Investigation of Seafloor Morphology through Multibeam Echo Sounding Data and geographic Information System (GIS)

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Abstract

Approximately two-thirds of the Earth's surface, equivalent to 362 million square kilometres, is covered by oceans. The identification and characterization of prevailing geomorphological processes and features through the mapping of the seafloor provide valuable insights into resource potential, environmental impacts, and the evolution of the surrounding geological landscape over time. The advent of multibeam echo sounding techniques since the 1980s has revolutionized seafloor mapping, making it the most efficient tool for large-scale mapping. By combining seafloor bathymetry and backscatter data, valuable information regarding sediment types, structural features, and localized geomorphological changes can be obtained. Additionally, single-beam echo sounding data, high-resolution seismic reflection data, and seafloor sediment samples are analyzed and interpreted to validate the primary observations derived from multibeam echo sounding data. The study area encompasses an area of over 105 square kilometers and is located 102 kilometers west of Marmagao (offshore Goa) along the central Western Continental Margin of India (WCMI). Water depths within the study area range from 145 meters to 330 meters. The WCMI, including the study area, is influenced by complex factors such as tectonic activity, variations in sea levels, prevailing geological and sedimentation processes, oceanographic circulation patterns, and the biological environment. The presence of dynamic bottom currents, which parallel the coast and undergo seasonal changes, has influenced fine-scale morphological variations of seafloor features. The primary objective of this research project was to identify the geomorphic features and processes prevalent in the study region using the multibeam echo sounding technique (dynamic SONAR), advanced mapping tools, and sophisticated analytical methods such as fractal analysis.

Keywords: Multibeam, echo, topographical area, geomorphic, reverbation

Introduction

The excessive exploitation and depletion of terrestrial resources have compelled humanity to turn to the oceans in search of resources. The sea covers two-thirds of the Earth's surface, equivalent to 362 million square kilometers. Various established techniques, such as remote acoustic methods, seafloor photography, and topographical surveys, have been extensively employed to explore and evaluate underwater resources. Echo sounding using frame-mounted transducers became established during

World War II, offering the advantage of rapid depth data acquisition. In the 1950s, advancements in physics made it possible to design cost-effective yet efficient transducers. By the 1960s, high-resolution single-beam echosounders with higher frequencies and narrower beam widths became available (Chakraborty and Fernandes, 2012).

Sound waves travel approximately 4.4 times faster in ocean water (~1500 m/s) than in the air (~340 m/s), enabling the acquisition of information about the seafloor by transmitting and receiving sound signals reflected or scattered back from the water-sediment interface and sub-seafloor structures. The time delay between the transmission and reception of sound is used to calculate water depth. Multibeam echo sounding has emerged as a recent advancement, replacing the single-beam echo sounding technique. The multibeam method utilizes multiple narrow beam transmissions and receptions, providing better seafloor coverage. In addition to acquiring depth data, multibeam systems have been modified to collect backscatter data. Backscatter information from the seafloor provides textural details about the seafloor sediments (Gardner et al., 2003). This information, combined with bathymetry, is highly valuable for understanding the seafloor. Moreover, angular backscatter strength data can be used to quantitatively measure seafloor roughness parameters, such as the silt-water interface and sediment volume roughness (Chakraborty et al., 2015). The combined use of seafloor bathymetry and backscatter strength reveals information about sediment types, structural features, and localized geomorphological changes. Due to its higher uncertainty, depending on the frequency of incident energy, backscatter data can also be utilized to understand the subsurface sediment structure. Therefore, bathymetry and acoustic backscatter data in combination are being used as a crucial tool for seafloor investigations (Gardner et al., 2003; Dandapath et al., 2010, 2012).

Seafloor mapping

It provides a comprehensive understanding of the shape, size, location, patterns, and variations of features in a specific area. It helps to connect the region with its surroundings by depicting direction and relief variations. Mapping the seafloor is crucial for studying ongoing geomorphological processes and the evolution of geomorphic features over time. Traditional methods such as single-beam echo sounders mounted on submerged vehicles have limitations in providing extensive seafloor coverage. While single-beam echo sounding data since the 1950s has allowed for studying relief variations along specific lines or tracks, it is multibeam data that has brought revolutionary changes to seafloor mapping. Multibeam technology enables real-time visualization of the seabed not only beneath the ship's track but also in adjacent areas. The commercial availability of multibeam echosounders has ushered in a new era of seafloor mapping. Currently, multibeam echosounders are the most efficient instruments for large-scale seafloor mapping. The increasing availability of seafloor maps, thanks to the growing number of multibeam echo sounding surveys, has shifted the focus of research from traditional sampling methods to map-based evaluations. Nowadays, map-based seafloor analysis is gaining momentum as a rapid assessment tool for potential resources across the marine domain.

