SLOPE FAILURE POTENTIALITY WITHIN THE NEW ENGLAND SEAMOUNT CHAIN: ANALYZING BATHYMETRIC PROFILES FOR POTENTIAL SUBMARINE LANDSLIDES

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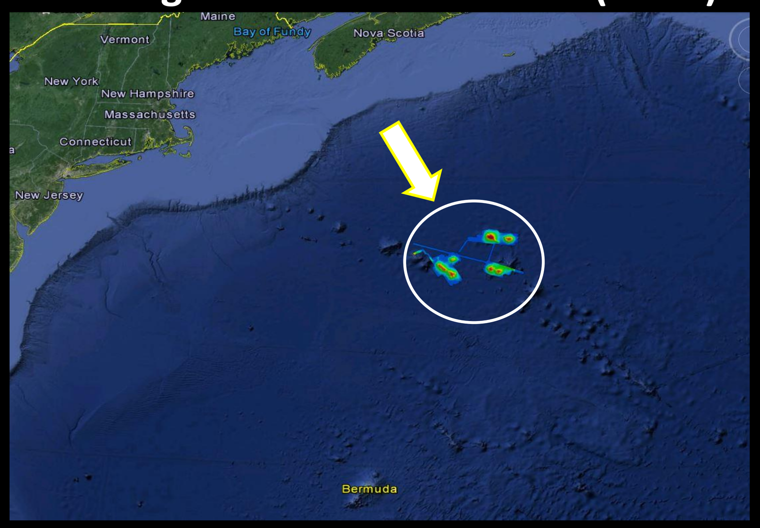
Abstract

The New England Seamount Chain (NESC) is a deep sea volcanic chain comprised of over 30 volcanic peaks. These seamounts developed from the Great Meteor mantle-plume hotspot between 100 and 80 million years ago, and extend over 1200 kilometers in the northwest Atlantic Ocean. Seamounts of the NESC exemplify eminently steep terrain that could potentially have hazardous implications if submarine landslides were to result. The Gulf Stream current coinciding with steep topography can possibly expedite erosional processes. In addition, the entire New England Seamount Chain is capped with a thin layer of sediment on top of basaltic rock, which can contribute to further instability. At the utmost, severe slope failure could produce a cataclysmic tsunami event on the prone shores of Bermuda or the coastline of New England. Bathymetric sonar data were acquired on a multibeam bathymetry survey completed in August 2014 by the NOAA Ship *Okeanos Explorer*, equipped with a Kongsberg EM302 transducer. Data were post-processed using CARIS HIPS & SIPS 8.1 software. Cross-sectional profiles allow for quantifiable comparisons of seamounts based on calculations of slope and hydrostatic pressure.

NOAA Ship *Okeanos Explorer*

Areas of Study: New England Seamount Chain (NESC)



