

# Power Spectra Analysis of Gravity Data from the Weddell Sea Embayment and Adjacent Areas

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**Abstract** To determine the depth of the crust-mantle boundary and other interfaces beneath the Weddell Sea embayment and adjacent area we used gravity data power spectra analysis. This method yields the depths of significant density contrasts in the crust, where there is little information on the crustal structure. The gravity data set used for this study contains marine and land gravity data acquired by several institutions. A distinct change in the power spectra is observed at the transition from the continental shelf beneath the Filchner and Ronne ice shelves to the East Antarctic Craton beneath Coats Land. Linear least square regression slopes of these power spectra yield Moho depths between 21.0 and 25.1 km beneath the continental shelf and 31.0 km beneath Coats Land. The estimation of the Moho depth along the Ronne Ice Shelf edge is confirmed by seismic refraction measurements. The thicker crust beneath Coats Land indicates a change in crustal composition; the crust evolves from a sedimentary basin underlain by stretched continental crust beneath the Filchner and Ronne ice shelves, to the Precambrian crust forming the East Antarctic Craton beneath Coats Land.

## INTRODUCTION

The Weddell Sea embayment is bounded on its western side by the Mesozoic magmatic arc of the Antarctic Peninsula and on its eastern side by the East Antarctic Craton formed by the Maudheim Province, which lies beneath Coats Land. The Maudheim Province consists of Proterozoic metamorphic rocks of Grenvillian age (Storey et al., 1994). Results from refraction seismic measurements in the Weddell Sea embayment, revealed an intra continental sedimentary basin beneath the Ronne Ice Shelf, with sediment thicknesses of at least 10 km (e.g. Jokat et al., 1997; Grikurov et al., 1991). Apart from the seismic refraction data along the Ronne Ice Shelf edge, gravity data is the only other data set available for the study of the lower crust. The gravity data has been acquired since 1970 by various institutions. Shipboard collected data were acquired by the Alfred Wegener Institute (AWI), the Federal Institute of Geosciences and Natural Resources (BGR) and the University of Bergen during the Norwegian Antarctic Research Expeditions (NARE). Gravity measurements on the ice shelves have been undertaken by Sevmorgeologia, St Petersburg (Russia). A compilation of shipboard and land gravity data sets in the Weddell Sea embayment has been used in this study (Fig. 1).

Forward modelling of gravity data depends critically upon the knowledge of sediment densities. Velocity-density relations for sedimentary rocks overcompacted by ice shelves during glacial times do not exist and seismic velocities are only known for a narrow area along the edge of the Ronne Ice Shelf. For this reason, we prefer to obtain information on the lower crustal structure in this

region by analysing the gravity data using the power spectra method.

## DATA PROCESSING

Meyer (1995) processed parts of the marine gravity data; we added and processed additional marine surveys during this study. To improve the internal consistency of the different marine gravity data sets, we applied a crossover correction to minimize discrepancies in gravity measurements at the ship track crossings. This levelling procedure reduces the total root mean square (rms) crossover error to 1.6 mGal, which can be regarded as an estimate for the marine gravity data uncertainty. Along the edge of the Ronne Ice Shelf, marine and land data cover the same region and therefore can be compared. The marine and land gravity data along this narrow stripe can differ by up to ~3 mGal. For grid compilation, 5 km by 5 km block mean values were computed using a L2-norm filter. These mean values were minimum curvature gridded with a tension factor of 0.25 using the algorithm of Smith & Wesel (1990). Figure 1 shows the distribution of the data used in this study.

## METHOD REVIEW

In order to obtain mean depths to interfaces of significant density contrasts in the crust, we applied the spectral factorization method (Spector & Grant, 1970; Karner & Watts, 1983). This

spectral approach is based on the assumption that interfaces are essentially horizontal with some small relief. The gravitational variation of this subsurface topography can be described in the frequency domain by the first term of Parker's (1972) expansion. Assuming a group of prismatic sources distributed over the subsurface topography, the gravity power spectrum of the group of bodies reveals a quasi-linear relationship between the wavenumber  $k_r$  and the power spectral density (PSD). Plotting the natural logarithm of the radially averaged power spectrum of the free-air anomaly versus wavenumber results in several linear segments, which correspond to the mean depths of the density contrasts. The slopes of the best fitting lines multiplied by -0.5 yield the mean depths to the sources.

