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# Mapping Submarine Geohazards in the Ceará Basin for Offshore Wind Farms Deployment

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## Abstract Summary

Seismic interpretation is a fundamental tool for identifying seafloor features that may represent geohazards to the installation of offshore infrastructure. This study adopts an approach based on the analysis of exploratory well data and public 2D and 3D post-stack seismic data provided by the ANP, focusing on the interpretation of the seafloor in a sector of the Ceará Basin. The results indicate significant morphological variations along the continental shelf, suggesting potential areas of instability that should be taken into account in the planning of offshore wind farms. This information is essential for reducing geological risks associated with the deployment of wind turbines in marine environments of the Equatorial Margin.


## Introduction

Offshore wind energy has become one of the main alternatives for the energy transition, contributing to the reduction of greenhouse gas emissions and the diversification of the energy matrix. Driven by technological advancements and climate policies, these renewable sources have been gaining prominence in several countries. In Brazil, the Brazilian Equatorial Margin represents a strategic region for the development of this sector, with emphasis on the Ceará Basin, which presents high wind energy potential and favorable conditions for the installation of offshore wind farms (e.g. Figure 1). The estimated energy potential for the region is 356 GW (Worlk Bank, 2024).

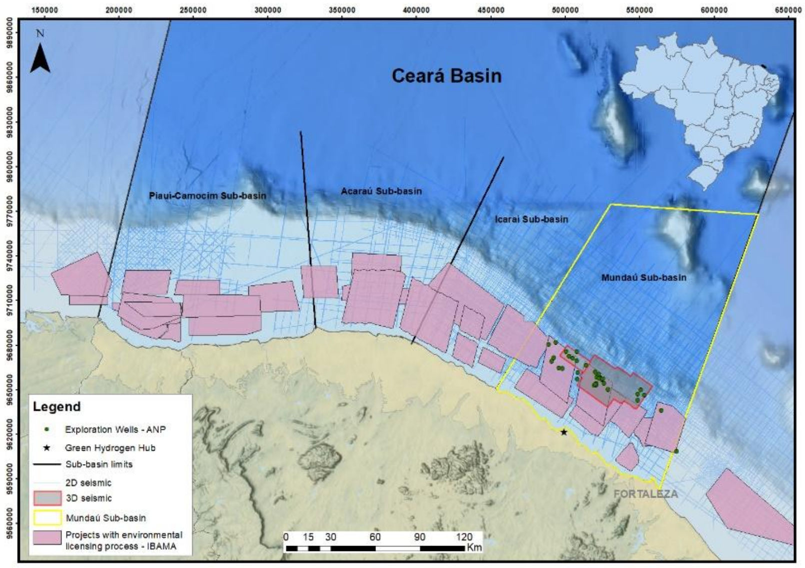


**Figure 1:** Location map of the study area, situated on the continental shelf of the Ceará Basin, Brazilian Equatorial Margin. Source: GEBCO; ANP (GeoMap); IBAMA. Geodetic reference system: SIRGAS 2000.

The upper portion of the shallow shelf of the Ceará Basin is composed of the Tibau and Guamaré formations (TGFs), consisting respectively of coarse sandstones and carbonates (bioclastic calcarenites and calcilutites) (Condé et al., 2007). Carbonate environments can pose significant challenges to the implementation of offshore infrastructure, as they are more susceptible to chemical dissolution, favoring the development of karst systems (Ford and Williams, 2007). These processes can lead to the formation of underground cavities, collapses (Palmer, 2007), and zones of instability, compromising the integrity of installations such as wind turbines. Thus, a detailed mapping of the seafloor is essential, as certain morphological features may indicate areas with geotechnical instability potential. Therefore, this study aims to map the top of the carbonate facies of the TGFs to determine the presence of carbonates up to 150 meters below the seabed, as well as to identify morphological features indicative of potential geohazards.

**Method and/or Theory**

Geological and geophysical data from wells and post-stack 2D and 3D seismic surveys provided by the National Agency of Petroleum, Natural Gas and Biofuels (ANP) were utilized. In total, 85 exploratory wells with composite logs were analyzed. Regarding seismic data, this research encompasses approximately 12,247.235 km of 2D seismic lines and a 3D seismic volume of 1,152.159 km². The 3D seismic datasets used in this research include volumes 0058_ATUM_1B and R0258_0223_0267_CEARA_MERGE.

