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FINAL REPORT
Morphology Of Hudson Canyon And Hudson Apron

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ABSTRACT

Hudson Canyon is the most prominent submarine canyon on the U.S. east coast, and it lies just north of Hudson Apron, an extensive depositional region on the continental slope that is unusually unstructured ('stable') compared to the slope along the remainder of the margin. With funding from this grant, we processed bathymetric and backscatter data from an existing SeaBeam 2112 multibeam survey of these two provinces and made a preliminary analysis of the results. Hudson Canyon exhibits a wide range of morphological features which, to first order, can be related to lithology of the seafloor, the behavior of turbid down-canyon flows in response to regional seafloor gradient, and possibly the presence of gas hydrates beneath the continental rise. Hudson Apron, while regionally stable, shows small-scale indications of incipient slope failure.

LONG-TERM GOALS

Numerous studies along continental margins have documented a vast array of geological, biological, and oceanographic processes that shape the continental shelf, slope and rise. Because of their increased seafloor gradients, the slope and rise are in many ways more complex than the continental shelf. They are affected extensively by differential sediment accumulation, biological erosion, current scour, ground-water expulsion and sapping, gas-hydrate disassociation, slumping, sliding, debris flows, and turbidity currents. Environmental assessment of these areas, and particularly understanding operative processes and evaluating their effects in material transfer between the shelf and slope/rise, is of fundamental scientific interest and has important practical implications. Long-term goals of our research are to assess the geomorphology and stratigraphy of the continental slope and rise off the eastern U.S., to understand the nature and efficacy of processes that have shaped these provinces, and to evaluate the potential that these processes have for further modification of the sea bed.

OBJECTIVES

All of the processes noted above have some level of impact on slope stability and control of channel and canyon development on the continental slope and rise, but their relative importance, spatial distribution, and changes with time are not well known. Many existing studies are deficient because they used instrumentation with very limited coverage (e.g., submersible) and they had no larger-scale detailed 3-D data other than simple trackline bathymetry within which to interpret observations. Consequently, we still do not know which processes are primarily responsible for initiation and maintenance of features such as slope channels and canyons, nor do we know why some slope areas are unusually stable.

To begin analyzing the structure and processes operative on the continental slope and rise, we selected Hudson Canyon and part of the adjacent Hudson Apron for study. These areas are unique along the U.S. East Coast in that they combine within a small region two end members in the spectrum of slope stability. At one end of the spectrum, Hudson Canyon is the largest on the eastern U.S. margin, it has had a long history of development (Late(?) Cretaceous-Recent), it evolved by means of a wide variety of sedimentation and erosion processes, and it is associated with a major, long-lived subaerial drainage system (Hudson River, and Hudson Valley on the shelf). The canyon incises widely variable lithofacies (e.g., chalks, sandstones, shales) over a large age range (Upper Cretaceous to Quaternary). Because of the variable composition, consolidation, porosity, and permeability of these facies, very different styles of failure (and very different resultant morphologies) are present throughout the canyon.

The virtually undeformed Hudson Apron is at the other end of the spectrum. This sedimentary blanket covers the outer shelf and upper slope immediately south of Hudson canyon, and it appears to have been deposited during the most recent (and perhaps also the penultimate) sea-level cycle. There are no canyons or channels in this apron and there are only minor indications of incipient slope failure. The apron is a rare example of undeformed continental slope along the U.S. East Coast margin. By studying and understanding why it has not experienced significant failure, we can better constrain the necessary conditions for slope failure in other areas. Furthermore, the stratal and morphological simplicity of the apron can a) facilitate acquisition of accurate, high-resolution sediment-velocity information, b) aid correlation of seismic reflections across the shelf-slope break, and c) allow us to examine the origin of stratigraphic sequences and their bounding unconformities along the outer shelf and slope in terms of glacial-eustatic fluctuations, sediment supply, and physiography.

The Hudson canyon/apron area has a wealth of existing data available for study. Analysis of these data is a necessary first step to constrain the sedimentary environment and to define what field work will eventually be needed to understand the 4-D characteristics (space and time) and relative importance of sedimentary processes that have controlled development of the contrasting canyon and stable-slope environments. The research supported by this grant constituted an initial part of this analysis, and it was devoted to processing and interpreting existing SeaBeam 2112 multibeam bathymetric and sidescan-sonar data over Hudson Canyon and Hudson Apron. These data provide a fundamental morphological foundation for all future studies that may occur in the region.

APPROACH

We conducted a 6-month study of the morphological framework of Hudson Canyon and apron using SeaBeam 2112 multibeam bathymetric data and its associated 'sidescan' (backscatter) data. We acquired these data during a survey aboard R/V Atlantis in April 1997 at no cost to ONR. The survey obtained 100 percent sonar coverage of Hudson Canyon and the bordering, uneroded seafloor of Hudson Apron. The survey extends from the westernmost canyon incision in the shelf near 80 m water depth out to ~3500 m depth on the central continental rise. Funds provided by this grant allowed us to process the SeaBeam 2112 data from this survey.