## RESULTS

The depths corresponding to the density contrasts were estimated in three different areas (Fig. 1). These subgrids are a compromise between uniform area and size. Areas should contain provinces of uniform geology, but on the other hand should be large enough to resolve longer wavelengths and therefore greater depths. In addition, the selected areas should contain no large gaps in the data coverage.

The three regions cover areas of 900 km<sup>2</sup> each. Region I covers the continental shelf north of the Filchner Ice Shelf. Region II is located west of Berkner Island and contains a section of the continental crust beneath the Ronne Ice Shelf. In contrast to region I and II, region III, which is located in Coats Land, contains Precambrian crust which forms part of the East Antarctic Craton. Results of the power spectra analyses are shown in figure 2 and summarized in table 1.

Each of the linear segments was fitted by a least squares best fitting line. The choice of the endpoints for the linear regression was made by visual inspection. For this reason, the results are subjective. Confidence limits for the depth estimations given in figure 2 and table 1 were calculated from the standard errors of the slopes of the best fitting lines for the linear segments. Errors in depth are greater for deeper interfaces because longer wavelengths (i.e. deeper sources) are mapped in the spectral domain by only a few points. Hence, small changes in the standard deviation of the slope will produce large standard errors in the depth. At high frequencies, PSDs typically flatten out and the spectrum turns to white noise by the Nyquist wavenumber (0.63 km<sup>-1</sup>). Since there is still a linear alignment of the PSDs at high frequencies, these PSDs seem not to be contaminated by white noise.

For regions I and II, we obtained two distinct linear segments corresponding to a deeper and a shallower interface. The deeper interface ( $d_1$ ) of region II corresponds to a depth of 21.0 km. This density contrast is interpreted to reflect the transition from the crust to the mantle. Jokat et al. (1997) report a depth to the Moho along the Ronne Ice Shelf edge of 27 km. A second possible explanation is a change in seismic velocities, which occurs at 19 km depth in this area (Jokat et al., 1997). This layer was interpreted by Hübscher et al. (1996) as magmatic underplating. Gravity modeling in the same region (Hunter et al., 1996) show as well a density contrast at this depth. However, the observed interface  $d_1$  of region II is interpreted to represent the Moho within the confidence limit, because the density contrast of the crust-mantle transition is the

most significant one in this area.

The deeper interface ( $d_1$ ) changes from 21.0 km (region II) to 25.1 km (region I) depth. The shallower interface ( $d_2$ ) of 4.4 km for region I and 5.2 km for region II, may represent a density variation in the sedimentary rocks of the basin. The above results are in good agreement with depth estimations from seismic refraction measurements. A shallower, distinct variation in seismic velocities was observed in the sedimentary sequence at a depth of 5 km (Jokat et al., 1997). All these changes in seismic velocities occur at depths, which are within the confidence limits of our power spectra analysis results.

The power spectrum of region III is different from region I and II. Beneath Coats Land, we observe a Moho depth of 31 km, an intermediate depth of 8.3 km and a shallow interface at 4.9 km. The relatively thick crust beneath this area can be explained as a change in crustal composition, from a sedimentary basin underlain by stretched continental crust beneath regions I and II (Jokat et al., 1997) to the East Antarctic Craton of Coats Land in region III. The crustal thickness in this area is lower than expected for Precambrian crust. Region III was chosen under the constraint of the data distribution (Fig. 1) and therefore is not situated further to the East well away from the Filchner Ice Shelf. For this reason, the estimate is some sort of weighted average of thick crust beneath the East Antarctic Craton and the stretched crust below the Filchner Ice Shelf. However, the method applied only yields mean depth with considerable errors. No seismic data are available beneath Coats Land, and therefore, the origin and nature of the intermediate ( $d_2$ ) and shallow ( $d_3$ ) density contrasts remain unclear.

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on the lower right-hand side.

**Table 1:**

Table 1:						
Area	d <sub>1</sub> [km]		d <sub>2</sub> [km]		d <sub>3</sub> [km]	
I	25.1	5.6	4.4	0.1	-	
II	21.0	6.1	5.2	0.1	-	
III	31.0	5.0	8.3	1.6	4.9	0.3

## FIGURE CAPTIONS

Fig. 1 - Location map and place names used in this study. Thin black lines denote location of shipboard gravity profiles and circles indicate gravity measurements on the ice shelves. Areas I-III are used for power spectra analysis and are marked by white boxes. Dark grey fill indicates the Antarctic continent, medium grey fill indicates the Ronne and Filchner ice shelves and light grey fill extends to the 2000 m bathymetric contour. Abbreviations are: AP, Antarctic Peninsula; BI, Berkner Island; CL, Coats Land; FIS, Filchner Ice Shelf; RIS Ronne Ice Shelf; WSE, Weddell Sea embayment. Within this article, the term Weddell Sea embayment includes the embayment area covered by the Filchner and Ronne ice shelves and the continental shelf north of the Ronne and Filchner ice shelves.