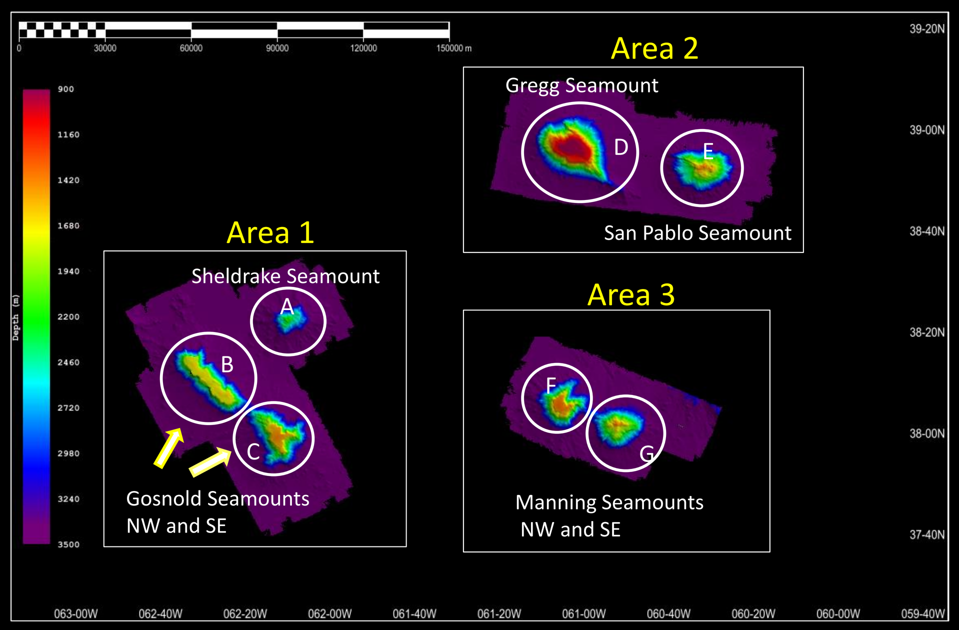


Figure 1: (Left) The portion of the New England Seamount Chain (NESC) studied lies approximately 1200 km east of New Jersey and 750 km north of Bermuda. **(Right)** 20 m resolution CUBE BASE surfaces of Areas 1, 2, and 3 were made, and each area was partitioned into localities with potential slope failure. Cross-sectional profiles (Fig. 2) further examine a section of each peak expressing the highest slope failure feasibility.

Methods

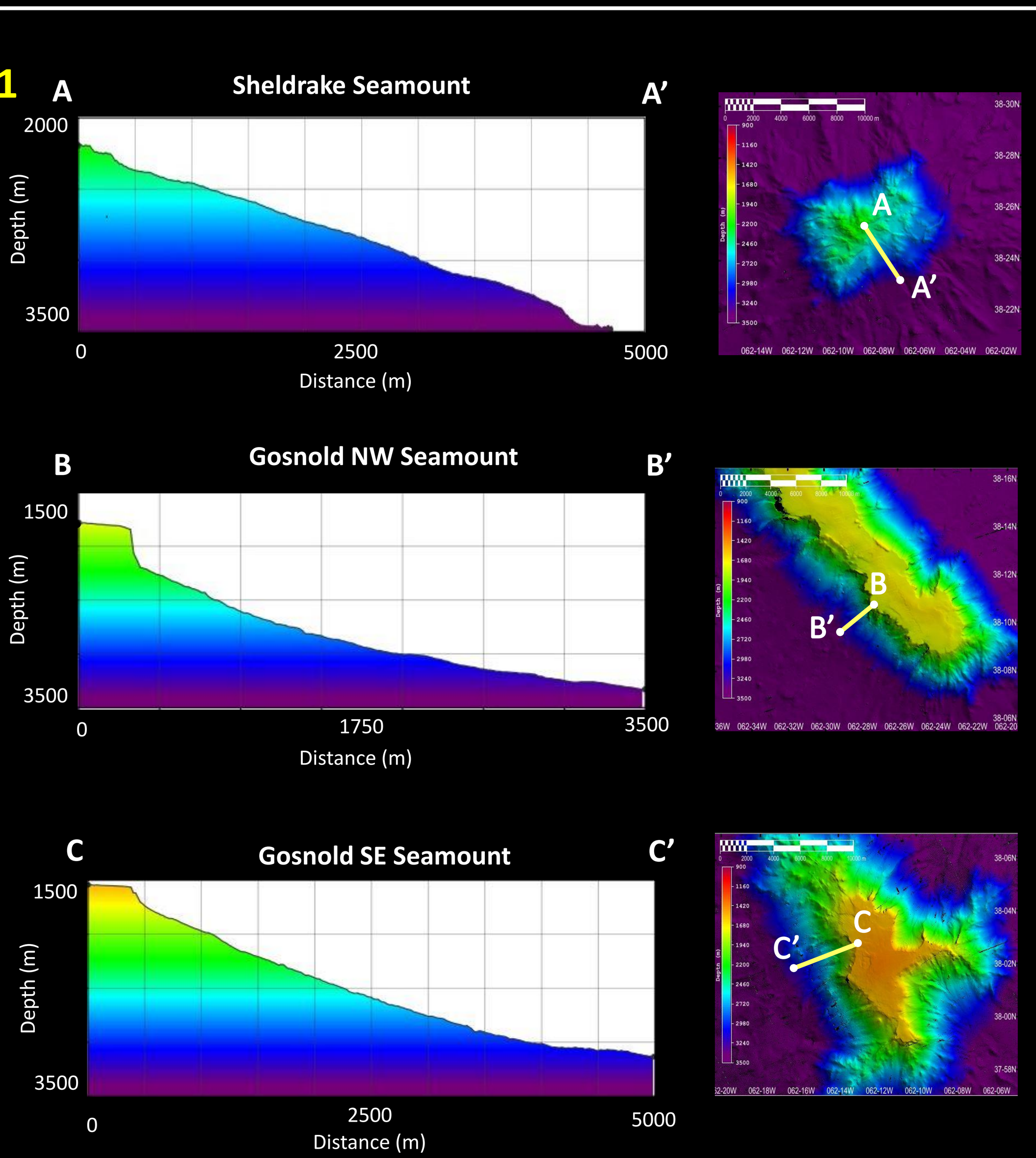
- NOAA Ship *Okeanos Explorer*, equipped with a Kongsberg EM302 transducer, surveyed this portion of the NESC in August 2014.
- Data were downloaded from NOAA NGDC's online bathymetric resources.
- CARIS HIPS & SIPS 8.1 software was used to post-process raw multibeam data.
- X, Y and Z values and bathymetric profiles & reliefs were used for calculations using the following formulas: $\frac{y_2 - y_1}{x_2 - x_1}$ and $\int_0^h \rho g \; dh + P_o = \rho gh + P_o$
- Pressure was calculated using approximate ocean water density of 1027 kg/m^3, gravity of 9.8 m/s^2, and atmospheric pressure of 1 atm.

