UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

LATE NEOGENE AND QUATERNARY GEOLOGY OF THE SOUTHWESTERN FLORIDA SHELF AND SLOPE

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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Abstract

Seismic information obtained during a high-resolution geophysical survey of the southwestern Florida (south of lat 26°N) shelf suggests that the modern shelf and slope overlie a karstic Miocene(?) platform. The platform surface is covered by a lens of late Tertiary-Quaternary sediments, which thicken from the central shelf to a maximum of 150 m at the upper slope break and thin against the ridgelike outcrop of the Miocene(?) platform on the upper slope. A 8-km wide north-trending double reef complex on the central shelf separates the post-Miocene sediments offshore from the subcropping Miocene(?), which is thinly covered by a veneer of biogenic sand.

Over the thickest post-Miocene section and marking the edge of the modern shelf is a second double-reef complex. The lower reef of this set forms a well-developed 40-m scarp; the upper reef is characterized for most of its extent by a low-amplitude ridge. In addition to the reefs, two stratigraphic units are recognized above the Miocene(?): (1) a lower unit of unknown age, which can be traced under the shelf-edge reefs and is continuously onlapping the Miocene(?) ledge of the central shelf; and (2) an upper unit, which is composed of sediment derived from the shelf edge and pelagic sources and exhibits evidence of downslope creep by its accordianlike morphology on the lowermost portion.

A Miocene(?) ridge (400-510 m) below sea level trends north-south along the west-facing Continental Slope of the Florida shelf. This ridge is buried in the Florida Straits region. The reefs that mark the shelf break and central shelf are also being covered by more recent material in like manner. The age of the reefs is unknown, but the stratigraphic position indicates that the shelf-edge reefs are older than the central-shelf reefs. The encroaching recent reefs and associated platform sedimentation are extending the present shelf to the south and west. The reef-forming processes play an important role in the construction of the modern southern Florida shelf.

INTRODUCTION

The west Florida shelf, which has an area of more than 78,000 km^2 in the eastern Gulf of Mexico, is the only wholly carbonate continental margin of the United States (Fig. 1). Despite this uniqueness, this margin has been studied less than other margins of the country. Studies that have been made are confined either to the margin north of lat 26°N (Mitchum, 1978 ; Pyle and others, 1975; Gould and Stewart, 1955; Holmes, 1973; Doyle and Sparks, 1980) or to the slope (Bailey and Garrison, 1980; Pyle and Antoine, 1973; Bryant and others, 1969). This report presents seismic data on the part of the shelf that has been reportedly unsurveyed along with additional high-resolution data on the slope.

The data were collected by a minisparker (800 joule) and 3.5-kHz subbottom profiler. A multi-tip (48) sparker source was used. The detection and recording system consisted of a 24-element hydrophone streamer, an amplifier and broad band (130-1060 kHz) filter, and an analog and magnetic tape recorder. Eleven transects were made across the southwestern Florida shelf south of lat 26°N; seven of these are east-west

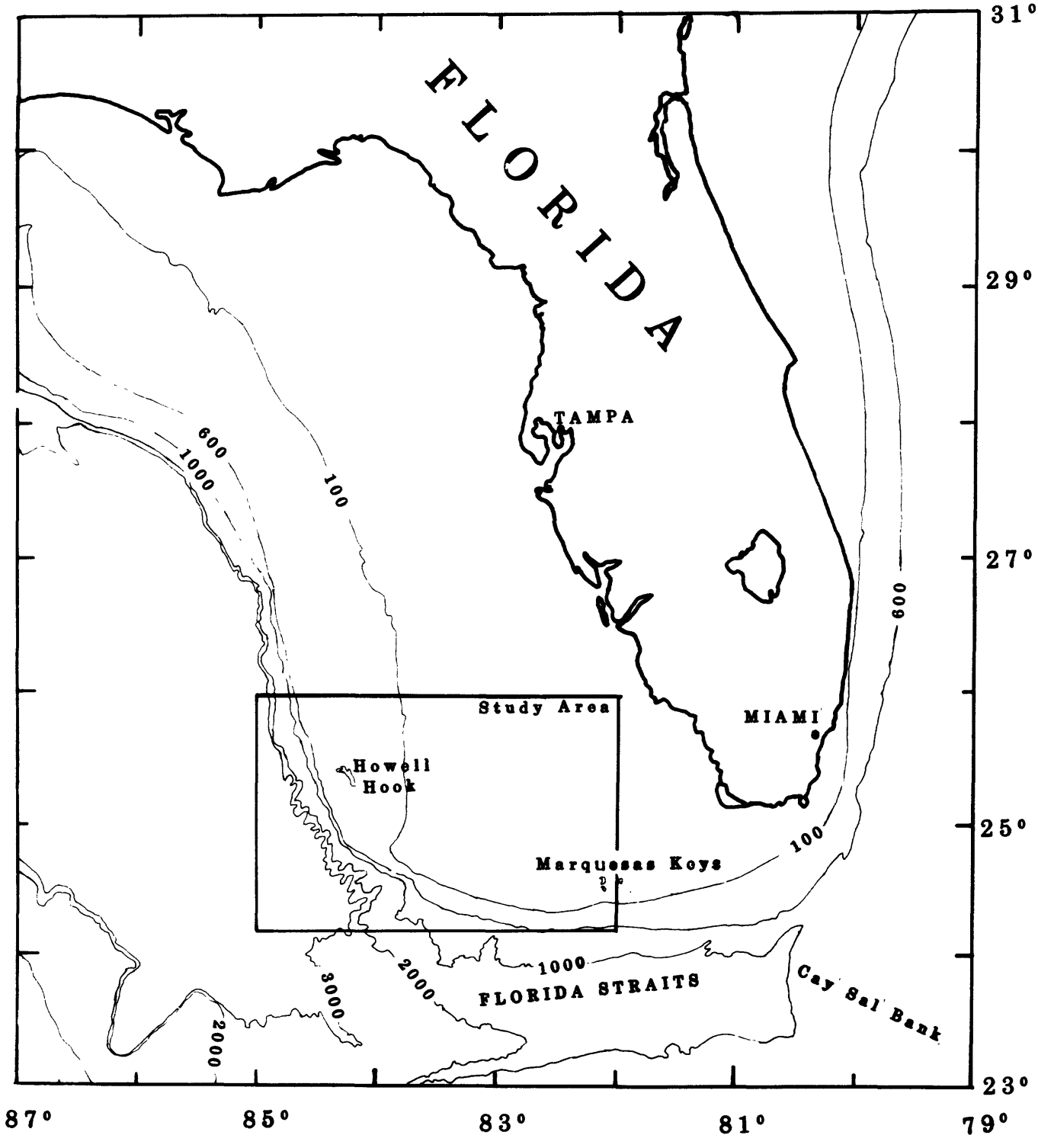

Fig. 1. Index map of study area. Bathymetric contours in meters.

and spaced about 18 km apart (Fig. 2). The remaining transects south of lat 25°N and in the Florida Straits region are oblique to the shelf. Navigation was by Loran C, and the position was recorded every 5 minutes.

GEOMORPHIC UNITS

Geomorphically and geologically the southwestern Florida margin consists of eight units; the southern banks, the inner shelf, outer shelf, upper slope, central slope, escarpment, basin, and Miocene(?) surface.

Southern Banks

A series of banks, crowned in the shallower areas by coral growth (Dry Tortugas and Marquesas Keys), borders the continental margin along the Florida Straits. These banks, trending east-west, become progressively deeper westward. Shinn and others (1977) found that the shallower banks are Holocene in age and are founded on topographic highs of Pleistocene age. No information is available on the ages of the deeper banks; however, dredged material from a biohermlike feature at the western edge of the bank trend contained material similar to that of the Pleistocene substrate in the Dry Tortugas region. Grady (1971) mapped the texture of the sediment for the region surrounding the Dry Tortugas. He found that the Florida Strait side and the crests of the banks were veneered with sand; the region immediately north of the banks was covered by finer material described as silt. This textural distribution of carbonate sediments is common in the regions protected by topographic highs.

Inner Shelf

North of the banks bordering the Florida Straits, the inner shelf (Fig. 3) extends from the coast to a water depth of 70 m, some 210 km from the shoreline. The surface of the sea floor of the innermost portion of this zone, from the coast to a depth of 40 m, is pockmarked by circular depressions, some as large as 2 km in diameter. The seismic signatures of these features are identical to those of known active karst features. These features are probably the result of ground-water migration and solution during lower stands of sea level and are carved into rock of Miocene age, which presently crops out on the southwestern peninsula of Florida. Some evidence indicates that subsea springs are active immediately north of this area, which could indicate that some of these depressions are still being modified by water flow.

In water depths of 40-70 m, the sea floor is smooth. The subsurface data show that the karst surface that crops out shoreward is buried by a thickening wedge of younger sediment (Fig. 4). Apparently, the processes responsible for this sediment deposition were intense enough to fill the depressions and form a featureless plain.

The inner shelf is separated from the outer shelf by a 10-km-wide biohermal complex (Figs. 5, 19, 20). This complex, which appears to be a series of carbonate reeflike structures, forms a series of steps dropping the shelf from 70 to 90 m. The age of this complex has not been determined. However, its stratigraphic position, lack of solution features, and shallow burial (Fig. 6) suggest that much of this zone was

