displayed at a 200 m interval (dashed where location is less certain) with thickening at every 1000 m; bedrock above sea level is plotted in red. Sources include: Sevmorgeologia seismic and radio-echo sounding data (Vaughan et al. 1994, Popov & Leitchenkov 2000); AWI, BGR, NARE bathymetric surveys (Schenke et al. 1997); Digital Bathymetric Data Base (DBDB5) (Johnson et al. 1983). Rock outcrops and coastline source: Antarctic Digital Database (1993). Abbreviations of names referred to in the text are: AP = Annandags Peaks; BLIS = Bailey Ice Stream; BM = Borgmassivet; EG = Endurance Glacier; EVIS = Evans Ice Stream; FWP = Fowier Peninsula; HF = Heimefrontfjella; HIR = Henry Ice Rise; KIR = Korff Ice Rise; KV = Kirwanveggen; MK = Mannefallknausane; ORVC = Orville Coast; PKG = Pencksokket Glacier; RUP = Ritscher Upland; SHR = Shackleton Range; SLG = Slessor Glacier; SWIS = Stancomb-Wills Ice Stream; TM = Theron Mountains; TH = Touchdown Hills; VF = Vestfjella.

Abb. 1: Karte des geglätteten subglazialen Reliefs und der Meeresbodentopographie. Die Verteilung der Gesteinsausbisse sowie das Untersuchungsgebiet für die Schweremessungen (Rahmen in Magenta) sind markiert. Die Kontourintervalle betragen 200 m (gestrichelt, wenn die Daten unsicher sind). Die 1000 m Linien sind dick hervorgehoben. Das subglaziale Relief über NN ist in Rot dargestellt. Folgende Daten sind berücksichtigt: Seismische und Eisdickendaten von Sevmorgeologia (Vaughan et al. 1994, Popov & Leitchenkov 2000); AWI, BGR, NARE bathymetrische Daten (Schenke et al. 1997) sowie Daten des DBDB5 (Johnson et al. 1983). Quelle für die Lokation der Ausbisse und Küstenlinie ist die „Antarctic Digital Database" (1993). Die benutzen Abkürzungen werden im Text benutzt und haben folgende Bedeutung: AP = Annandags Peaks, BLIS = Bailey Eisstrom, BM = Borgmassivet, EG = Endurance Gletscher, EVIS = Evans Eisstrom, FWP = Fowier Peninsula, HF = Heimefrontfjella, HIR = Henry Ice Rise, KIR = Korff Ice Rise, KV = Kirwanveggen, MK = Mannefallknausane, PKG = Pencksokket Gletscher, RUP = Ritscher Hochland, SHR = Shackleton Range, SWIS = Stancomb-Wills Eisstrom, TM = Theron Berge, TH = Touchdown Berge, VF = Vestfjella.

for the first time made it possible to compile the computer-derived free-air and Bouguer anomaly maps based on integrated results of Russian surveys in the entire surveyed area (Fig. 1). Evaluation of creditability of this compilation depends to a large extent on characterization of input data and the procedures used for their processing. All data processing and computer mapping were made using software developed in Geological Survey of Canada (Atlantic) on a "Sun SPARC Station 20" in VNIIOkeangeologia, St. Petersburg.

SOURCE DATA: ACQUISITION AND QUALITY CONTROL.

Logistic support for both air-borne and aircraft-supported land surveys was provided from seasonal base stations Druzhnaya-1, Druzhnaya-2 and Druzhnaya-3, which were located close to edges of ice shelves (Fig. 2). All three bases were connected by tie-flights at the beginning and the end of each field season to the Duke Ernst Bay, on-rock gravity station (77° 53'S, 34° 10'W), which was used as a main reference point in all Russian surveys. This gravity base at the head of an outlet glacier near Duke Ernst Bay was established in 1958/59 by J.C. Behrendt and connected via the American Ellsworth base to Madison, Wisconsin, by ship-link (THIEL 1959). The original absolute value of gravity determined for the Duke Ernst Bay station was revised by the Russian team in 1979 and corrected by 2 mGal.

Airborne gravity surveys were carried out mainly over the northern part of the Weddell Sea embayment and in the coastal region of western Dronning Maud Land between 4 °W and 25 °W (Fig. 2). Aerogravity data have been acquired during five field seasons using an IL-14 aircraft flown at a constant barometric elevation varying from 1800 m to 2400 m for individual surveys. The average spacing between flight lines was 20 km. The aircraft altitude was determined by radio and pressure altimeters with an accuracy within ±12 m. Navigation was relied on radio-geodetic system "Poisk" and "DISS" Doppler units with supplemented photographic methods providing the position accuracy of the order of 1 km. Flight-line positioning was improved to 500 m for 1989 season, when the Global

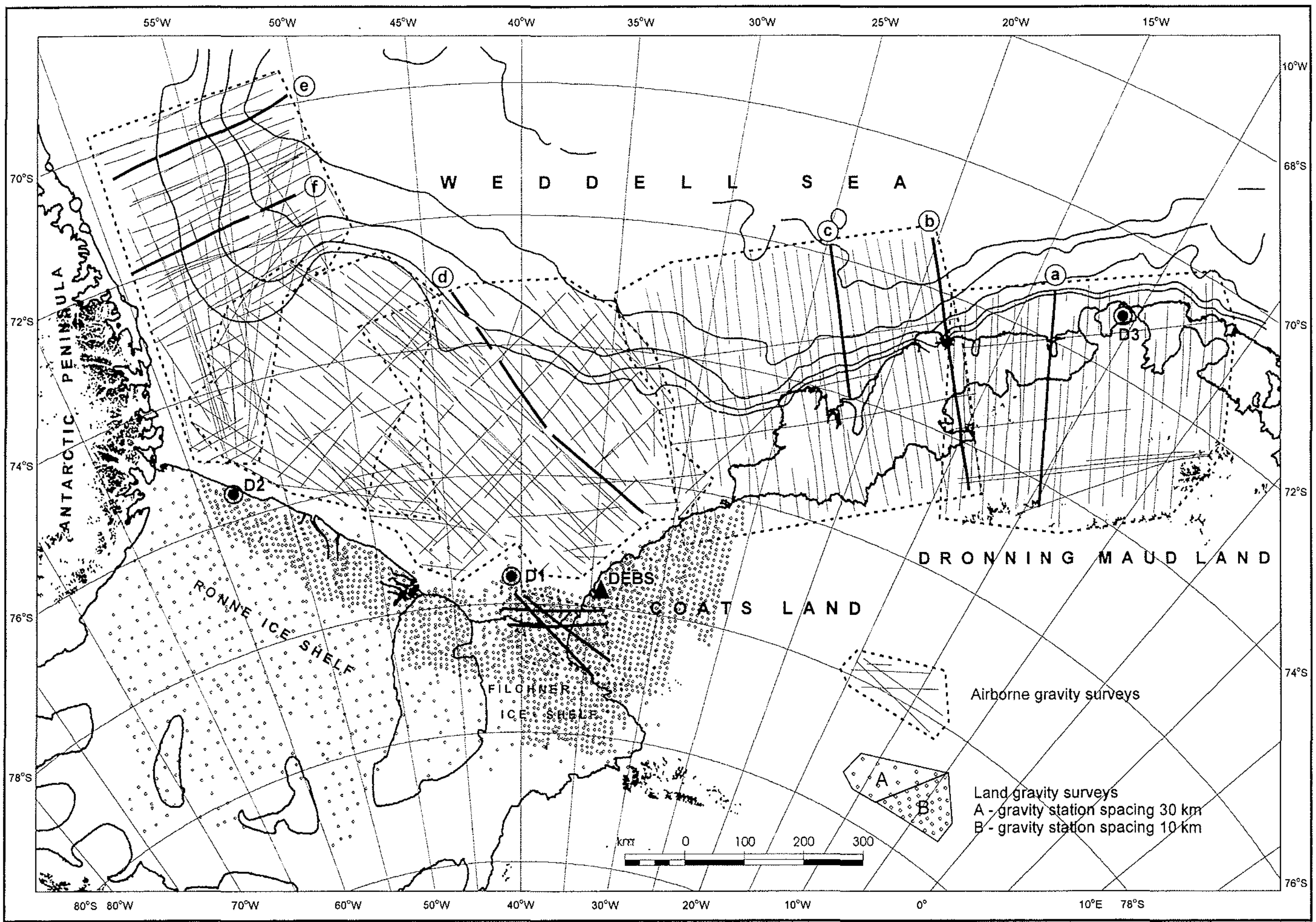

Fig. 2: Location map of gravity observations in the southern Weddell Sea region. Closed circles mark the field base stations Druzhnaya-1 (D1), Druzhnaya-2 (D2) and Druzhnaya-3 (D3). Location of the main reference gravity base station Duke-Ernst-Bay (DEBS) is shown by filled triangle. Heavy lines indicate the position of aerogravity profiles illustrated in Figures 3 and 4 (lines with circled letters). Thickened contour lines are the isobaths: 600 (nearly shelf break), 1000, 2000, 3000 and 4000 m.

Abb. 2: Lage der aerogravimetrischen Profile und Punktmessungen im südlichen Weddellmeer. Die Abkürzungen D1, D2, D3 (Druzhnaya 1-3) markieren die Basisstationen. Die Dreiecke zeigen die Position der Schwere-Referenzstation Duke-Ernst-Bay (DEBS). Die dicken Linien zeigen Profile, die in den Abbildungen 3 und 4 eingehender diskutiert werden. Die Kontourlinien zeigen die Bathymetrie in der Nähe des Schelfs (1000, 2000, 3000 und 4000 m).

Positioning System (GPS) was used for the first time. Digital data acquisition was provided by "Graviton" system mounted aboard the IL-14 and comprising 2-3 damped string sea gravimeters GSD-M, modified for airborne use. The system also included precise sensor-units providing information about horizontal and vertical accelerations of the aircraft. Data were recorded with a 15 s interval at a typical cruising speed of 240-260 km per hour. Control for airborne gravity observations and measuring equipment was achieved by gravity measurements made on the ground at the field base stations at the beginning and the end of every survey day.

