Neotectonic and other features of the Victoria Land Basin, Antarctica, interpreted from multibeam bathymetry data

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Summary From 19 January to 18 February 2004, the NBP0401 cruise of *RVIB Nathaniel B. Palmer* surveyed the Terror Rift and southern half of the Victoria Land Basin (VLB) of the Ross Sea, Antarctica. The very large iceberg, B-15, split latitudinally at the end of October 2003, and then split longitudinally in mid-December 2003. These large pieces restricted ice movement out of the VLB and left about half of our proposed study area covered in icebergs or very thick multi-year ice. Approximately 3000 km^2 of continuous multibeam bathymetry coverage were successfully collected in McMurdo Sound between 77˚S and 77˚40'S and from 164˚40'W to Ross Island. Additional multibeam coverage were collected in the VLB, north of Franklin Island and in a 15 by 40 km area near 76˚N, 176˚E. The multibeam data revealed numerous features indicative of significant neotectonism. Lineated submarine volcanic cones and dykes radiating from Mt. Erebus are common in the eastern side of McMurdo Sound. On the western side of the Sound, a narrow, steep-walled channel, less than 200 meters wide and up to 60 meters deep, drains the Taylor Valley/Ferrar Glacier. It trends due north, parallel to the shelf before turning northeast into the basin. The unusual direction of the channel is possibly controlled by resistant volcanic features or by older faulting. Sinuous submarine channels in the well-defined 'flexural moat' surrounding Ross Island, are found to a depth of 800-850 m, indicating northward directed flow into the basin. Northwest of Franklin Island is a distributed field of pockmarks, with individual nearly circular pits up to 500 m in diameter and 30 m deep. In a 15 by 40 km area about 60 km west and slightly north of Franklin Island, are eight nearly circular features up to 4 km in diameter and 100+ m high. Their nearly, circular shapes suggest a magmatic origin but they do not have a magnetic signature which suggests that they may in fact be glacial in origin. The features are asymmetrical with the southeastern side being quite steep and the northwestern side gradually sloping to the northwest. As glacial features, the closest analogue for them are drumlins albeit these are very large. If magmatic, they resemble tuyas found in Iceland. The new bathymetric data, although limited, show that there are still many seafloor features in the western Ross Sea to be found.

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Introduction

The NBP0401 cruise collected bathymetry, seismic, gravity and magnetic data in order to determine the neotectonic structure and development of the Terror Rift. In addition, eight dredges and one shore excursion on Franklin Island, collected olivine rich, Cenozoic volcanics. During the 2003-2004 austral spring and summer, unusually heavy ice conditions in the VLB and McMurdo Sound hampered our efforts to survey the entire Terror Rift, particularly between 77˚S and the Drygalski Ice Tongue at 75˚20'S. Our shiptrack (shown in Figure 1) indicates the impact of the ice conditions on the full realization of our objectives. B-15, a very large iceberg, broke off the Ross Ice Shelf in 2001 and by the 2002-2003 season had essentially trapped the annual ice in the western Ross Sea. The initial latitudinal break of B-15 produced B-15A to the north and B-15J to the south. B-15K, a sliver broke off the western margin of B-15A about a month before the NBP0401 cruise and lodged against Beaufort Island in the south and an unnamed seamount to the north. During the first part of the cruise, we mapped and collected seismic data primarily between Franklin Island/B-15A and B-15K, and to the north and northeast of Franklin Island. A few weeks into the cruise, the southern part of McMurdo Sound opened up and we were able map it, but only north to 77˚S. At the very end of the cruise, the western edge of McMurdo Sound opened up and we collected data under difficult ice conditions which at times even required us to cease operations. The seismic data collected show numerous examples of active faulting, all the way to the east of Franklin Island while the multibeam seafloor mapping gives insight into some intriguing and heretofore unseen seafloor features. Two of the most intriguing seafloor morphological features are on the ice-limited edge of the 2004 survey so their complete areal extents are unknown.