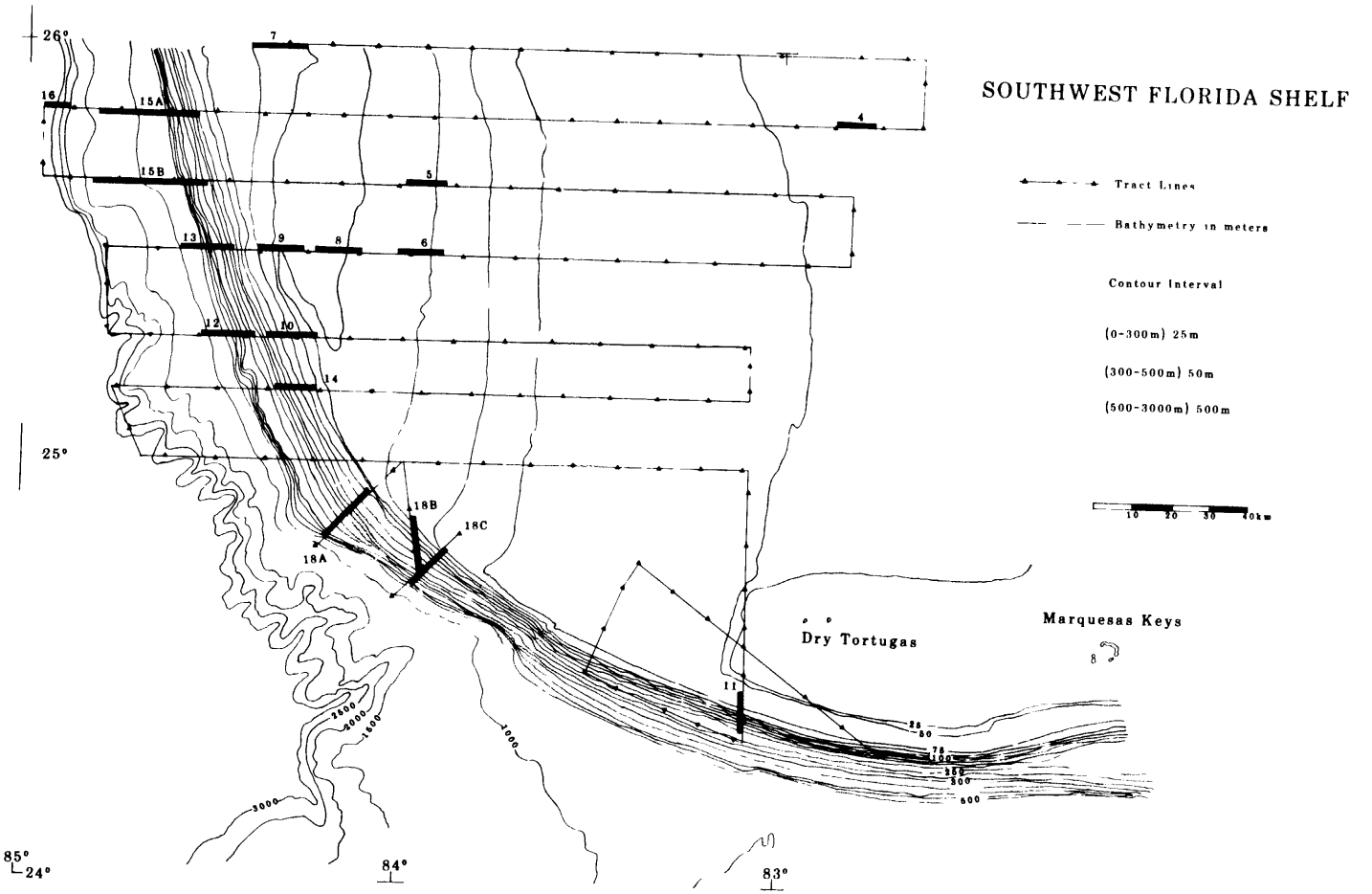

Fig. 2 Track map of RV GYRE (80G-6B). Numbers refer to location of subsequent figures.

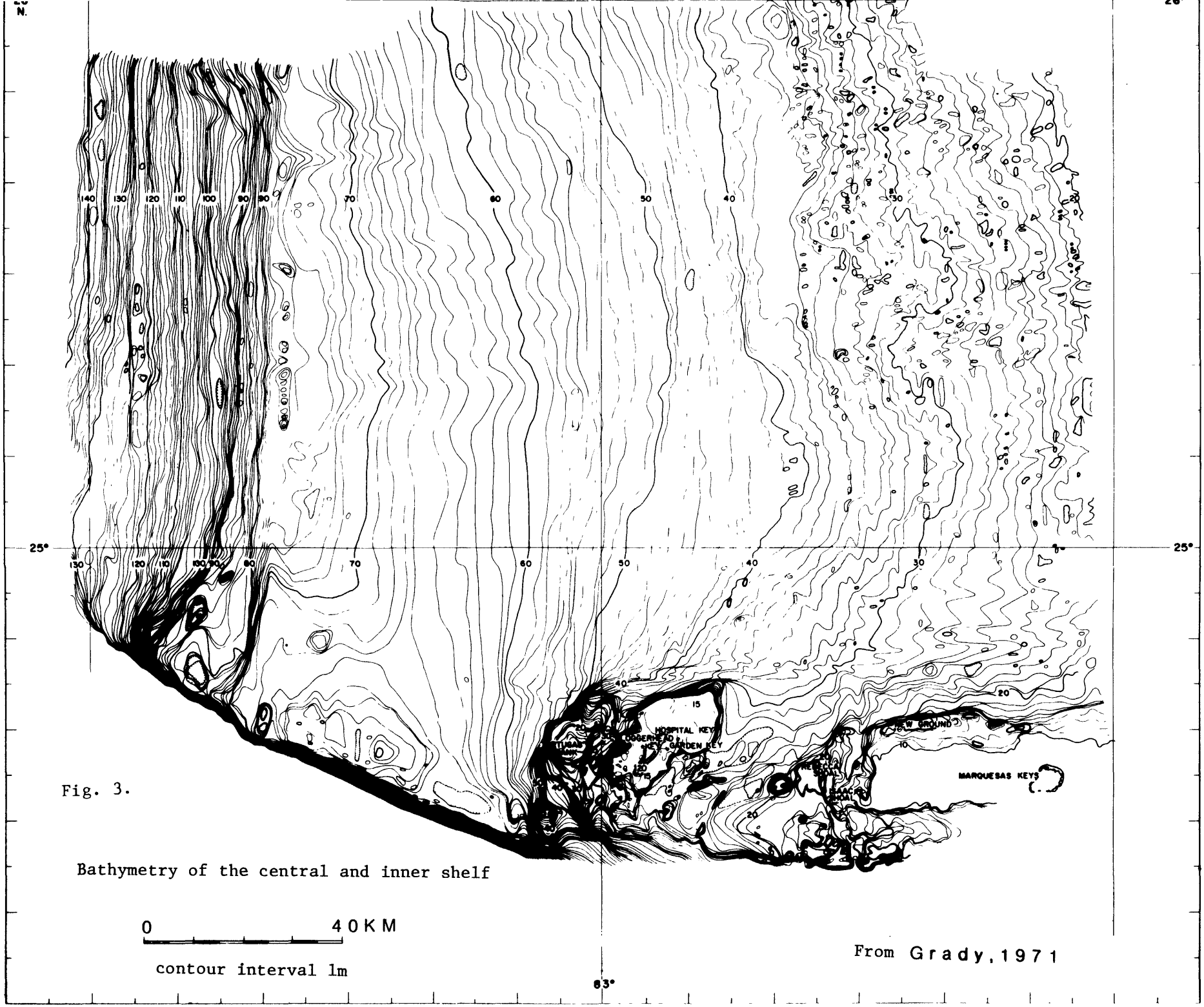

Fig. 3.

Bathymetry of the central and inner shelf

From Grady, 1971

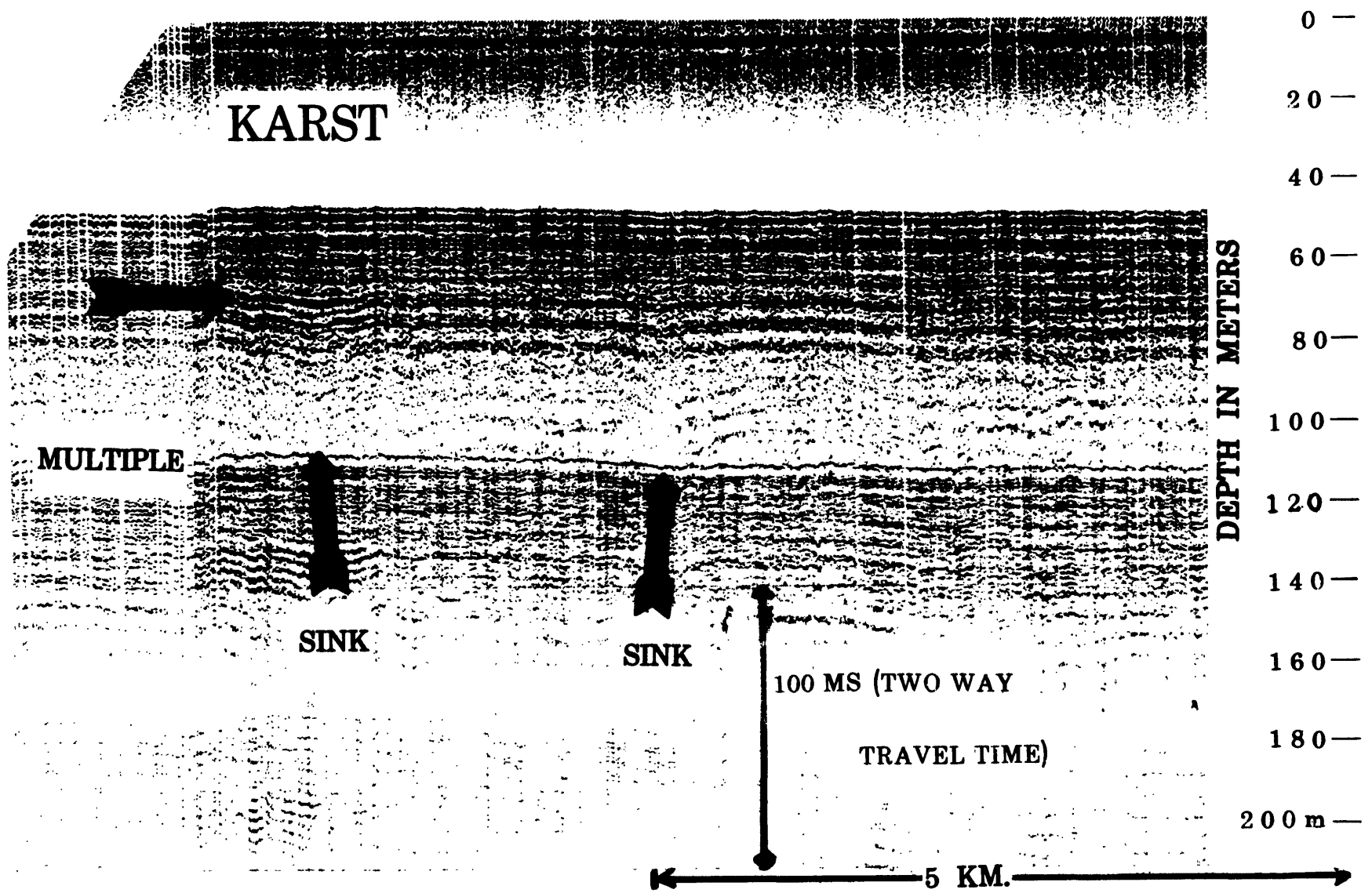

Fig. 4 Seismic profile on inner shelf. The profile has two units with the divide mark by arrow. The lower unit has features that are interpreted to be karst.