Processing of raw field data for each survey area included digital correction for horizontal and vertical accelerations, Eötvös effect and normal gravity (height and latitude) and recovering of free-air anomalies from airborne measurements by a special technique developed by Lozinskaya (1973). Airborne gravity measurements were reduced to sea level assuming a free-air gradient of 0.3086 mGal/m. The resulting gravity values were printed out as catalogues containing relevant point information at a 1 km interval along flight lines. Lack of adequate computer facilities at that time resulted in further manual manipulation of tabulated point data. Hand-drawn free-air gravity profiles were adjusted at intersections using an iterative approach and a least square fit to minimizing mis-ties. Subsequently the internally adjusted data for each survey area were presented as final catalogues differing from original ones in a wider sampling interval (every 4-5 km except for the 1987 survey data, which were sampled at a 16-18 km interval). The resulting five individual catalogues contained point data whose accuracy (RMS of intersection values) ranged between 4 and 8 mGal. Tapes with digitally processed raw field data were not preserved, therefore these catalogue data were used as primary input aerogravity information for our digital map compilation.

The stationary over-the-ice point gravity measurements (land surveys) were carried out on western Coats Land and over the Ronne and Filchner ice shelves covering the southern Weddell Sea embayment (Fig. 2). Land measurements were performed with a regular spacing of 10 or 30 km. They were accompanied by seismic soundings providing data on the floating ice thickness, seabed depths and sub-ice bedrock elevations accurate to about ±15-25 m. Position and altitude of gravity stations were derived from astronomical observations and barometric leveling with errors within ±500 m and ±5 m, respectively. Gravity measurements were conducted by 2-3 termostatic, astatic-type "GAK" gravimeters. The errors of gravity measurements range between ±0.4-0.6 mGal. All gravity observations were tied to the field base stations (Druzhnaya-1 and Druzhnaya-2) within a few hours and corrected for gravity meter drift. The Bouguer gravity calculations were based on the seismic reflection measurements of the ice/water thickness and were made in the usual manner. The simple Bouguer gravity anomalies were calculated assuming densities of 1.03, 0.9 and 2.67 (or 2.3) g/cm^3 for water, ice and rock, respectively. The resulting land gravity observations catalogues (in total eight for the different survey areas), which were used as input data for map compilation, had estimated accuracies within ±1 mGal for absolute gravity values and about ±2.5 mGal and ±4 mGal for free-air and Bouguer gravity anomalies, respectively.

MAP COMPILATION: DATA REPROCESSING AND COMPUTER MAPPING

References to "Sevmorgeologia" archive reports containing catalogue data are given on the map sheet. After digitizing the information contained in the source catalogues, all data employed in compilation were adjusted to conform the IGSN71 gravity datum and reduced using the 1930 International Gravity Formula.

Subsequent treatment of data was performed separately for aerogravity and land gravity sets. To examine fitness of digitized data for computer mapping the both sets were interpolated onto equally spaced grids using the minimum curvature algorithm (Briggs 1974) but with different grid interval. Airborne data were gridded at a 10 km interval, equal to one half of flight-line spacing. Whereas for all land data grid interval was taken at 5 km based on a good agreement between contour plots derived from 5 and 10 km grids in the area with 30 km observation spacing. This 5 km grid was accepted as satisfactory for final map compilation in the entire area covered by land surveys. Much more complex processing procedures appeared necessary to obtain final grid for airborne data. Direct contouring of anomalies from initial 10 km grid resulted in significant distortions of gravity field demonstrated by elongated along flight-tracks anomalies, excessive corrugation of anomalies contours, emergence of isolated small highs and lows, etc.. Apparent association of such grid "noise" with individual flight lines evidenced for lack of suitable correlation of anomaly profiles inherent in input data set. That may be largely produced by residual errors of conventional tie-line leveling of airborne survey data, which had to be reasonably adjusted prior to final gridding.

A new cross-over analysis applied to aerogravity data sets revealed enlarged RMS errors (6-12 mGal) of data compared to those reported earlier (4-8 mGal). This may be accounted for by a wider along-flight-lines spacing of digitized gravity data in relation to that of the original gravity recording, at least in part. To diminish crossover errors several filtering techniques were attempted but turned out unsuitable due to obvious distortions introduced into airborne gravity profiles. Therefore, the following simple procedure was used for data reprocessing as the most adequate and successful. At first, an internal adjustment of data sets was done separately for each individual survey. Data adjusting was performed iterately and based on applying to lines constant gravity offsets derived from data cross-over analysis. Successive data gridding and contouring used to examine spatial correlation of gravity profiles and to identify the erroneous line fragments or the whole lines, which produced severe distortions of gravity anomalies. Erroneous data were excluded from further processing. For subsequent mutual adjusting the processed data sets of individual surveys were merged into the single database. Cross-over analysis of the unified data showed some gravity datum offsets between incorporated sets of data (5-8 mGal) with large standard deviation of the obtained values. Therefore the possible gravity offsets were also defined through comparison of individual surveys grids. Resulting mean values of RMS crossover errors and grid differences of adjacent, overlapped surveys were used as 'DC shifts' to remove level discrepancies between gravity data sets. The large mis-tie values at the intersection points of lines remaining after leveling within the overlap areas of adjacent surveys were minimized in a similar way to the earlier line-network adjustment. The final crossover error of the reprocessed and unified regional database of aerogravity data was 6.7 mGal for 343 crossings. After successive data gridding and smoothing this error was diminished to 5.2 mGal. The last value of RMS crossover error can be regarded as the best estimate for uncertainty of free-air aerogravity anomalies displayed on the large map sheet. For computer contouring the processed aerogravity data were interpolated to an equally spaced 10 km grid, which then was transformed by means of linear interpolation to a 5 km grid to be compatible with that of land gravity data.

Examination of the internal consistency between land and airborne gravity data sets preceded the joint map compilation. The overlap area of land and airborne gravity surveys is negligible except for five surveying flight-lines over the Filchner Ice Shelf and on adjacent small area onshore (Fig. 2). Though these lines have been flown outside the main area of aerogravity surveying they offer the only opportunity for a direct comparison of gravity anomalies derived from airborne and land gravity measurements. To compare two data sets the gridded 5 x 5 km land gravity field was resampled along the flight-line tracks (Fig. 3) and subtracted from the observed aerogravity profiles. The average difference between free-air anomalies was 5.09 mGal. The average difference of both gridded (5 x 5 km) aerogravity and land gravity data examined along the same airborne track lines was 4.7 mGal. The obtained values are close to RMS crossover error (5.2 mGal) of the reprocessed aerogravity data after gridding and smoothing. Therefore to produce the free-air gravity field map on the entire surveyed area the final grids of land and airborne gravity data were simply united. To avoid undesirable distortion of the more reliable and accurate land gravity measurements no additional leveling of final grids was performed. Insignificant level discrepancies (gravity offsets) between two parts of the joint map are noticeable in the vicinity of the ice shelves front, where a large gap in gravity coverage exists. The necessary adjusting of aerogravity and land gravity sets may be accomplished by incorporating in future compilations marine gravity data available for this area (JOKAT et al. 1996). To reduce any distortions between two gridded data sets in the overlap area they were evenly connected by interpolating within a radius of 20 km. The merged grid was smoothed by running mean technique with a 15 km radius and then computer contoured.

The new map of free-air gravity field of the southern Weddell Sea region was compiled at 1 : 2 500 000 scale. Free-air anomalies are displayed on the map at 10 mGal color-contour interval, which suits the smooth regional character of gravity field observed over most of the study area. The data quality of the compiled map and its resolution are best illustrated by comparison of the individual airborne gravity profiles from the created regional database with the corresponding profiles constructed from the gridded free-air anomaly values used for contouring (Fig. 4). The example graphs show a good correlation (in shape, size) of gravity anomalies for features of wavelength larger than 30 km, as well indicate a considerable reduction of the most intensive anomalies in the total (peak-to-peak) amplitudes of more than 25 mGal after gridding and subsequent smoothing. The short-wavelength features (<20 km) almost disappeared due to significant data filtering caused by these procedures.

The map of simple Bouguer anomalies was compiled only from land gravity data collected on western Coats Land and Filchner-Ronne Ice Shelf (FRIS). Bouguer corrections could not be made for aerogravity data sets because of lack or paucity of the appropriate subglacial and seabed topography data. This map is presented at the same 1 : 2 500 000 scale as the free-air anomaly map but covers only the southern part of the entire surveyed region. The land gravity measurements were reduced to simple Bouguer anomaly values using a rock density of 2.3 g/cm^3, which is more representative for the thick sedimentary basin underlying FRIS (KUDRYAVTZEV et al. 1987). Furthermore, the low seismic velocities 1.9-2.5 km/s obtained in the subsurface sediments (HINZ & KRISTOFFERSEN 1987, HÜBSCHER et al. 1996b) for the embayment area of the southern Weddell Sea point to very low density sedimentary units. In this case the calculated Bouguer anomalies more correctly eliminate gravity effect of the seabed topography and thus primarily display the gravity response of deeper crustal features, i.e. the buried basement structures fully covered by sediments. Bouguer anomalies are displayed at 10 mGal color-contour interval.