Multibeam bathymetric data collection

Multibeam bathymetric data were collected using a Simrad EM120 multibeam sonar system. The raw multibeam data were logged in hour-long files in the Kongsberg-Simrad EM120 raw format and converted to MB-System format 57 files. The MB-System 4.6 software package (Caress and Chayes, 2004) was used for all multibeam post-acquisition processing, including data editing and quality control. Edited data were then gridded using the Generic Mapping Tools

(GMT) software of Wessel and Smith (1998). Experiments with gridded cell size, illumination intensity, and illumination angle, highlighted notable seafloor morphologic features.

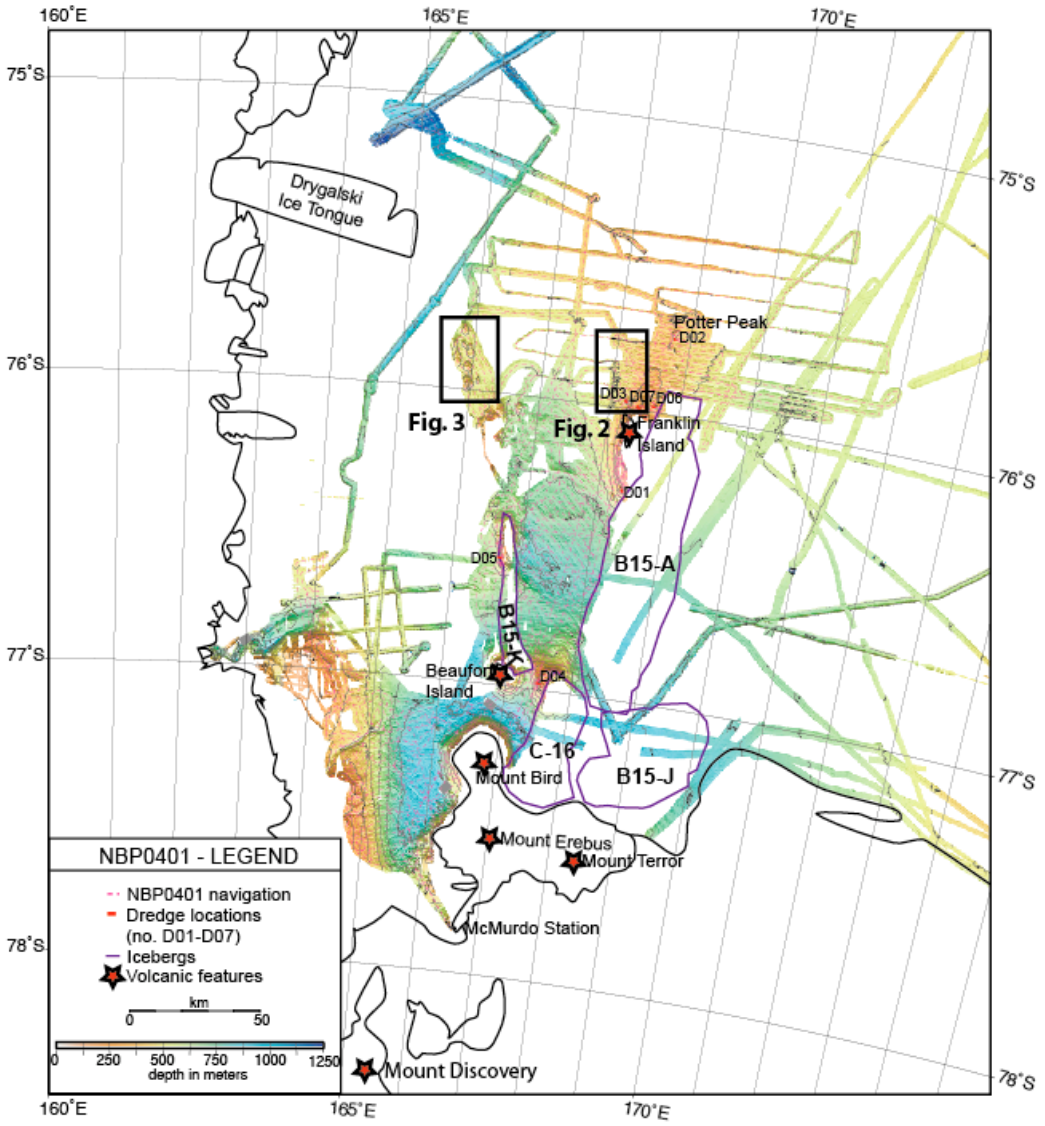

Figure 1. Location map with NBP0401 seismic data as dashed line with additional multibeam bathymetry data shown from all available *RVIB N.B. Palmer* cruises. Large tabular icebergs shown in solid purple outline, ie. **B15-J**. The area of McMurdo Sound to the north and west of our survey track was ice-covered north to the Drygalski Ice Tongue. Locations of figures 2 and 3 shown as black boxes.

NBP0401 bathymetry data reveal several intriguing features in the western Ross Sea, including canyons, diking just west of Ross Island, pockmarks north of Franklin Island and strange circular highs to the west of Franklin Island. Along the western margin of our mapped area, we found excellent examples of canyon cutting in the East Antarctic margin which dissipated by about 500 meters water depth. To the north of 77˚S, the MacKay Sea Valley region has been mapped by other groups so we did not duplicate their work. On the east side of the southern McMurdo Sound we mapped dike features off Ross Island, with one dike having the remarkable length of 4 km by 600 m wide and 175 m high. Immediately to the northwest of Ross Island, the preliminary draft of the Davey (2004) bathymetric chart of the Ross Sea showed a prominent seamount with a minimum depth of 585 m at 77.15°S, 165.5°W. That seamount was identified as a prime dredge target so we spent time specifically looking for it. As it turned out, the 585m seamount does not exist and has been removed from the final version of the Davey map.

To the northwest of Franklin Island, a number of pockmarks are seen in the seafloor (Figure 2). The pockmarks are roughly circular, average approximately 400 m in diameter, and are up to 30 m deep. They are found concentrated at

depths between 430 to 475 m, with a seafloor gradient on the order of 10 m per km or a nearly flat seafloor. To the north of the concentrated survey area, a few elongate pockmarks are seen on an isolated multibeam profile at 75°35'S and the pockmarks disappear to the south as the bottom morphology steepens along the western margin of Franklin Island.