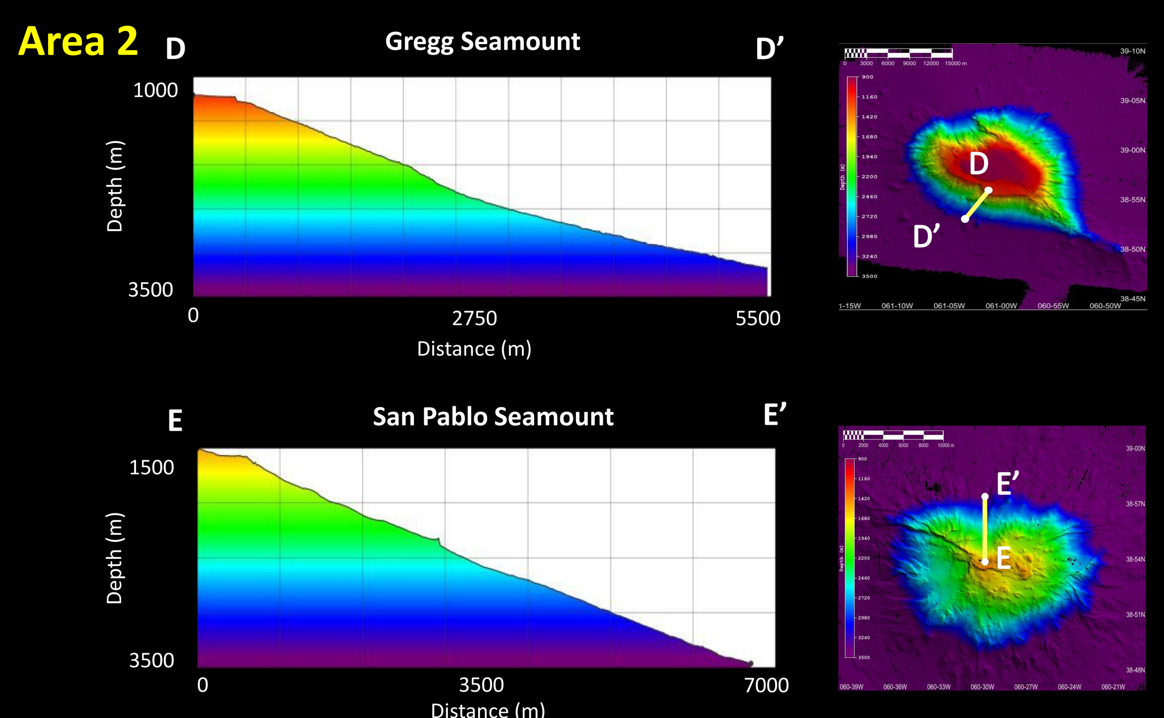
Introduction

The New England Seamount Chain (NESC) is an extinct submarine volcanic chain created from the movement of lithospheric plates across the Great Meteor Hotspot approximately 80 to 100 million years ago. Hot mantle plumes, also known as hot spots, ascend as a function of lower density until they contact the base of the crust. At contact, mantle plumes partially melt the lower crust and volcanoes are formed from rising magma solidifying after penetrating the surface of oceanic or continental crust. As the North American lithospheric plate migrated due to mantle convection, a hot spot track of seamounts was created on the seafloor. Volcanoes that pierce the ocean's surface are referred to as volcanic islands. Over geologic time, volcanic islands undergo subaerial weathering and erosion (Caplan-Auerbach et al., 2000). As the plate moves away from the hot spot, the islands contract, sink, and develop into extinct, flat-topped submarine volcanoes called a guyots.

The NESC is one of the longest hot spot tracks in the Atlantic Ocean, stretching over 1200 kilometers. The volcanic chain is exposed to ocean currents of the intermediate area and their subsequent upwelling (Hall & Krupa, 2006). Furthermore, the NESC is located in the pathway of the Gulf Stream current, which could further accelerate erosional processes. Weathering and erosion of seamounts are inevitable; however, if a catastrophic slope failure event transpired, regional shorelines have limited time to react before a probable tsunami struck. Studying and interpreting measurements and calculations of slope degree, bathymetric cross-sectional profiles, XYZ values, and surficial hydrostatic pressure can potentially determine slope failure implications and the odds of a forthcoming natural disaster.

Figure 2: Cross-sectional analyses of seamounts in Areas 1, 2, and 3 focused on localities with potential high-risk slope instability. Profiles were commenced from a point on the surface of each summit to an approximate depth of 3500 m.





