High Resolution Mapping in support of UNCLOS Article 76: Seeing the seafloor with new eyes

James V. Gardner  
University of New Hampshire, Durham, jim.gardner@unh.edu

Larry A. Mayer  
University of New Hampshire, larry.mayer@unh.edu

Andy Armstrong  
University of New Hampshire, Durham

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High-resolution Mapping in Support of UNLOS Article 76: 
Seeing the Seafloor with New Eyes

James V. Gardner, Larry A. Mayer and Andrew A. Armstrong
CCOM-JHC, University of New Hampshire, Durham, NH 03824

Introduction

Since 2003, the Center for Coastal & Ocean Mapping/Joint Hydrographic Center at the University of New Hampshire (UNH) has been conducting multibeam mapping of many U.S. continental margins in areas where there is a potential for an extended continental shelf as defined under Article 76 of the United Nations Convention on the Law of the Sea. UNH was directed by Congress, through funding by the National Oceanic & Atmospheric Administration, to map the bathymetry in areas in the Arctic Ocean, Bering Sea, Gulf of Alaska, Northwest Atlantic, northern Gulf of Mexico, the Northern Mariana Islands, Kingman Reef and Palmyra Atoll (Fig. 1). The purpose of these surveys is to accurately locate the 2500-m isobath and to collect the bathymetry data required to eventually determine the location of the maximum change in gradient on the continental rises. A total area of about 862,000 km² has been completed; approximately 250,000 km² remains to be mapped. The area between the ~1000 and ~4800-m isobaths has been mapped on each of the completed margins.

The mapping has been conducted with multibeam echosounders (MBES) that typically collect soundings with a spacing of ~50 m or less in the focused water depths. After each area is mapped, the data are gridded at 100-m spatial resolution although higher resolution is possible in the shallower regions. The depth precision achieved on all of the cruises has been <1% of the water depth and typically has been <0.5% of the water depth, based on cross-line comparisons. Navigation on all of the cruises has been acquired with inertial-aided DGPS using commercial differential corrections that provide

Figure 1. Locations and year of bathymetry mapping (yellow areas) for U.S. UNCLOS concerns.
position accuracies much better than ±5 m. All of the MBES systems used produce acoustic backscatter as well as bathymetry but the backscatter quality varies among systems and conditions.

Table 1 is a summary of the mapping completed and of areas yet to be mapped for bathymetry. The data are all processed at sea by UNH personnel during their collection and the data, grids and views of the processed data are posted on the worldwide web soon after completion of each area. The data, grids and images can be viewed and downloaded at http://ccom.unh.edu/law_of_the_sea.html.

The Areas Mapped To Date

A desktop study was conducted by Mayer et al. (2002) to examine U.S. data holdings relevant to a potential U.S. submission for an extended continental shelf under UNCLOS Article 76. The desktop study identified eight regions that would benefit from new bathymetric mapping. The areas have been systematically mapped, one after the other. Several areas (Arctic Ocean, U.S. Atlantic margin, Gulf of Alaska margin, Marianas insular margin) have required more than one cruise to complete and, as of this writing, the Arctic and Mariana margins have not been completed.

Table 1. Map areas, dates of survey, MBES system and areas mapped.

<table>
<thead>
<tr>
<th>Area</th>
<th>dates of survey</th>
<th>provider/ship</th>
<th>MBES system</th>
<th>area (km²)</th>
<th>area (nmi²)</th>
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<tr>
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<td>2003</td>
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<td>SeaBeam 2112</td>
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<td>5,800</td>
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<td>Bering Sea</td>
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<td>Thales/Davidson</td>
<td>Reson 8150</td>
<td>20,900</td>
<td>6,061</td>
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<td>NAVO/SAIC/Henson</td>
<td>Simrad EM121A</td>
<td>403,500</td>
<td>117,015</td>
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<td>NAVO/Pathfinder</td>
<td>Simrad EM121A</td>
<td>148,500</td>
<td>43,065</td>
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<td>2005</td>
<td>UH/Kilo Moana</td>
<td>Simrad EM120</td>
<td>162,000</td>
<td>46,980</td>
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<td>Marianas</td>
<td>2006</td>
<td>NAVO/Bowditch</td>
<td>Simrad EM121A</td>
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<td>26,680</td>
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Cruises scheduled for 2007

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<th>provider/ship</th>
<th>MBES system</th>
<th>area (km²)</th>
<th>area (nmi²)</th>
</tr>
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<td>C&amp;C/Northern Resolution</td>
<td>Simrad EM120</td>
<td>25,000</td>
<td>7,250</td>
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<tr>
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<td>2007</td>
<td>Coast Guard/Healy</td>
<td>SeaBeam2112</td>
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<td></td>
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</table>

Cruises yet to be scheduled

<table>
<thead>
<tr>
<th>Area</th>
<th>dates of survey</th>
<th>provider/ship</th>
<th>MBES system</th>
<th>area (km²)</th>
<th>area (nmi²)</th>
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<td>Marianas II</td>
<td></td>
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<td></td>
<td>82,500</td>
<td>23,925</td>
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<td>Kingman/Palmyra</td>
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<td></td>
<td>88,995</td>
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1 ability to map Arctic area very dependent on ice cover.
The following is a brief discussion of initial interpretations of the bathymetry of the areas mapped to date. The following discussions of the Bering Sea, Arctic Ocean and the northern half of the U.S. Atlantic margin are summarized from Gardner, et al. (2005; 2006), so the interested reader should refer to those documents for more details. The southern half of the U.S. Atlantic margin, the Gulf of Alaska margin and an area west of the Northern Mariana Islands have been mapped since the U.S. Hydrographic Conference 2005 and are given more discussion.