The interpretations of features prone to geohazards were carried out using the precepts of seismic stratigraphy and geomorphology. Since well data are in the depth domain and seismic data are in the time domain, a time-depth conversion was required. For this purpose, well logs were utilized, including density (RHOB) and sonic (DT) curves, together with checkshot data. After calibrating the sonic log with the checkshot, a synthetic seismogram was generated and correlated with the seismic data, enabling the identification and tying of seismic horizons. Several seismic attributes were used to highlight different features.

**Results**

Of the 85 wells analyzed, 34 revealed carbonate facies extending to depths of up to 150 meters below the seafloor. In some wells, this facies outcrops at the seafloor surface, while in others it occurs in the subsurface, with thickness ranging from 5 to over 80 meters.

Seismic interpretations revealed various morphological features potentially associated with geological hazards. Paleovalleys were identified in the study area based on their erosive geomorphological characteristics, exhibiting elongated geometries and typical U- or V-shaped cross-sections, along with variable sedimentary fill (e.g. Figure 2A).

2D seismic data revealed features interpreted as the initial stages in the development of a submarine canyon (Wu et al., 2021) (e.g. Figure 2B). Submarine canyons well developed were also recognized, with the identification of their heads at the continental shelf break, lateral walls, axial valleys, and gullies, highlighting a pronounced erosional dynamic along this portion of the study area (e.g. Figure 2C; E).

In the central part of the study area, bedforms linked to environments shaped by hydrodynamic processes — such as tidal and ocean currents — were also identified, with the potential to be mobile seabed features (Clare et al., 2017) (e.g. Figure 2D). In addition, zones with chaotic and disorganized reflectors were identified as fault zone, possibly related to structural or diagenectic processes that affect the stability of the seafloor (Alrefaee et al., 2018) (e.g. Figure 2G).

Mapped faults and fractures are preferential pathways for fluid migration as they are directly associated with gas escape features, such as seismic chimneys (zones with chaotic or transparent reflections in vertical or sub-vertical patterns) and gas curtains (e.g. Figure 3A; B). These structures are frequently associated with pockmarks and mounds on the seafloor surface (Yoo et al., 2013).

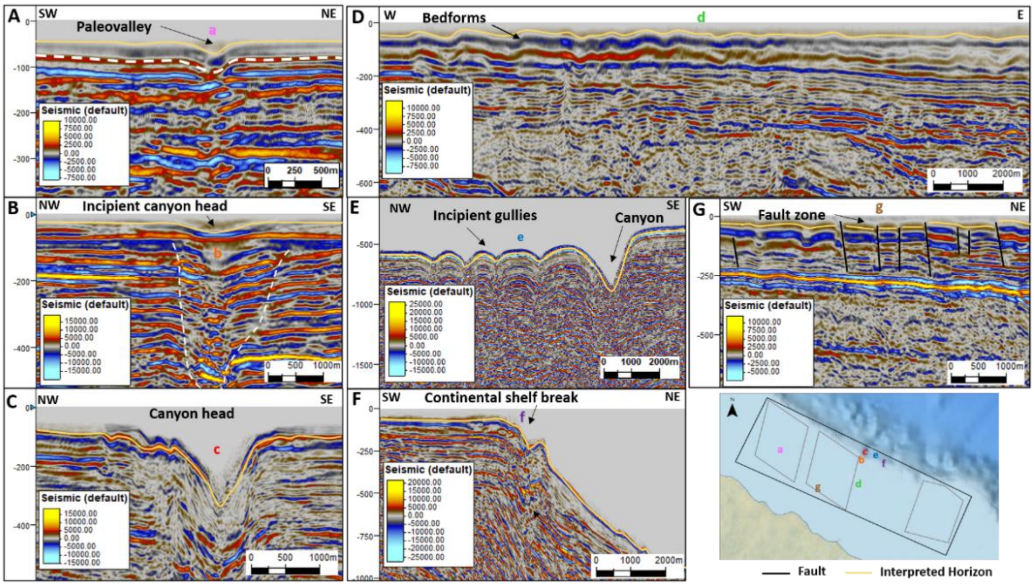


**Figure 2:** Seismic sections illustrating features associated with potential geohazards: A) Paleovalley; B) Incipient canyon head; C) Canyon; D) Bedforms and unstable zones; E) Incipient gullies and canyon; F) Continental shelf break; G) Fault zone.

