Translated Article

High-resolution Bathymetry at the European Continental Slope

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Within the scope of the GEOMOUND project a systematic survey of the seafloor was carried out using the German research vessel *Polarstern* on the European continental slope south-west of Ireland. The main interest was directed towards carbonate mounds whose properties are to be investigated closely in the GEOMOUND project. Within this project the Alfred Wegener Institute (AWI) has the task of providing a complete bathymetric map base of

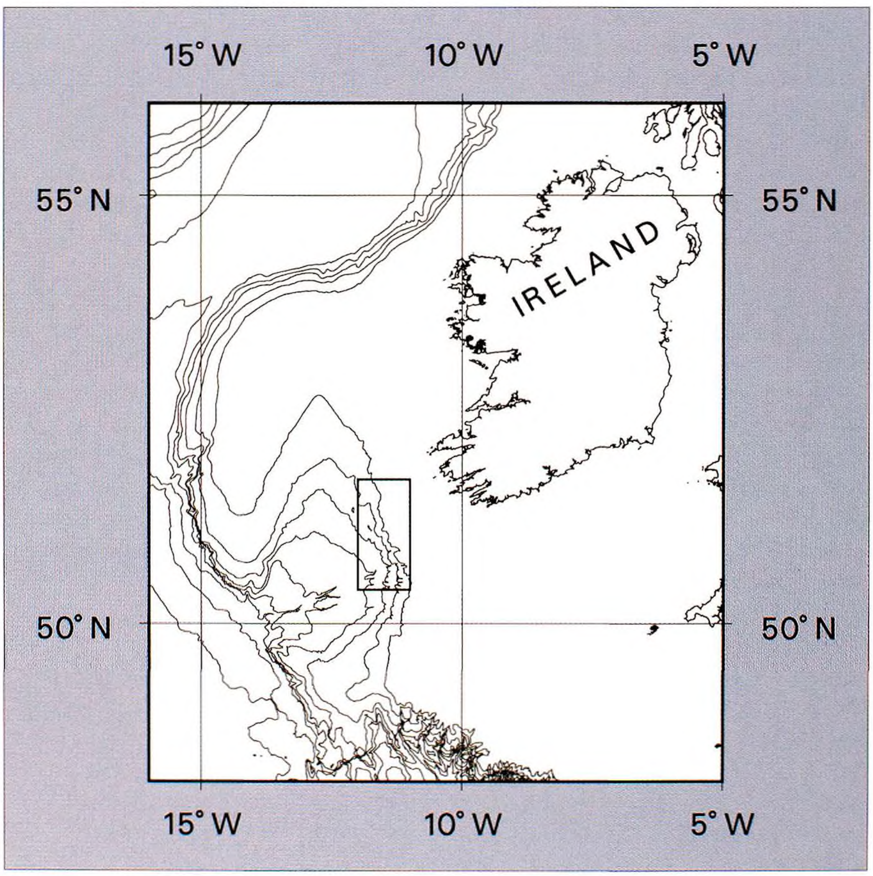

Figure 1: Overview of the research area, contour interval 500 m

the survey area. Therefore, the survey profiles were set up in such a way that a total overlap of the seafloor was guaranteed. The collected multibeam data were used to generate a Digital Terrain Model (DTM) as well as to derive contour lines. During the data processing the specific properties of the multibeam system 'Hydrosweep DS-2' were considered. This article especially focuses on the data recording and on the generation of the DTM and the contour lines.

The GEOMOUND Project

GEOMOUND is a European research project which investigates the structures and the origin of carbonate mounds (Hovland et al., 1994). Science and Industry from several European countries are involved in this project. So far, little has been known about the formation of these hilly morphological forms and their interaction with the surrounding ecosystem. Hypothesis exist which link the carbonate mounds to subsurface fluid migration.
The essential objectives of the GEOMOUND project are (GEOMOUND, 1999):

- Recording and making an inventory of all mounds, as well as their properties (morphology, spatial distribution, chemical constitution) to understand growth and factors of influence. Besides recent data recording, historical data will be taken into account, too
- Analysis of the recorded data to find out whether the mounds are able to serve as an indicator for the existence of hydrocarbons and for fluid migration
- Development of a model to describe the migration of liquids in the sub bottom strata
- Preparation of a European Ocean Drilling Action

Within the GEOMOUND project there are four mound provinces which are each marked by different mound properties. These provinces are situated in the west of Ireland at the Rockall Trough, at the Porcupine Bank and at the Porcupine Seabight. The activities of the AWI concentrate on the Porcupine Seabight (Figure 1).