**Bering Sea**

The north flank of Bowers Ridge and a portion of the southern Beringian margin (Fig.1) were mapped in 2003. Bowers Ridge is an aseismic ridge thought to be a Mesozoic to early Tertiary island arc that was rafted northward during Late Mesozoic to Early Tertiary seafloor spreading while riding on the Pacific or Kula plates (Ben-Avraham and Cooper, 1981). When subduction shifted south to the Aleutian Trench, the plate upon which Bowers Ridge sits was isolated and became docked to the Aleutian Ridge.

The new mapping reveals the northern flank of Bowers Ridge as steep (~20°), heavily incised and complex, with an abrupt foot of the slope. The flank is dissected with numerous straight canyons and channels. The mapping discovered a series of three plateaus along the northern flank, two of which have eastward-projecting ridges (Fig. 2) that follow the general curvature of Bowers Ridge. One of the ridges is more than 50 km long.

![Figure 2. Color-coded shaded relief map of northern flank of Bowers Ridge, Bering Sea. Note the plateaus located north of the flank margin as well as the eastward-projecting ridges.](image)

The mapped area of the Beringian margin (Fig. 3) lies between Pervenets and St. Matthew Canyons. The base of the Beringian margin is thought to have been a subduction zone in the latest Mesozoic to early Tertiary that may have consumed the Kula plate (Ben-Avraham and Cooper, 1981). As with Bowers Ridge, the Beringian margin subduction zone died with the formation of the Aleutian Trench subduction zone
about 50 million years (Ma) ago during the early Tertiary. Today, the margin appears to be collapsing with large landslides and debris flows deposited along its base (Karl et al., 1996).

Figure 3. Color-coded shaded relief map of NW Beringian margin, Bering Sea. Note the large sediment tongues extending far out onto the basin floor.

The new data show that even with a geological history similar to Bowers Ridge, the Beringian margin has a considerably different morphology (Fig. 3). The Beringian margin is composed of a series of seaward-projecting sediment tongues or drifts, some of which reach more than 40 km beyond the steep continental slope.

**Arctic Ocean**

A short cruise in 2003 and longer one in 2004 were conducted in the Chukchi Borderland and the Alaskan Margin in the Amerasian Basin of the Arctic Ocean (Fig. 1). The Chukchi Borderland is composed of continental rocks with a range of ages from as old as 500 Ma to as young as a few hundred years. The older rocks were part of Arctic Canada and Alaska prior to the rifting that created the Amerasian Basin (Grantz, et al., 1999). Counterclockwise rotational rifting of Arctic Alaska away from North America began in early Jurassic time (~200 Ma) and created the Amerasian Basin. The “natural prolongation” of the Chukchi Borderland from mainland Alaska as well as the thick
accumulations of sediment in the Amerasian Basin makes this region a viable target for an extended continental shelf under UNCLOS Article 76. However, severe constraints imposed by pervasive ice in the Chukchi Borderland have limited the mapping thus far to the 2500-m isobath. The restrictions of working in heavy ice have prevented the collection of more than one or two swaths over any area of the Chukchi Borderland, thus, so far these surveys offer little insight into the detailed morphology of this margin.

A 20-day Arctic cruise in 2004 encountered very heavy ice conditions (9/10 to 10/10) in the Chukchi Borderland, although a 18,500 km$^2$ region on the Alaskan margin northeast of Barrow, AK was completely mapped (Fig. 4). The MBES coverage of the Barrow margin shows a remarkable set of parallel, asymmetric ridges and valleys spaced ~10 km apart and rising >500 m high. The source of this sediment is most likely the MacKenzie River drainage system, because the Alaskan margin has had few major sediment sources (Grantz et al, 1990).

**U.S. Atlantic Continental Rise**

The entire U.S. Atlantic continental slope and rise was mapped in 2004 and 2005 (Fig. 5), although a small section was classified by the U.S. Navy as a “Restricted Zone” and has not been released to the public. The Atlantic continental slope and rise is the product of processes that began with the initial breakup and rifting of Pangaea about 185 Ma ago and that formed the Atlantic Ocean (Manspeizer, 1988). The U.S. Atlantic continental rise is underlain by ~10 km of sediments that have been, and still are, shed off the eroding Appalachian Orogen for the past 185 Ma (Poag, 1992). The area has been influenced by numerous periods of sea level fluctuations, large swings in climates that altered erosion and deposition rates, strong geostrophic currents that helped shape the seafloor geomorphology and even an Eocene meteorite impact that hit the Chesapeake Bay region ~35 Ma ago (Poag, 1997).
Figure 5. Multibeam color-coded bathymetry of the U.S. Atlantic continental rise. Only a few of the submarine canyons have been labeled. Dashed line shows approximate extent of surficial mass-failure deposits.

