Current-Controlled Topography on the Continental Margin
Off the Eastern United States

Roger D. Flood and Charles D. Hollister

INTRODUCTION

Since the development of high-resolution precision echo sounders in the 1950s, marine geologists have been characterizing different types of sea floor on the basis of the echo return. Short-ping (less than 5 msec) high-frequency (3.5-12 kHz) echograms have been used to provide much information on the nature of the microtopography and the sediment stratification and have been used as a basis for interpreting the erosional and depositional processes acting in the deep sea (Heezen et al., 1959; Heezen et al., 1966; Hollister, 1967; Schneider et al., 1967; Heezen and Johnson, 1969; Hollister and Heezen, 1972).

The continental margin is one region of the sea floor where these techniques have proved especially useful in delimiting areas that appear to be quite active sedimentologically. The classification of the echo types from the margin is generally based on three criteria: (1) the coherence of the echo return, i.e., whether the echo is made up of one or more mushy or sharp returns; (2) the presence of topography below the limit of resolution of the echo sounder as evidenced by the presence of hyperbolic echoes; and (3) the wavelength, amplitude, and regularity of the larger-scale relief.

The echogram character of large areas of the western North Atlantic continental margin, especially the continental rise, can be mapped on the basis of an echogram classification similar to that first developed by Hollister (1967) (Figs. 1 and 2). Other parts of the ocean basins thought to be under the influence of current activity exhibit similar echo patterns, implying that to some extent the topographic forms developed may be related to the current activity.

Several characteristics of the microtopography, in particular, have often been cited as evidence of bottom-current activity. These characteristics are (1) hyperbolic echoes with wavelengths of up to several hundred meters and vertices approximately tangential to the sea floor, and (2) large abyssal mud waves (termed “giant ripples” by Ewing et al., 1971) with internal stratification often showing that these waves have migrated.

Many questions have arisen as to the actual nature of the topography that yields these types of echo traces:

1. What, in fact, are these features? What are their dimensions, degree of lineation, and orientation with respect to regional topography and to the currents observed?

2. Are there smaller features superimposed on the larger-scale features? If so, what are they and how are they related to the larger features?

3. Are these features, in fact, related at all to bottom-current activity, or are they a manifestation of other processes taking place on the continental margin?

4. If the topography is current-controlled and the features are some type of current bed form, are these bed forms currently active? If they are, what are the dynamics of their formation? If not, how recently have they been active and what can they tell us about the flow conditions at the time they were active?

In this study we shall attempt to address these questions through a newly organized program of sediment dynamics that is a combination of field investigations and laboratory studies.

FIELD TECHNIQUES

Previous investigations into the nature of the topographic forms present on the continental rise and on outer ridges have been severely hampered by the sampling techniques employed. These difficulties have been twofold. First, the features to be studied are larger than the field of view of a normal bottom photograph (several square meters), and the relationship between successive bottom photographs is usually not known. Second, these forms are also at or below the lower limit of detection by surface 3.5- and 12-kHz profilers. Often only a hyperbolic echo is recorded at the surface or, if the features are larger, side echoes tend to obscure the true form of the features. For the larger features (greater than several hundred meters) the navigational accuracy has not usually been good enough and the sounding lines have not been close enough to establish an unambiguous trend for these features. Hence features that are apparently similar have been mapped as being parallel to (Ballard, 1966), perpendicular to (Rona, 1969), and at 45° to (Heezen and Schneider, 1968) the regional contours. Although this variation could be real, it could also be a result of sampling technique. Since even the general form of the feature is not known, the sampling strategy has not been adequate, nor have the nature and structure of the bottom boundary layer as well as the sediments that make up these bed forms usually been studied.

Most of these difficulties have been overcome by the recent development of a deeply towed instru-
Fig. 1. Echogram character on the continental margin and Sohm Abyssal Plain off Nova Scotia. Zones of similar echo reflectivity generally follow bathymetric contours and can easily be correlated from profile to profile. The zones of hyperbolae and mushy echoes also run parallel to near-bottom isotherms, suggesting a relationship between echo character and water masses. (From Hollister and Heezen, 1972.)

Fig. 2. Echogram character off the east coast of North America; can be related to the inferred and measured bottom currents of the Western Boundary Undercurrent (Schneider et al., 1967). Zones of prolonged and hyperbolic echoes on the continental rise parallel the regional contours. Above 3,500 m a tranquil, current-free bottom is usually seen, but below 3,500 m, swift contour-following currents appear to be transporting sediment toward the south (contours in meters).

ment package by the Marine Physics Laboratory of the Scripps Institute of Oceanography (Spiess and Mudie, 1970). This instrument package is towed at a height of 10-100 m above the sea floor, and with its side-scan sonar, narrow-beam echo-sounder, 4-kHz sub-bottom profiler, stereo camera, continuous-temperature recorder, and transponder navigation it can resolve sea-floor features such as bed forms with relatively small dimensions and can give information as to the temperature structure of the overlying water column.

It appears that an instrument of this type is almost required when studying features in the order of about 3 to several hundred meters. With good insight and adequate sampling procedures, good, though less complete, data can be collected by more conventional methods and a more subjective interpretation is usually involved.

In an effort to determine the character of the bottom morphology responsible for the hyperbolic echoes observed over the Blake-Bahama Outer Ridge and to search for answers to many of the questions listed above, two areas on the outer ridge were the objects of detailed investigations utilizing the MPL deep tow.

NEAR-BOTTOM INVESTIGATIONS OF MICROTOPOGRAPHY ON THE BLAKE-BAHAMA OUTER RIDGE

Clay and Rona (1964) noted the presence of hyperbolic echo returns in the Blake-Bahama Basin and related them to north-south corrugations which they thought could be sand waves. Later Bryan and Markl (1966) mapped the distribution of different echo types and determined, on the basis of the shape of the hyperbolic echoes, that these corrugations were generally parallel to the regional contours.

The Scripps deeply towed instrument package (Spiess and Mudie, 1970) was used to determine the nature of intermediate-scale bed forms responsible for the hyperbolic echoes on the Bahama Outer Ridge, the secondary ridge of the Blake-Bahama Outer Ridge complex, and to study the abrupt acoustic/sedimentologic contact between the Blake-Bahama Abyssal Plain and the Bahama Outer Ridge. Four giant piston cores (Hollister et al., 1973), 25 bottom-camera stations, 3 boomerang cores, and 7 current-meter records of up to 153 hours duration were obtained in the two areas studied on the Bahama Outer Ridge (Fig. 3). Area 1 is in a region of large (2-km wavelength) mud waves near the crest of the secondary ridge; Area 2 is at the contact between the Bahama Outer Ridge and the Blake-Bahama Abyssal Plain.

Previous studies of the Blake-Bahama Outer Ridge region have generally supported the concept that bottom currents have transported mud into the region and deposited it in the form of large lens-shaped ridges and swells (Heezen and Hollister,