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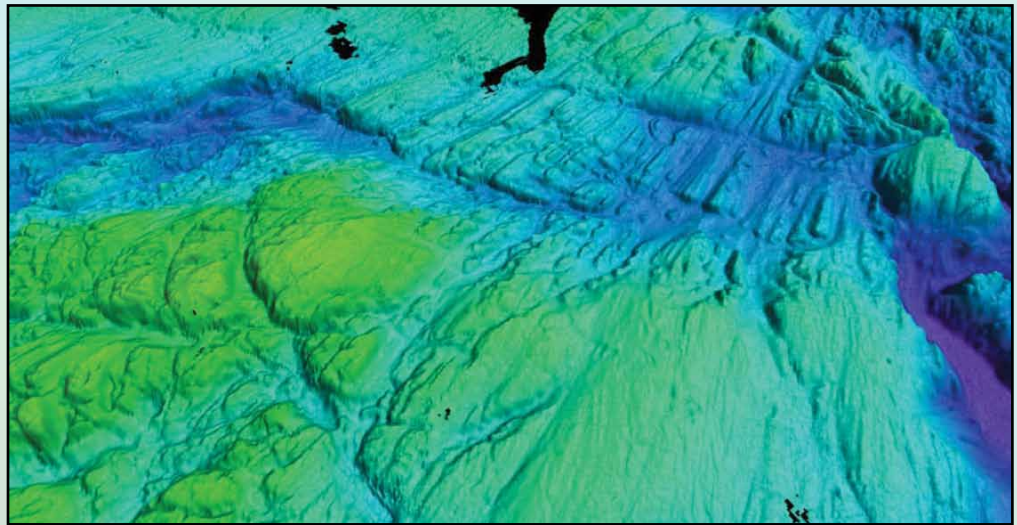
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# SEEING THE SEAFLOOR

## DISCOVERIES OF THE RVIB NATHANIEL B. PALMER MULTIBEAM SYSTEMS

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Three-dimensional view of  
a ~ 30 km wide section in  
800–1,400 m water depth  
showing glacial lineations and  
subglacial meltwater features  
in Pine Island Bay.



**ABSTRACT.** The detailed seafloor topography around Antarctica was virtually unknown until RVIB *Nathaniel B. Palmer* and other ships started to collect multibeam swath measurements in the 1990s. These new, high-resolution bathymetric data allowed the creation of topographic maps of the Antarctic continental shelf and rise with unprecedented detail. The multibeam data revealed glacial morphological features that allowed reconstruction of paleo-ice flow and maximum ice extent of the formerly glaciated continental margin. Furthermore, these data provided the basis for new insights into the continent's tectonic evolution and defined the nature of marine biological habitats in polar regions.

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### INTRODUCTION

Antarctica was the last continent to be discovered. It took many scientific expeditions and technological improvements, especially in airborne and satellite imagery, to obtain a complete image of the continent's surface. Although large areas of the ice sheet had been mapped in detail by the end of the twentieth century, dense sea ice cover and a limited number of capable ships made it difficult to map the seafloor of the continental shelf and ocean that surround the continent. Early expeditions provided glimpses of the seafloor, first using lead line and later single-beam echosounding devices. In frequently visited areas such as the Ross

Sea and the western side of the Antarctic Peninsula, these data provided a good outline of major banks, channels, and the shelf edge (e.g., Davey et al., 2007). In other areas, they provided at least an overview of the continental boundaries. However, these limited data points barely hinted at the complexity of the glacially carved continental shelf, and large areas of the seafloor remained unknown. In fact, outside of several extensively surveyed areas, much seafloor detail is still unknown today (Figure 1).

Seafloor mapping capabilities increased significantly with the introduction of swath or multibeam mapping systems. These new technologies provide bathymetric (and, more recently, backscatter) information from a wide swath across the ship track, resulting in wider and more detailed coverage of the seafloor. At the same time, the introduction of civilian use of Global Positioning System (GPS) signals improved navigation accuracy, allowing exact location of bathymetric data. The new systems revealed seafloor features at much greater detail and allowed for the first time the study and analyses of geological and other processes at finer scale.

