ACTIVE MARGIN STRUCTURES WITHIN THE NORTH SLOPE OF THE MUERTOS TRENCH[1]

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ABSTRACT

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Seismic reflection records from the north slope (landward slope) of the Muertos Trench south of Hispaniola reveal features similar to those seen on reflection records from Pacific active margins. Tectonically rotated sediment ponds characterize the slope; landward-dipping reflection horizons within the wedge of sediments underlying the slope suggest possible fault planes. Oceanic crust can be traced landward of the trench axis for tens of kilometers beneath the sediment wedge. Seismic refraction velocities are similar to velocity profiles found in Pacific inner trench slopes.

The above similarities between the Muertos Trench inner slope and the inner slopes of Pacific trenches suggest similarities in tectonic origins. Although the Muertos Trench, unlike Pacific trenches, is not associated with a belt of active volcanism or a well-defined Benioff zone, models that explain the structure of Pacific trench inner slopes in terms of imbricate thrusting may also apply to the north slope of the Muertos Trench.

INTRODUCTION

Within the last few years investigations of deep-sea trenches and their associated volcanic arcs in the Pacific have led to interpretations of these trench-arc systems in plate-tectonic terms in which ocean floor is underthrusting island arcs or continental margins. Generally this underthrusting is associated with active volcanism landward of the trench and a landward-dipping zone of earthquake hypocenters defining a seismic Benioff zone. Interpretations of sea-floor magnetic patterns have led to calculations of convergence rates on the order of 10 cm/yr for most of these Pacific active margins (MINSTER ET AL., 1974).

Seismic reflection records from Pacific inner slope regions generally show that the sediment wedge is a zone of discontinuous and weak reflectors above a landward-dipping re-

flector usually interpreted as the continuation of ocean crust. Landward-dipping reflections within the sediment wedge have been interpreted as thrust planes mirroring on a smaller scale the thrusting occurring along the Benioff zone (BECK & LEHNER, 1974; SEELY ET AL., 1974). On several trench inner slopes, reflection records reveal ponded sediments in which the deeper reflectors dip more steeply landward than shallower reflectors (VON HUENE, 1972). This has been interpreted to indicate progressive tectonic rotation of the inner slope (G. F. MOORE & KARIG, 1976). Deep-sea drilling of the toe of inner slopes has revealed folded and dewatered sediments (CREAGER ET AL., 1973; KARIG ET AL., 1974; J. C. MOORE & KARIG, 1976). Seismic refraction experiments have shown that sound velocities within the landward wedge of sediments (SHOR & VON HUENE, 1972; VON HUENE, 1972) are higher than would be expected from normal compaction due to the present overburden. These higher velocities may be attributed to tectonic dewatering of sediments in a compressive regime (MOORE, 1974; CARSON ET AL., 1974; CARSON, 1976) and to possible slices of oceanic crust within the sediment wedge.