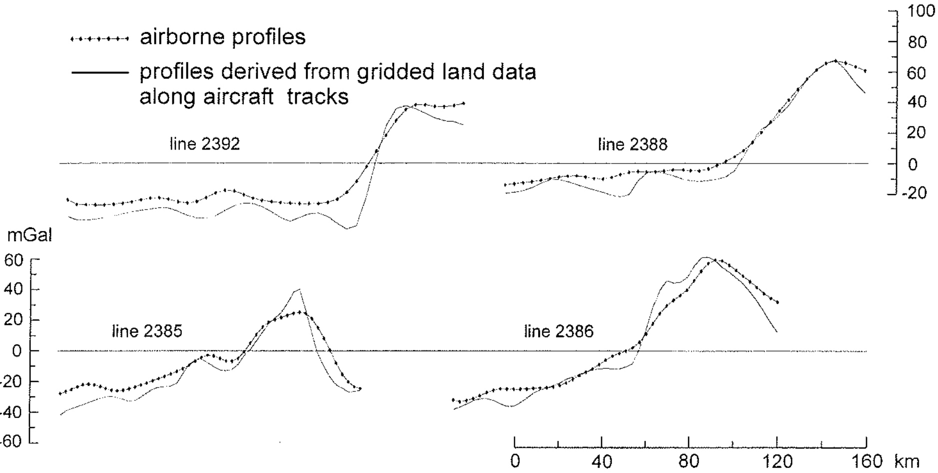

Fig. 3: Comparison of airborne gravity profiles and profiles derived from gridded land gravity data. Locations of selected aerogravity lines are shown in Fig. 2.

Abb. 3: Vergleich von aeromagnetischen Profilen mit Daten, die aus den Punktmessungen gewonnen worden sind. Die Position der ausgewählten Flugprofile sind der Abb. 2 zu entnehmen.

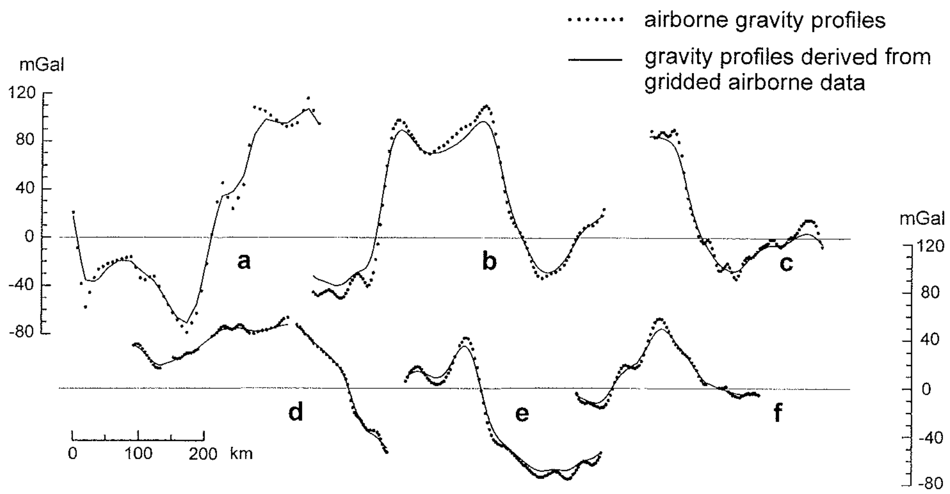

Fig. 4: Comparison of processed aerogravity profiles and corresponding profiles derived from gridded free-air anomaly values contoured on the attached map sheet. Locations of selected aerogravity lines are shown in Fig. 2.

Abb. 4: Vergleich von bearbeiteten aerogravimetrischen Profilen mit Daten, die aus der geglätteten Freiluftschwerekarte (s. beiliegende Karte) entnommen worden sind. Die Position der ausgewählten Flugprofile sind in Abb. 2 enthalten.

The color-contoured gravity field maps are supplemented by color-shaded relief images of gravity anomalies and their analytical transformations (Figs. 5-9). The images were produced using the ER Mapper software system (Earth Resource Mapping Pty Ltd. 1995) from the original grids values, which were scaled to a color-range of 256 by means of histogram-equalization. Application of analytical and graphical techniques allowed to enhance structural grain of gravity anomalies and thereby provided new helpful information for subsequent data analysis and interpretation of the regional tectonic fabric impressed in gravity field features. As alternative presentation of data color-shaded relief images enable to highlight the general field structure as well particular anomaly characteristics, which are not clearly visible in the original contour maps. That is primarily due to emphasizing gradients and enhancing the subtle, low-amplitude, linear features from either longer or shorter wavelength anomalies. Small-scale images of the compiled free-air and Bouguer gravity field (Figs. 5, 6) give a synoptic view of the regional gravity anomalies described and discussed below.

CONTINENTAL MARGIN ANOMALIES OF THE SOUTHERN WEDDELL SEA.

The most conspicuous feature of free-air gravity field is a large dipolar anomaly extending along the entire length of the continental margin for more than 2000 km (Fig. 5). It combines a broad zone of regional positive anomalies varying in amplitude from about 40 to 140 mGal with the conjugate less intensive negative anomalies ranging from -20 to -60 mGal. These gravity lows have been mapped only in part in the north of the study area but are well documented by marine and satellite altimeter data available for the region (Jokat et al. 1996, McAdoo & Laxon 1996). The large gravity dipole represents the well known "shelf-edge effect anomaly" (Litinsky 1972), the maximum and minimum of which locate the morphologic hinge points of the margin. The positive peaks are usually centered over the shelf break, whereas the minima rests over the base of the continental slope. Coinciding with the steeper upper slope the strong gradient of the shelf edge/slope anomaly(ies) (SESA) delineates the major morphostructural boundary of transition to the oceanic basin (Fig. 7). A typical magnitude of dipolar gravity anomaly observed across the most continental margins varies from 50 mGal to 100 mGal. The amplitude of positive anomaly is approximately equal that of the negative one. The positive anomalies mapped at the shelf edge in the eastern and central parts of the study region are unusually high-amplitude and wide (Fig. 5). They spread far from the shelf break over a large area of the continental shelf indicating a significant contribution of the deep crustal structure to the general edge effect anomaly.

Following the main features of the seabed morphology (Fig. 1) the SESA clearly divides into three segments characterized by diverse anomaly amplitudes, wavelengths and trends (Fig. 5). These segments are associated with continental margins of the different geotectonic provinces of Antarctica surrounding the Weddell Sea. To the east and southeast the Weddell Sea is bounded by the Precambrian craton of East Antarctica, whereas to the west by the predominantly Mesozoic magmatic arc of the Antarctic Peninsula. A vast region of the southern Weddell shelf (Fig. 1), termed the Weddell Sea embayment (King et al. 1996), separates the arc terrane and the East Antarctic craton. It contains a large Mesozoic extensional basin with a thickness of sediments up to 15 km, which are thought to be underlain by highly stretched continental crust (Grikurov et al. 1991b, Hübscher et al. 1996). The apparent distinctions in the SESA signatures appear to be directly related to tectonic segmentation of the extended continental margin of the southern Weddell Sea and reflect considerable changes in the overall crustal composition along its strike. General fabric of horizontal gradient field of free-air anomalies clearly reproduce abrupt alterations in gravity field structure at the southern Weddel Sea margin (Fig. 7).

Western Dronning Maud Land margin

The eastern segment of SESA is associated with the continental margin of western Dronning Maud Land of the East Antarctic craton, which on the base of marine seismic data is interpreted as a typical volcanic passive margin (Hinz & Krause 1982, Hübscher et al. 1996a). The prominent positive anomaly, hereinafter referred to as the East Antarctic Craton Margin Anomaly (EACMA), is the dominant feature of the region (Fig. 5). It trends SW-NE and extends from 27 °W to the eastern edge of the surveyed area. The 150-200 km wide anomaly covers the entire continental shelf with a large,