*Nathaniel B. Palmer* was one of the first icebreakers operating in Antarctica equipped with a swath sonar system. This paper provides an overview of the contributions and shows examples of the bathymetry data collected on the *Palmer*.

### PALMER'S SWATH BATHYMETRY SYSTEM

The US icebreaking research vessel *Nathaniel B. Palmer* was equipped with its first swath system in 1994, a Seabeam 2112, operated at 12 kHz and capable of recording 120 beams with a 2° x 2° lateral

resolution. In 2002, the Seabeam system was replaced with a Simrad EM120 system, which has 191 beams with 1° x 2° lateral resolution and also operates at 12 kHz. Both systems have an opening angle of 120°, which corresponds to 3.5 times water depth (3.5 km total swath width in 1,000 m, 14 km in 4,000 m). However, in deeper water (> 4,500 m), the usable swath width is narrower, especially for the older Seabeam 2112.

The transducers of the multibeam systems are mounted in the bottom of the ship's hull, with a special cover that protects them from ice damage. They are integrated with the ship's motion sensors and receive data from surface salinity and temperature sensors to accurately correct the soundings for orientation of the ship and sound speed variations.

Basic and, if time allows, full processing of the data are done on the ship. Because the *Palmer* often operates in uncharted waters on the Antarctic continental shelf, the resultant bathymetric maps are essential for planning scientific missions and for ship management.

### DATA COVERAGE

Since the installation of its first multibeam system, the *Palmer* has collected multibeam data on 93 of its ~ 179 expeditions through 2011. Most of these data have been assembled and made available through the Antarctic portal of the Marine Geoscience Data System (<http://www.marine-geo.org/antarctic>) and can be visualized using GeoMapApp (<http://www.geomapapp.org>) and other tools (Ryan et al., 2009).

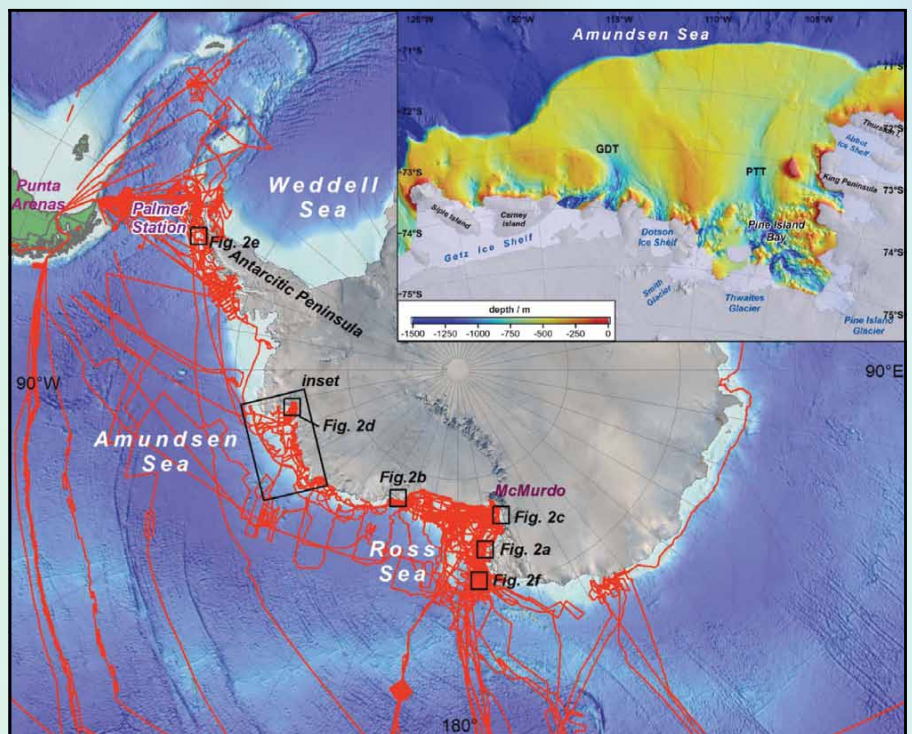


Figure 1. Overview of the multibeam coverage of RVIB *Nathaniel B. Palmer* from 1994–2011 (red lines). Black boxes mark location of inset map and examples shown in Figure 2. (inset) Bathymetry compilation of the Amundsen Sea continental shelf, which shows a clearly defined shelf break and two major, deep (> 1,500 m) trough systems that indicate the location of former ice streams. GDT = Getz-Dotson Trough. PIT = Pine Island Trough. Modified from Nitsche et al. (2007)