Hydrographical Survey

The survey presented in this article was carried out at the eastern slope of the Porcupine Seabight. In

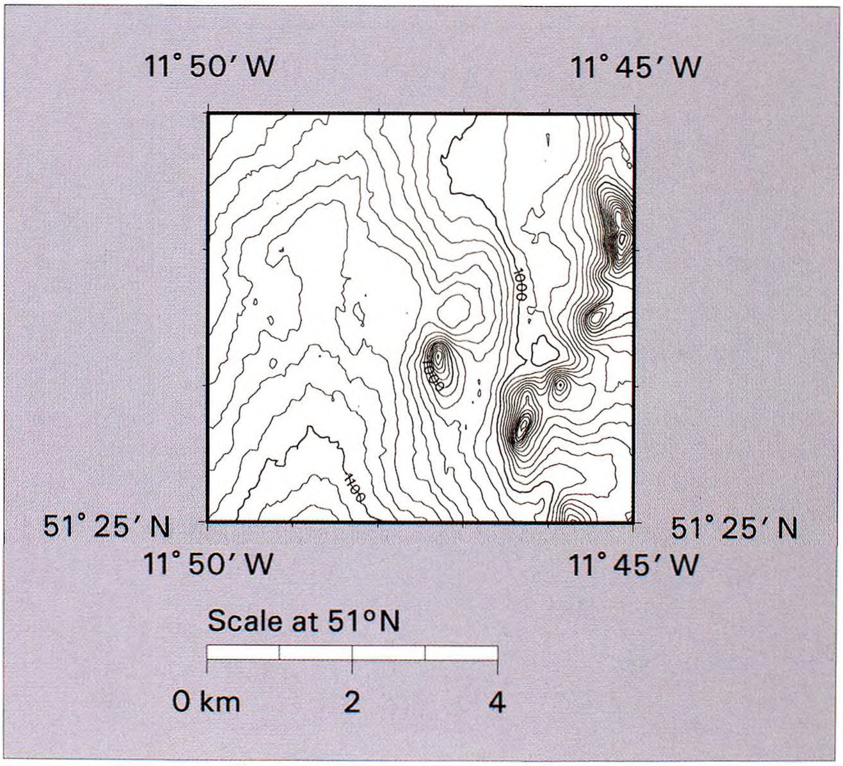

Figure 2: Comparison of the original and generalised depth lines

order to achieve the aim of a complete systematic survey existing bathymetric data were used for the track line planning. Mainly, the depth contours of the GEBCO Digital Atlas 1997 (GDA 97) served as a foundation (GEBCO, 1997). The survey lines were placed parallel to the slope to minimise the depth dependent variation of the sounded fan width. Moreover, the distance between the profiles was chosen in such a way that a 10 per cent overlapping of neighbouring swathes was guaranteed. For positioning Differential GPS was used in order to follow the planned track lines. During the survey some changes of the planned track were necessary since the data of the GDA 97 were not exact enough in places.

The survey area has a size of approximately 140 km x 20 km and was surveyed with 14 profiles within four and a half days. The velocity of the vessel was about 10 knots.

For the depth measurement the multibeam echo sounder 'Hydrosweep DS-2' was used. It operates with a transmitting frequency of 15.5 kHz and the fan width was 90° during the survey. The fan is divided into 59 pre-formed beams (PFBs). Each beam has a width of 2.3° and the beams are spaced 1.53° apart (Atlas, 1997). A depth value is determined for each of them. Due to the constant beam width the sounded area varies according to the depth and slope which results in a variable data density in the survey area.

At the beginning of the survey the sound velocity in the water column was measured with a CTD (conductivity, temperature, depth) at two locations in order to correct the refraction of the depth measurements. One of the profiles was taken at the south-western border of the research area and the other one in the northern part. The difference between these two measurements was very little and the accuracy requirements could be achieved with an average sound velocity profile.

Besides the depths measurements backscatter intensities and pseudo side scan were also recorded. Further analyses are focused on drawing conclusions from these data towards the surface or sediment properties.

