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Bathymetric study of the Bay of Bengal based on open source satellite and sounding data

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ABSTRACT

Bathymetry or underwater mapping is an important tool to understand the bottom topography of any water body. It ensures safe and fastest navigation. Furthermore, commercial fisheries and sailors use them to prevent shipwrecks while scientist use them to predict the extent of natural devastations, to explore the unexplored regions, to better understanding of the nature of waves, tides and currents and to study Paleobathymetry etc. An attempt has been taken to produce a bottom topographic 3D map using open source sounding and satellite data available for the Bay of Bengal area. Topographic data has been collected from the Environmental Research Division's Data Access Program (ERDDAP) live server under griddap protocol. Swatch of no ground, found at the northern part of the bay was most probably due to the heavy sedimentation load from the upper streams of the mighty river systems. Likewise, except the uneven features have been observed at 85°E longitude in between 14°N to 7°N known as 85°E ridge, rest part of the ridge was found to be buried under the huge sediment load. An unidentified bathymetric positive elevation in between 86.0°E to 86.4°E and 6.2°N to 6.7°N with a height of 250 m suggested some tectonic or geophysical activities around the elevation. The Ninety East Ridge, most prominent and important feature, was found to be headed at the Bay of Bengal with height variation of 1000 to 1500m.

Keywords: Bathymetry, Bay of Bengal, Ninety East Ridge, Bengal Fan, Swatch of Ground.

1. Introduction

Due to recent developments of satellites, new techniques and instruments, we have good maps of several properties of the surface of the sea, but we know only a little about the bottom features. Ocean explorations are expensive to carry out and need to be carefully planned in order to maximize the amount of observed information in the least amount of time. Therefore, for effective exploration or research planning, scientists or explorers should have a general idea of the region of interest and information about the site and the form of features. Lack of prior knowledge of the bottom topography (Bathymetry) of the area of exploration increases the risk of losing equipment or even losing human life. Consequently, mapping of the sea floor (Bathymetry) is an important part of almost all ocean exploration expeditions. Only with good maps and charts can the researchers can focus their time and energy effectively.

'Bathymetry' is the measurement of the depth of the water bodies including oceans, seas, rivers and lakes etc. Or, the process of measuring and portraying the depth of the water bodies is called bathymetric mapping. Bathymetric mapping reveals underwater features including submarine canyon, mid-oceanic ridge, seamounts and bank etc, the unique features of the ocean floor. Bathymetric charts are almost similar to bathymetric maps designed to present more accurate, measurable description and visual presentation of the submerged terrain (Vanderstraete et al., 2002). These are typically produced to support safe navigations and usually show seafloor relief or terrain as contour lines. (UAF, 2008; NOAA, 2006)

The satellites orbiting the earth get data in a regular manner and in wide range which is worldwide well accepted and used for bathymetry mapping along with available sounding data. Satellites use altimetry to measure depth of the ocean. Satellites with Radar altimeter emits a radar wave which travel towards the earth and bounces off the surface, received by the satellite receiver which records the round trip time and its position. Surface height is then measured from difference between the satellite's position on orbit with respect to an arbitrary referenced surface (the reference ellipsoidal earth surface) and the satellite-to-surface range which calculated by measuring the time taken for the signal to make the round trip (Rosmorduc et al., 2009, Monahan, 2011).

Bay of Bengal, the largest bay of the world, covers a watery of 2.2 million km² and reaches a depth of up to of 5,258 meters. Only a few research and expeditions take place so far at this one of the most turbid and dynamic bay. Very little is known about the features associated with the oceanic basement of the Bay of Bengal (Sarma, 2000). Existing bathymetry of Bay of Bengal around Bangladesh coast largely depend on sounding charts provided by Bangladesh Inland Water Transport Authority (BIWTA) and Bangladesh Navy (BN) while general use is restricted of BN Bathymetric map. The last bathymetric survey conducted by BIWTA was about 24 years ago in 1980 (Department of Hydrology, BIWTA, Nov 1979- Jan 1980) which seems backdated for such a turbid bay (Roy, 2003). So, this work is concern the following objectives with producing a bottom topographic 3D model of the Bay of Bengal for better understanding of its bottom topology and to get familiar with the special topographical features.