The general picture developed from these observations and interpretations is that the inner slope of the trench along active margins is a zone where sediment and possibly slices of ocean crust are being scraped off the ocean crust as it slides beneath
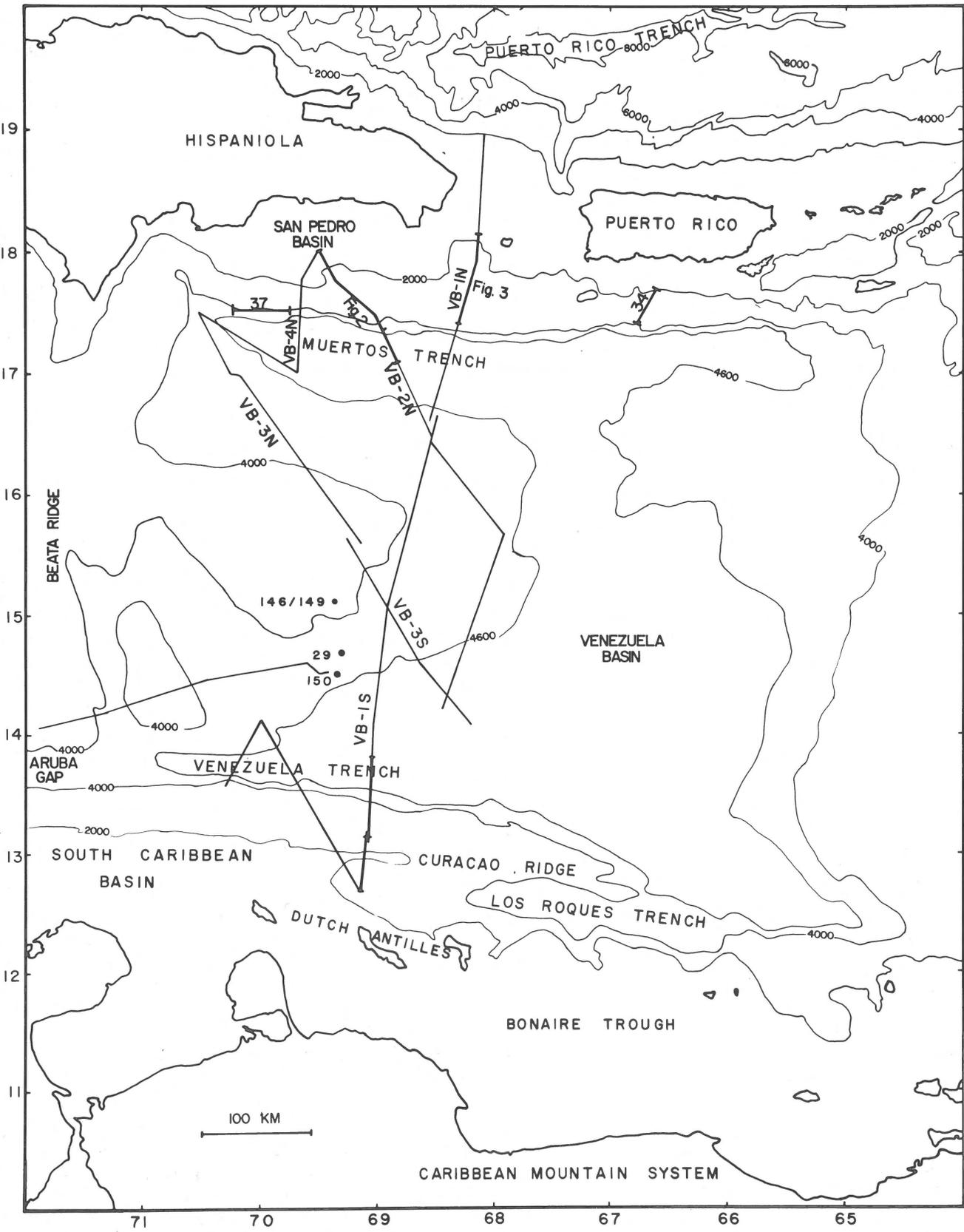
Fig. 1
Track of the R/V *Ida Green* along which CDP seismic reflection data was acquired.

the island arc or continental edge. The offscraped sediments and ocean crust are being piled in imbricate slices within the trench inner slope with younger slices being thrust beneath older slices and progressively lifting the seaward edge of the older slices (SEELY ET AL., 1974). Terrigenous sediment from the adjacent island arc will also be incorporated in the inner slope as the terrigenous material moves downslope and accumulates in sediment ponds on the inner slope, in sediment aprons that blanket the slope, and in the trench axis. These latter processes of downslope mass wasting and deposition have been emphasized by VON HUENE (1972), by WORZEL (1976), by LADD ET AL. (1977), and by SCHOLL ET AL. (1977). So far there has emerged little evidence with which to evaluate the relative significance of offscraped sediment vs. downslope accumulations of sediment within any active trench environment.

The observations summarized above have so far been primarily from trench environments closely associated with active volcanism and well-developed seismic Benioff zones. However, as will be shown below, the inner-slope sediment structures summarized above may occur in other areas which are not related closely to well-defined Benioff zones or active volcanism. This paper presents a seismic profile across one such area, the north slope of the Muertos Trench, which clearly shows inner-slope structures that are similar to structures of active Pacific margins. We suggest that the same processes are occurring landward of both the Muertos Trench and Pacific trenches.

MUERTOS TRENCH INNER SLOPE

Fig. 1 is a chart of the track of the R/V *Ida Green* from a cruise in 1975 along which multichannel CDP data were collected. The data collected from seismic lines VB-2N and VB-4N have been presented elsewhere (LADD ET AL., 1977; LADD & WATKINS, 1978). Fig. 2 is a sketch of the time-section along line VB-2N and shows the general structural and topographic setting of the Muertos Trench and the north slope of the trench. Several features suggest a similarity in tectonic regime between this area and other active margins described in the literature: the turbidite fill in the trench axis, ocean basin layers extending landward beneath a contorted sediment wedge, the structural high at the trench slope break which ponds sediment to the north in the San Pedro Basin, 1 or 2 midslope terraces, and a possible landward-dipping fault trace within the contorted sediment wedge.

