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Seafloor geological impacts associated with drilling disturbance

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ABSTRACT

This study describes the sedimentological composition and morphology of the sea bottom in an area located at 902 m depth in the Campos Basin of Brazil, and compares characteristics before and after drilling activity for oil exploration. The results show no significant sedimentological variation in the area affected by drilling. The most noticeable effects were observed during the second (MD2) of three cruises, in terms of change to grain size distribution, total organic carbon and clay mineral composition around the Eagle well. This impact occurred over the seabed in a direction that corresponds to the near-bottom circulation pattern, predominantly northward. In the third cruise (MD3), 12 months after drilling, some recovery was observed. Side-scan sonar imaging was used to explore the extent of the area affected by drilling, and sedimentological samples from it confirmed the effects of drilling.

1. Introduction

The deposition of sediments on continental margins is a result of complex interactions between tectonic processes, sea-level change, climatic change, and oceanographic processes. Tectonic and eustatic changes control the sediment deposition. Tectonics, eustatics, climate, and oceanographic processes interact to control the supply and distribution of sediments. During periods of intense activity in the marine environment, such as in storms and when strong currents occur, sediments originating from the continental area can be carried beyond the shore zone and deposited on the continental shelf, often reaching the shelf edge and the continental slope, and sometimes moving down slope by landslide or gravitational flow.

Interest in how these slope environments may be affected by drilling disturbance comes from the discovery of large, morphologically complex oil fields, for example, in the Gulf of Mexico, in the North Sea, and in the Campos Basin of Brazil. Assessing the response to different parameters controlling the evolution of such deposits—slope gradient, bottom morphology complexity, sediment flow and size, base level changes—is a task requiring detailed geological knowledge.

As a first approach to investigating the effects of small-scale sediment disturbance from deep-sea drilling, the MAPEM Project (Environmental Monitoring of Offshore Drilling for Petroleum Exploration, Toldo and Ayup Zouain, 2004) began in 2001 at 902 m depth in the southwestern Atlantic Ocean in the Campos Basin. This project aims to assess the effect of drilling activity upon oceanic benthic ecosystems, when submitted to the discharge of drill cuttings generated with non-aqueous fluids (NAFs) used in drilling. The present paper describes the texture of the sediments covering a continental slope area situated in the northern part of the Campos Basin. It focuses essentially on characterizing the variation in bottom sediments in this area: prior to drilling activity, 30 days after, and 1 year after the conclusion of a deep-water exploratory well (Corrêa et al., 2004).

2. Location

The Campos Basin lies to the southwest of the South Atlantic Ocean, in an area off the Brazilian continental margin between latitudes 20°30′S (the region of the Vitória high in the State of Espírito Santo) and 24°S (the region of the Cabo Frio high in the State of Rio de Janeiro). The basin covers over 100,000 km^2 (Fig. 1). Over 70% is in water deeper than 200 m. The continental shelf has an average width of 100 km, and the depth of the shelf break ranges from 80 m deep in the northern part of the basin to 130 m in the southern part, with a mean depth of 110 m (Viana et al., 1998).

The slope base is shallower in the north of the basin than in the south, with average depths ranging from 1550 to 2000 m, respectively. The transition from continental slope to a continental rise is marked by an intermediate zone, called the Sao Paulo Plateau, a deep ocean area with low gradients controlled by the presence of salt diapers. The Eagle well, around which the environment was monitored, was operated by the company UNOCAL.

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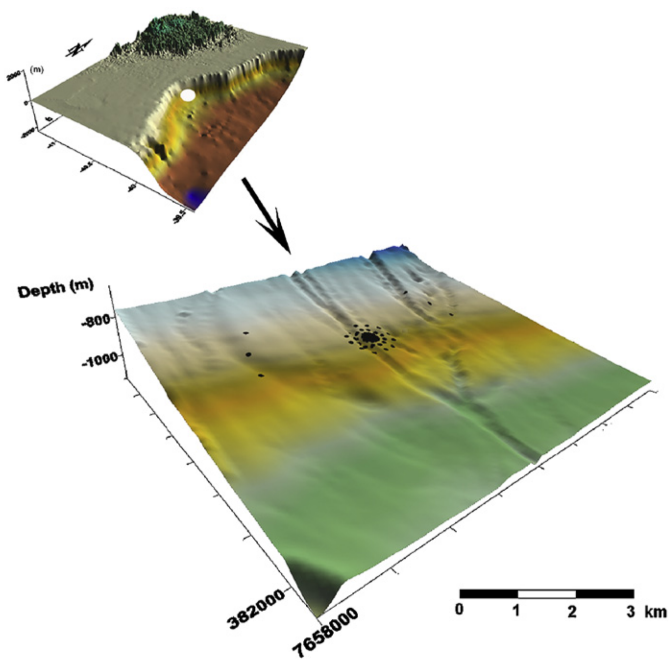

Fig. 1. Location of the study area (white dot) on the SE continental margin of Brazil and 3D view of continental slope morphology in the adjacent area with sampling design for the 54 stations.