2. Study area

The Bay of Bengal with an area of about 2.2 million sq km is a northern extended arm of the Indian Ocean. It is located between latitudes 5°N and 22°N and longitudes 80°E and 95°E, and bordered by Sri Lanka, India, Bangladesh, Myanmar, and the northern Malay Peninsula. On the west, the Bay is bounded by the south-eastern coast of India and eastern coast of Sri Lanka, on the north by the deltaic region of the Ganges-Brahmaputra-Meghna river system, and on the east by the Myanmar peninsula extended up to the Andaman-Nicobar ridges. The Andaman and Nicobar Islands, the Bay's only islands, separate it from the Andaman Sea to the southeast. The southern boundary of the Bay is approximately along the line drawn from Dondra Head in the south of Sri Lanka to the northern tip of Sumatra.

3. Materials and methods

3.1 Data collection

Data has been collected from the Environmental Research Division's Data Access Program (ERDDAP) live server under griddap protocol.

Data Title : Topography, SRTM30+ Version 6.0, 30 arc second, Global

Dataset ID : usgsCeSrtm30v6

Institution : Scripps

Data extend : Latitude 23°N to 5°N and Longitude 79.5°E to 95°E

Data Counts : Active data : 4021621

Maximum Z variable : 2931

Minimum Z variable : -5145

3.2 Data visualization

Golden Software's Surfer (version 10) has been used for 3D visualization, contouring and surface modeling. Surfer software has used to generate 3d surface map and contour map with SRTM30+ grid data for further analysis.

Grid information :

Data Counts : Active data : 4021621

Original data : 4021621

Maximum Z variable : 2931

Minimum Z variable : -5145

Gridding Method : Kriging

Kriging Type : Point

Grid Geometry :

X Minimum : 79.5

X Maximum : 95

X Spacing : 0.18235294117647

Y Minimum : 5

Y Maximum : 23

Y Spacing : 0.18181818181818

4. Results

The Bay of Bengal is a U-shaped basin with its south opening to the Indian Ocean along with a thick uniform abyssal plain gently sloping southward direction. In this study a maximum depth of 5145 m has been found.

The Bay of Bengal holding the world's largest submarine fan can be divided into 3 regions: Upper fan (extended between 1000 to 2250 m depth which increases towards the middle fan region), Middle fan (comparatively more flat extended betweens 2000 to 3000 m depth) and Lower fan (extended from 3000 m depth to the end of the bay covering the largest area of the bay) (Figure 1).

The coastal part of the bay can also be divided into 3 parts: West coast, Central coast and East coast, with some distinct characteristics for better understanding and comparison. The West coast has been found to be associated with the Indian and Sri Lankan country boundary (Figure 2b). The Palk Strait bay separated Sri Lanka from India while both countries are found to be situated at the same crustal plate. Sri Lankan continental slope has been found to be steeper than the Indian part. Depth was found to be increased from north to south direction with abrupt changes in the sea floor features.

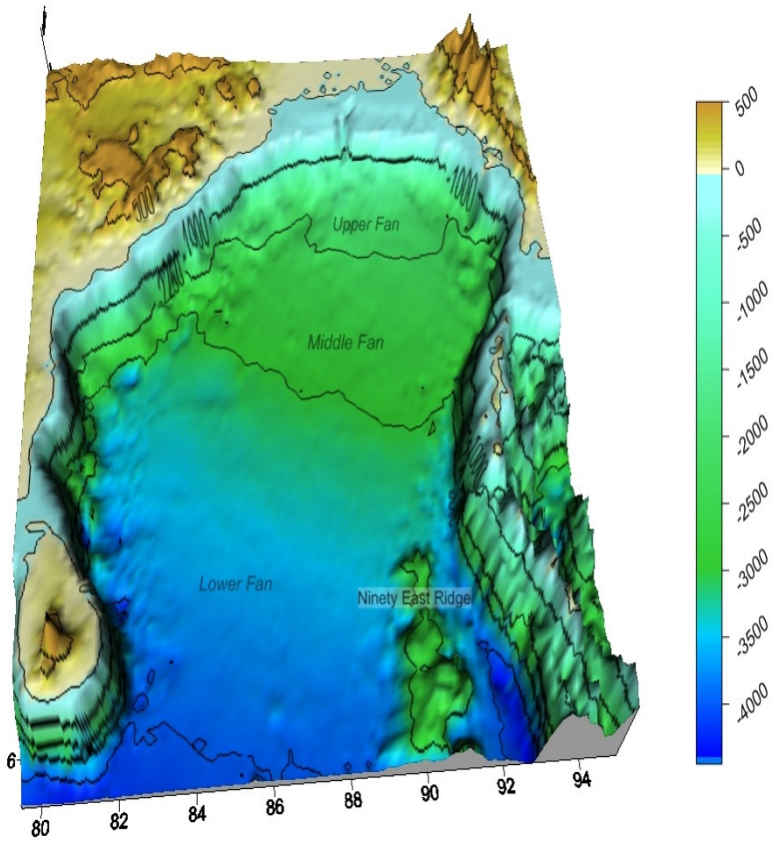

Figure 1: 3D model of Bay of Bengal as produced in the study.