The newly available time-section of line VB1N (Enclosure I and Fig. 3) shows more clearly the structural style of the north slope of the trench. The section begins just south of Mona Passage off the Greater Antilles island platform and descends to within a few kilometers of the trench axis. The most immediately obvious features on the slope are the terraces with their ponded sediments. There is a large sediment pond in about 3 sec of water and 3 small sediment ponds farther downslope.

The lower part of the sediment section ponded in the two shallower basins appears folded in a broad syncline, which may indicate original depositional dip in a pre-existing topographic basin or may indicate tectonic folding. The sediments which have filled the large shallow basin have at times preferentially filled the topographic axis of the basin as indicated by lateral pinchouts, while at other times the sediments may have accumulated on a seaward-dipping topographic slope as indicated by the northward thickening of the deeper units of the basin. The horizon at 3.5 secs which appears horizontal in the center of the large basin actually dips landward in a depth section. The units above and below this horizon which pinch out laterally were probably originally deposited horizontally in a topographic basin and have since been tilted landward by tectonic processes.

The sediments in the two deeper sediment ponds do not show the synclinal form of older sediments but instead a landward fanning of horizons which pinch out against a structural high to the south and abut another structural high to the north. While the older sediments in these ponds could have been deposited originally on northward-dipping topographic slopes and younger sediments on seaward-dipping slopes, it is also possible that tectonic rotation of these ponds has occurred during sedimentation.

Beneath some of the sediment ponds a landward-dipping zone of irregular reflections is observed which is in line with the landward-dipping base of the sediment pond. It appears that the inner slope is composed of a series of northward-dipping blocks with the seaward termination of each successively higher block being further northward. The sediment ponds accumulate in the depressions formed by the northward-tilted staircase of blocks.

Between 8.0 and 8.5 sec on the southern end of line VB-1N a zone of faint reflections can be seen which has a much gentler northward dip than the reflection zones beneath the sediment ponds. This gently-dipping zone, which can be correlated farther south with the top of Venezuela Basin crust, indicates that Venezuela Basin crust extends at least 40 km northward beneath the sediment wedge.

Sound velocities within the sedimentary prism beneath the north slope of the Muertos Trench have been reported by OFFICER ET AL. (1957). Their refraction profile 34, shot south of Puerto Rico about 70 n.m. east of the reflection section presented here, included a station in about 4.4 sec of water on the inner slope of the Muertos Trench. They found 0.94 km (0.9 sec 2-way travel time) of a 2.0 km/sec layer immediately beneath the water bottom and overlying 5.56 km (2.9 sec 2-way travel time) of 3.8 km/sec material. Velocities of 5.9 km/sec were observed at a depth of 9.78 km (8.2 sec 2-way travel time) which is about the level of the gently-dipping reflection zone seen on the south end of Fig. 3.