The major features revealed in more detail by the new bathymetric data include the numerous large and small submarine canyon channels, many of which have been known for decades but have been mapped only with single-beam echosounders or seismic-reflection profiles, the western portion of the New England Seamounts and the Blake-Bahama Outer Ridge. The new data show that most of the length and about 80% of the mapped width of the margin is mantled by mass-failure deposits (Folger, 1988; O’Leary and Dobson, 1992; O’Leary, 1996). The mass-failure deposits are organized as tongues of sediment that stream to the SE in the area NE of Hydrographer Canyon channel but, SW of Hydrographer Canyon channel, the mass-failure deposits represent a continuous wedge of sediment that extends to the limit or beyond the mapped area. Baltimore Canyon appears to be the southern limit of a large (>100 km wide) collapse area of the upper margin. Only two canyon channels were found south of Hatteras Canyon channel, signaling a change in the transport regime from north to south.
Almost all of the Blake-Bahama Outer Ridge and the Blake Spur (Fig. 6) were mapped and the new bathymetry show in great detail a variety of features, including an erosional moat round the base Blake Spur, erosion on the surface of Blake Spur and a series of linear bedforms and erosional scours on the Blake-Bahama Outer Ridge (Hollister et al., 1974). All this erosion and redeposition is related to the strong southflowing Western Boundary Undercurrent (Heezen et al., 1966).

**U.S. Gulf of Alaska Margin**

The U.S. Gulf of Alaska margin was mapped in 2005. The new data reveal a startling array of deep-sea channels that incise two large submarine fans, the Surveyor Fan in the western part of the mapped area and the Baranoff Fan to the south. Some deep-sea channels meander across the margin whereas others are fairly linear in trend (Fig. 7). Several of the deep-sea channels were known, although poorly mapped, from previous studies (Stevenson and Embley, 1987), but several others channels were unknown prior to this mapping.

Several large-scale features were mapped in detail for the first time, including the Transitional Fault that marks the seaward edge of the enigmatic Yakutat Terraine (Bruns, 1983; Plafker, 1987; Gulick et al., 2007) and a buried seamount that is part of the Bowie-Kodiak Seamount chain (Fig. 7). However, many surprises were discovered, including a meandering channel that incises the flank of a channel levee and traverses along the flank rather than down its steeper dip (Fig. 8), and cascades and plunge pools on the steep margin and at the base of the margin, respectively.
Figure 7. Multibeam color-coded bathymetry overlain on ETOPO2 bathymetry of the U.S. Gulf of Alaska margin. Deep-sea channels are marked with white dashed lines. Known channels are labeled. White arrow points to buried seamount.

Figure 8. Oblique view of a Gulf of Alaska meandering channel incised as much as 80 m into the flank of a levee. Vertical exaggeration 15x, looking NE.
Western Margin of the Northern Mariana Islands

Approximately half of the western insular slope the West Mariana Ridge, Northern Mariana Islands was mapped in 2006 (Fig. 1 and 9). The new data reveal a shallow ridge along the eastern edge of the mapped area that is mantled by very shallow seamounts, 12 of which are less than 500-m deep (Fig. 9). Volcanism along the ridge ceased ~17 Ma ago (Mrozowski and Hayes, 1979; Okino et al., 1998), so the ridge should have subsided to depths in excess of 4000 m by now (Park et al., 1990). Apparently, deep-seated processes have either kept the ridge elevated or tectonic activity has been renewed along the length of the ridge.

One of the most surprising discoveries is a series of channels that are similar to subaerial drainage systems (Fig. 10). The deep-sea channels begin on the eastern edge of the ridge in water depths of less than 2000 m and trend down slope to depths greater than 4300 m. Typical channel widths are ~3 km and typical channel incisions are ~100 m. Typical channel gradients are ~2° on the upper reaches and <0.2° on the lower reaches.

![Figure 9. Oblique view of color-coded West Mariana Ridge bathymetry overlain on ETOPO2 background bathymetry. View is from 40° elevation, looking SE with 10x vertical exaggeration. White arrows indicate volcanic peaks less than 500-m deep. Only two of the seamounts have cratered summits and only one is a flat-topped guyot.](image)
The channels are sinuous rather than straight, with cut banks on the outside of bends and bars on the inside of bends, just as is found on sinuous rivers. In addition, large depositional lobes are found at the terminus of each channel (Fig. 10, right; dashed yellow lines). These channels have never seen the light of day and have developed below sea level, apparently in the not too distant past.

Figure 10. Map views of West Mariana Ridge channels. North is up in both views. Right view shows channel paths (red) and depositional lobes (yellow).

References Cited