The Central coast, associated with Indian and Bangladesh boarder, revealed a decreasing gradient towards the north (Figure 2a). The Upper Bengal fan, situated at this part along with Swatch of no ground is one of the world largest canyons of the world. Continental shelf of the central coast has been found to be more flat and extended around 150 to 200 km (1.5 to 2 arc degree) in width. Continental slope was found to be extended in between 100m to 2000m with the depth increasing gently towards southwest part.

The East coast bordered by Bangladesh, Myanmar and Andaman Islands (Figure 2c). The continental shelf of this part has been found to be broader in comparison to the west part. Andaman Islands are situated at the south portion of the region. All Andaman Islands, situated at the same crustal plate, have been found in this portion of the region.

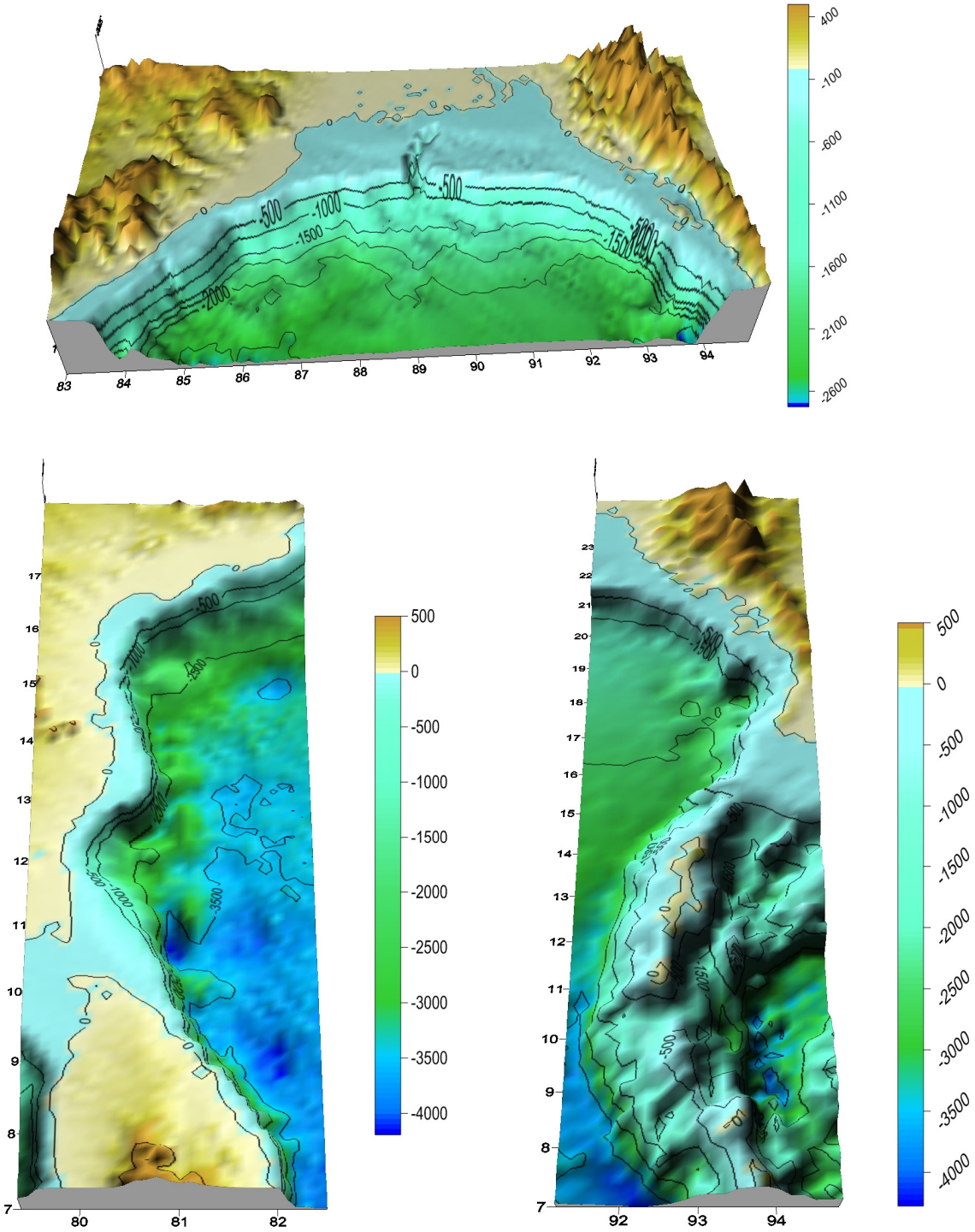

Figure 2: Central coast (Upper One), West coast (Lower Left) and East coast (Lower Right) of Bay of Bengal.