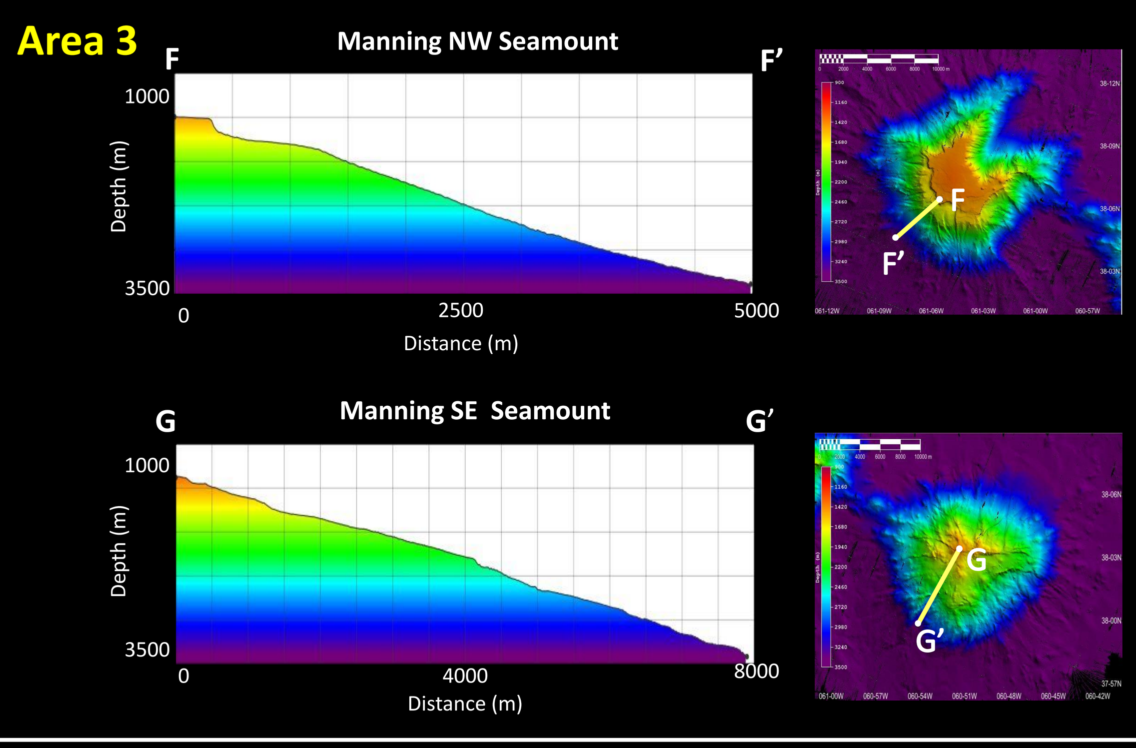


Figure 3. 3D images of Areas 1, 2, and 3 with a vertical exaggera-tion of 2.0x.

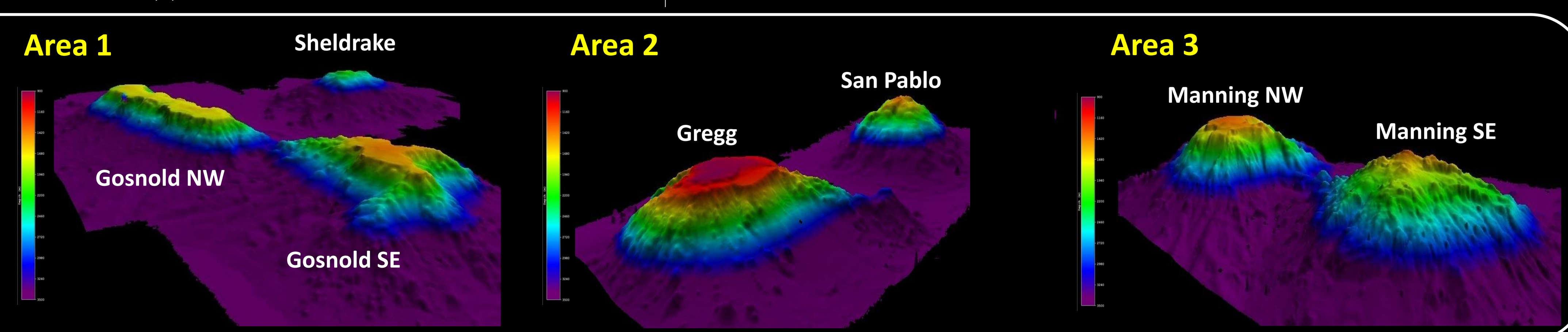


Table 1.
Differences in slope and hydrostatic pressure calculated for 7 seamounts to demonstrate the link between peak depth and hydrostatic pressure.

Seamount	Peak Depth (m)	Pressure (mPa)	Slope	Angle of Inclination (°)	Angle / Pressure Tier
A) Sheldrake	2203.83	22.28	.258	14.47	7 / 1
B) Gosnold NW	1782.05	18.04	.447	24.08	1 / 2
C) Gosnold SE	1541.36	15.61	.320	17.74	4 / 3
D) Gregg	1204.17	12.22	.356	19.60	3 / 7
E) San Pablo	1527.26	15.47	.289	16.12	5 / 4
F) Manning NW	1496.50	15.16	.382	20.91	2 / 5
G) Manning SE	1378.18	13.97	.259	14.52	6 / 6