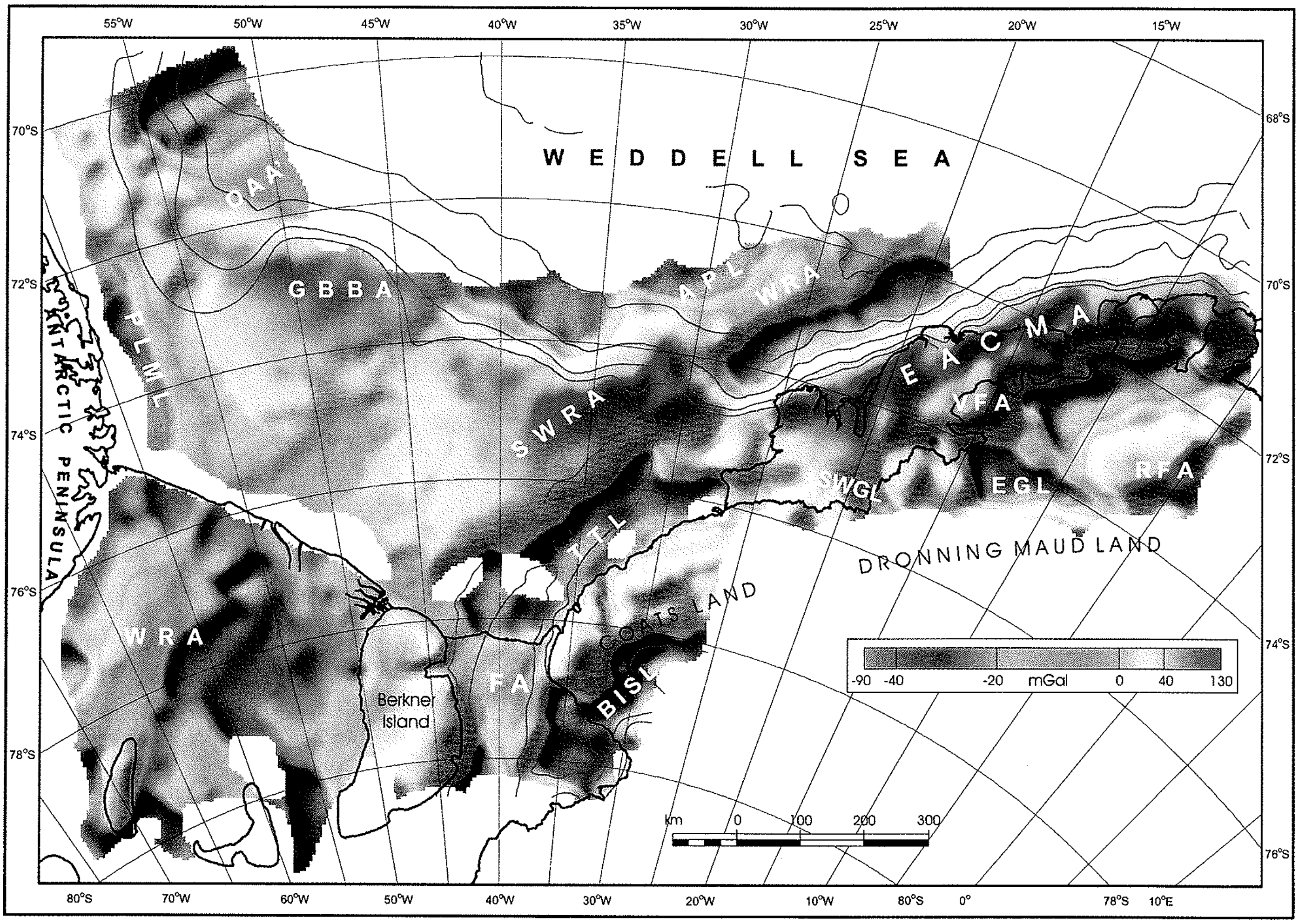

Fig. 5: Color shaded-relief map showing free-air gravity anomaly field of the southern Weddell Sea and coastal sides of western Dronning Maud Land and Coats Land. The map was produced using the ER Mapper software system (Earth Resource Mapping Pty Ltd. 1995) from the original grid values contoured on the attached map sheet. Point of illumination is located at 315 degrees and 45 degrees of inclination. Original grid values, ranging from 140 mgal to -90 mGal, were scaled to a color-range of 256 using histogram-equalization. Positive gravity anomalies are displayed in yellow to red, negative gravity anomalies are displayed in green to violet. Thin blue lines are the isobaths in metres (600, 1000, 2000, 3000 and 4000). Bold lettered anomalies discussed in the text are: APL = Andenes Plateau gravity low; BISL = Bailey Ice Stream gravity low; EACMA = East Antarctic craton margin anomaly; EGL = Endurance Glacier gravity low; FA = Filchner anomaly; GBBA = General Belgrano Bank anomaly; OAA' = gravity anomaly coincident with magnetic Orion Anomaly; PLML = Palmer Land margin gravity low; RFA = Ritscherfjella anomaly; RDA = Ronne Depression anomaly; SWRA = southern Weddell Rift anomaly; SWGL = Stancomb-Wills gravity low; TTL = Thiel Trough gravity low; VFA = Vestfjella anomaly; WRA = Weddell Rift anomaly; WNRA = Western Ronne anomaly.

Abb. 5: „Shaded Relief" Darstellung der Freiluftschwere im südlichen Weddellmeer, dem westlichen Dronning Maud Land und Coats Land. Die Karte wurde mit Hilfe der ER Mapper Software (Earth Resource Mapping Pty Ltd. 1995) erstellt. Beleuchtungspunkt liegt bei 315 Grad, die Inklination beträgt 45 Grad. Die Gitterpunkte variieren zwischen 140 mGal und -90 mGal. Sie wurden auf 256 Farben mit Hilfe einer „Histogram Equalization" skaliert. Positive Schwereanomalien sind in gelb bis rot dargestellt, negative Anomalien in grün bis violett. Dünne blaue Linien sind Isobathen in Meter (600, 1000, 2000, 3000 und 4000 m). Die weißen Buchstaben sind Abkürzungen für die Anomalien, wie sie im Text verwendet werden: APL = Andenes Plateau Minimum, BISL = Bailey Ice Stream Minimum, EACMA = East Antarctic craton margin Anomalie, EGL = Endurance Gletscher Schweretief, FA = Filchner Anomalie, GBBA = General Belgrano Bank Anomalie, OAA' = Schwere Anomalie identisch mit der magnetischen Orion Anomalie, PLML = Palmer Land margin Schwereminimum, RFA = Ritscherfjella Anomalie, RDA = Ronne Graben Anomalie, SWRA = South Weddell Rift Anomalie, SWGL = Stancomb-Wills Schwereminimum, TTL = Thiel Trough Schweretief, VFA = Vestfjella Anomalie, WAR = Weddell Rift Anomalie, WNR = Western Ronne Anomalie.

onshore part masked by ice shelves. The EACMA is complicated by a number of short wavelength anomalies of 30-40 km across, suggesting the presence of the shallow-seated sources, supposedly of intrusive origin. Approximately along 18 °W the marginal anomaly is broken by a linear relative gravity low (about 60 mGal) in two regional highs differed markedly in amplitudes. The most intensive eastern high reaches up to 140 mGal in amplitude and has a mean amplitude value of more than 80 mGal. Whereas the western one averages to only 40 mGal and attains a maximum amplitude of more than 80 mGal over the shelf break. Similar high-amplitude gravity anomalies observed along the worldwide volcanic margins are usually accounted for by dense mafic injections in the lower crust, which has been affected by magmatic underplating at the earlier stages of continental break-up (RABINOWITZ & LABRECQUE 1977). The seismic refraction experiments carried out across the WDML continental margin (HÜBSCHER et al. 1996a, KUDRYAVTZEV et al. 1991) give evidence for high crustal velocities of 7.2-7.5 km/s at the depths below 15 km, which might indicate both magmatic underplating and intrusions responsible for the observed, remarkable gravity highs.

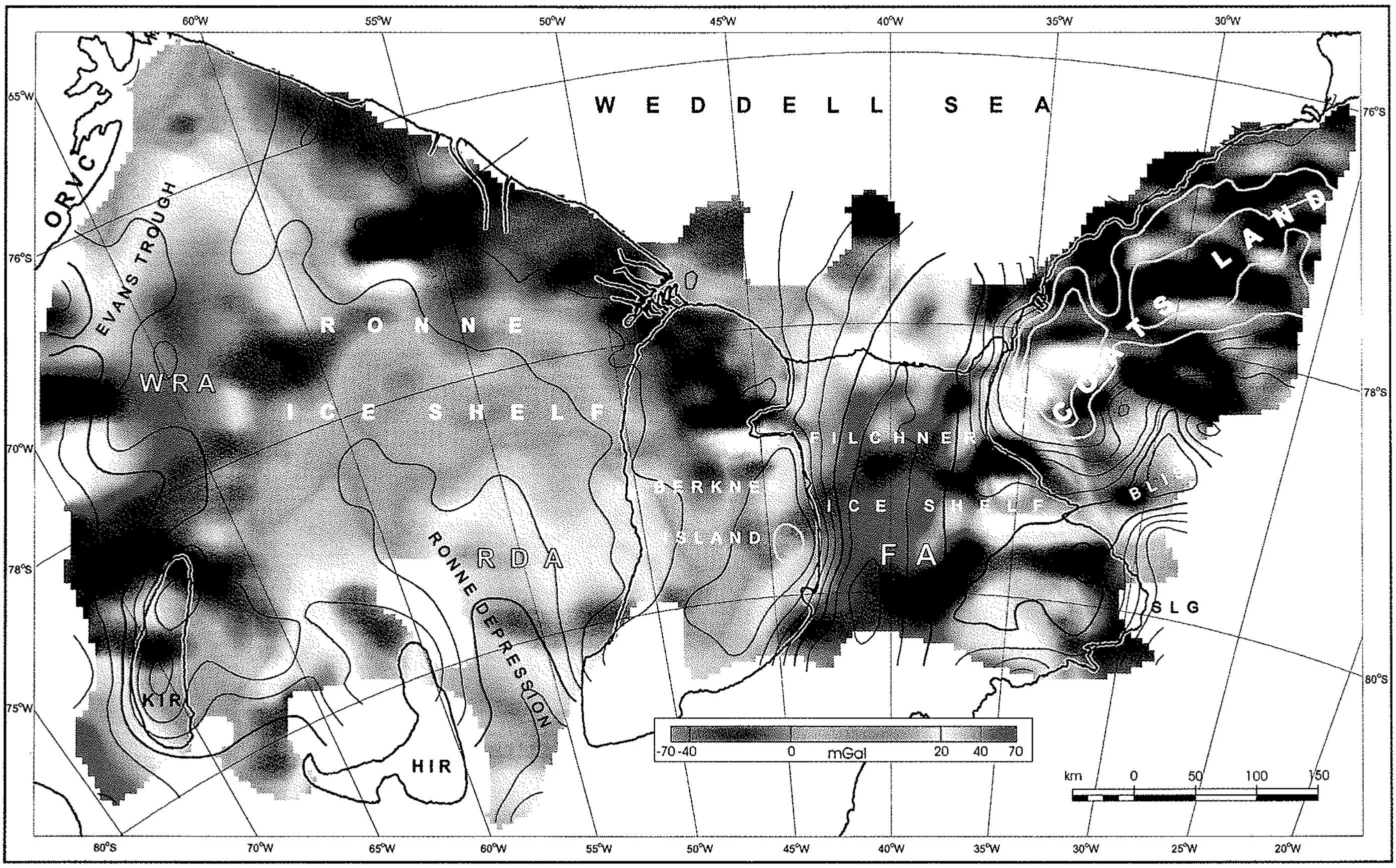

Fig. 6: Color shaded-relief map showing the Bouguer gravity anomaly field of the Ronne and Filchner ice shelves and coastal side of Coats Land. The map was produced using the ER Mapper software system (Earth Resource Mapping Pty Ltd. 1995) from the original grid values contoured on the attached map sheet. Point of illumination is located at 315 degrees and 45 degrees of inclination. Original grid values, which are in the range from over 70 mGal to less than -60 mGal, were scaled to a color-range of 256 using histogram-equalization. Positive gravity anomalies are displayed in green to yellow to red, negative gravity anomalies are displayed in blue to violet. Superposed contours of bathymetry (black) and subglacial bedrock relief (yellow) are displayed at 200 m interval with thickening at 1000 m.

