
NOAA Ship *Okeanos Explorer*

Seamount Chain Geomorphology West of the Mariana Trench Subduction Zone Using High Resolution Sonar

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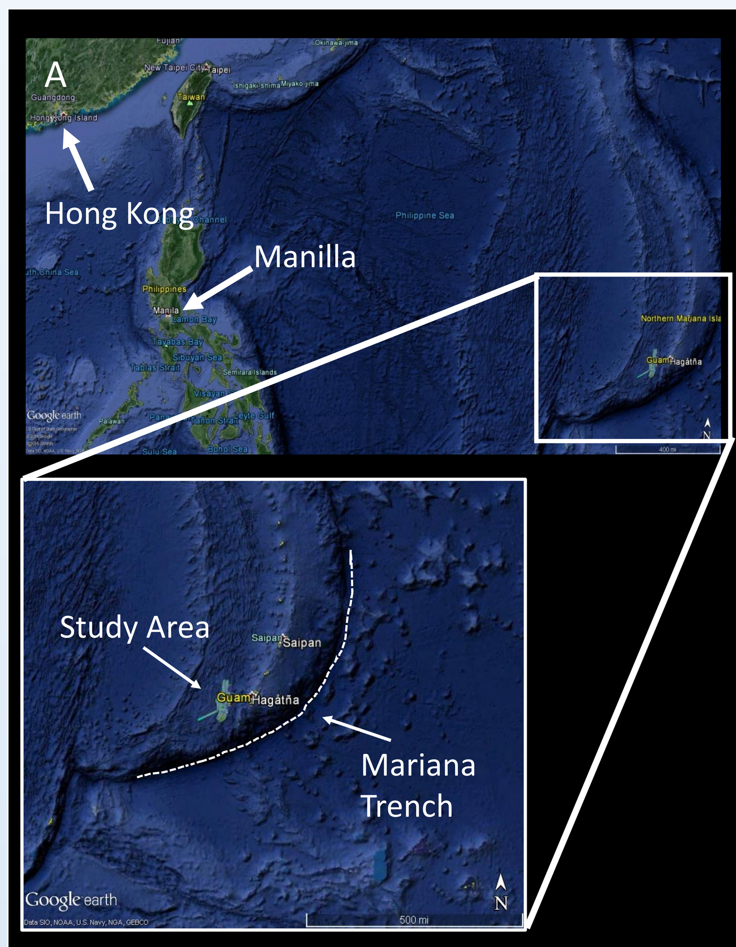
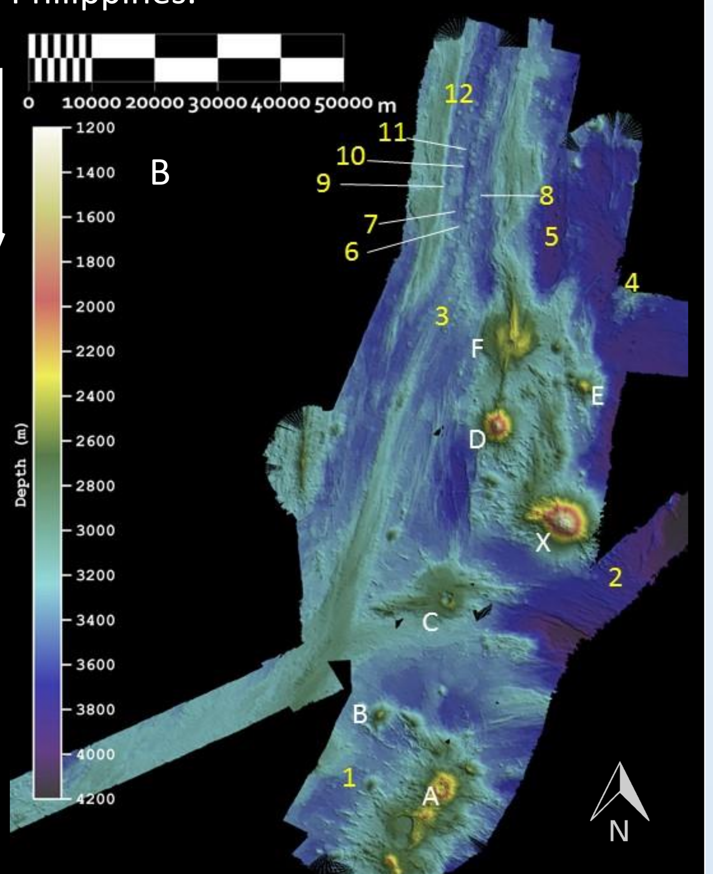