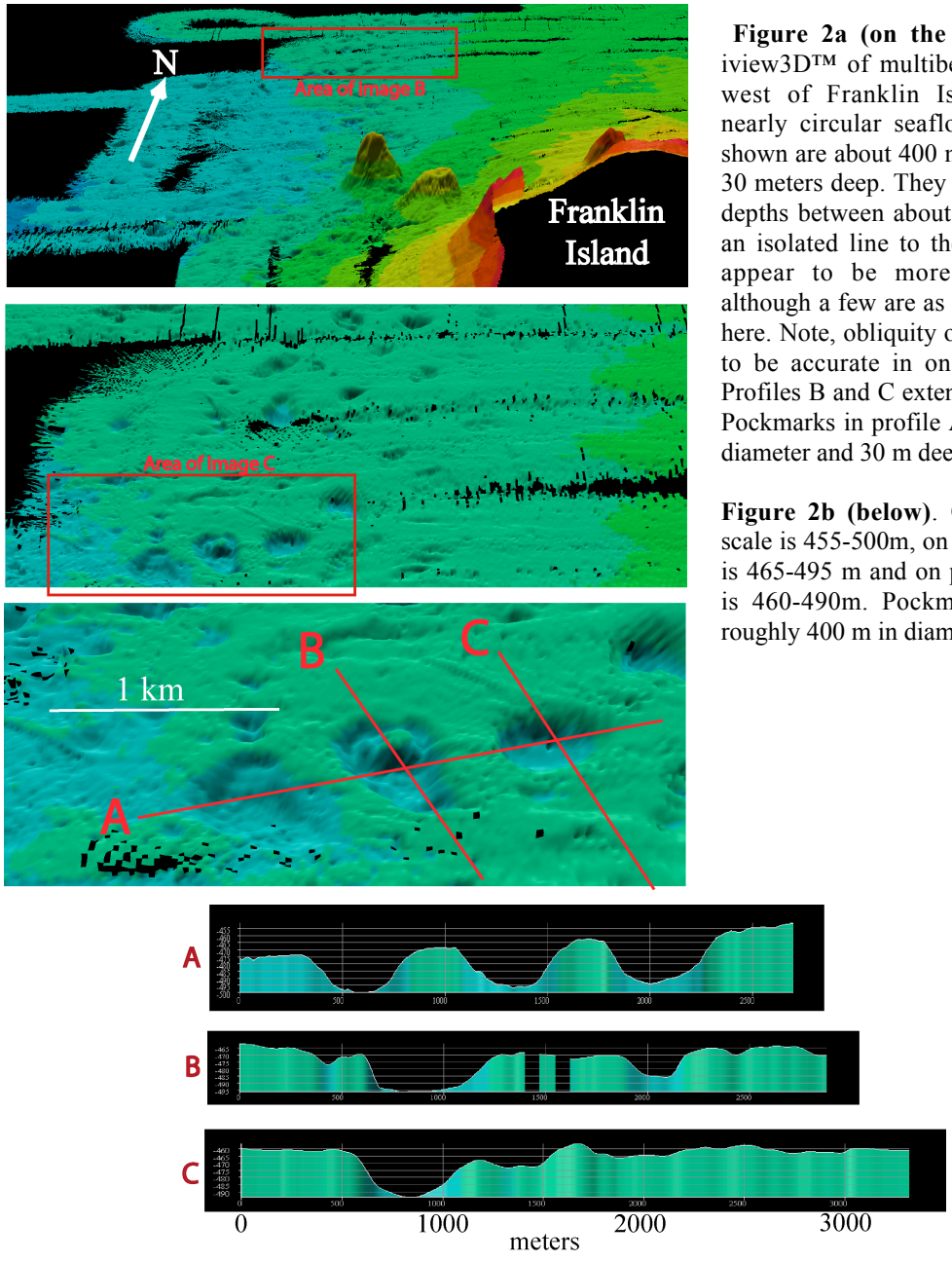

Figure 2a (on the left). Highly oblique iview3D™ of multibeam bathymetry northwest of Franklin Island. Pockmarks are nearly circular seafloor features. The ones shown are about 400 m in diameter and about 30 meters deep. They seem confined to water depths between about 430 m and 470 m. On an isolated line to the north the pockmarks appear to be more elongated east-west although a few are as circular as those shown here. Note, obliquity of view causes scale bar to be accurate in only east-west direction. Profiles B and C extend beyond image frame. Pockmarks in profile A are roughly 400 m in diameter and 30 m deep.

Figure 2b (below). On profile A, vertical scale is 455-500m, on profile B, vertical scale is 465-495 m and on profile C, vertical scale is 460-490m. Pockmarks in profile A are roughly 400 m in diameter and 30 m deep.

Similar pockmarks have been found in the Barents Shelf region north of Norway and in the Skagerrak area, offshore Norway in the North Sea where Rise et al. (1999) describe an extensive pockmark field in water depths >400 m. The largest Skagerrak pockmark is 150 m wide and 16 m deep, with average dimensions being 70 m in diameter and 6 m deep. Most of the observed pockmarks occur where the Lower and Middle Jurassic rocks subcrop (Rise et al., 1999) and are thought to result from gas or liquid escaping from subcropping permeable bedrock strata rather than from biogenic gas in Quaternary sediments. In the central Ross Sea, high methane gas content was found by McIver (1972) at DSDP site 272 (77°07.6'S, 176°45.6'W) in the Glomar Challenger Basin to the southeast of Franklin Island. Given the proximity to the pockmarks found on NBP0401, methane and higher order hydrocarbons could be responsible for the pockmarks northwest of Franklin Island. Prevalent evidence of iceberg keel marks in the Franklin Island pockmark field suggest that the pockmarks must be young to have survived the ice movement intact.