Abb. 6: „Shaded Relief" Darstellung der Bouguerschwere für das Filchner-Ronne-Schelfeis und der angrenzenden Ostantarktis. Die Karte wurde mit Hilfe der ER Mapper Software (Earth Resource Mapping Pty Ltd. 1995) erstellt. Beleuchtungspunkt liegt bei 315 Grad, die Inklination beträgt 45 Grad. Die Gitterpunkte variieren zwischen 70 mGal und -60 mGal. Sie wurden auf 256 Farben mit Hilfe einer „Histogram Equalization" skaliert. Positive Schwereanomalien sind in gelb bis rot dargestellt, negative Anomalien in grün bis violett. Die schwarzen Kontourlinien stellen die Bathymetrie dar, die gelben Kontourlinien zeigen das subglaziale Relief. Das Kontourintervall ist 200 m; 1000 m-Linien sind dick gezeichnet.

The negative anomaly, conjoined with the EACMA, was mapped off WDML between 18 °W and 28 °W as a linear gravity low of up to a 100 km width with a general SW-NE trend (Fig. 5). It has a mean amplitude about -30 mGal ranging from -25 mGal to less than -40 mGal. This low covers the uppermost continental rise and base of the steep and narrow (70-90 km) slope descening to a water depth of approximately 3000 m. It spatially correlates with a buried suite of seaward dipping reflectors known as "Explora Wedge" (EW), formation of which is presumably related with excessive sub-aerial volcanism accompanying the early Gondwana rifting (HINZ & KRAUSE 1982). Within the area of the coastal low (18-28 °W) volcanic deposits of EW lie on the landward side of a wide (80-100 km) acoustic basement depression running parallel to the margin of the East Antarctic craton west of 25 °W (KRISTOFFERSEN & HINZ 1991). On its oceanward side the depression is bordered by volcanic basement plateau with a ridge-like summit structure of the Andenes Escarpment (KRISTOFFERSEN & HAUGLAND 1986). The above features of the crust disclosed at the WDML margin were interpreted by KRISTOFFERSEN & HINZ (1991) as elements of the failed Weddell Rift, which evolved during initial Gondwana fragmentation and produced pre-Late Jurassic oceanic crust of at least 40 km width. An elongated zone of diffuse relative gravity highs, which reach maximum absolute amplitudes of 10 mGal, delineates the axial depression of the proposed failed rift. Referred below as the Weddell Rift Anomaly (WRA) (Fig. 5) it extends along the margin for over 250 km showing SW-NE trend and average width of 100 km. In the southeast the WRA is bounded by the coastal gravity low and in the northwest by a broad (>200 km across) low of more than -60 mGal mapped only in part over the upper continental rise (27-34 °W). This regional low coincides with the volcanic basement high flanking Weddell Rift to the northwest and is denoted as the Andenes Plateau Low (APL) (Fig. 5).

The existing tectonic models of Gondwana break-up and Weddell Sea evolution alternatively identify the area of the Andenes Plateau with ancient oceanic (JOKAT et al. 1996) or ensialic crustal domain (GRIKUROV et al. 1991a, KRISTOFFERSEN & HINZ 1991, LIVERMORE & HUNTER 1996). Associated with the basement rise the intensive APL may be

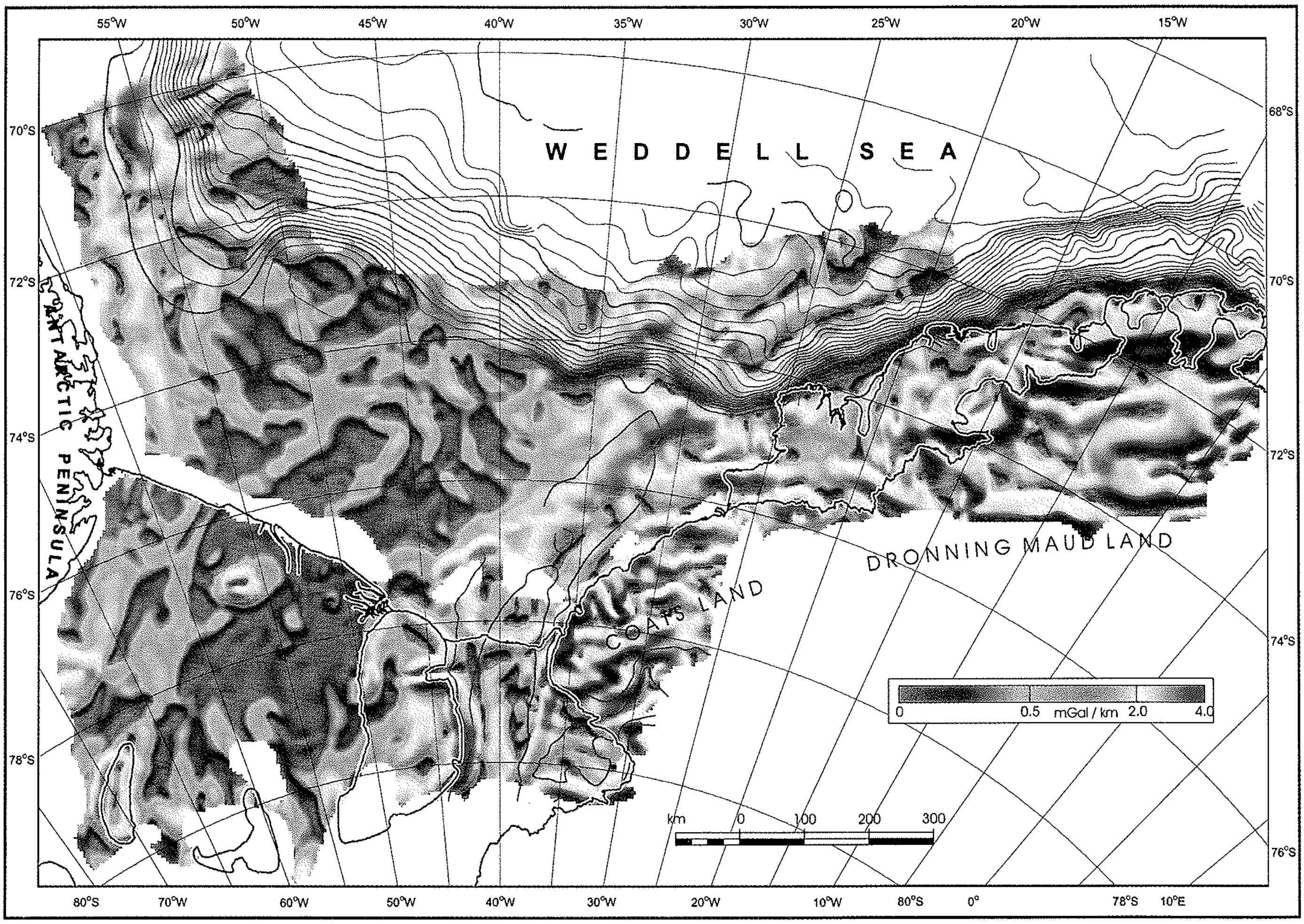

Fig. 7: Color shaded-relief map showing the horizontal gradient magnitudes of the free-air gravity anomaly field compiled for the southern Weddell Sea and coastal sides of western Dronning Maud Land and Coats Land. Sun elevation angle is 45 degrees and illumination azimuth is N-S. Thin blue lines are the isobaths in meters.

Abb. 7: „Shaded Relief" Darstellung der horizontalen Ableitung der Freiluftschwere im südlichen Weddellmeer und der angrenzenden Ostantarktis. Beleuchtungspunkt liegt bei 360 Grad, die Inklination beträgt 45 Grad. Die dünnen blauen Linien sind Isobathen in Meter.

produced by either enlarged thickness of the 'solid' crust (up to 14-16 km) or by great mass deficiencies in its upper part. Both seems almost atypical for pure igneous oceanic crust but might indicate that transition to the oceanic crust (in its true sense) occurred further to the north. This is supported by regional fabric of the magnetic anomaly field (GHIDELLA & LABRECQUE 1997). The prominent linear WRA disrupting the dominant negative background field off WDML may be accounted for a substantially reworked (intruded by mafic injections) high-density crust and/or shallow upper mantle underlying the Weddell Rift structure.

The characteristic gravity lineations mapped at the WDML margin are abruptly terminated by an intensive positive anomaly striking almost perpendicular to their general SW-NE trends (Fig. 5). It stretches out from the shelf edge in the SE-NW direction for 250 km and reaches maximum amplitude of more than 100 mGal when crossing the Weddell Rift. Towards the ends it gradually fades but can be continued further to the northwest by a relative gravity high (-20 mGal), which appears to separate the intensive Andenes Plateau Low from another similar one mapped at the Weddell Sea embayment margin. Overall the positive gravity anomaly corresponds to a dog-leg bend of the continental slope to the NW at approximately 28 °W, 75 °S (Fig. 1). At this point the SESA sharply changes its direction and follows the bathymetry towards the W-NW along the margin of the Weddell Sea embayment, associated with a wide and deep intracontinental sedimentary basin (GRIKUROV et al. 1991b). Both gravity field features and seabed morphology give evidence for presence of a considerable crustal discontinuity, likely a deep transverse fault, between two margins pertaining to various morphotectonic types.

Weddell Sea Embayment.

A vast, more than 1000 km across, shelf of the Weddell Sea embayment occupies the largest part of the surveyed region (Fig. 1). Along the margin gravity anomalies are characterized by enlarged wavelengths and diminished total amplitudes compared to those observed off WDML (Fig. 5). This may be connected with a more gently dipping and much wider continental slope (Fig. 1) as well as with thick sedimentary successions underlain it. Estimated from magnetic data sediment thickness exceeds 8 km along the entire length of the

WSE margin (GOLYNSKY et al. 2000, LABREQUE & GHIDELLA 1997). Tectonic evolution of the WSE basin province is believed to be closely related to Gondwana separation and may be presented in terms of increasing extension and transformation of primeval sialic lithosphere prior to and during continental break-up (GRIKUROV et al. 1991b). The resulting stretching and reworking of the crust due to multiphase rifting was accompanied by subsequent vigorous sag sedimentation on the growing continental margin (IVANOV 1989).