The velocities of 2.0 km/sec and 3.8 km/sec are appropriate for clastic sediments, but the velocity of 3.8 is higher than normal for the observed depth of burial. For comparison, see
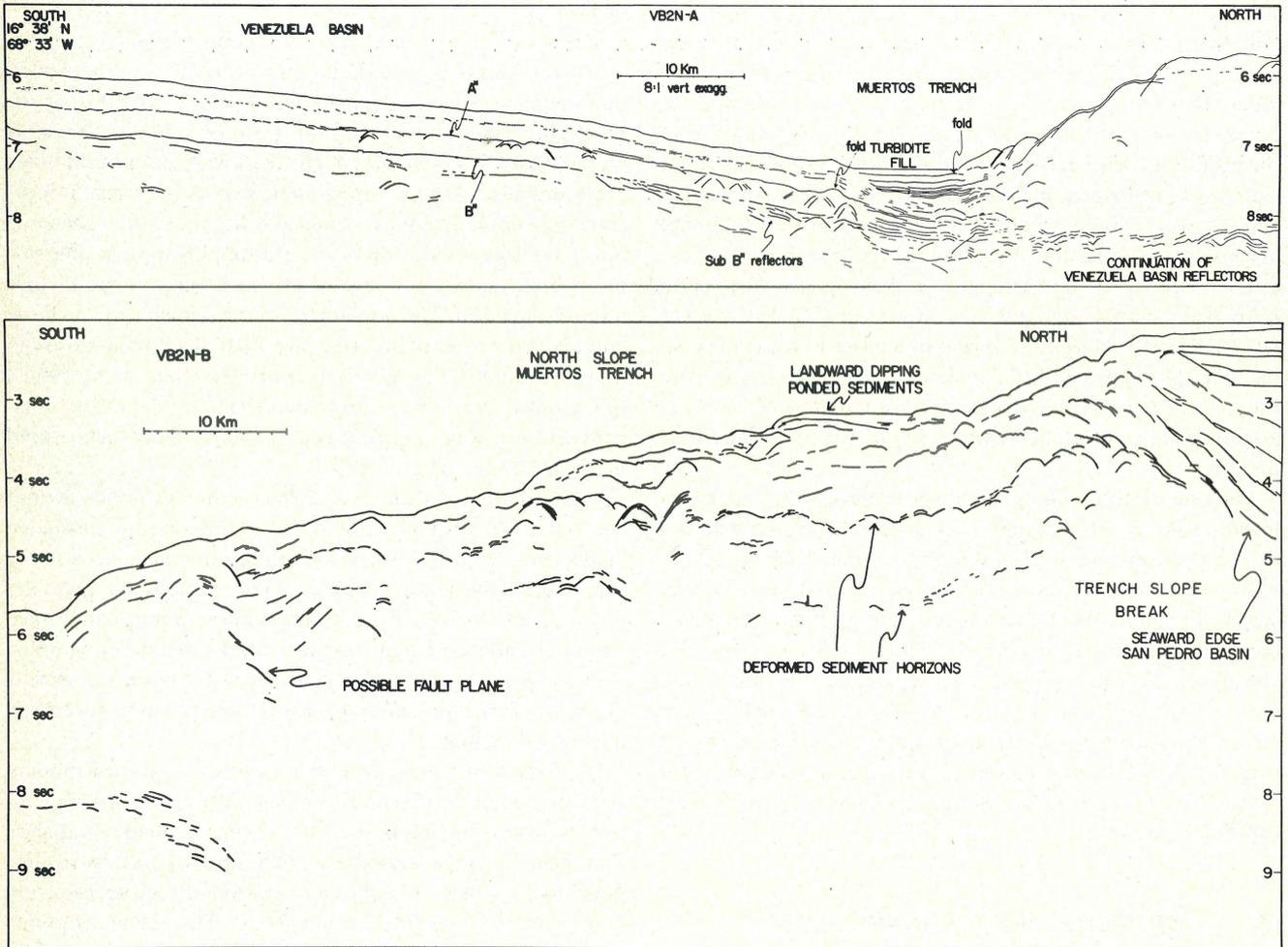
Fig. 2
Drawing of seismic section VB-2N showing the general nature of the north slope of the Muertos Trench. See Fig. 1 for location of the section.

NAFE & DRAKE (1957) and HOUTZ & LUDWIG (1977, Fig. 5). These unusually high sediment velocities may indicate processes other than normal vertical compaction, possibly horizontal compression and dewatering. The velocity of 5.1 km/sec is appropriate for the upper portion of Venezuela Basin crust (FOX & SCHREIBER, 1973; LUDWIG ET AL., 1975) as well as shallower portions of the island platform (OFFICER ET AL., 1959).

Similar results were obtained by EWING ET AL. (1960) on profile 37 on the Muertos Trench north slope west of our reflection data. At the east end of this profile in 2.56 km of water they found a 2.8 km/sec layer (3.1 km thick) overlying a 4.4 km/sec layer (3.8 km thick) overlying a 6.4 km/sec layer. The top of the 6.4 km/sec layer which lies at 7.3 sec 2-way travel time on profile 37, may correspond to reflections on line VB-2N at about 8 sec that appear to be continuations beneath the sediment wedge of Venezuela Basin reflections. The 6.4 km/sec velocity is high for shallow Venezuela Basin crust (LUDWIG ET AL., 1975). Perhaps the 4.4 km/sec material not

seen on profile 34 is a mixture of sediment and imbricate slices of shallow crustal 5.0 km/sec material.