During the entire survey the sediment sub-bottom

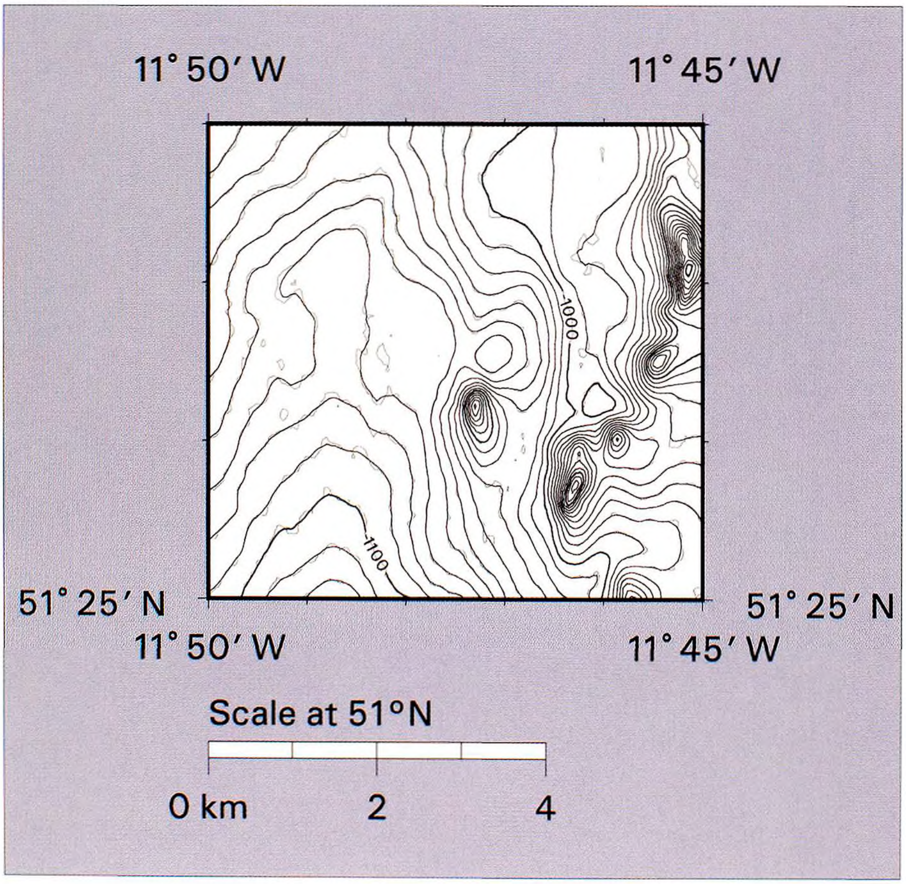

Figure 3: Comparison of the original and generalised contour lines. After generalisation noise is reduced and the generalised depth contours represent the bathymetry very well

profiler 'Parasound' was used. Therefore, systematic information on the sediment structure and the position of reflectors in the sediment were available. In the research area a penetration into the seafloor of between 20 and 50 metres was characteristic. However, due to the beam width of 4° the penetration was reduced in areas with steeper slopes, e.g. the mounds.

Data Processing/Surface Modelling

To derive a high-resolution terrain model of the area from the depth measurements, these have to be examined first to remove spikes and systematic errors. In particular at some places artefacts are visible due to depth measurements of outer PFBs. In addition, there exist systematic changes of the