The following special geophysical features have been found in the present study most of which were supported by previous studies:

Ninety East Ridge, located at the south-eastern part of the Bay, extends southward towards the Indian Ocean with its head lying at 9.5°N and 90°E (Figure 1) and the heights was found to vary between 1000m and 1500m from the ocean basin. The ridge runs along 90°E longitude and hence it named as Ninety East Ridge.

Swatch of no ground, the largest submarine canyon of the Bay of Bengal, located at Bangladesh shelf, has been proclaimed by this study to be deeply incised into the Bangladesh shelf connecting the active channel–levee system network in the Bengal Fan and its distal area (Figure 3a).

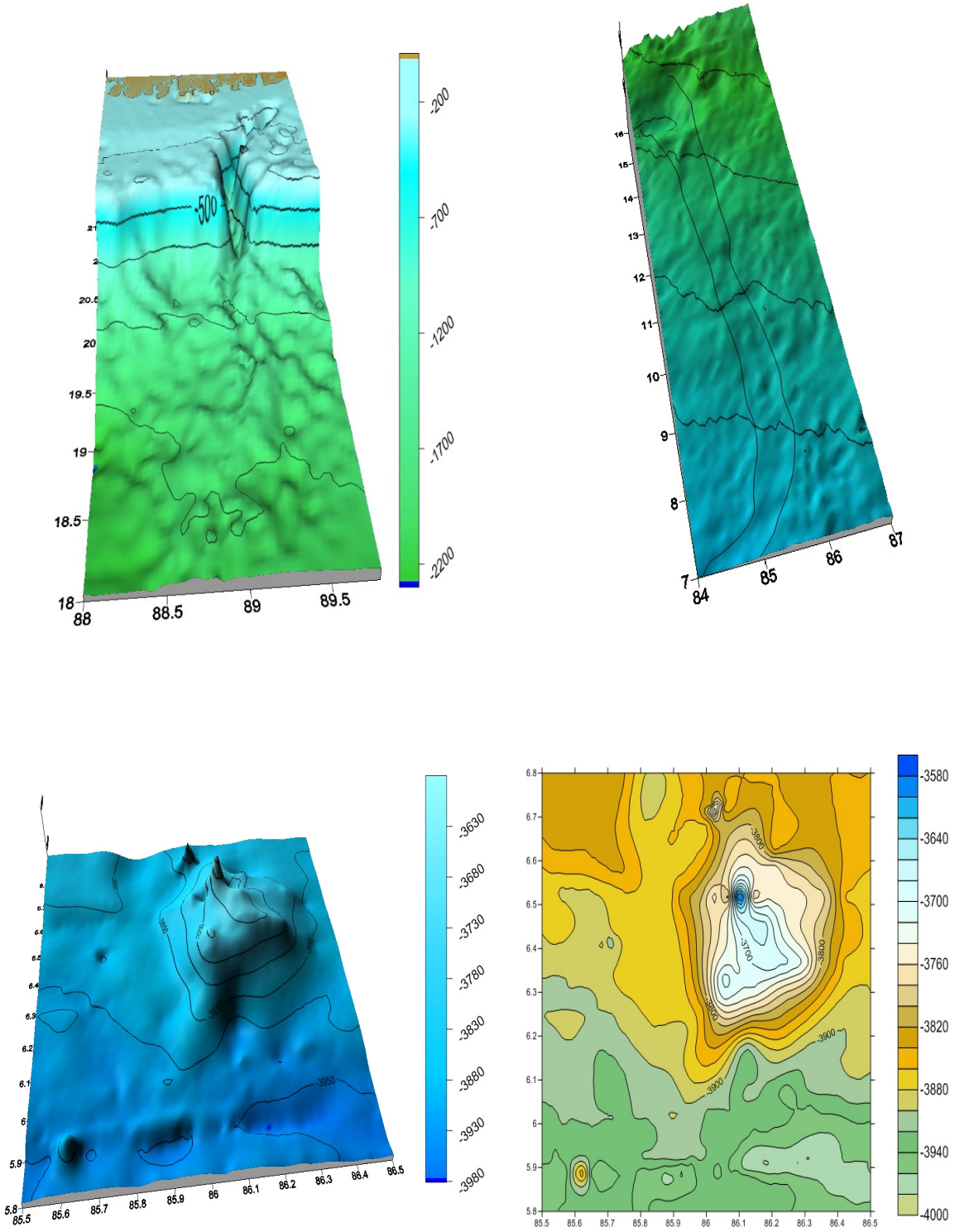

Figure 3: Some bathymetric features of the Bay of Bengal, 3a (upper left) Swatch of No Ground, 3b (upper right) 85°E Ridge, 3c (lower left) unidentified elevation and 3d (lower right) unidentified elevation contour map.