Figure 1. A) Google Earth image showing the study site in the Philippine Sea, southeast of China and east of the Philippines.



B) CUBE BASE Surface image of the study area at 30m resolution. Seamounts A-X are labelled.

ABSTRACT

Scientists from the National Oceanic and Atmospheric Administration's Office of Ocean Exploration and Research collected multibeam sonar data 150 km west of the Mariana Trench from June to August, 2010. Kongsberg EM302 multibeam sonar data from the NOAA Ship *Okeanos Explorer* were post-processed with CARIS HIPS 9.0 software to create 2D and 3D bathymetric and backscatter intensity surfaces. The study area is on the western slope of the Mariana Trench's forearc basin, and ranges in depth from 4200 to 1250 m with deeper areas towards the east. The area's geomorphology was characterized using quantitative and qualitative methods, focusing on large serpentine mud mounds, compressional features, and the seven largest seamounts that have vertical relief ranging from 1919 to 606 m. Subduction of the Pacific Plate beneath the Philippine Plate creates a north to south arcuate trend of volcanic features located between ridges which are orthogonal to compressional stress direction and parallel to the Mariana Trench. East to west stress is further observed with north to south trending mud mounds that resulted from the lower density serpentine being forced out of the surrounding matrix during occurs.

Mud Mounds and Seamounts

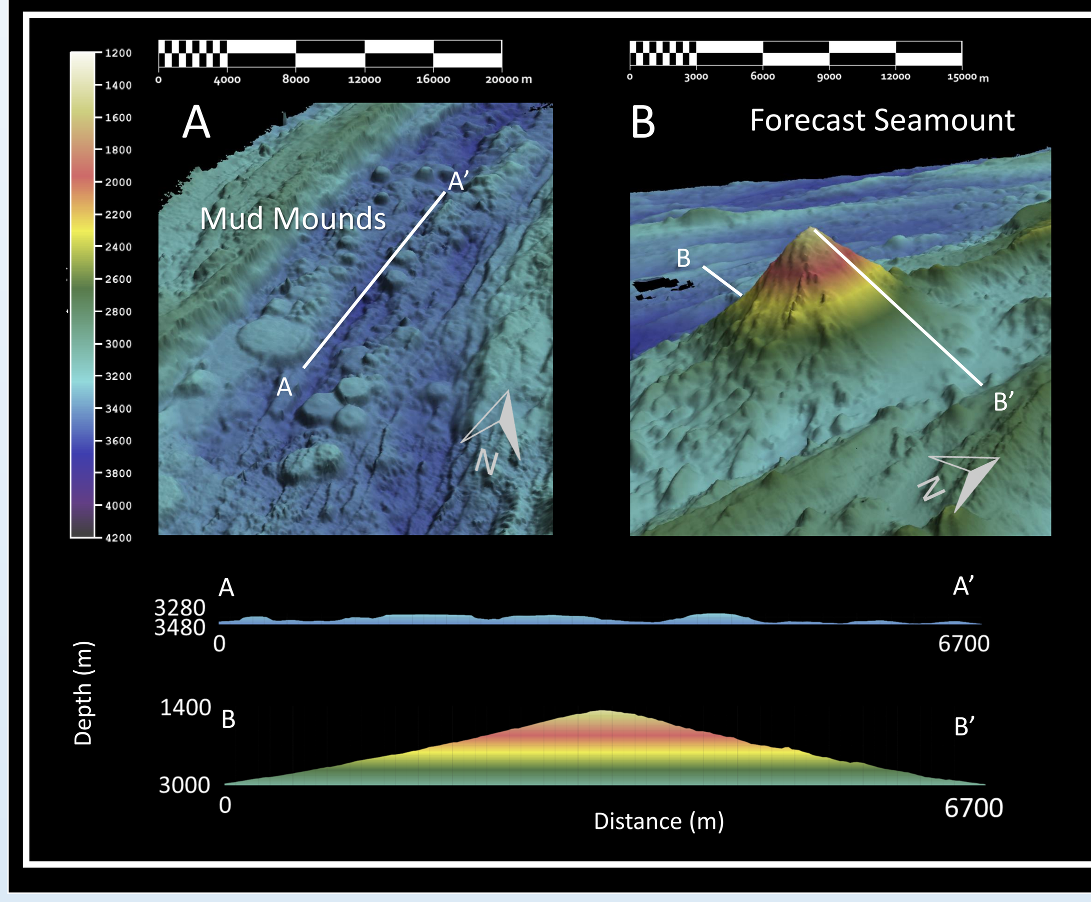