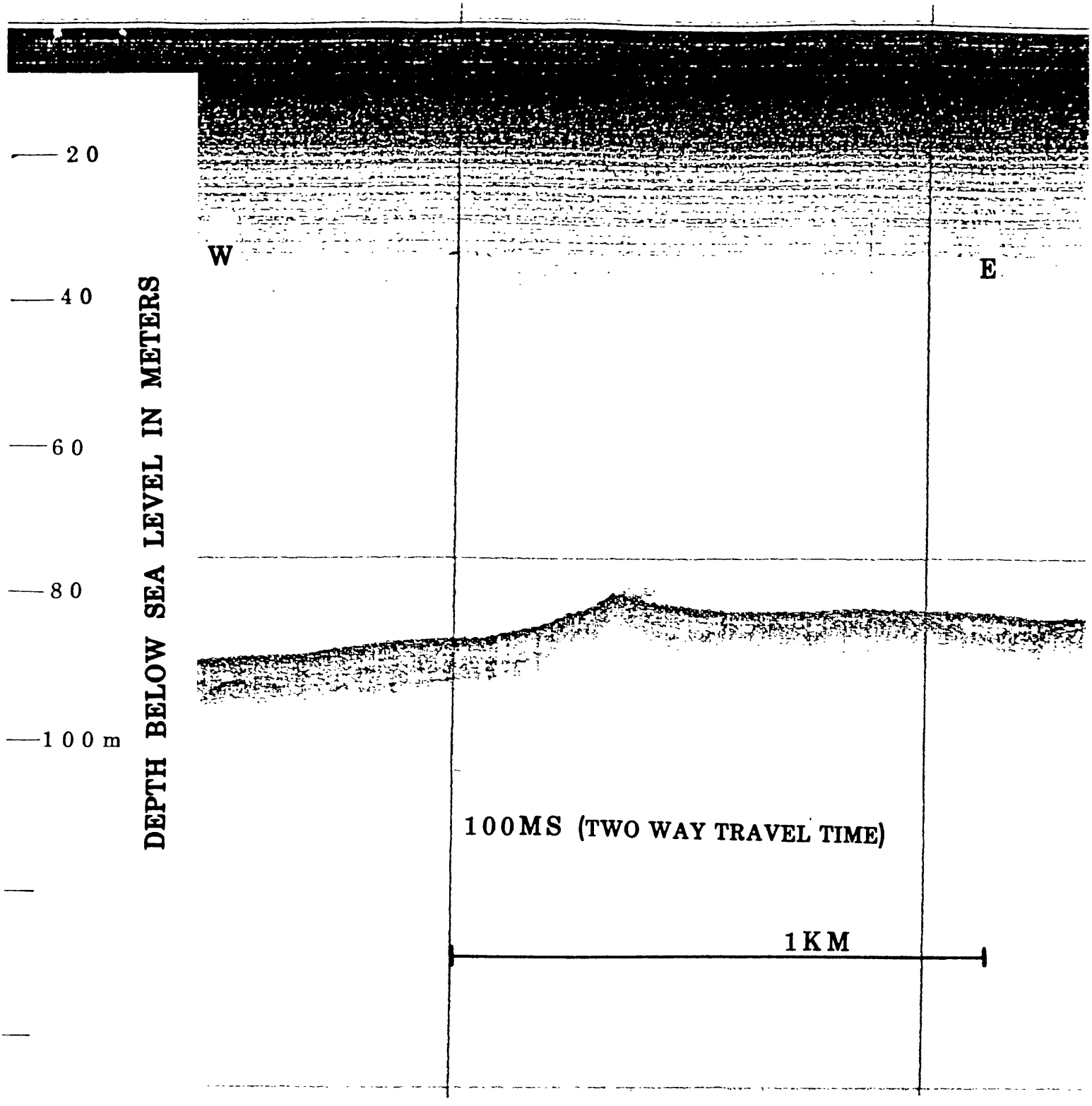

Fig. 5. 3.5-kHz profile over central reef complex. The central high is an outcrop of the reef which is partially buried.

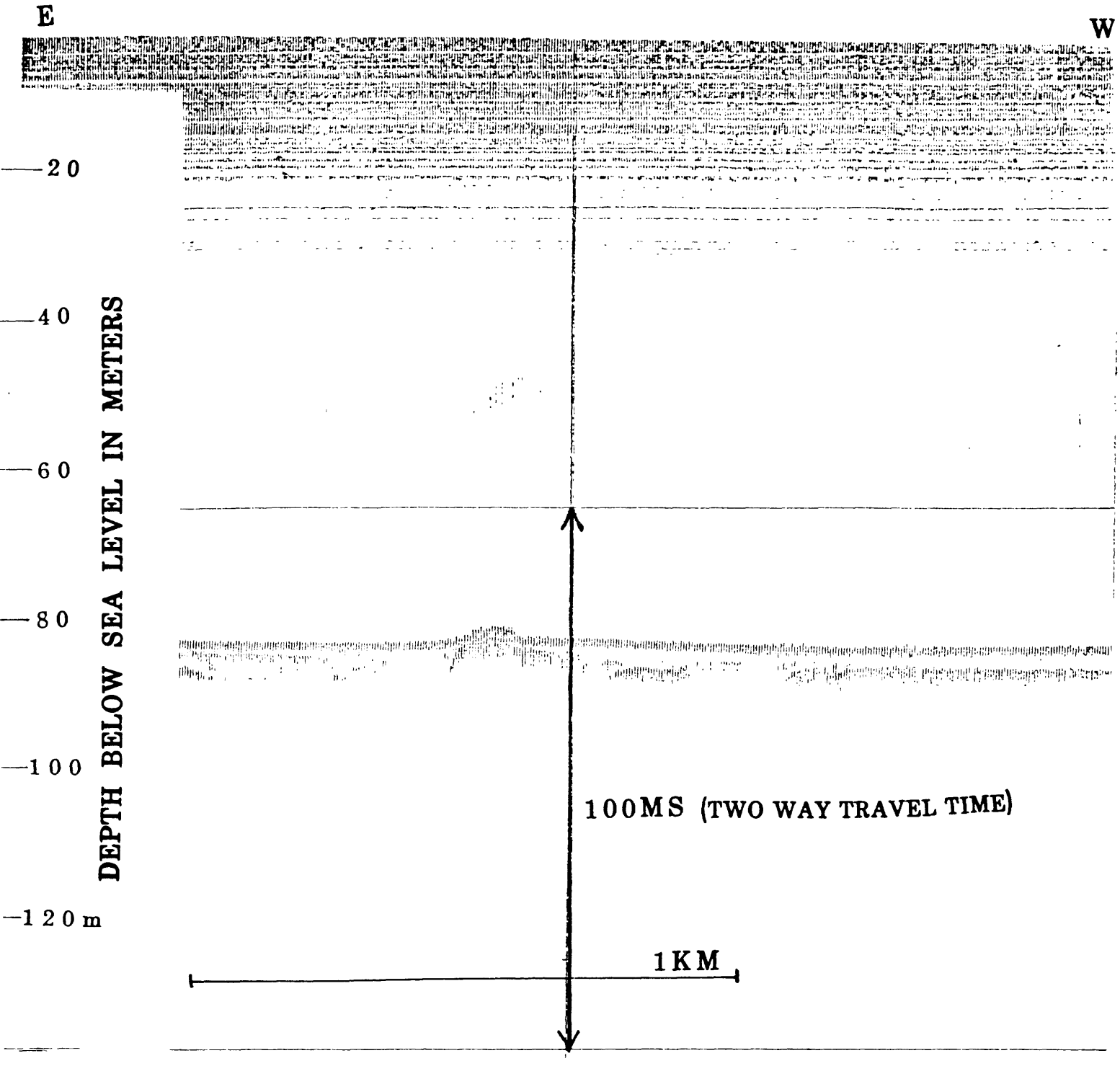

Fig. 6. 3.5 kHz profile over the central reef complex. The bulge is an outcrop of the partially buried reefal material.

formed during the last major transgression. The sea-level curve constructed by Milliman and Emery (1968) indicates that at the Holocene-Pleistocene boundary (10,000 B.P.) (J. Tracey, pers. commun., 1980), the sea was between 40 and 70 m below present with a best fit value of 55 m. If sea level were 55 m below present sea level, then the bioherm complex would have been well within the photic zone. In addition, the complex is apparently related to a break in slope of the underlying Miocene(?) surface, but the role of this slope break is not clear. The stratigraphic relationships between the complex and the inshore sediment overlying the karst Miocene(?) suggest that reef development provided the environment for the production and impoundment of sediment of the inner shelf.

Outer Shelf

The comparatively smooth surface of the outer shelf, in water depths of 90 to 200 m, sloping at 0.1°, is broken by 2- to 3-m-high wave-cut terraces formed during hiatuses in the rise of sea level. In this zone, unseen on the 3.5-kHz records but prevalent in the sidescan data, are shallow pockmarks (Jan Rietman, pers. commun., 1980). These features are nearly circular and have a central depression approximately 20-30 m in diameter and less than 2 m deep. The origin of these pockmarks is currently under investigation but is probably related to the hydrology of southern Florida. In addition to these features, seismic profiles indicate that the Miocene(?) surface in this zone is severely carved by solution (Fig. 7). In some sections, the subsurface karst features appear to have some relationship to large surface depressions (Fig. 8). Whether any of these solution features are active or related to some paleohydrologic activity is open to speculation.

Shelf Break

The shelf edge is marked by a double-reef complex. The shallowest reef, cresting from 130 to 150 m subsea, does not closely parallel the shelf break but veers landward north of lat 25°10'N. This reef forms the feature named the Howell Hook by Jordan and Stewart (1959). The feature encloses a basin some 3,300 km^2. Jordan and Stewart (1959) and Ballard and Uchupi (1970) speculated that Howell Hook was a spit formed by northward moving sediment. The lack of internal clinoform bedforms common in spits and the presence of an internal structure similar to that of actively growing bioherms (Enos, 1977; Holmes, 1978) suggest that this feature is also a bioherm (Fig. 9). If this interpretation is correct, the area encompassed by the reef would have been a lagoon or a sound similar in size and extent to Carl Sound near Miami, Florida.

The lower reef crests at -210 m in the south and -235 m in the north and forms a west-facing 40-m high scarp (Fig. 10). At the base of the scarp to the south is a 3- to 4-m depression. Both bioherms abruptly turn east at about lat 24°50'N and are buried by the banks that rim the Florida Straits (Fig. 11). As these banks are considered to be late Pleistocene (Shinn and others, 1977), the stratigraphic positions of these bioherms suggest that these are early or middle Pleistocene in age.