Fig. 2 - Power spectra of free-air gravity data. Plots I-III show the natural logarithm of the radially averaged power spectra (PSD) as a function of radial wavenumber  $k_r$ . Mean depth to crustal interfaces estimated from the slope of the corresponding PSD's are shown. Plots I-III correspond to divisions shown in the inset map

FIGURE 1

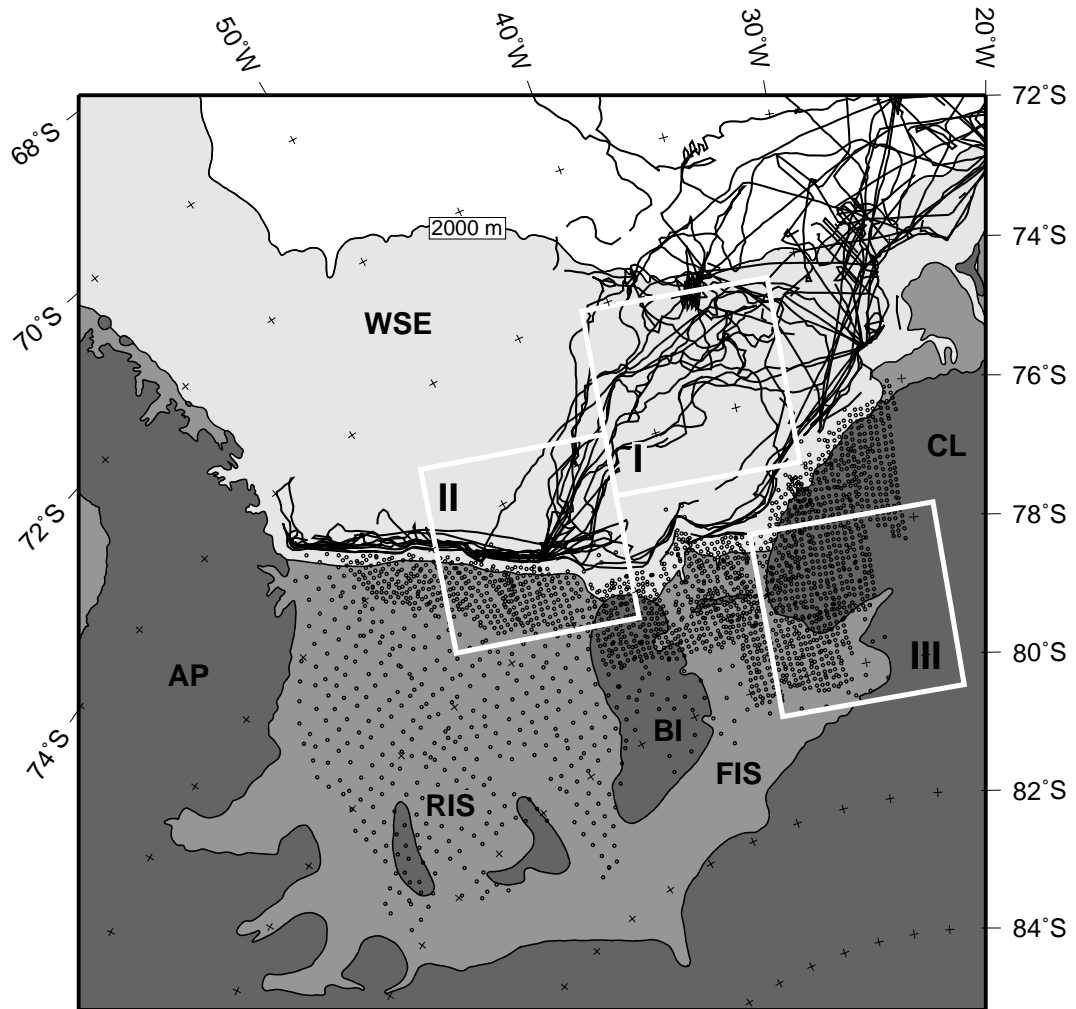


FIGURE 2