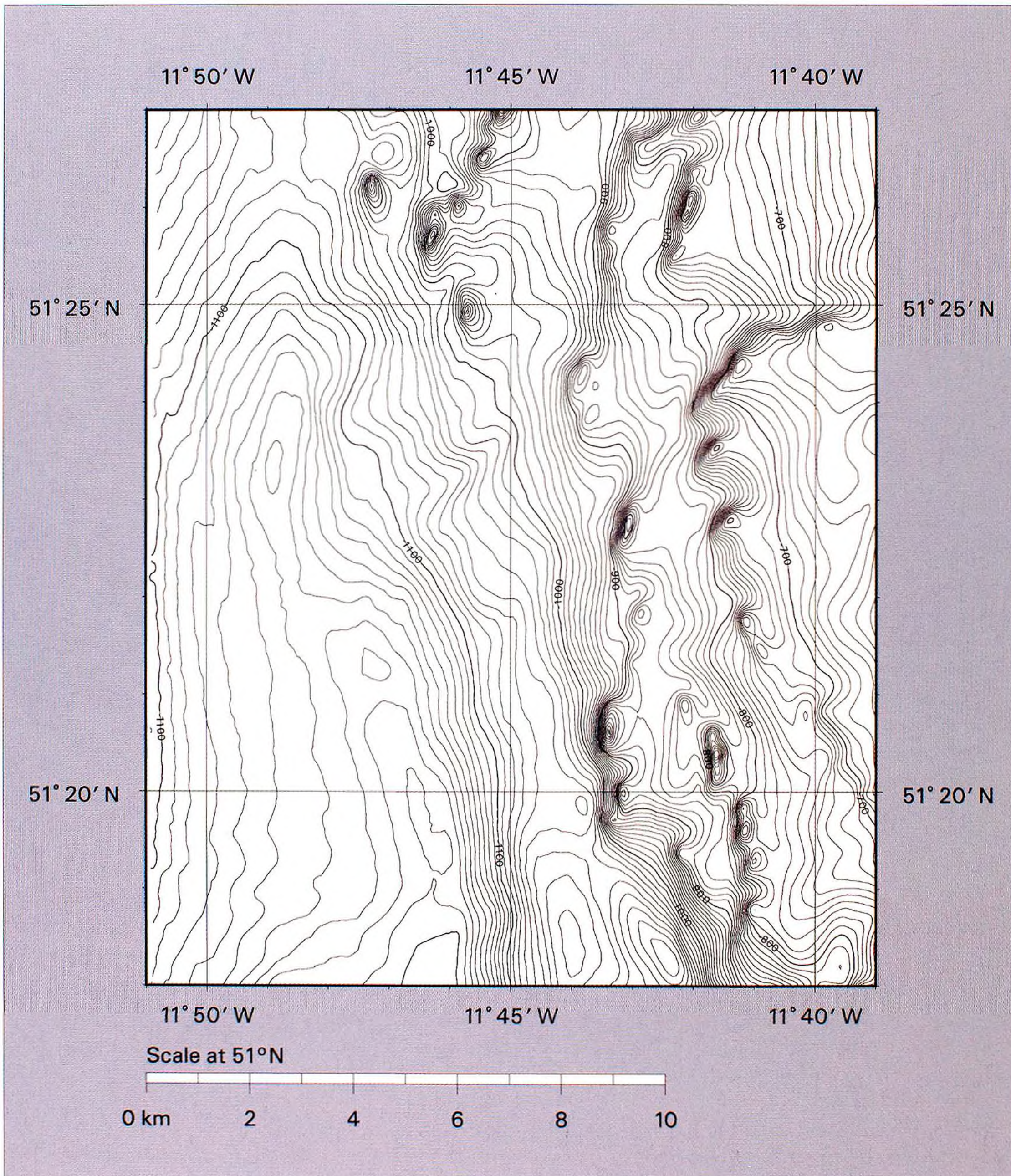

Figure 4: Section from the mound area of the Porcupine Seabight

central PFBs at some steep slopes crosswise to the course which affected the depth measurements known as omega-effect (DeMoustier, Kleinrock, 1986). For the data editing automatic and manual techniques within the 'Hydrographic Data Cleaning' Software (HDCS) were applied (Caris, 1998). At first the single measurements were roughly tested for their plausibility. An automatic error detection followed, based on the standard deviation of the values related to an mean surface. Thus mainly incorrect data within the overlapping areas of neighbouring survey lines could be removed.

Due to the satisfying data density and data distribution a raster Digital Terrain Model (DTM) was used for the calculation (for this data set less memory capacity is necessary than for a comparable triangulated irregular network). After tests of different modelling programmes a routine developed at the AWI was finally used. It was possible to weight every single PFB according to the distance from the central PFB. Another important detail concerning modelling of surfaces can be found in the influence radius around each raster point within which the depth measurement is used to calculate the raster point depth. This radius was set to twice the average distance of the footprints of a swath. This average distance is depth dependent and varies between swathes. It accounts for the depth dependent footprint size of the PFBs and reduces the occurrence of gaps in the DTM if single depth measurements have been removed. Furthermore, a raster point depth is only computed if depth measurements exists within at least 3 out of 4 quadrants around the raster point. The raster width of the DTM was fixed to 50 m. This grid size enables a complete coverage even in deeper parts of the investigation area and retains the morphological information of the shallow areas.