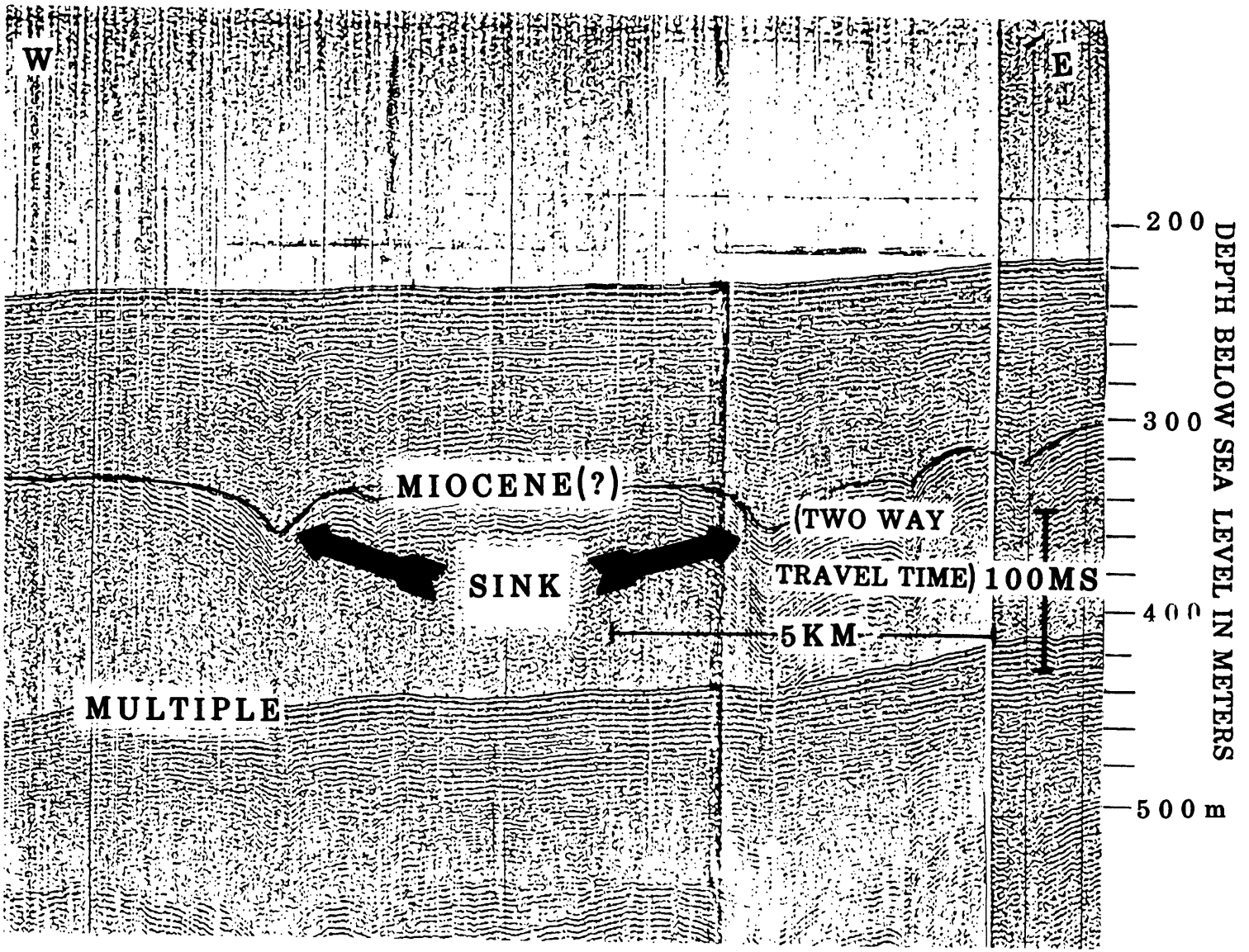

Fig. 7. Seismic profile of well-developed karst in lower strata. The lower unit is considered to be rocks of Miocene age.

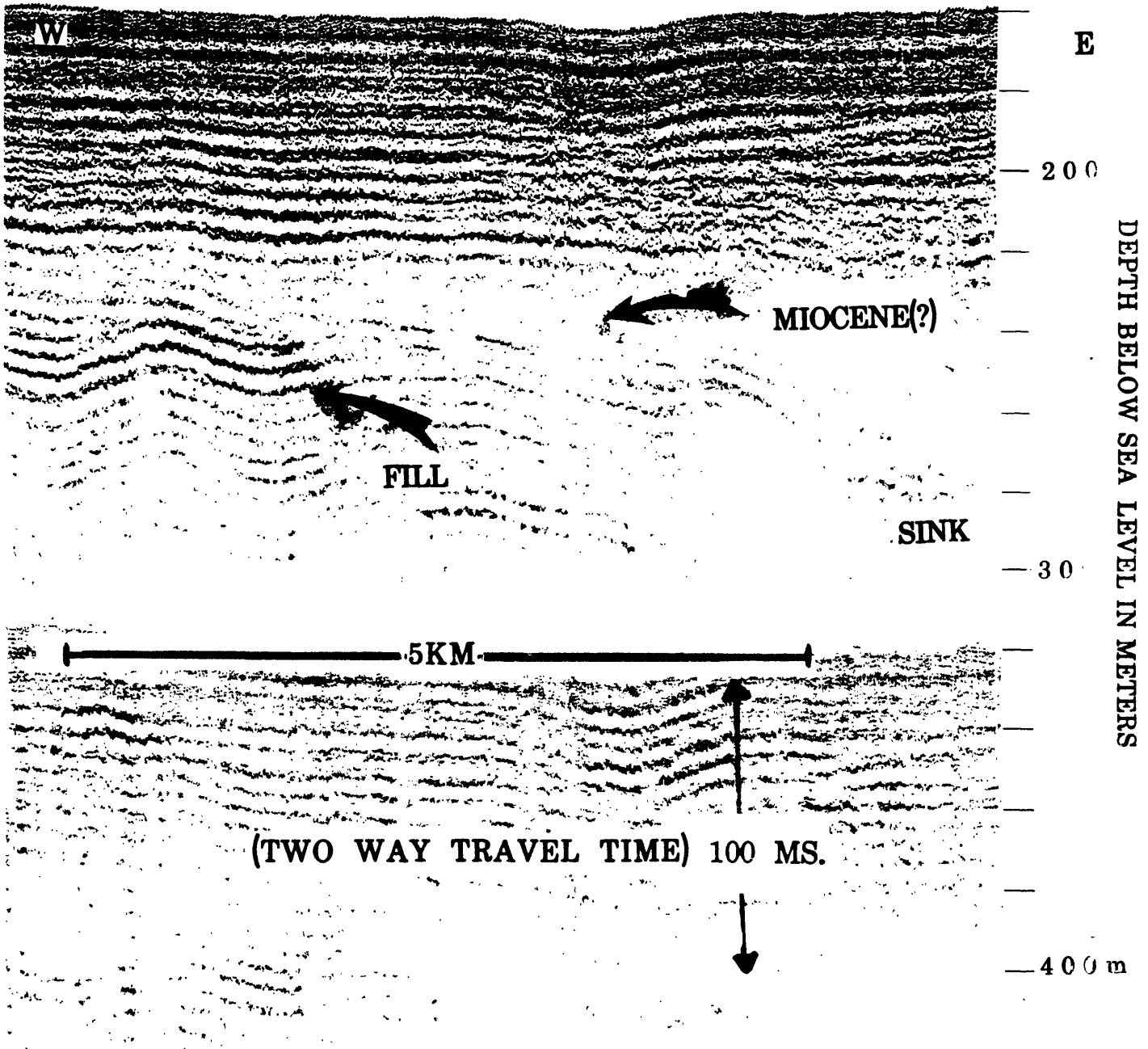

Fig. 8 Seismic profile on outer shelf. The depression on the surface appears to be related to the "sink" at the right of the section.

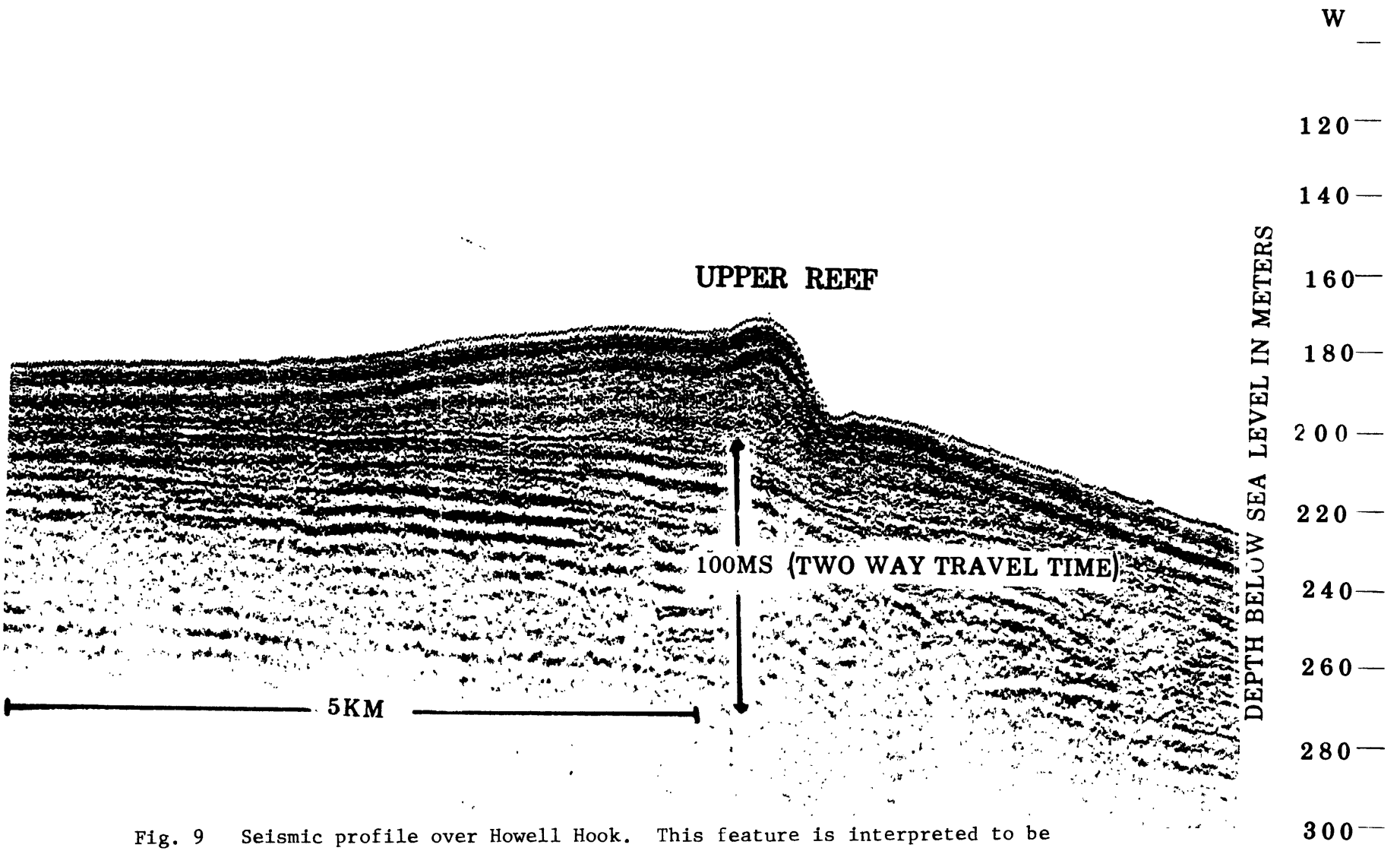

Fig. 9 Seismic profile over Howell Hook. This feature is interpreted to be a reef.