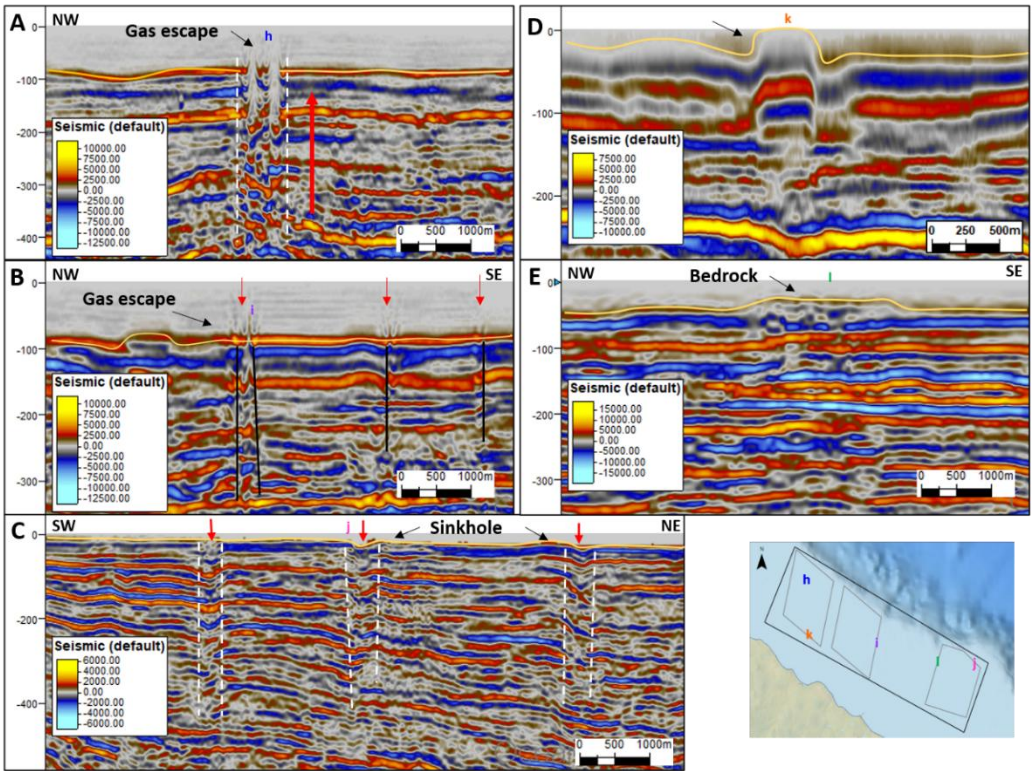


**Figure 3:** Seismic sections illustrating features associated with potential geohazards: A) e B) Gas escape; C) Sinkholes; D) Mound; E) Bedrock.

Features like sinkholes were identified, characterized by collapsed reflectors and generally associated with fault zones and paleokarst features (e.g. Figure 3C) similar to the features observed by Cross et al., (2021). Carbonate mounds were also prominent, identified by their domal morphology and interpreted as pull-up anomalies (e.g. Figure 3D). Finally, segments of the seismic line revealed evidence of exposed bedrock, suggesting areas of outcrop or thin sediment cover, which represents an important factor in the assessment of submarine terrain stability (e.g. Figure 3E).

## Conclusions

Several features potentially associated with geohazards were mapped throughout the entire study area. Many of these features were identified for the first time on the Ceará continental shelf, representing a significant technical and scientific contribution in this area of the Equatorial Margin. The identification of these features, as well as the carbonate facies top, is essential for the safe planning of offshore wind projects, aiding in the delineation of areas unsuitable for turbine installation. It is recommended that future investigations include the acquisition of high-resolution geophysical surveys to enhance the quality of the mapping and increase the reliability in the planning of infrastructure deployment.

## Acknowledgments

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