At 76°S, 166°E we surveyed eight roughly circular features with nearly planar tops, that have a diameter of up to 4 km and rise up to 120 m above the surrounding seafloor. These 'pepperonis' may be analogous to Iceland's Hlodufell Tuya, a sub-ice hyaloclastic eruption (Chapman et al., 2001). Hlodufell erupted under the Langjökull icesheet and is characterized by basal pillow-type lavas covered by hyaloclasts. Hlodufell is clearly within the central rift zone of Iceland and in line with other volcanic features that are elongate rather than circular. A lack of an anomalous magnetic signature suggests that a non-volcanic origin must also be considered. A chirp seismic survey to determine internal structure coupled with dredging the steep eastern scarp and coring or using a grab sampler on the surface would help determine if these features are volcanic or glacial.

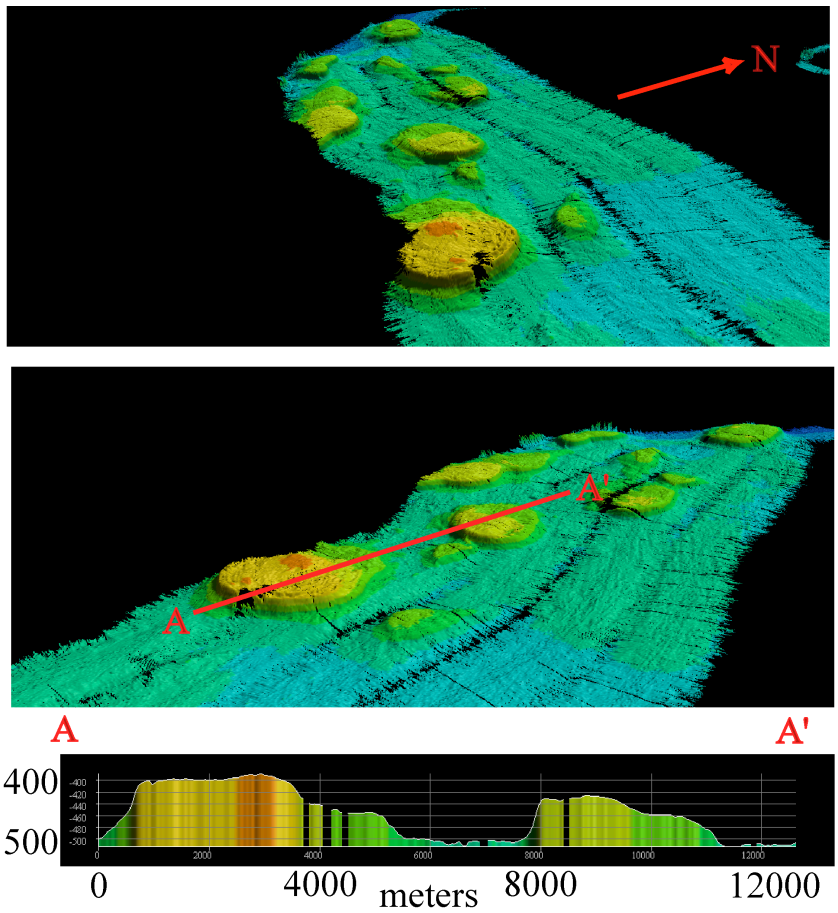

Figure 3. Survey area at 76°S, 167°E found nearly circular features up to 4 km in diameter and up to 120 m high. The features have a generally very steep eastern to southeastern side with the northwestern side appearing to be more gradual. The upper image is looking very obliquely to the west-northwest while the middle image is looking to the west-southwest. Ice cover to the south and west precluded surveying the "pepperoni" field in those directions. The features had no magnetic signature although the unnamed seamount just to the east of this area did show a distinct magnetic anomaly. Dredging the steep eastern scarp and coring or using a grab sampler on the surface should determine if the feature is volcanic while a chirp seismic system should give internal structure if the features are glacial. Vertical scale on cross-section is in meters below sea level.

Summary

Even though NBP0401 had to contend with exceptionally heavy ice conditions and four named icebergs, multibeam mapping of the region revealed that there are a lot of previously unknown, neotectonic features to be found in the Victoria Land Basin. It is hoped that systematic mapping of the western Ross Sea can be continued in the future.

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