Figure 2. A) Mud mounds found west of Mariana Trench and north of Seamount F, with A-A' cross-sectional profile. B) The nearby Forecast Seamount (referred to here as Seamount D) with B-B' cross-sectional profile. Both profiles are shown at the same horizontal and vertical scales to illustrate unique characteristics of size, slope and shape.

BACKGROUND

The study area lies within the Mariana Trough in the forearc of the Mariana Trench (Figure 1). The Mariana convergent margin is between the Pacific and Philippine Plates and is a highly faulted nonaccretionary system. As the Pacific Plate slab is subducted, dehydration causes fluids to be channeled into the overriding Philippine Plate (Fryer, 1996). Volatiles and basalt are both found in the fluids released during slab dehydration. Due to fluid behavior and lack of an accretionary wedge, there are many seamounts in the forearc that are composed of serpentinized mantle peridotite (Fryer et al., 1999). The faulting in the area creates a place for the rich slab-fluids to reach the surface, forming many mud volcanoes observed in the area. While the serpentinite fluids and deposits occur at other convergent margins, the faulting in this region has allowed more distinct mud volcanoes to form (Fryer et al., 1999).

Many other seamounts are present east of the Mariana Trench on the Pacific Plate. Fryer and others (1985) have suggested that the seamounts are being subducted which, in turn may be causing the forearc basin to go through uplift. The location and size of the seamounts found in the forearc are likely related to the fracturing and structural forces acting on them, making this area important for studying both the slab fluids and the geomorphology of its features (Fryer et al., 1985).