WORK COMPLETED

The survey data were the first acquired with the SeaBeam 2112 system on the then-new *R/V Atlantis*, and although the data were generally of good quality, they required extensive editing to remove beam-point errors and delete segments of spurious data. We completed this processing and created gridded bathymetric files at 50-m or 100-m grid intervals, depending on water depth, which ranged from <100m to 3500m. We also were able to do first-pass processing of the associated backscatter data. Available funding did not allow for extensive analysis of the data, but we summarize our preliminary observations below.

RESULTS

Hudson Canyon exhibits significantly different morphologies along its length. These changes appear to be controlled at least in part by lithology, by response of turbid flows to changes in regional seafloor gradient, and possibly by the presence of gas hydrates in the underlying sediments. In the uppermost canyon from about 80m water depth, where the canyon merges with the Hudson Shelf valley, to about 500m water depth, the canyon has a broad U-shaped profile with relatively smooth walls and some small tributary valleys along the eastern wall. This part of the canyon appears to be accumulating sediments that are swept in from the surrounding continental shelf.

At 500m to ~2200m water depth in the canyon axis (i.e., where the canyon cuts through the continental slope), the canyon walls are extensively gullied, the canyon floor is relatively flat and ~0.5-1.0 km wide, and the axis is relatively straight. An apparent scarp extends ~15 km along the top of the northeast canyon wall, suggesting ongoing slope failure there. This section of the canyon appears to be a bypass zone for sediments moving seaward, and these flows may also erode the canyon walls and floor. It is likely that indurated Tertiary and Cretaceous rocks crop out extensively in the canyon walls. Both Eocene and Upper Cretaceous rocks have been dredged from this part of the canyon, and extensive outcrops of Eocene chalk/limestone are known to occur on the adjacent continental slope just south of Hudson Apron. Jointing, fracturing and failure of these rocks may be a primary control of morphology in this section of the canyon.

The Hudson Apron just south of the canyon exhibits relatively smooth morphology, but the SeaBeam data show small scarps (a few meters) oriented both parallel and orthogonal to the regional bathymetric contours. A few shallow (meters) and wide (~kilometer) troughs also cross the slope. Thus, while this segment of the continental slope is relatively intact, there are signs of incipient slope failure.

Where Hudson Canyon reaches the continental rise at about 2200m water depth, a large levee is developed. The levee begins at the slope-rise break and extends seaward some 45 km along the south margin of the canyon. It rises ~500m above the canyon floor at the base of the continental slope and decreases to about 250m height at its seaward end. The canyon itself exhibits its shallowest average relief (~150-200m) across the upper continental rise out to about 2900m water depth. Here it meanders gently, and it has moderately irregular and gently sloping walls. This section of the canyon, including the levee, represent a depositional system developed by turbid flows that respond to the decreasing seafloor gradient as they pass from the continental slope to the continental rise.

Farther seaward on the central continental rise, Hudson Canyon develops large, often sharp meanders, it becomes progressively more incised (relief ~500m near 3500m water depth), and it has steeper canyon walls that are cut by valleys orthogonal to the canyon axis. The canyon thalweg reaches to the base of the wall at the outside edge of some meanders, and in several places 'point-bar' deposits are developed on the inside edges. This part of the canyon system appears to represent an approximate balance between alternating deposition and erosion by flows passing down the canyon.

Where the canyon passes across the central and upper continental rise, it is underlain by gas hydrates which are manifested at their base by a bottom-simulating reflector near 600m sub-bottom in seismic reflection data. It is possible that slope failure observed in the canyon walls here is partly related to escape of gas from decomposition of the hydrates. However, more extensive study of seismic reflection data in relation to morphology will need to be conducted to evaluate this possibility fully.

The SeaBeam backscatter data, although not fully processed, show several general patterns. Canyon walls tend to exhibit high backscatter, and they also show the effects of fine-scale disruption (slope failure) in varying forms. The canyon floor is locally absorptive (taken to indicate deposition of fine-grained sediments in 'drifts') and in other places is reflective (probably either erosional or covered by coarse debris). In places across the central continental rise, low backscatter in the canyon seems to correlate with depositional patterns expected at 'point-bar' locations in meanders. Further processing and analysis of the backscatter data would clarify these reflectivity-morphological relations.

IMPACT AND APPLICATIONS

Understanding the structure and formative processes of continental slope and rise morphology and stratigraphy has practical applications for assessing such diverse factors as geohazards, hydrocarbon resources, dispersal of contaminants from marine dump sites, relation of seafloor environment and environmental alteration to fisheries, stability and effects of emplacement of manmade cables and structures, and civilian and military navigation and security. The digital database of multibeam bathymetry and backscatter patterns developed with funds from this grant provide a firm foundation for these kinds of studies, and they also constitute an essential data base necessary to any future fieldwork in the Hudson Canyon and Hudson Apron region.