3. Sedimentology and geomorphology

Siliciclastic and bioclastic sands occupy the inner to middle part of the continental shelf of the Campos Basin. Predominately siliciclastic sands dominate the outer shelf, ranging from moderately rounded to well-rounded. At the southern area of the shelf, sands are finer than in the central and northern portions. They have quartzose, locally glauconitic, composition, with only a few types of heavy minerals. Bioclastic constituents are primarily molluscs, bryozoans, algae fragments, and foraminifers. In the central and northern portions of the shelf, between its middle and outer parts, sands are well sorted, covered with a thin layer of iron oxide form extensive sub-aqueous dunes that drift to the NE. Those dunes have an average height of 0.5–1 m and are dozens of meters long.

From the edge of the shelf seaward, fine sands occur in the southern part of the basin, whereas coarser sands are found to the north and mixed with bioclastics. Muddy sands cover extensive areas and are bioturbated. In the mid-slope, at depths ranging from 550 to 1200 m, these deposits change gradually to fine sands, sandy silts, ferricrusts and deep-water corals. Antarctic Intermediate Water (AAIW), with its high dissolved oxygen content, is responsible for the generation of crusts.

The continental shelf is relatively flat, characterized by bedforms from ripples to sand dunes, locally with lithified sediments up to 100 m long and 5 m high, as well as long carbonate bars over 5 km in length and heights up to 10 m.

Sets of parallel canyons can be seen beyond the edge of the continental shelf, and, according to Viana et al. (1998), seismic data indicate that these systems were active on the shelf edge during former periods of low sea level. The upper slope is flat, gradually changing to a convex outer form in its intermediate part, at depths ranging from 600 to 1200 m. Its convex shape is attributed to an accumulation of deposits from gravitational flows developing irregular bottom topography. Such deposits occupy an area of approximately 1660 km^2, with six flow events identified in high-resolution multi-channel seismic profiles, all after the Upper Miocene, the most recent having occurred between 85,000 and 53,000 years ago. Coralline deposits have been mapped in waters between 570 and 800 m.

The area described in this report is located on the continental slope. It shows a bottom morphology cut by numerous valleys and canyons, mostly oriented east–west (Fig. 1). Water depth ranges from 800 to 1050 m, taking only into account the area included in the 500 m radius from the well, which, as stated above, is at a depth of 902 m. The morphology of the continental slope is regular, with homogeneously distributed isovalue curves. The average declivity of the area is on the order of 4%, typical of many continental slopes.

4. Current patterns on the continental shelf edge

In this study, water masses were vertically grouped into: surface and deep water. Surface waters are mainly influenced by mid-latitude atmospheric circulation. They consist of the Superficial Tropical Water (STW) and South Atlantic Central Water (SACW) (Fig. 2). The contour current, also called the Brazil Current (BC), flows along the east, southeast and south coasts as a relatively shallow surface current following the line of the shelf break at a maximum depth of 700 m. This current carries the STW to the southeast between the surface and 200 m water depth. The processes of mass and energy exchange with the atmosphere through intense radiation and excessive evaporation make the

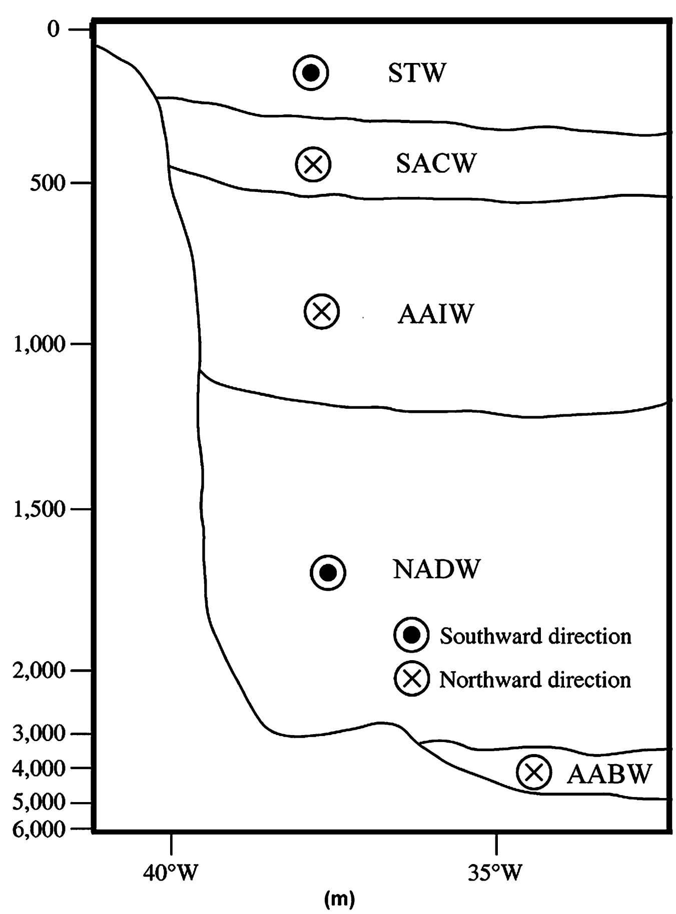

Fig. 2. Stratification of water masses near the Brazilian southeastern continental margin, latitude 22°S. STW = Superficial Tropical Water, SACW = South Atlantic Central Water, AAIW = Antarctic Intermediate Water, NADW = North Atlantic Deep Water, and AABW = Antarctic Bottom Water (modified from Viana et al., 1998).