Data were collected mainly in the Southern Ocean and Antarctic continental shelf waters but also during several expeditions near New Zealand, Chile, and in the southern Pacific (Figure 1). In Antarctica, most data were collected in the Ross Sea and around the western Antarctic Peninsula. These areas are focus sites of US scientific activities in Antarctica.

## EXAMPLES OF APPLICATIONS AND DISCOVERIES

The wealth of new and detailed bathymetry data from the Antarctic seafloor and the Southern Ocean has substantially increased our knowledge of the shape of the continental margin. In the early 1990s, information about the seafloor around Antarctica was poor in many areas. For large sections of the Antarctic

margins, even the exact location of the shelf break was uncertain.

The bathymetry data collected by the *Palmer* and other ships have provided the basis for several compilations and maps that have revealed the shape of the continental margin (e.g., Amundsen Sea; Figure 1 inset; Nitsche et al., 2007).

### Glacial Morphology (Traces of Past Glaciations)

One of the key discoveries from the new seafloor bathymetry data on the Antarctic continental shelf was the presence of glacial morphological features that allowed the reconstruction of ice flow across the previously glaciated margin (Anderson, 1999; Wellner et al., 2001, 2006). Although the locations of some troughs were known from single-beam soundings, the reduction of multibeam data resulted in better outlines of these cross-shelf troughs and revealed features indicating that they were formed by fast-flowing ice streams when grounded ice sheets occupied the outer shelf (Shipp et al., 1999; Canals et al., 2000). These features include megascale glacial lineations, drumlins, and grooves (see graphic on p. 136; Figure 2a–d), as well as gullies on the upper continental slope. In some troughs, a ridge indicating a temporary halt during ice retreat (grounding zone wedge; Figure 2c) can be observed (Mosola and Anderson, 2006).

### Tectonic and Geologic History

Detailed bathymetry data from deeper parts of the seafloor such as mid-ocean ridges and seamounts provide important information about the tectonic evolution and related volcanic history of the Southern Ocean (e.g., Croon et al., 2008; Barclay et al., 2009) and the Ross Sea (e.g., Wilson and Luyendyk, 2006). High-resolution swath bathymetry not