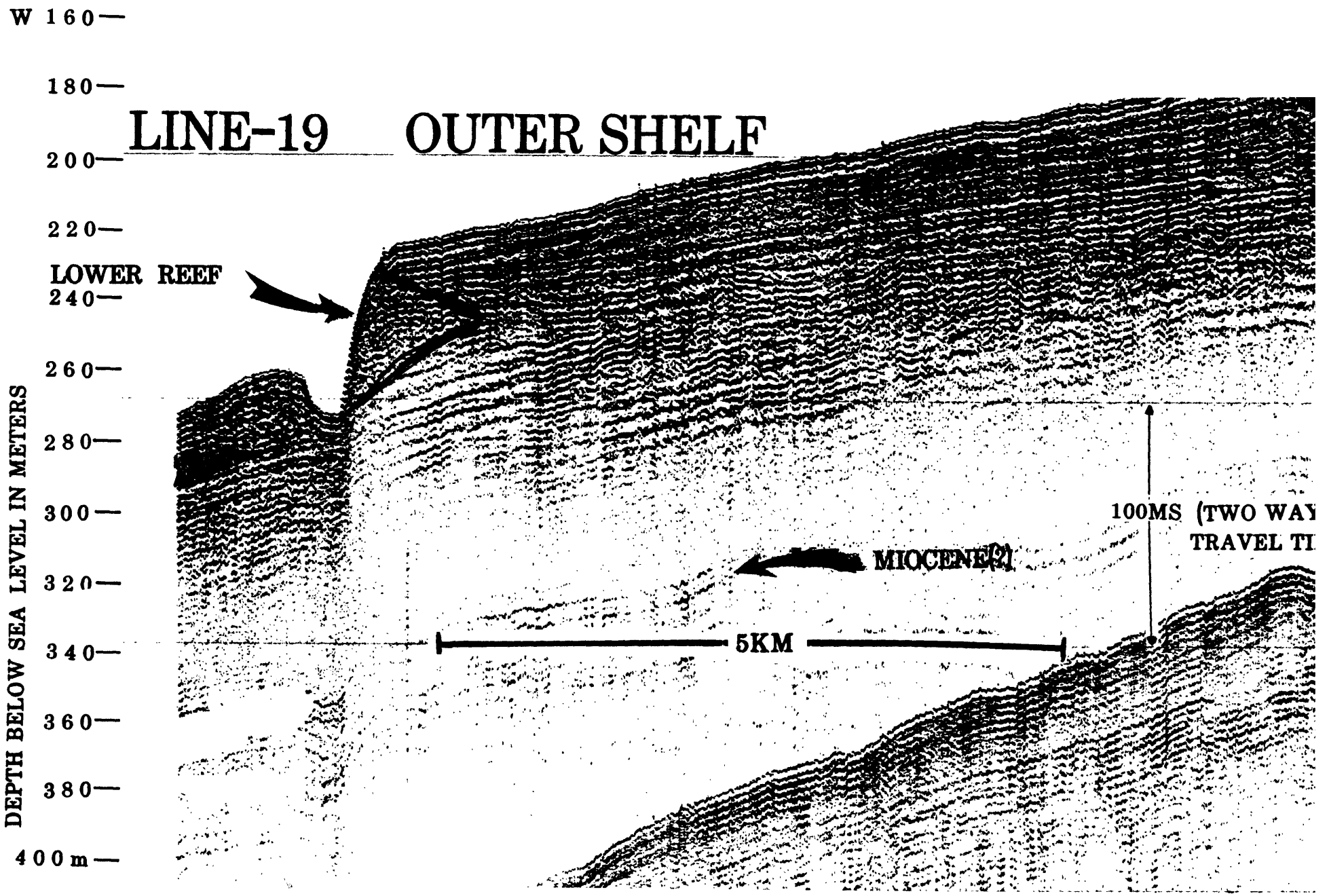

Fig. 10 Seismic profile at the shelf break. Example of the shelf-break reef

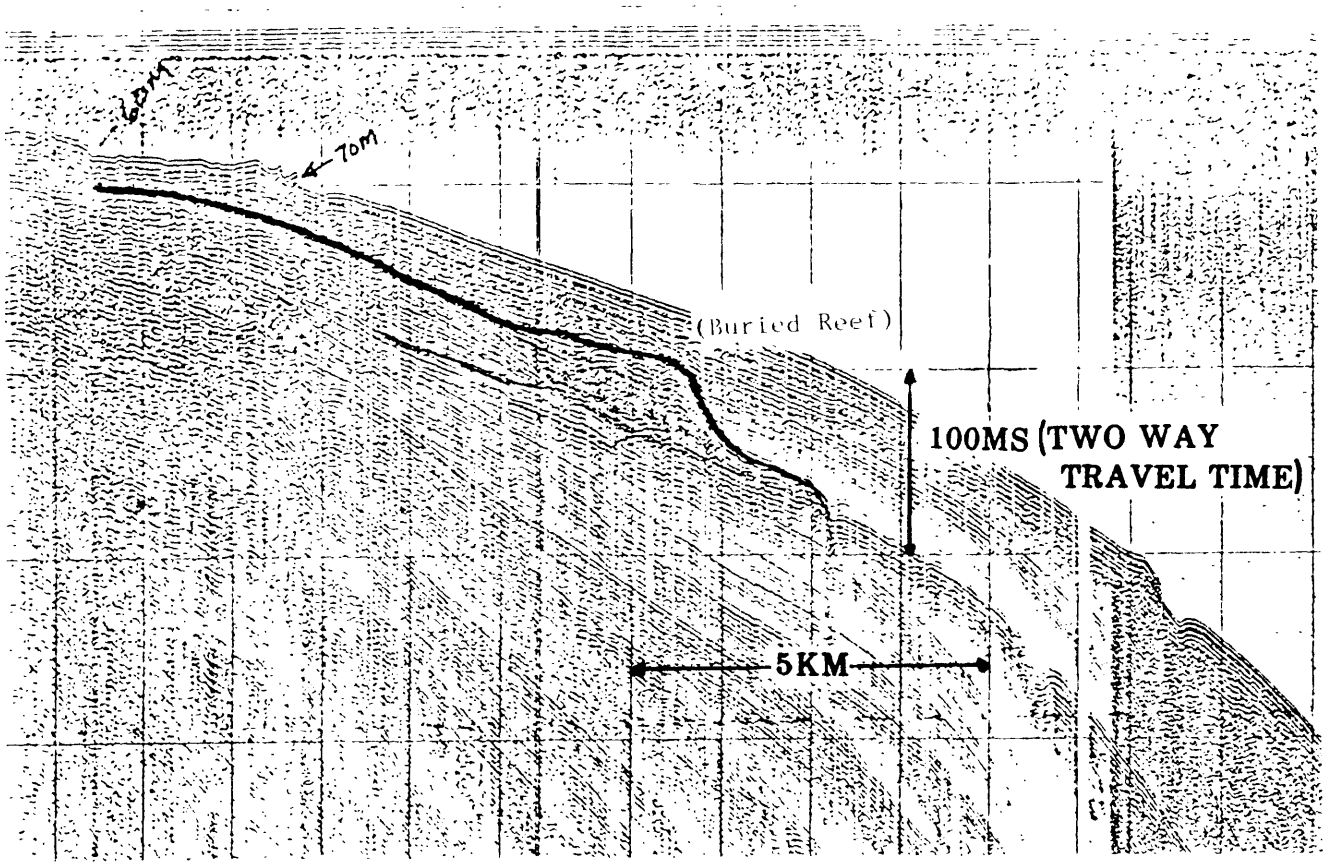

Fig. 11 Seismic profile south of the Tortugas. Example of a buried reef which stratigraphically is contemporaneous with the shelf-edge reef of fig. 10.

Upper Slope

The upper slope between the shelf break at -200 m and a ledge formed by an outcrop of the Miocene(?) platform (-475 to -500 m) has a 1° slope. The shallower surfaces are comparatively smooth (Fig. 12) in contrast to the accordianlike surface immediately above the ledge (Fig. 13). Reflections suggest that a thin surface sediment section is sliding basinward and that the accordianlike surfaces are caused by the sediment crumpling against the ledge (Fig. 13). In addition, the movement may have been the cause of the depression at the base of the lower bioherm, which was formed by mass wasting away from the scarp (Figs. 13, 14). The cause and the triggering mechanisms for this activity are not understood and are the targets of ongoing investigations.

Central Slope

The central slope extends from the ledge (-475 to -510 m) to approximately 2,000 m and has an average incline of 5°. The northern portion of the central slope is dominated by large block slides. Features on the Atlantic margin having seismic character similar to that of these block slides (Fig. 15) were studied and were found to be artifacts of the seismic signals; the apparent slip surfaces are actually channels (Hathaway and others, 1980). However, strike lines (Jordan and Stewart, 1959) show no channels dissecting this portion of the Florida slope. Thus, I conclude that large blocks are sliding basinward on the central slope. The southern central slope, in contrast, is characterized by a hummocky surface and no internal reflections. The region between the northern and southern sections of the central slope is also smooth and has no internal reflectors.

Escarpments and Basins

The Florida Escarpment between -2,000 m and -3,300 m has an average incline of 35°-45°. The profiles obtained on the scarp are of poor quality, and no significant geologic information is discernible. Hemipelagic sediments are present at the base of the escarpment. In the northern portion of the area, a wedge of discordant sediment overlies the parallel beds of the hemipelagic material (Fig. 16). This material probably was derived from a massive slump area directly north of the study area and has been studied by L. J. Doyle and L. E. Garrison (unpub. data, 1980).

Miocene(?) Surface

The surface of the ledge that separates the central and upper slope (Fig. 15a) can be traced landward under the upper slope and outer shelf. This surface has many large depressions (Fig. 17) interpreted to be karst related. The surface underlies the region of the central biohermal complex, and crops out around the 40-m isopleth, and continues landward to form the Miocene bedrock of the southwestern Florida Peninsula. On the basis of this configuration and seismic stratigraphic ties from well data to the north, this surface is interpreted to be developed on rocks of Miocene age. A similar ledge on the Pourtales Terrace in the eastern Florida straits was determined to be Miocene bedrock (Jordan and others,