Seamounts

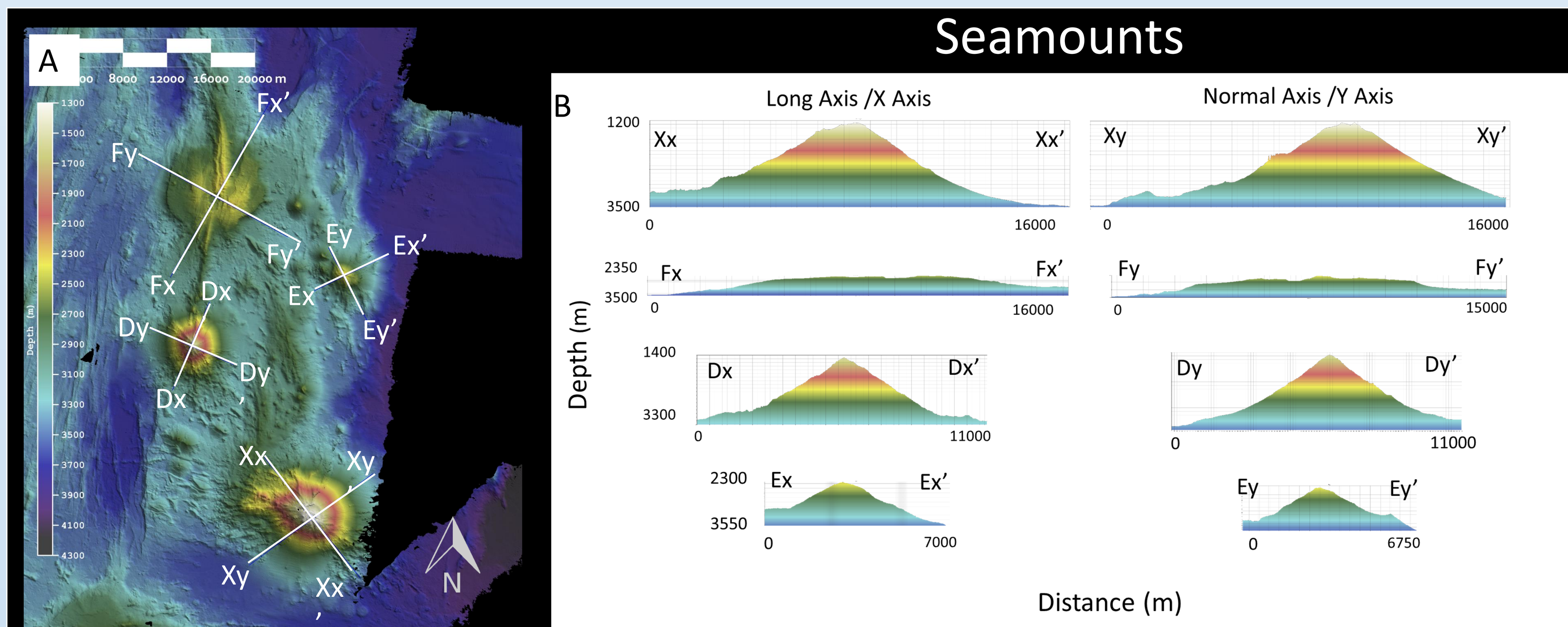


Figure 3. A) Image of CUBE BASE surface showing the locations of profile lines for Seamounts D through X. B) Profiles made at each of the four seamounts with same scale and VE = 1.5x.

METHODS

- Data were collected by Steve Hammond with NOAA on the NOAA Ship *Okeanos Explorer* using Simrad EM302 from June to August, 2010.
- Data were processed using CARIS HIPS 9.0 to create 2D and 3D bathymetric and backscatter surfaces, as well as cross-sectional profiles.
- Seven seamounts were measured and their roundness (R) was calculated using R=x/y, where the Long Axis was used as the x-axis and the Normal Axis was used for the y-axis (Fig. 1).
- Slope measurements were made along seamount flanks from each profile to get average X and Y slopes for each seamount (Fig. 3).
- The same roundness and slope methods were used to characterize twelve mud mounds in the study area (Figs. 1 and 5).