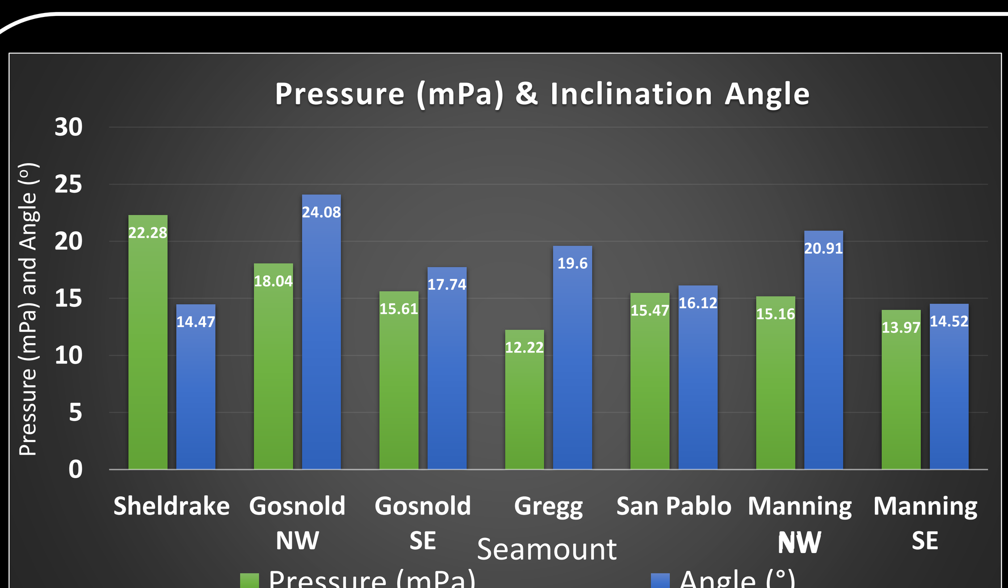


Figure 5. Slope (blue) and hydrostatic pressure (green) for the seven seamounts studied (Table 1).

Results

- Seamounts with greater relief endure greater hydrostatic pressure.
- Seamounts Sheldrake, San Pablo, and Manning SE exhibit low slope with low relief values (Figs. 2A, 2E and 2G).
- Gosnold NW seamount has a low relief, steepest slope angle and the second greatest hydrostatic pressure exerted on its surface (Table 1 & Fig. 5).
- Gosnold NW seamount exhibits a cross-sectional profile shape abnormality (Fig. 2B) compared to other profiles in the study.
- Sheldrake seamount has the lowest relief and slope angle (Table 1 & Fig. 2A)

Discussion

Hydrostatic pressure calculations applied to the depth of each seamount demonstrate that a seamount with lower relief from the seafloor, thus a deeper summit, can have a higher probability of slope failure, despite its appearance. For instance, Gregg Seamount (Fig. 2D) portrays an illusion of most likely having the highest potential for slope failure considering it has the highest relief; however, the summit of Gregg is closer to the water's surface than any other seamount within the data set, and therefore has less overlying water to exert hydrostatic pressure. In addition, Sheldrake Seamount has the deepest summit and consequently sustains the greatest amount of hydrostatic pressure, exemplifying that hydrostatic pressure is a function of depth.

Gosnold NW Seamount exhibits a cross-sectional shape abnormality within the data set, depicted in Figure 2B, which is consistent with a traditional guyot. Gosnold NW has a steep slope near the summit and the steepest general slope of seamounts in the data set (Table 1). In contrast, the other seamounts studied no longer possess steep slopes near the summit and now have gradual slopes due to probable weathering and erosion, which suggests that all seamounts in the study area had defined guyot morphologies in the geologic past. For instance, seamounts Sheldrake, San Pablo, and Manning (Figs. 2A, E and G, respectively), exhibit low slope with relief values without displaying well-defined guyot morphology in cross-sectional profiles. These observations imply the steep slopes near the summit of guyots have high vulnerability to slope failure.

In conclusion, hydrostatic pressure and slope angle should be collectively evaluated for slope failure assessment of submarine topography. Accordingly, Gosnold NW Seamount (Fig. 2B) has the highest potentiality for slope failure within the group of seamounts studied, due to having the steepest slope and the second highest hydrostatic pressure exerted on its surface (Table 1).

References

Caplan-Auerbach, J., Duennebier, F., Lto, G., 2000, Origin of intraplate volcanoes from guyot heights and oceanic paleodepth: Journal of Geophysical Research, v. 105, no. B2, p. 2679-2697.

Hall, N., Krupa, T., 2006, The New England Seamount Chain: The Traprock, v. 6, pp. 9 -13.

Acknowledgements

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