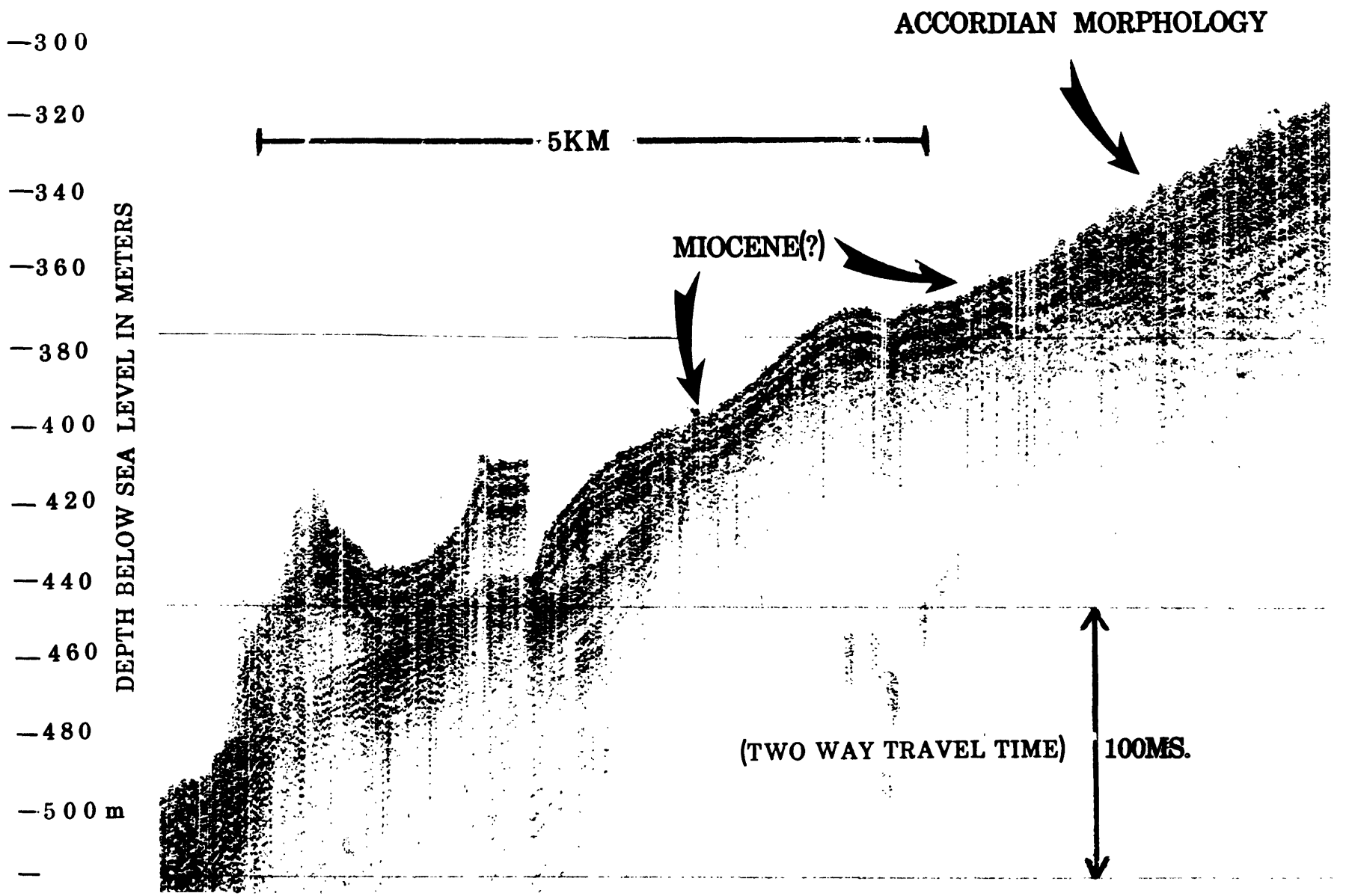

Fig. 12 Seismic profile of the deep portion of the upper slope.

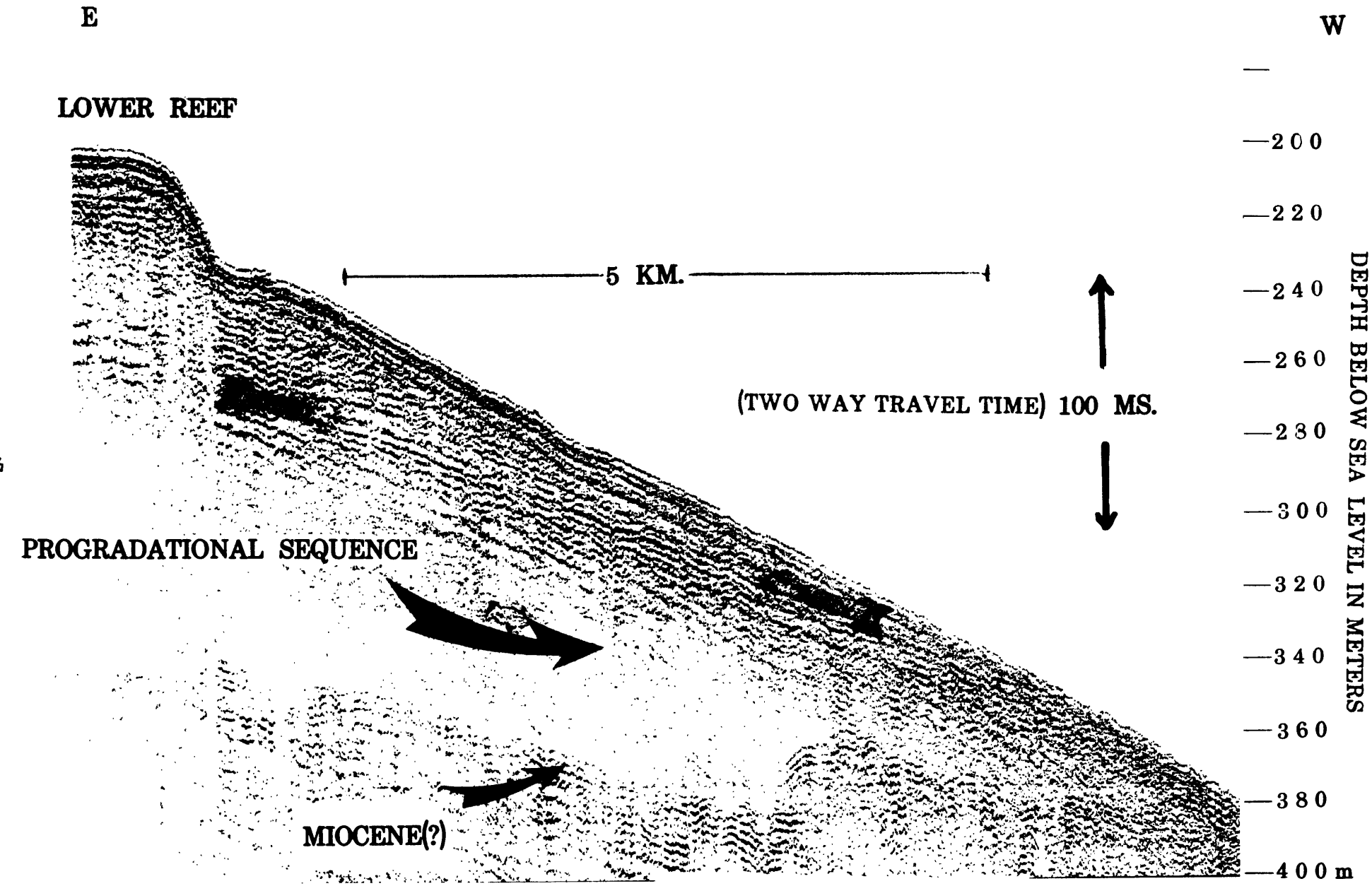

Fig. 13 Seismic profile of the upper slope with examples of a progradational sequence.

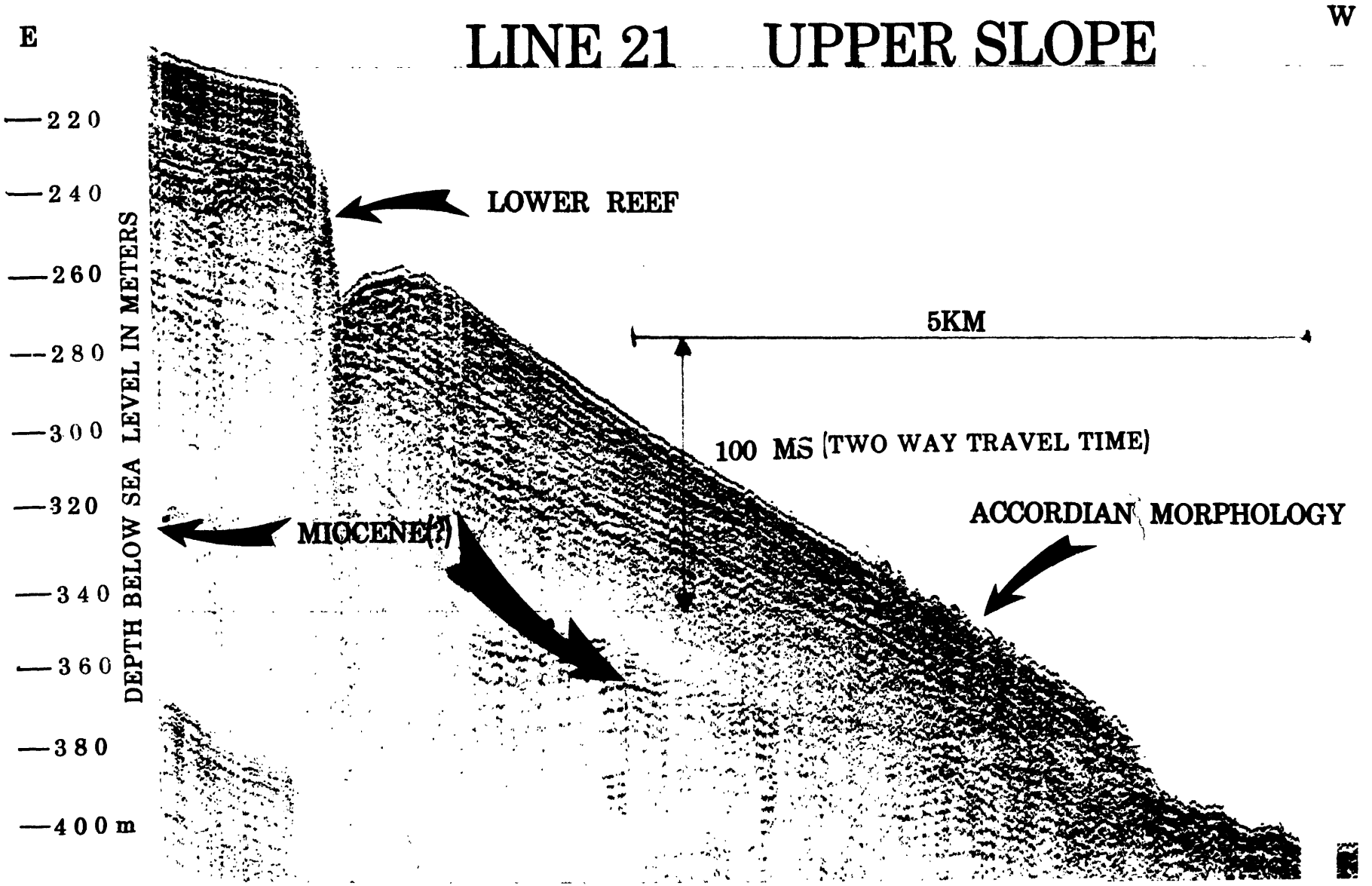

Fig. 14 Seismic profile of the upper slope with examples of the stratigraphic relations between the lower reef, the Miocene surface, the progradational sequence and accordian morphology.

Fig. 15a. Seismic profile of central slope. This profile shows the relationship between the Miocene(?) strata and the slope break.