The Muertos Trench inner slope velocity structure resembles the lower inner-slope velocity structure of several Pacific trenches. For example, at station LF 21-22 on the inner slope of the Aleutian Trench, SHOR & VON HUENE (1972) found a similar velocity structure with layers of 2.1 km/sec, 2.6 km/sec, and 4.4 km/sec overlying an apparent northward continuation of oceanic crust with velocities of 5.1 km/sec. YOSHII ET AL. (1973) found a sequence of 2.0 km/sec over 3.5 km/sec over 4.4 km/sec on the inner slope of the Nankai Trough off Japan, and LUDWIG ET AL. (1966) found 1.9 km/sec sediment lying directly on 4.8 km/sec material on the inner slope of the Japan Trench. HUSSONG ET AL. (1975) found 1.0 km of 2.0 km/sec sediment overlying 1.6 km of 4.1 km/sec material lying on 6.2 km/sec rock beneath the lower slope of the Peru-Chile Trench. In each case the ± 4 km/sec material can probably be interpreted as consolidated sediment and upper oceanic crust that has been tectonized and incorporated into the lower inner
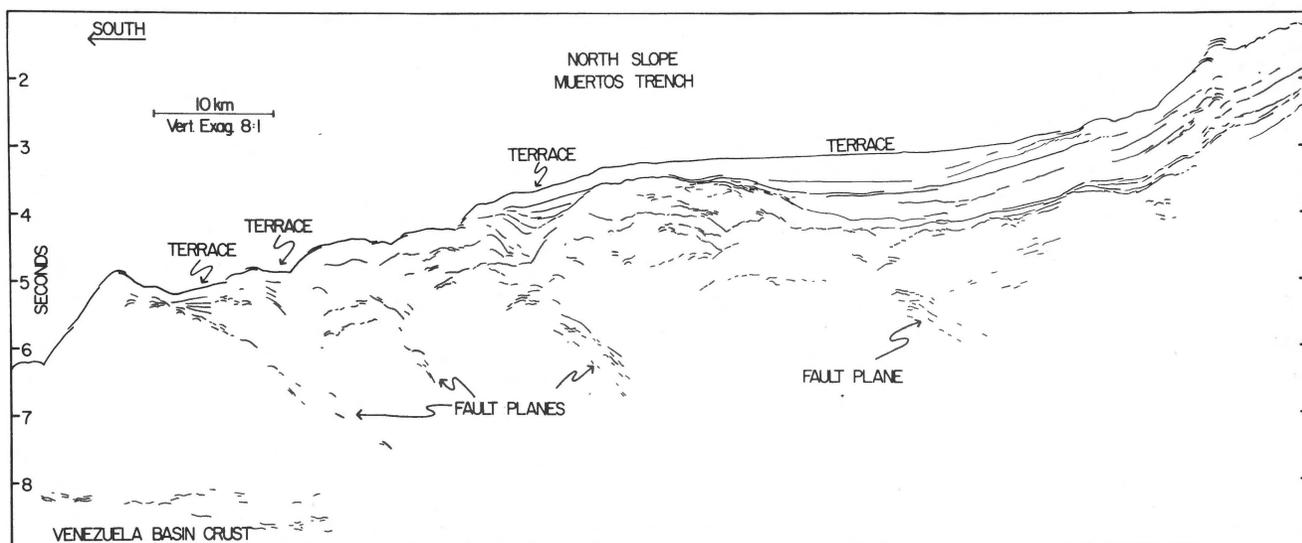
Fig. 3
Drawing of Enclosure I to emphasize the reflections seen in the seismic reflection data.

trench slope. The 2^+ km/sec sediment is probably a nontectonized sediment blanket, and the 5^+ km/sec material is probably ocean crust.

CONCLUSIONS

Observations of magnetic anomalies in the North and South Atlantic led LADD (1976) to calculate Tertiary rotations of South America with respect to North America. MINSTER ET AL. (1974) published an instantaneous rotation of South America with respect to North America which supposedly represents motion occurring at present. Both published rotations give a rate of convergence of North America with respect to South America of 0.7 cm/yr. This is a low convergence rate compared with many of the rates along Pacific margins. This convergence may be accommodated in several places, including the deformed southern margin of the Venezuela Basin, the Puerto Rico Trench, and the deformed zone of the north slope of the Muertos Trench (LADD & WATKINS, 1978).

Presumably then the convergence rate in the Muertos Trench zone is about two orders of magnitude less than the convergence rate in many Pacific trenches. Yet structures on the inner slope of the Muertos Trench are similar to structures in the Java Trench (BECK & LEHNER, 1974), the Banda and Palawan Trenches (HAMILTON, 1977), the Middle America Trench (SEELY ET AL., 1974), the Aleutian Trench (VON HUENE, 1972; MARLOW ET AL., 1973) and various other Pacific trenches (KARIG & SHARMAN, 1975).

Assuming that similarity in structure indicates similarity in mode of origin, it then seems reasonable to interpret the landward slope of the Muertos Trench in the same way as the landward slopes of Pacific trenches. SEELY ET AL. (1974) interpreted the landward slope of the Middle America Trench as the site of imbricate thrusting in which slices of ocean crust and overlying sediments become stacked within the inner slope by repeated breaking and underthrusting of ocean crust. In the Muertos Trench sediment ponds bear witness to the uplift and rotation that would accompany this process, and the landward-dipping reflection horizons beneath the sediment ponds may be reflections from interfaces between imbricate slices. Perhaps the much slower rate of convergence in the Muertos Trench as compared to Pacific trench systems is responsible for the lack of volcanism and of a well-defined Benioff zone in the late Tertiary of the Greater Antilles.

ACKNOWLEDGEMENTS

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