The northern, offshore area of WSE is dominated by two regionally broad gravity highs making up the central segment of the SESA (Fig. 5). Extending far from the shelf edge towards the south they cover almost entirely the outer shelf plain and terminate close to the front of the Ronne Ice Shelf. On average, the marginal gravity highs are about 40 mGal in amplitude and reach maximum values of 60 mGal over the General Belgrano Bank and more than 100 mGal at the eastern limit of the WSE margin, around the mouth of the Thiel Trough (Fig. 5). A linear gravity low stretching from the shelf break (43-45 °W) towards the southwest disrupts the positive background field offshore. The low widens southward and decreases in amplitude from 35 mGal to -15 mGal at the Ronne Ice Shelf. It coincides with a wide (>80 km), elongated bathymetric depression of more than -500 m in depth, which separates the General Belgrano Bank from another one located to the southeast, the Central Plateau (Fig. 1).

A margin low, conjugate to the shelf-edge gravity highs, was mapped in part over the continental slope between 35 °W and 43 °W (Fig. 5). This negative anomaly is of more than -50 mGal and is 150 km wide. Towards the northwest it joints with the Andenes Plateau Low. As well as the APL it corresponds to a broad volcanic basement rise, Andenes Plateau (JOKAT et al. 1996).

The high-amplitude positive anomaly in the eastern part of the WSE is situated just to the southwest of the failed rift proposed by KRISTOFFERSEN & HINZ (1991). It follows a general NE-SW trend of the linear zone of diffuse gravity highs, the Weddell Rift Anomaly, and may be evidence for a southward continuation of the rift structure within the WSE basin up to the northern end of Berkner Island (Fig. 5). Results of depth calculations to magnetic sources support this suggestion (GOLYNSKY et al. 2000). Both rift-related gravity highs, the WRA and its southern continuation, termed as the Southern Weddell Rift Anomaly (SWRA), coincide with a broad magnetic basement depression, which is up to 12-14 km deep and about 120 km wide. This striking structure extends from the continental rise towards the Ronne Ice Shelf parallel with the coast of WDML and Coats Land. The magnetic basement depression appears to represent the main graben of the assumed paleorift system bordering the East Antarctic craton at the base of the WSE basin. In the east the SWRA is delimited by a wide regional zone (>130 km) of intensive gravity lows (-40 to -60 mGal) corresponding to the deep Thiel Trough (Fig. 5). The strong rectilinear gradient separating the southern Weddell Rift anomaly and the Thiel Trough Low (TTL) roughly coincides with the axial part of the prominent seabed depression (Fig. 7), which is identified as a graben-like structure of more than 600 km in length running along the East Aantarctic craton margin. It gradually deepens towards the south from about 600 m at the shelf edge to more than 1500 m below the Filchner Ice Shelf (VAUGHAN et a. 1994) (Fig. 1). From seismic data the basement of the East Antarctic craton crops out at seabed along the base of the Thiel Trough in approximately 50-60 km off the coast (HINZ & KRISTOFFERSEN 1987, JOKAT et al. 1997). The adjoining to the coast free-air gravity lows outline a shallow plateau of the basement (KRISTOFFERSEN & HINZ 1991) and spatially correlate with lows of similar amplitude (-40 to -60 mGal) in the Bouguer gravity field (KADMINA 1985, STUDINGER & MILLER 1999), which are the offshore continuation of the exclusively negative anomalies associated with the East Antarctic craton beneath Coats Land (Fig. 6). Moreover, the characteristic pattern of short wavelength magnetic anomalies mapped over Coats Land (GOLYNSKY et al. 2000) also broadens to the outer shelf thus being spatially coinciding with the regional Bouguer gravity low. Such relations of gravity and magnetic fields features with the upper crustal structures indicate that a thick and almost unaltered Precambrian cratonic crust underlies this part of the WSE basin. The western limit of the Coats Land crustal block is well defined east of 38 °W and north of 78 °S by the strong gradient of gravity field (Fig. 7).

Another regional gravity low of about -60 mGal amplitude was mapped offshore in the western WSE (Fig. 5). It stretches along the Palmer Land margin of the Antarctic Peninsula and mirrors the Thiel Trough Low. Similar to the TTL the Palmer Land margin gravity low (PLML) corresponds to seabed trough occurring here while the origin of the PLML is uncertain due insufficient gravity and only poor seismic evidence. The Thiel Trough Low expresses combined gravity effect of deep seabed depression and thickened crust. It is most likely that the Palmer Land Margin Low is produced by thick sediments filling the large depression in the magnetic basement (GOLYNSKY et al. 2000).

The free-air gravity field in the area of the Filchner-Ronne Ice Shelves is characterized, in the main, by wavelength of more than 80 km with amplitudes of 20-50 mGal (Fig. 5). The negative regional background of about -20 mGal contrasts sharply the positive regional anomaly field offshore and indicates a greater sedimentary thickness of the basin in this area. Crustal response to the greater sedimentary load is reflected in positive Bouguer gravity anomalies mapped in this part of the basin (Fig. 6). The structural boundary between basin areas is probably delineated by the low amplitude negative Bouguer anomaly (-10 mGal) extending along the edge of the Ronne Ice Shelf. The gravimetric quiet central seabed plain on the Ronne Ice Shelf is disrupted by a few isolated short wavelength free-air gravity highs and lows of ±20 mGal corresponding to ice rises and local seabed features. The elevated Korff Rise is marked by a local low-amplitude (about 10 mGal) positive anomaly. The prominent positive regional anomaly of more than 50 mGal corresponds to Berkner Island. It shows a steep gravity gradient along the eastern side of Berkner Island at the edge of the deep Thiel Trough. The deepest part of the trough is delineated by narrow linear low (-30 mGal), while weak positive anomaly (10 mGal) is associated with the coastal side of the trough. A similar positive anomaly (15 mGal) runs parallel to the Orville Coast of the Antarctic Peninsula. Both free-air positive anomalies are much clearly expressed in the Bouguer gravity anomaly field.

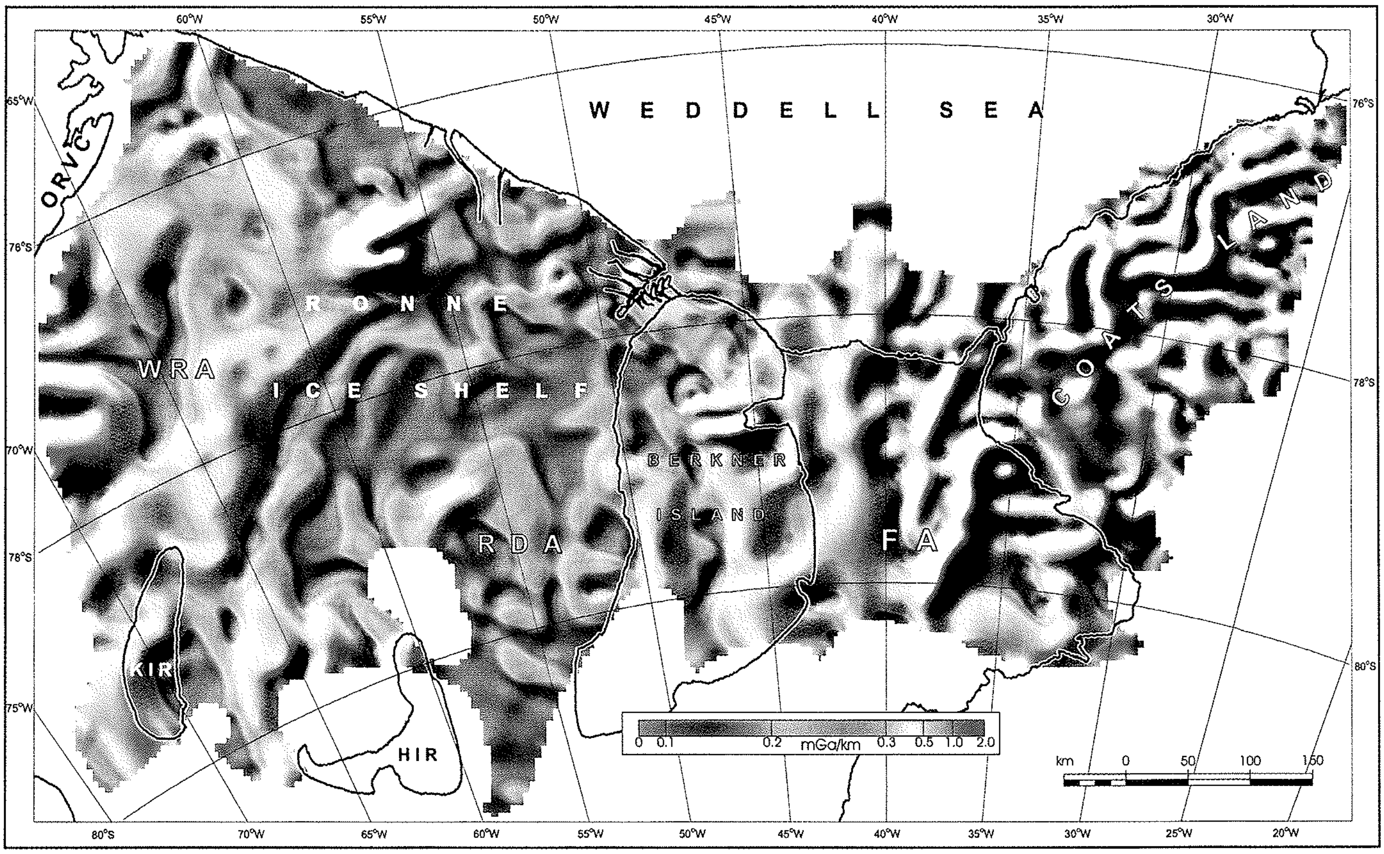

Fig. 8: Color shaded-relief map showing the horizontal gradient magnitudes of the Bouguer gravity anomaly field compiled for the Filchner-Ronne Ice Shelves and coastal side of Coats Land. Sun elevation angle is 45 degrees and illumination direction is 315 degrees (see Fig. 6).