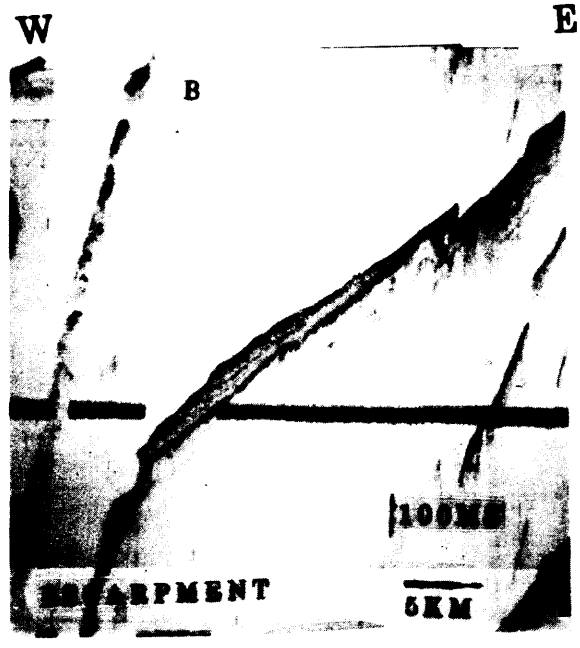

Fig. 15b. Seismic profile of central slope. This profile shows the relationship between the escarpment and central slope.

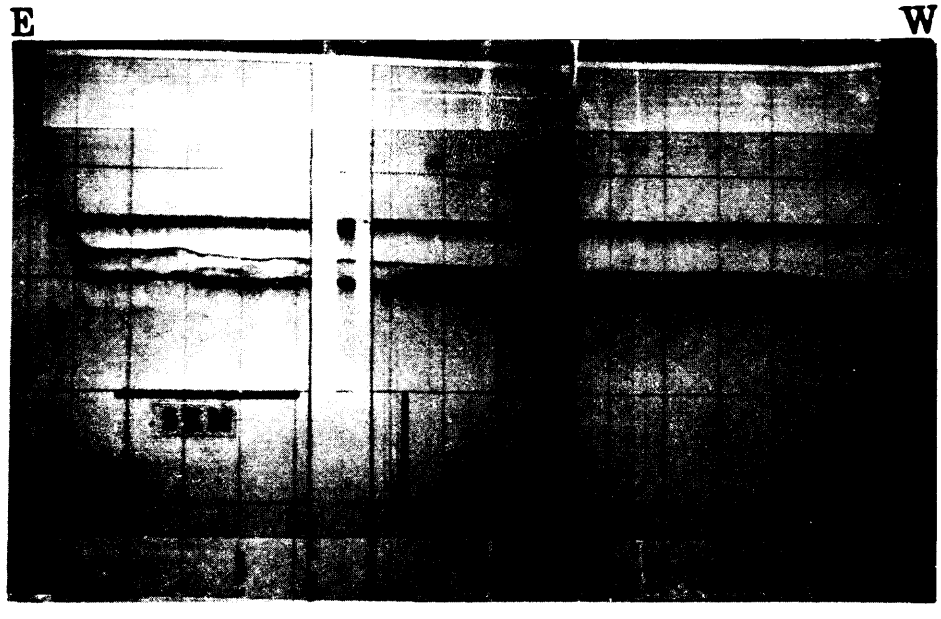

Fig. 16. 3.5-kHz profile of a debris deposit at base of the Florida escarpment.

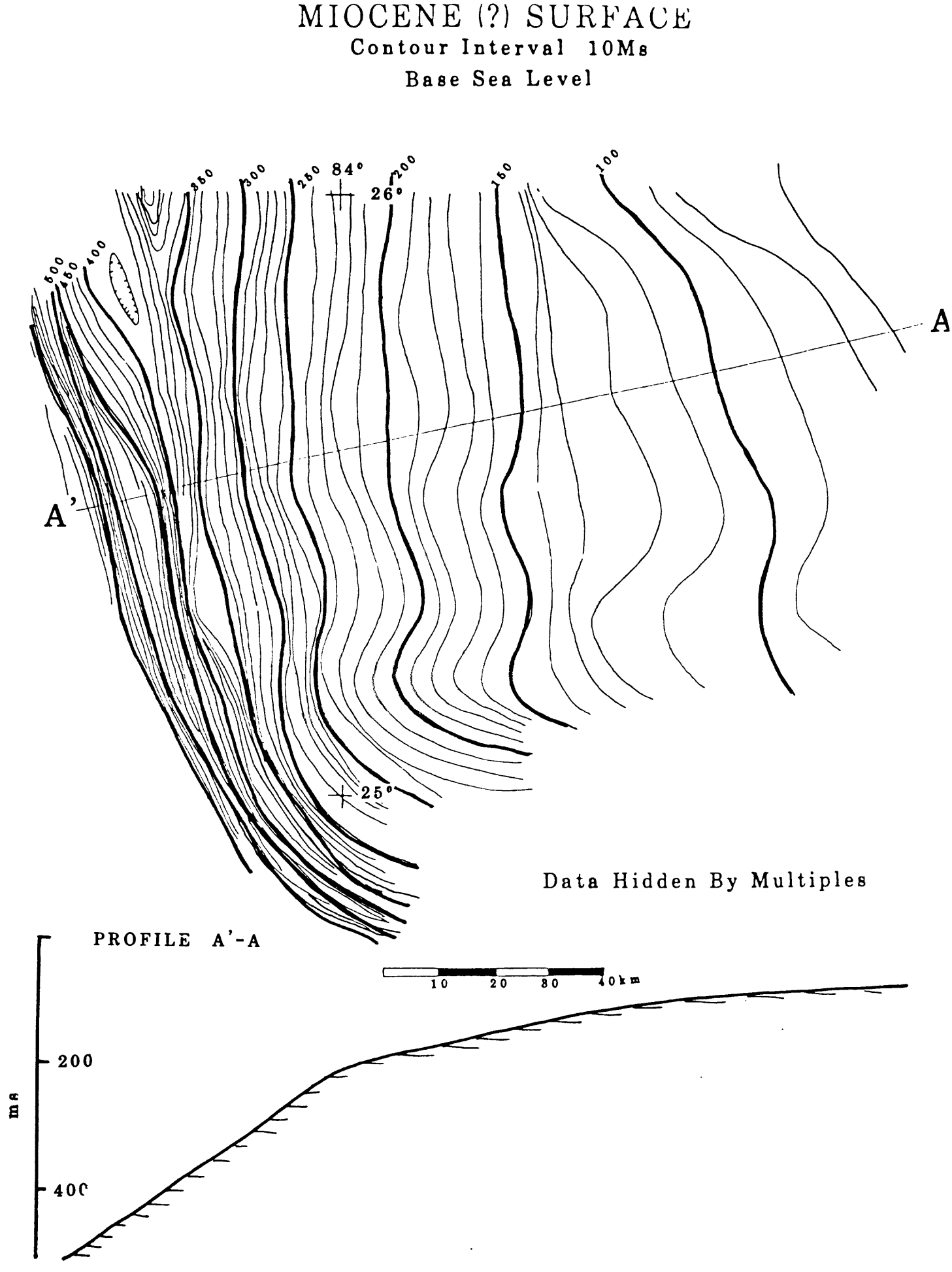

Fig. 17. Structural contours of the Miocene(?) surface.

1964; Gomberg, 1976). In the Pourtales area, the surface is less than -300 m subsea, whereas in the southwestern region, the surface is -400 m in the south and -510 m in the north, suggesting a dip of 0.03° in a northwesterly direction. The platform edge, like the two reefs that mark the shelf break, is buried by sediment of younger reefs and banks bordering the Florida straits (Figs. 18a, b, c).

SUMMARY AND CONCLUSIONS

The seismic data of the southwestern Florida shelf suggest that the Neogene and Quaternary deposits of this part of the Florida platform are composed of eight stratigraphic units: (1) the Miocene(?) surfaces and outcrops on the slope, (2) the wedge of Pliocene-Pleistocene sediments, (3) the upper slope which has creep-derived features, (4) the reef system at the shelf break, (5) the outer shelf, which is characterized by pockmarks and wave-cut terraces, (6) the central reef complex, (7) the inner shelf where a shoreward thinning sediment wedge has buried a karst surface, and (8) the southern banks. The stratigraphic relations of the surface expression of these features are mapped in Figure 19. A diagramatic cross section of the west Florida shelf is shown in Figure 20.

It is premature to construct a detailed history of the shelf development or discuss the processes involved in the mass movement on the slope. However, on the basis of the presently held concepts of sea-level fluctuations and the stratigraphic relationships recognized from the seismic profiles, a thumbnail historical sketch can be constructed. The foundation of the Neogene deposits is the karst surface that is considered to have developed in Miocene strata. This development could have been the result of the late Miocene fall in sea level (Vail and others, 1977), which exposed part of the shelf and produced conditions for a significant hydraulic ground-water head. These conditions are necessary to produce the large solution features interpreted to exist on the surface. Subsequent relatively short term fluctuations in sea level in the Pliocene and Pleistocene are responsible for the sediment wedge that underlies the outer shelf and upper slope. The age of this material is speculative, and its history has been obliterated by the rapid sea-level fluctuations. As a result, only the deposits of the last transgression remain relatively undisturbed.

At the beginning of a late Pleistocene transgression, the outer shelf reefs were formed, the lower reef formed first. It is unclear if the upper reef, Howell Hook, was formed during this transgression or if it was formed during a minor sea-level regression. In any event, during this period, the shelf started its southward movement overlapping the Miocene shelf break to the south, as seen in the superposition of these reefs over the Miocene(?) strata.