Mud Mounds

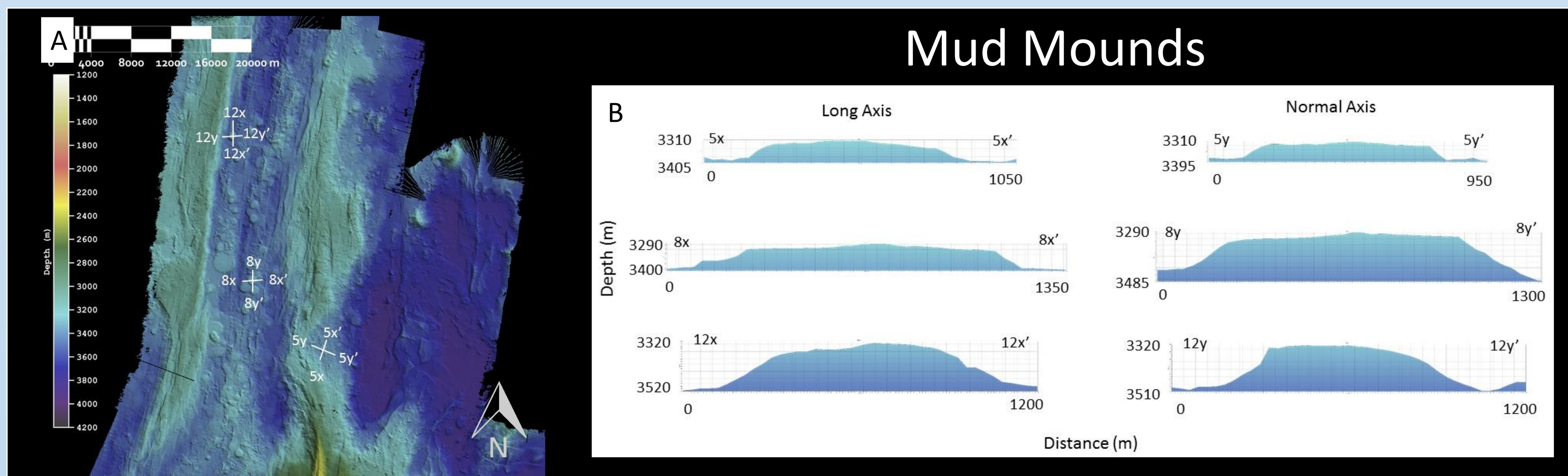
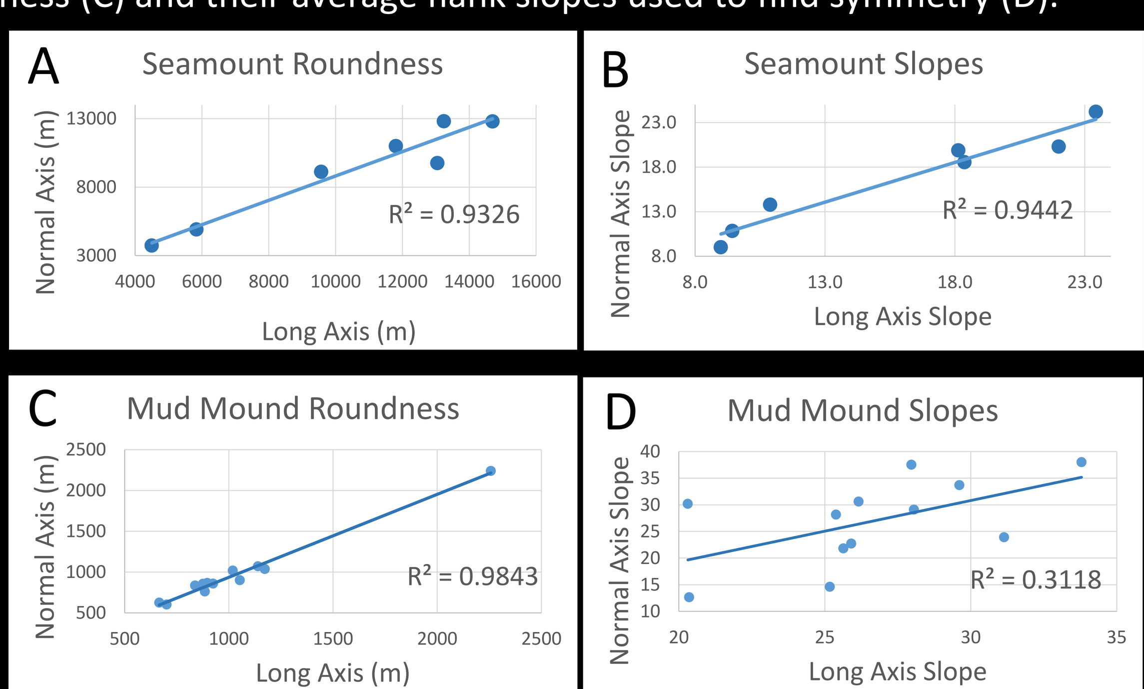


Figure 5. A) Image of CUBE BASE surface showing the locations of profile lines for Mud Mounds 5, 8, and 12. B) Profiles made at each of the three Mud Mounds with the same scale and VE = 1.