Abb. 8: „Shaded Relief" Darstellung der horizontalen Ableitung der Bouguerschwere für das Filchner-Ronne-Schelfeis und das angrenzende Coats Land. Beleuchtungspunkt liegt bei 315 Grad, die Inklination beträgt 45 Grad (vgl. Abb. 6).

Three major crustal morphologies (structural zones) within the Filchner-Ronne Ice Shelves can be recognized in the Bouguer gravity anomaly field (Figs. 6, 8, 9). These structural units are: a western marginal zone located off the Orville Coast of the Antarctic Peninsula, a central zone extending beneath the largest part of the Ronne Ice Shelf and the western part of the Berkner Island, and the Filchner zone underneath the Filchner Ice Shelf at the eastern margin of the basin. The main characteristics of the zones are well displayed in Figures 8 and 9, which enhance the major structural grain of the Bouguer gravity anomaly field and give a fairly clear image of the spatial distribution of anomaly sources. The map of the Bouguer anomalies (Fig. 6) is dominated by two pronounced regional gravity highs mapped along the WSE basin margins. They spatially correspond to a continuous chain of very deep troughs (>-1000 m), which bounds the Weddell Sea Embayment from the coastal highlands. This implies a strong tectonic control of the subsidence of the sedimentary basin. The most intensive, eastern positive anomaly of 70 mGal in amplitude is associated with the prominent bathymetric feature of the Thiel Trough. It is referred as the Filchner anomaly (FA). The similar but weaker gravity structure with an amplitude of about 40 mGal (labeled WNRA) runs along the Orville Coast. It corresponds with less prominent Evans Trough outlining the southern edge of the Antarctic Peninsula (Fig. 1). The observed relations between morphological and gravity features are evidence for rifted-type crust and rising of a high density upper mantle (as an isostatic compensation of graben-rift structures) associated with a structural transition to the WSE basin province.

Antarctic Peninsula margin.

At the western edge of the map the continental margin anomaly (SESA) turns to the north (60 °W, 72 °S) exhibiting shorter wavelengths and lower amplitudes at the shelf break contrasting those observed eastward. What by itself is very surprising because the eastern margin of the Antarctic Peninsula Mesozoic magmatic arc is associated with thick (>8 km) Jurassic back-arc sedimentary basin termed the Larsen Basin (LaBrecque & Ghidella 1997). Trending S-N subparallel to the coast of the Antarctic Peninsula the SESA is characterized by a narrow and linear high of 40-50 km width and of an average 30 mGal amplitude. The wide (about 200 km across), round-shape conjugate gravity low is of about -60 mGal amplitude. Similar features mapped by the airborne gravity field along the western Weddell Sea margin have been reported previously by Bell et al. (1990). One of the main results of the United States-Argentina-Chile (USAC) airborne surveying was relocation of the continental shelf edge presented in the bathymetric map compilation of the Digital Bathymetric Data Base (DBDB5). Our gravity data also give evidence for a necessary correction of DBDB5, which we used

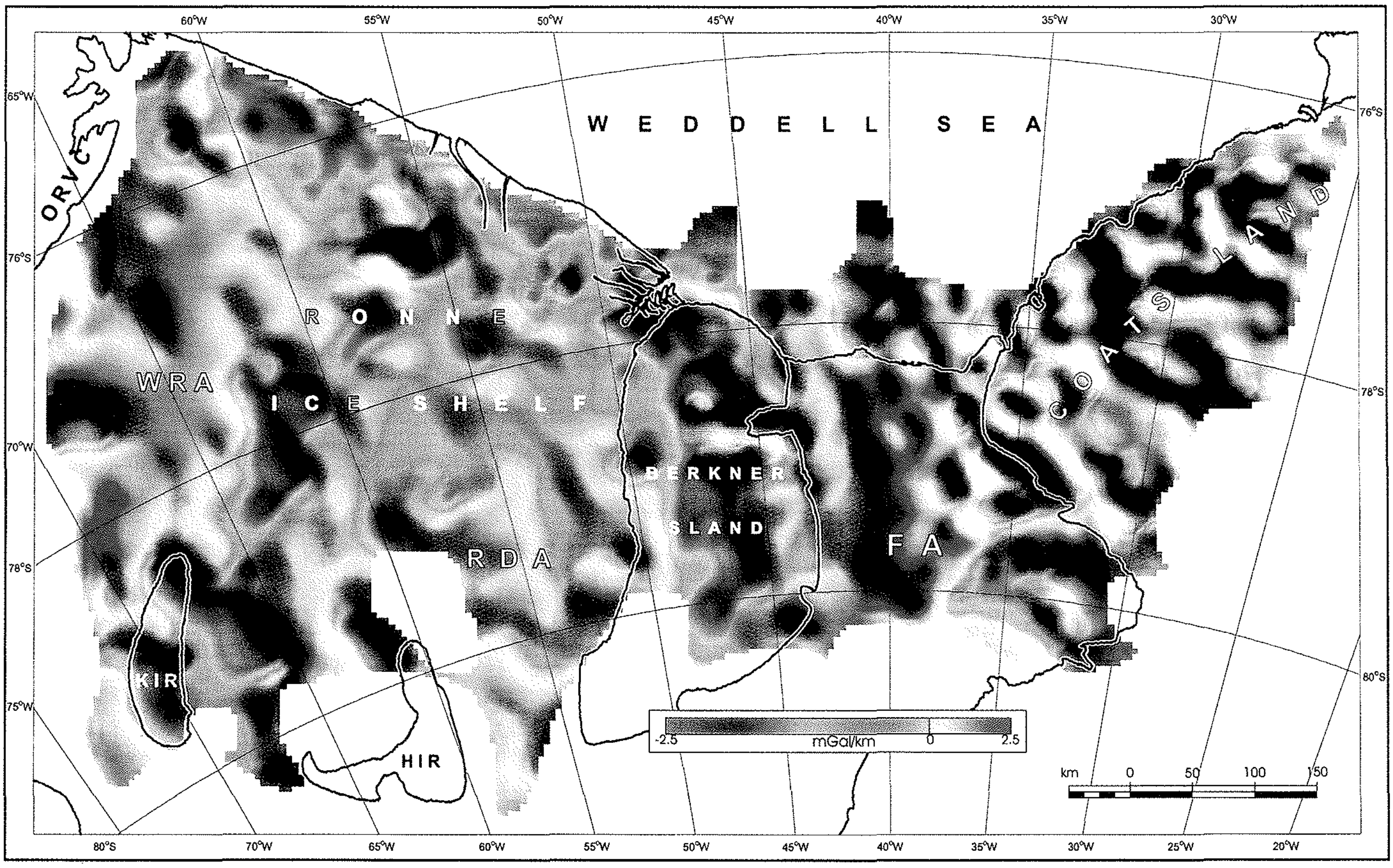

Fig. 9: Color shaded-relief map showing the first vertical derivative of the Bouguer gravity anomaly field compiled for the Filchner-Ronne Ice Shelves and coastal side of Coats Land. Sun elevation angle is 45 degrees and illumination direction is 315 degrees (see Fig.6).

Abb. 9: „Shaded Relief" Darstellung der vertikalen Ableitung der Bouguerschwere für das Filchner-Ronne-Schelfeis und die angrenzende Coats-Land-Küste. Beleuchtungspunkt liegt bei 315 Grad, die Inklination beträgt 45 Grad (vgl. Abb. 6).

for the generalized seabed topography in the figures of this paper. The maximum of the SESA is clearly offset from the continental shelf edge taken from DBDB5 compilation (Fig. 5). The gravity low dominated the continental slope is greatly amplified in amplitude and may be explained by bending of lithosphere beneath the double loading at the margins that intersect at 90 degrees (BELL et al. 1990). Relative linear high trending E-W (labeled as OAA') edges the margin low in the south (Fig. 5). This gravity lineation was identified by MCADOO & LAXON (1996) as a scarp-like feature in gravity field derived from ERS-1 altimetry data coinciding with the magnetically expressed Orion Anomaly (OA), which is interpreted to reflect the position of the continent-ocean boundary (COB) (LABREQUE et al. 1986). Great amount of the igneous rocks likely volcanic pile has been suggested as a source of Orion Anomaly.

COASTAL SIDE ANOMALIES OF WESTERN DRONNING MAUD AND COATS LANDS.

Notable changes in free-air gravity field pattern are visible across the transition from the continental margin towards the coastal sides of western Dronning Maud Land and Coats Land (Fig. 5), where it displays much rugged relief (Fig. 7) in correspondence with the main morphologic features of sub-ice bedrock relief.

Coastal region of western Dronning Maud Land.