The central shelf reef complex suggests a stillstand, possibly an event associated with Holocene-Pleistocene boundary (10,000 years B.P.). The development of this reef complex appears to have been vigorous as this reefal feature buries both the Miocene shelf break and the double reef which forms the shelf break to the north. It is also suggested that this complex produced the sediment that was deposited landward. This reef development, and associated sediment production and deposition, is

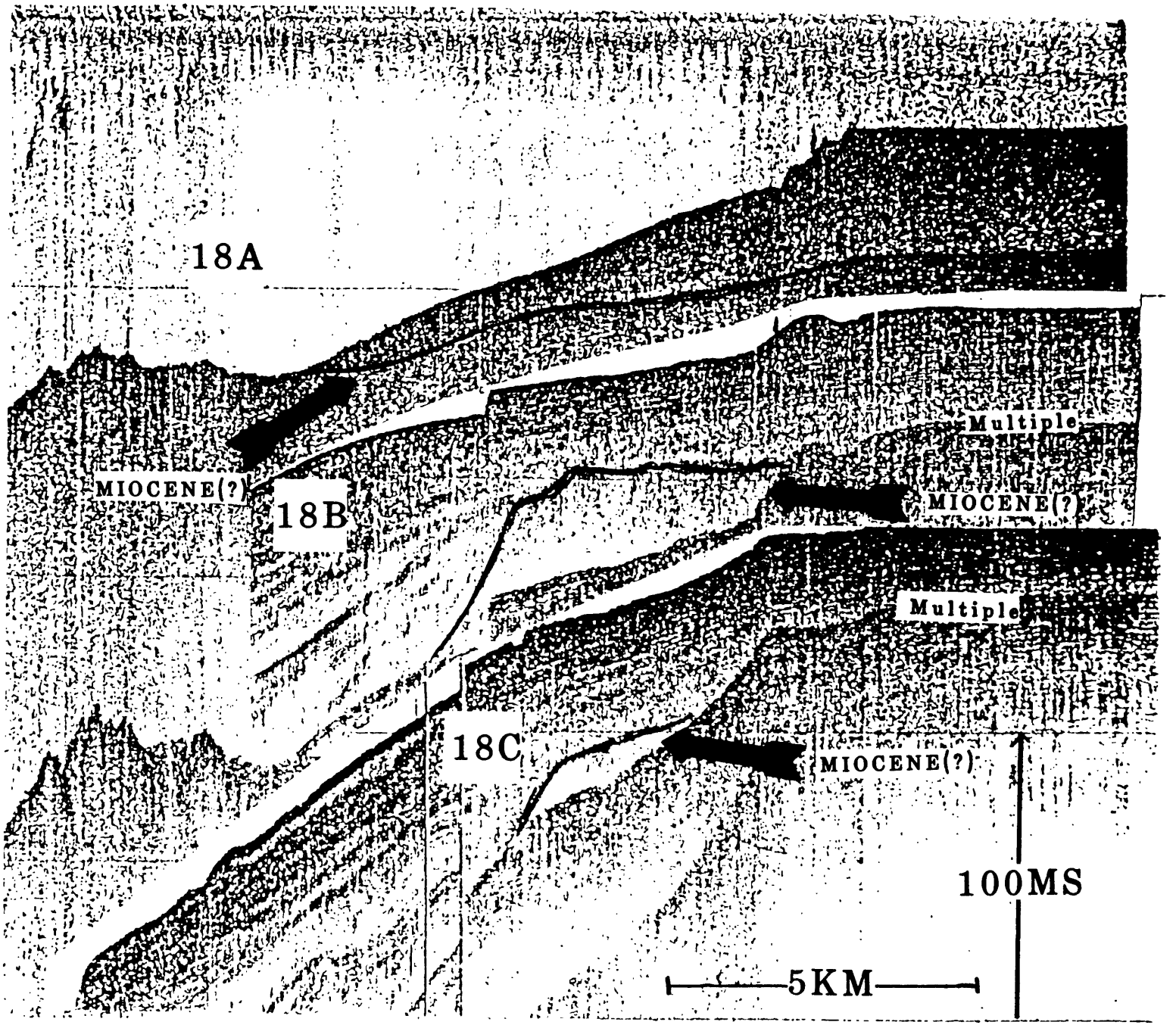

Fig. 18a-c. Sequence of west to east profiles showing the increasing burial of the Miocene(?) strata.

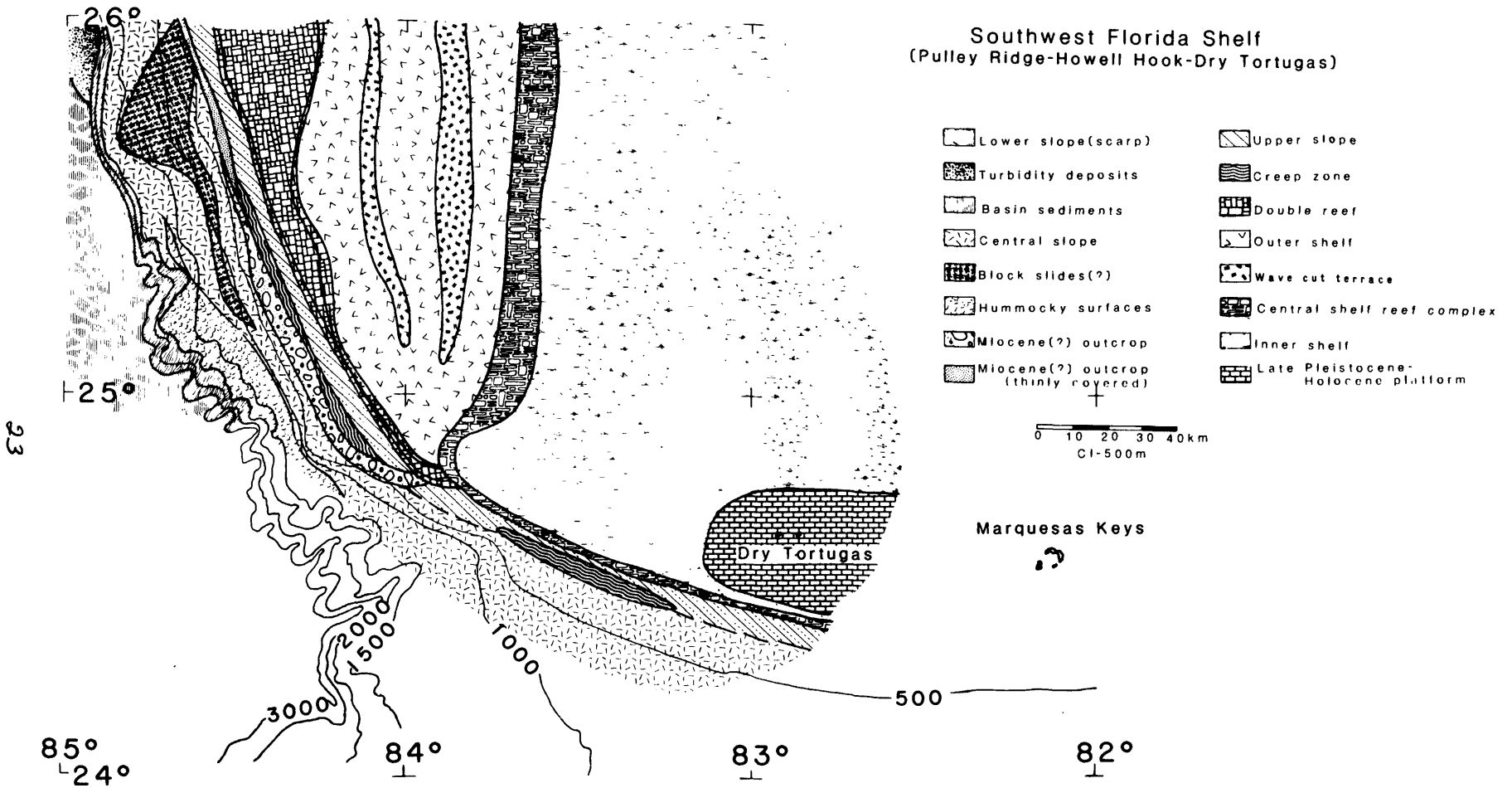

Fig. 19. Map of major features of the southwest Florida shelf

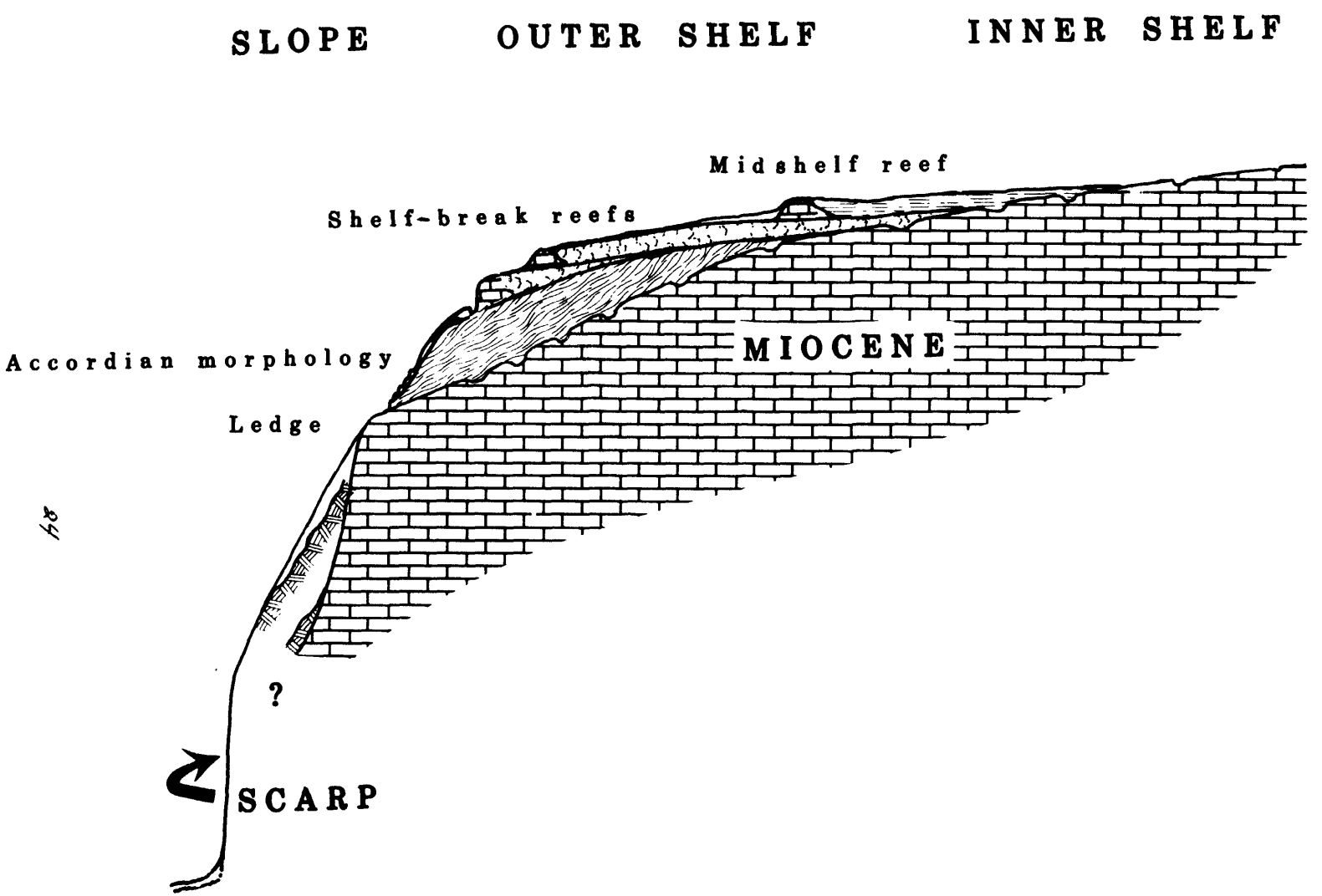

Fig. 20. Diagramatic cross section of the west Florida shelf

apparently the major process responsible for carbonate deposition on the inner portion of the west Florida shelf.

The last event was the development of the southern banks. These have encroached over the previously deposited reefs and slope sediments. These banks are still active and appear to be building to the west, directed by the Gulf Stream.

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