Seafloor Morphology

Geomorphology as a control essentially centers on the investigations of landforms as get reflected by the shape and construction of the earth surface in any topographical area, and the cycles mindful to the arrangement of such landforms (Hagget, 2011). In contrast to their partner, the geomorphology of the ocean bottom was obscure to the human culture because of its detachment until the creation of present day oceanographic review devices and procedures (Prior and Hooper, 1999; Steele et al., 2009). Indeed, even today, there are numerous regions underneath the oceans/seas are yet to be found. In the current investigation, an endeavor has been made to comprehend the ocean bottom geomorphology as mulled over by the slant, silt, and constructions. Detail depiction of recognized geomorphic highlights and the related geomorphic measures in the focal Western Continental Margin of India (WCMI) as seen by the multibeam reverberation sounding, residue, and other related information are additionally clarified.

Objectives of the Study

The primary objective of this study is to map the seafloor of the central Western Continental Margin of India (WCMI) in order to identify the prevailing geomorphic features and processes in the area. This will be achieved through the use of advanced techniques such as multibeam echo sounding, sophisticated mapping tools, and advanced analytical methods like fractal analysis. In addition to the main objective, there are several secondary objectives that stem from it, **Summary of Research Findings**

Present work is chiefly centered around the investigation of ocean bottom morphology with the assistance of incorporated progressed geospatial apparatuses and procedures with uncommon accentuation on blemishes and related hydrocarbon drainages in the focal Western Continental Margin of India (WCMI). The investigation of the ocean bottom blemishes incorporates itemized examination of the beginning and advancement of pits and their current morphology in the focal WCMI. Then again, the investigation of blemish related hydrocarbon leakages utilizing fractal procedures is another strategy utilized for zonation and planning of the drainages nearby. The presence of pits and leakages in the space means arrival of hydrocarbon gas from the sub-ocean bottom to the air adding to the a worldwide temperature alteration. By implication, it means that conceivable collection of the hydrocarbons in the sub-surface ocean bottom which might be utilized as an elective wellspring of energy. The synopsis of the examination is given underneath: (I) On methodological points of view, the current exploration has resolved a few issues. It incorporates information obtaining, information handling, geospatial planning (utilizing different accessible very good quality programming bundles), estimation of highlights and picture based investigation of the ocean bottom utilizing fractals. The utilization of GIS in estimating the pit morphology and fractal insights to picture information towards the improvement of the comprehension of the ocean bottom cycles and drainage design is a spearheading endeavor in the WCMI. The reconciliation of different geospatial planning instruments has gigantically helped in the ID of limited scope geomorphic highlights situated in the area.

The silt in the locale are primarily clayey sand type with overwhelming shell materials with an admixture of high natural carbon content. Variable backscatter qualities from the current investigation region uncover fluctuating sedimentological changes on one or the other side of the 210 m isobath. The high backscatter in the more profound pit zone 108 recommends coarser dregs, potentially connected to the precipitation of digenetic minerals from biodegradation of leakage material and the presence of shallow gas. Gases are perhaps put away in the sub-surface residue causing upgraded backscatter strength in the multibeam backscatter picture. They are frequently seen to be situated in the upslope side of the blemishes. For the most part low yet fluctuating backscatter strength in the shallower region is related with ocean bottom inhomogeneity because of residue developments over a clayey surface. The dregs development in the shallow locale is fundamentally because of dynamic base flows. In the more profound locale, generally higher ocean bottom slant assumes a significant part. A large portion of the unmistakable highlights (if not all) are situated toward NNW-SSE, corresponding to the coast and inverse of the ocean bottom slope.

The geomorphic highlights that have been found in the examination region are pits, shortcomings, ocean hills, patio and reefs. The pits are more inescapable than some other highlights and have significantly added to the ocean bottom morphology of the investigation region. Out of the three flaws saw in the district, the halfway found deficiency at around 230 m water profundity has impacted the most. Ocean hills are periodically connected with scars and blames towards the headwall side. The porch and the reefs are situated in generally shallow locale and are divided in nature.

Conclusion

Despite having not many impediments, present work has unfurled not many new realities with respect to the presence of divided reefs, ocean hills, and changing scar morphology along the focal WCMI. The conceivable reason for beginning of the blemishes through the primary shortcoming (i.e., blames for this situation) of ocean bottom and their connection with hydrocarbon related drainages has additionally been tended to. The effective execution of semi-computerized fractal insightful strategies to measure, portray, and in the long run characterize the ocean bottom leakage design is an extra commitment of the current examination. Other than the drainages, the job and effect of different geomorphic measures i.e., base flows, gravity stream, limited scope tectonics on adjusting the dregs development and the general morphology of the ocean bottom has been brought out for this piece of the sea base interestingly.

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