The canyon head has been demonstrated to be located at 21.5°N latitude and 86.5°E longitude extending towards the Indian Ocean. The canyon was demonstrated to be U shaped and depth was more than 1000 m. The canyon has been asserted to become featureless from 19°N latitude most probably due to heavy sedimentation which buried the canyon under the sediment load. The Depth of the continental shelf around the head of the canyon has been pronounced to vary between 10 and 100 m. The canyon was also found to be steeped down from this shallow region to depth up to 350 to 650 m and increased southward. At 19°N, the canyon was seemed to be lost and some undulations was found running down southward from 18.5°N which suggested discontinuity of the canyon.

85° Ridge, also known as Eighty Five East Ridge, situated between 16°N and 7°N running along with 85°E longitude and hence its named as 85°E Ridge (Figure 3b). The ridge was buried under the sediment with only 5 to 7 m depression of difference from the surrounding sea floor. It supposed to be continuous till the Rajmahal trap at the north and towards Indian Ocean at south but due to heavy sedimentation it's become featureless and seems to be discontinuous.

In addition an Un-named elevation have been identified at around 6.4°N and 86.1°E shown in details (Figure 3c). The extension of the elevation was found between 86.0°E to 86.4°E and 6.2°N to 6.7°N. The height of the elevation above its surroundings averages about 250 m, with the shallowest tip of the elevation is at 3584m deep while the surrounding sea floor depth averaged 3825m.

4.1 Discussion

The continental shelf of central part of the bay has found to be comparatively flat without the cut off by the submarine canyon (swatch of no ground) and continental shelf was found to be extended around 150 to 200 m which agreed with the findings of Lafond (1957) who recorded extension of the shelf around 100 fathoms (approx. 180m). The continental shelf of the central part of the bay was found to be broader than the east and west part, and the continental slope of central part was found to be less steeper than that of other two parts.

The existence of Swatch of no ground at the central part of the bay was also recorded by Laford (1957), Roy (2003), Subrahmanyam et al. (1999 and 2008), Sarma et al. (2000), Rao et al. (1987), Michels et al. (2003) and Chamoli et al. (2003) which has found to be quite supportive to the present study results. This study revealed that the canyon has stepped down from the continental shelf with depth 10 m up to 350 to 650 m where as Laford et al. (1957) recoded the canyon was cut down into the surrounding plains at 3 to 400 fathoms (approx. 5.5m to 731m). Discontinuity of the canyon between 19°N and 18.5°N observed in the present mapping has been similar to the records of Laford et al. (1957) and Sarma et al. (2000).

The features found at the head of the Ninety East Ridge demonstrated that the ridge extension has been limited to the north at 10°N or it has been buried under the huge sediments which was also suggested by Rajesh et al. (2010). The 85°E Ridge found in between 16°N to 7°N along with 85°E longitude in this study was also supported by the records of Sarma et al. (2000 and 2002) and it was imbedded into the thick sediment layers showing the discontinuous nature.

Finally, an unidentified elevation was found at the study area of 6.4°N and 86.1°E which was quite similar to the finding of Sarma et al. (2000). So, further study is needed to identify the elevation (bathymetric high) with more details.

5. Conclusion

The Bay of Bengal, contains the huge Bengal fan, has comparatively a smooth topography with some distinct geophysical features. Furthermore, some unidentified bathymetric elevation has been noticed at the outer part of the Bay. Most part of the Swatch of no ground and 85°E ridge has been found to be buried under heavy sediment load, and smoothness of the fan suggests a huge sedimentation nature of the Bay along with the canyon.

The 30 arc second resolutions represent an area around 1 km seaward which is a huge area to ignore small seamount or depression within the study area. However, 30 arc second resolutions is the highest resolution available so far. Additionally, the interpolated data used in this study includes mostly Single Beam Sonar, geophysical sounding for gas exploration or navigation and satellite data rather than the most accurate and precise multibeam data. So, intensive multibeam and side scan sonar sounding data has been recommended to figure out a complete and comprehensive mapping of the study area to be more useful for the oceanographic research as well as national concern.

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