Figure 4: Long Axis and Normal Axis values were used to find seamount roundness (A), and the average X and Y slopes were used to find symmetry of the seamounts (B). For the mud mounds, the Long Axis and Normal Axis values were used to graph roundness (C) and their average flank slopes used to find symmetry (D).



RESULTS

- The seven seamounts were symmetrical and round (Figs. 2 and 3). Quantitative analysis confirmed their symmetry and roundness (Fig. 4 and Table 1).
- The twelve mud mounds were observed as also being round and symmetrical (Figs. 2 and 5). Quantitative analysis confirmed the roundness of the mounds but demonstrated no correlation between the mound flank slopes (Fig. 4 and Table 2).
- Seamounts tend to have more of a rounded to pointed top and a lower flank slope (average 9 to 24 degrees), whereas mud mounds have a very flat top and a steeper flank slope (average 14 to 38 degrees).
- Seamount return intensity averaged more than -169 dB. Mud mound return intensity averaged less than -169 dB (Fig. 6).

Table 1: Distances and slopes measured on seamounts A through X.

Seamount	Long Axis (m)	Normal Axis (m)	Average Long Axis Slope	Average Normal Axis Slope
A	13049	9758	10.9	13.8
B	4500	3736	23.4	24.2
C	11808	10988	9.4	10.8
D	9570	9111	22.0	20.3
E	5834	4912	18.1	19.9
F	13244	12800	9.0	9.0
X	14699	12791	18.4	18.6

Table 2: Distances and slopes measured on mud mounds 1 through 12.

Mud Mound	Long Axis (m)	Normal Axis (m)	Average Long Axis Slope	Average Normal Axis Slope
1	885.0	762.1	25.9	22.7
2	1019.3	1018.6	25.6	21.8
3	875.8	855.4	25.4	28.2
4	1173.2	1035.9	31.1	23.9
5	665.9	625.5	28.0	37.5
6	1052.7	899.8	26.2	30.6
7	1140.2	1069.5	25.2	14.6
8	924.5	857.6	29.6	33.7
9	2257.3	2239.0	20.4	12.7
10	838.0	835.9	20.3	30.2
11	896.7	865.9	28.1	29.1
12	702.0	602.7	33.8	38.0

DISCUSSION

A non-accretionary system tends to have fewer sediments in the trough and more hard rock than an accretionary system. The Marianas Trench area is a non-accretionary system but is still capable of processing liquids and hydrous minerals and forming surface features such as mud mounds (Fryer et al., 1999; Moore and Vrolijk, 1992) (Figs. 1 and 2). Mud mounds usually form on hard rock as would be seen near a hydrothermal ridge system, but may be present in a non-accretionary trench system as well (Moore and Vrolijk, 1992).

The seamounts' low slopes are likely the result of different composition and formational processes than mud mounds (Figs. 3 and 5). Seamounts form from subducting slab dehydration melting and magma plumes rising in the overriding plate and, in this region, have basaltic composition. Some mud formations, such as mud volcanoes or mud diapirs, can have similar characteristics and appearance to seamounts but are composed of a serpentine material (Hyndman and Peacock, 2003). According to Moore and Vrolijk (1992), mud mounds result from hydrous minerals and pore water being compressed out of the overriding plate from subducted oceanic slab at an accretionary subduction zone.

Classified backscatter indicates different return strengths between seamounts and mud mounds (Fig. 6). Mud mounds have a slightly lower acoustic return than seamounts, indicating softer or unconsolidated sediment (Fig. 6). They may have formed within a hard rock area, but their slow formation may allow for softer, unconsolidated, pelagic sediment deposition on the mounds' surface. Seamounts had a stronger return, indicating a relatively harder substrate which is likely due to basaltic lava flows that formed the seamount. The results indicate that mud mound and seamount identification from bathymetric data collection can be accomplished through slope comparison, axes measurements, and backscatter classification (Fig. 4).