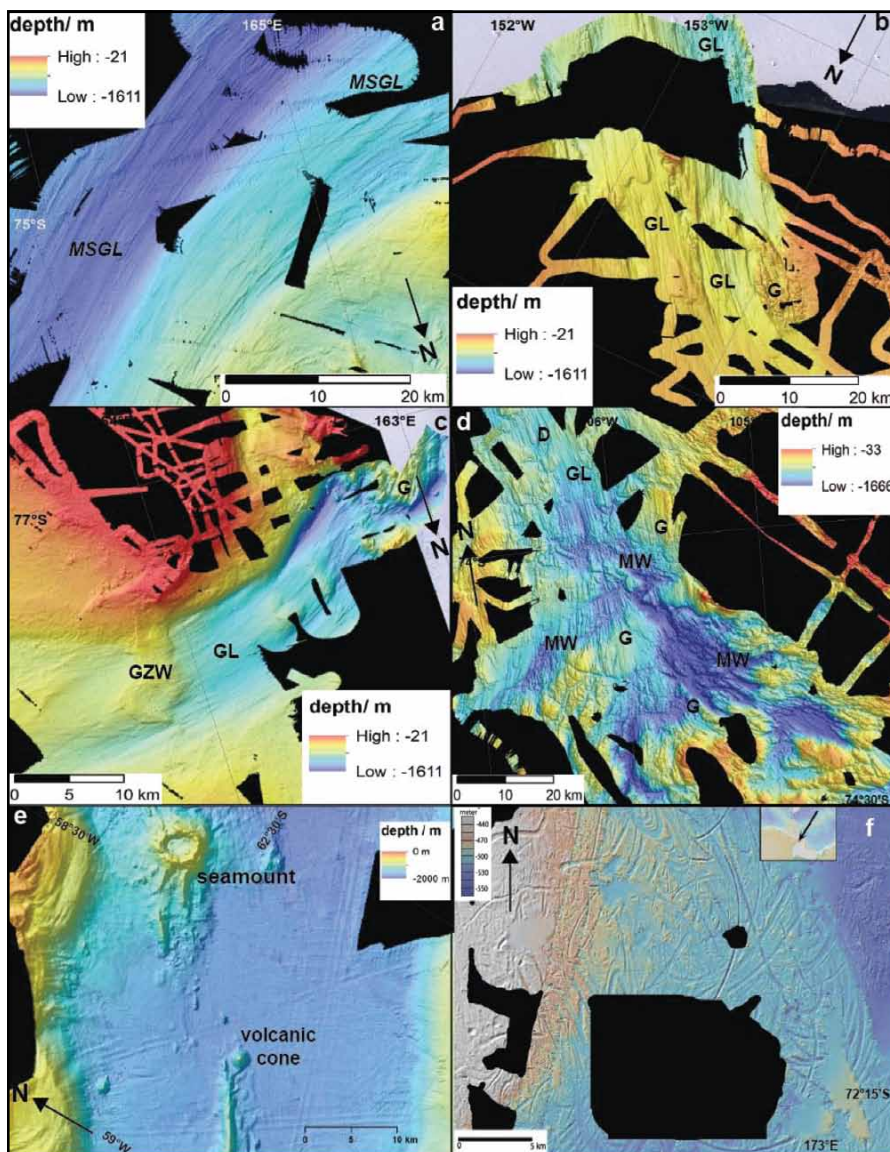


Figure 2. Examples of glacial morphological features: (a) Megascale glacial lineation (MSGL) north of the Drygalski ice tongue. (b) Glacial lineations (GL), and erosional features (G) in Sulzberger Bay. (c) Deep basin and grounding zone wedge (GZW) north of McMurdo. (d) Drumlins (D) and subglacial meltwater (MW) features in front of Pine Island Glacier. (e) Volcanic seamount and ridges in the central Bransfield Strait. The seamount at upper center reaches ~750 m above the surrounding seafloor. (f) Iceberg scours crisscrossing the outer continental shelf of the Ross Sea. See Figure 1 for locations.

only reveals these geological structures but also provides the basis for subsequent sampling.

### Biology and Habitat Mapping

In addition to providing geological information, some morphological features of the seafloor form important benthic habitats (Clarke, 1996). Bathymetric data collected by the *Palmer* have been essential for identifying and locating different habitats and studying cold-water corals on the steep flanks of seamounts (Sahling et al., 2005), as well as investigating potentially nonglaciated refuge areas on the continental margin and the impact of iceberg scours on benthic life (Figure 2f; Lee et al., 2001).

### Physical Oceanography

Furthermore, detailed bathymetry aids understanding of physical oceanographic processes, including deepwater flow routes and iceberg movement and behavior (Davey and Jacobs, 2007; Martin et al., 2010). Swath bathymetry data are also crucial for identifying suitable sites for deployment of oceanographic moorings, and collection of water property measurements.


### SUMMARY AND OUTLOOK

Since the first installation of a multibeam system on the *Palmer*, the data collected have significantly increased the resolution and portion of mapped Antarctic seafloor. The increased coverage and great detail of the swath bathymetry data contributed significantly to our current knowledge of subglacial processes, tectonic evolution, and benthic habitats all around Antarctica. However, much of the Antarctic seafloor remains uncharted, and there are still sections where the location of the shelf break is uncertain. Thus, there are possibilities

for significant discoveries during future expeditions of the *Palmer* and other multibeam-equipped research ships.

While it takes considerable effort, collecting new high-quality multibeam data is essential to progress in many scientific fields and, therefore, every opportunity should be taken to fill in gaps of data coverage and knowledge.

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