Generalisation of the Depth Contours

In the next step the depth contours were derived from the DTM. For further processing Arc/Info was used which offers a complete GIS-functionality (Geographical Information System). The generation of the depth contours showed that – despite the previous processing – they were still partly influenced by noise. Particularly in areas with a smooth surface the depth contours were strongly influenced. In contrast to that, the depth contours along slopes were hardly influenced by remaining noise. This fact is represented in Figure 2. Because of this situation a generalisation approach was developed which assumes an unfavourable signal-to-noise ratio in flat regions. This approach was applied to the original DTM which means that the depth contours were not directly generalised but derived from a generalised DTM. To realise this approach the original DTM was divided into five slope categories. However, to prevent mound tops and depressions from generalisation, the surroundings of each raster point were also considered during the classification.

For the generalisation filter matrices were used which were adapted according to the slopes within the research area. The slope categories and the corresponding filter matrices are listed in Table 1.

Number of Category	Slope	Filter Technique
1	> 15°	no filter
2	< 15°	3 x 3 binomial
3	< 6°	5 x 5 binomial
4	< 3°	5 x 5 mean value
5	< 1.7°	7 x 7 mean value

Table 1: Slope categories and corresponding filter matrices

Before the filtering could be conducted, the original DTM had to be prepared. Special attention had to be paid to the existence of gaps since they would enlarge because of the filtering. The sporadically existing gaps were closed by mean value filters. After finishing the filtering these gaps were restored so that the generalised contour lines were not influenced at these points.

By applying the slope dependent filtering the remaining noise of the depth contours could be removed. However, there still exist systematic effects which are only recognisable in combination and which, therefore, can hardly be reduced neither in the original data nor by automatic methods. The original and generalised depth contours are compared in Figure 3.

Bathymetry of the Survey Area

Porcupine Seabight expands approximately from 49° N to 52° N latitude and from 14° W to 11° W longitude. The survey area is situated at the eastern slope of Porcupine Seabight and expands from

50°25' N to 51°40' N latitude. This area can be divided into two parts. In the northern part the carbonate mounds occur. This area is slightly flatter than the southern part. A number of about 30 mounds were recorded here (Beyer et. al, 2000). They occur mainly in a depth range of 1,000 m to 700 m and are aligned along the slope. The shape of most mounds resembles an ellipse stretching along the margin roughly from the north to the south. Both axes have a length of approx. 0.5 km to 1.0 km respectively of 1.0 km to 1.5 km. The mounds are about 50 m high but can reach a height of up to 100 m. A section of the mound area can be seen in Figure 4.
The southern part of the research area is marked by submarine channels. They extend from east to west and are part of the 'Gollum Channel System'. They reach a depth of up to 400 m with a width of the bottom of approximately 1 km to 1.5 km. The flanks are rather steep and have a slope of up to 25°.

Literature

Atlas (1997): Service manual, ED 1029 G 042, ATLAS Hydrosweep DS-2, *Hydrographic Multibeam Sweeping Survey Echosounder Polarstern*

Beyer, A., Schenke H.W., Klenke M., Niederjasper, F. (2000): High precision multibeam survey of an area in the Porcupine Basin, *EOS Transactions AGU*, 81 (48), OS61B-15

Caris (1998): *Hydrographic Information Processing System, User's guide*, Universal Systems Ltd., Fredericton, N.B., Canada

GEBCO (1997): *General Bathymetric Chart of the Oceans (Data from GEBCO Digital Atlas)*, IOC, IHO and BODC, 'Supporting Volume to the GEBCO Digital Atlas', published on behalf of the Intergovernmental Oceanographic Commission (of UNESCO) and the International Hydrographic Organization as part to the General Bathymetric Chart of the Ocean (GEBCO); British Oceanographic Data Centre, Birkenhead. *GEBCO Sheet 97.3, bathymetric contours*

GEOMOUND (1999): Contract No. EVK3-CT-1999-00016, *The Mound Factory: Internal Controls*

Hovland, M., Croker, P.F., Martin, M. (1994): Fault-associated seabed mounds (carbonate knolls?) off western Ireland and north-west Australia, *Marine and Petroleum Geology, Vol. 11, No. 2*, 232-246

DeMoustier, C., Kleinrock, M.C. (1986): Bathymetric artifacts in Sea Beam data: How to recognise them and what causes them, *Journal of Geophysical Research, Vol. 91, No. B3*, 3407-3424

Biography

Andreas Beyer finished his studies of Geodesy at the Dresden University of Technology (Germany) in 1999 (diploma). Since then (2000) he has been working at the Alfred Wegener Institute for Polar and Marine Research (AWI) in the group 'Bathymetry and Geodesy'. His work focuses on modelling and analysing the seafloor and on multibeam backscatter strength.

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