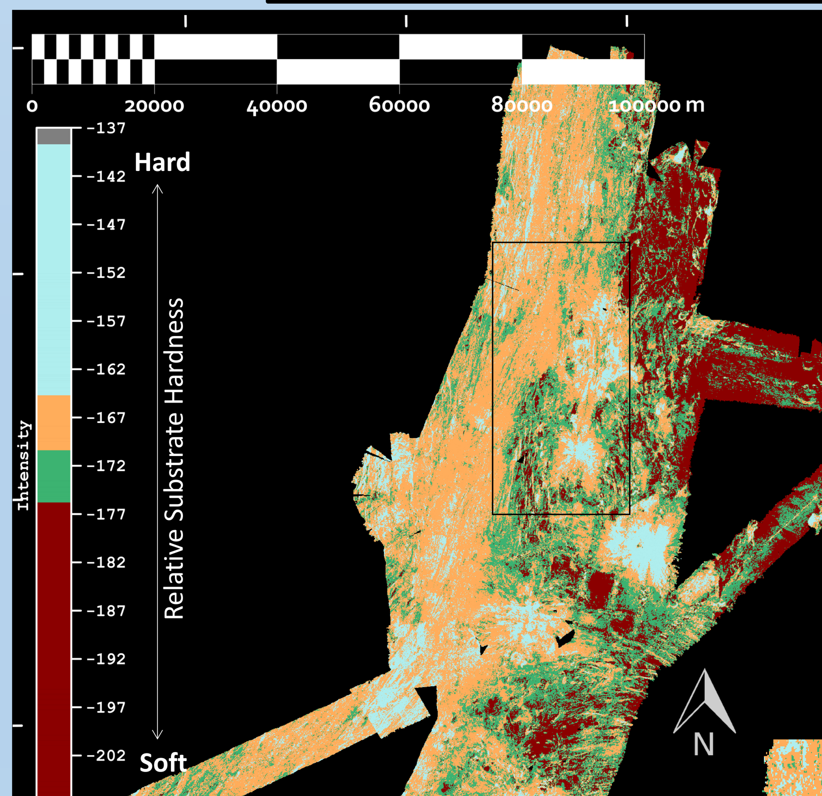
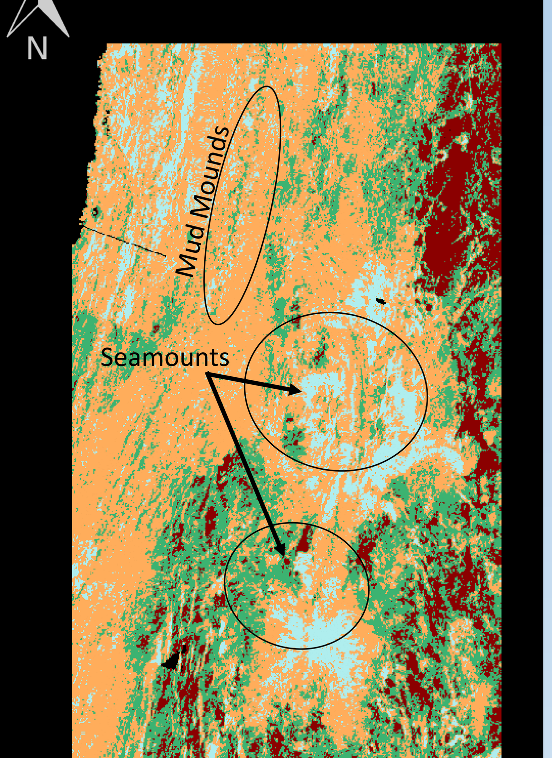


Figure 6. A) Classified backscatter showing the relative strength of return of the mud mounds and seamounts.



B) Seamounts have stronger (light blue) returns than mud mounds (peach and green), indicating a harder substrate.

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