The mountain region of WDML (Fig. 1) is clearly outlined by long wavelengths and high-amplitude positive gravity anomalies mapped at the southeastern limit of the investigated area (Fig. 5). The pronounced regional gravity high of about 110 mGal amplitude and 150 km wide at the edge of the map is associated with the western part of the spacious Ritscher Upland (RUP; Ritscherflya) elevated to more than 1600 m above sea level. The outcropping Annandags Peaks (AP; Annandagstoppane) and Borgmassivet (BM) exhibit a very rugged relief with a maximum elevation of more than 2000 m (POPOV & LEITCHENKOV 2000). Deeply incised mountain valleys edging the eastern scarp of Annandags Peaks and the southern side of Borgmassivet are marked by short wave-lengths (25 km) gravity anomalies of less than 40 mGal amplitude, which surround the Ritscherflya Anomaly (RFA) from the east and northeast. The mountain ranges of Heimefrontfjella (HF) and Mannefallknausane (MK) located further towards the SW have altitudes of more than 2000 m and 1200 m, respectively. They are delineated by a wide (>50 km) single zone of positive gravity anomalies showing a general E-W trend and amplitudes ranging from 110 mGal to 60 mGal (Fig. 5). In the north the gravity highs are bordered by linear regional low of less than -40 mGal in amplitude. The low is about 300 km long and has an average width of 50 km. It correlates with a broad bedrock depression occupied by the large outlet Endurance Glacier (EG), which dominates the area to the north of the Heimefrontfjella and Mannefallknausane mountains (Fig. 1). The bedrock depression gradually deepens from 400 m in the east to -800 m in the west underneath the Endurance Glacier. It locates the structural boundary between two mountainous regions of Ritscher Upland and HF-MK ranges. The steep gradient along the southern side of the Endurance Glacier gravity low (Fig. 7) is associated with a scarp of the Heimefrontfjella. The scarp has altitude of more than 2000 m indicative of its fault controlled origin.

Another regional gravity low but much intensive and wide stretches parallel to the coast flanking the East Antarctic craton margin anomaly (EACMA) in the southeast (Fig. 5). It covers the gently seaward sloped foot of the NW side of the Ritscher Upland, which turns into the coastal lowland. The negative anomaly is about 100 km wide and up to 200 km long. It has an average amplitude of about -40 mGal with single short wavelength (<30 km) lows reaching of less than -60 mGal. One of them is centered over a wide and deep (-800 m) bedrock depression bounded in the south by the Vestfjella (VF) highland (or Kraul Mountains) (Fig. 1). The isolated highland is topped by a chain of outcrops aligning in the SW-NE direction parallel to the coastline and having the maximum measured elevation below 700 m. In fact, the masked by ice Vestfjella highland represents a system of an elongated, W-E striking bedrock highs with altitudes of between 100 and 300 m above sea level (Popov & Leitchenkov 2000). The area of sub-ice bedrock highs is associated with the W-E trending negative anomaly of about -20 mGal in amplitude and of 50 km in width, which separates two regional gravity lows described above (Fig. 5). In the west it abuts a round-shaped (80 km across) intensive positive anomaly with two local highs of up to 95 mGal amplitude. These remarkable gravity highs correspond to the westernmost part of the Vestfjella highland. Similar high-amplitude anomalies are observed over the Heimefrontfjella mountain range (>2000 m), Ritscher Upland (>1600 m) and at the shelf edge (EACMA). The former two are of topographic origin, whereas the latter is possibly related to mafic intrusions emplaced into the middle/lower crust. Apparently the nature of the Vestfjella Anomaly (VFA) is alike the EACMA. An Olivine gabbro intrusion outcropping on the Utpostane and the Muren (Hjelle & Winsnes 1972, Luttinen et al. 1994) provides support for such suggestion.

At the southernmost limit of the surveyed mountain region there is a partially mapped linear negative anomaly coinciding with the Stancomb-Wills Ice Stream (SWIS). The anomaly is of -20 mGal amplitude and about 40 km wide. It has the E-W trend parallel to the gravity lineations to the north. All these linear anomalies end in 25-30 km offshore abutting the EACMA. From a few radio-echo sounding data the area between 18 °W and 21 °W is dominated by a broad bedrock depression with an average depth of about -500 m increasing to more than -1000 m at the base of bedrock trough underlying the ice stream. Apparently the bedrock trough continuous beyond the ice-grounding line further seawards and may be identified as a structural divide between crustal morphologies of WDML and Coats Land. It may also be related to the proposed crustal discontinuity (likely a deep transverse fault) between continental margins of western Dronning Maud Land and the Weddell Sea Embayment. This is supported by the clear change in the regional gravity field pattern within the both onshore and offshore areas to the southwest and the northeast from line of strike of the Stancomb-Wills Ice Stream gravity low (Figs. 5, 7).

Coastal side of Coats Land.

The dominant features of free-air gravity field in Coats Land are a wide (about 100 km) arcuate zone of positive anomalies extending along the coast and a broad (>80 km) high amplitude negative anomaly bounding the former to the south (Fig. 5). The gravity anomaly field fabric shows a high degree of correlation both in sign and amplitude with topographic features exactly reproducing the sub-ice bedrock morphology. The bedrock topography of Coats Land is represented by the weakly rugged plateau with a mean elevation about 300 m above sea level, which occupies the northern coastal area and has the coast-parallel arcuate trend (Fig. 1). The average width of the plateau is 100 km and the length is over 400 km. The notable bedrock trough stretching from NW to SE dissects the plateau nearly 32-33 °W. It is of 35 km width and of -400 m depth at the base. To the southeast the Coats Land highland is bounded by the prominent bedrock depression, of more than 100 km in width, of the Bailey Ice Stream descending in places to 1500 m below sea level. The large scarp (>2000 m) of the Theron Mountains bounds the bedrock depression in the south. Nearby the coastline the depression turns into a narrow (50-60 km) structure. Here it gradually passes into another one lying at an average depth of -1000 m underneath the Filchner Ice Shelf. As a whole the depressions form a morphologic feature extending for more than 300 km with a general SW-NE trend. It clearly outlined by wide, elongated in the same direction negative regional gravity anomaly, which consist of two high-amplitude lows merging close to the shoreline. The most intensive low of more than -90 mGal and of about 100 km in width is associated with the onshore bedrock depression running at the foot of the Theron Mountains. The other one, placed offshore, reaches of -60 mGal amplitude at the mouth of the Slessor Glacier. A wide (>100 km) arcuate zone of positive gravity anomalies ranging in amplitudes from 30-60 mGal, delineates the morphologic plateau in the north. The zone is disrupted by a short wavelength (25-30 km) negative anomaly of -20 mGal amplitude corresponding to the bedrock trough dissected the plateau at 32-33 °W. The western limit of the both negative and positive free-air anomalies associated with bedrock morphology of Coats Land is well defined by the distinct linear gravity gradient trending along the eastern side of the Thiel Trough (Fig. 7).

The Bouguer gravity field beneath Coats Land is dominated by a broad regional gravity low with an average amplitude of more than -40 mGal (Fig. 6). The Coats Land crustal block is well distinguished from the adjacent areas of the WSE basin province by exclusively negative Bouguer-gravity. The western boundary of the Coats Land block is structurally defined by a clean-cut gravity gradient, which can be traced from the mouth of the Bailey Ice Stream in the SE across the morphological plateau towards the Filchner ice-front in the NW (Figs. 6, 8). The peculiar features of the block are several diversely oriented linear minima locally reaching amplitudes greater than -60 mGal. The most intensive gravity lows form an elongated zone of 35-40 km in width stretching roughly in NW-NNW direction from the Theron Mountains for at least 200 km across the Bailey Ice Stream and the morphological plateau. It seems quite reasonably to suggest that the linear gravity lows are associated with a branching system of graben structures evolved in the crystalline Precambrian basement and filled by less dens sediments. Sub-horizontal Lower Permian sedimentary rocks intruded by doleritic sills or dykes crop out in the Theron Mountains (KAMENEV & IVANOV 1983) and quite probably may have more wide areal extent in the coastal region. The supposed grabens may be most likely of Permian age or younger. A noticeable feature in the southernmost part of this system is an intensive low of -65 mGal in amplitude centered over a topographic high in the bedrock trough of the Bailey Ice Stream. The topographic high has a relative altitude of about 500 m against bedrock elevations of more than 1000 m below sea level in the trough valley. This bedrock rise appears to be formed by an unusually low density sediments apparently of moraine origin, which produce an additional negative gravitational effect. As it was shown by BEHRENDT (1962) the subglacial moraine in the southern Weddell Sea region is responsible at least in part for negative gravity anomalies. Along with linear features a number of gravity highs and lows of different size and intensity are visible (Fig. 9). The sources of these anomalies, which primarily reflect wide variations in density properties of basement rocks, are not immediately evident. However, the gravity highs located at the sides of the proposed graben system appear to be associated with intrusions of different composition, genetically related to grabens formation since gravity and magnetic anomalies seem to be related (GOLYNSKY et al. 2000). Gravity highs of middle amplitudes, observed along the western boundary of the major graben, are closely correlated with positive magnetic anomalies reaching amplitudes up to 200 nT. They are presumably attributed to relatively dense and magnetic gabbro intrusions. The most intensive gravity highs observed at 29 °W, 77° 15'S and 32 °W, 77° 30'S are associated with negative magnetic anomalies and may be caused by high-density alcaline-ultramafic (ultra basic), non-magnetic rocks.

SUMMARY

The presented maps compiled on a great amount of data covering an area of approximately 1 500 000 km^2 give a comprehensive view of regional gravity field features and their spatial relationships, as well their relations with known geological structures and with those discovered by seismic and aeromagnetic surveying. Providing new gravity information these maps will be of valid reference for interpreting the regional tectonic fabric and for better understanding the nature of crustal morphologies in the southern Weddell Sea. The unified gravity database, which was created from available Russian data sets can be considered as an example to integrate geophysical data accumulated over a long span of time and by different investigators. Such integrated databases and their joint interpretation should provide new insight into crustal features and tectonic evolution of the rifted continental margins of the southern Weddell Sea and thereby should give strong constrains for subsequent Gondwana reconstructions. That is of vital importance since poor geological knowledge, limited to scarce isolated rock exposures, together with a great insulation of geophysical data sets acquired different countries and used as a base for paleotectonic suggestions have led to many diverse models and contradictory views on the tectonic development of the southern Weddell Sea Province (GRUNOW 1993, KRISTOFFERSEN & HINZ 1991, HÜBSCHER et al. 1996, JOKAT et al. 1996, GHIDELLA & LABRECQUE 1997).

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