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DELINEATION OF SEA FLOOR ROUGHNESS IN THE NORTH PACIFIC

by

R. G. Markl and G. M. Bryan

Technical Report No. 4
CU-4-67 NAVSHIPS N-00024-67-C-1186

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INTRODUCTION

During the past several years, Lamont Observatory research vessels have been investing an increasing amount of effort in exploring the Pacific Ocean.

Increased understanding of the relation between sea floor roughness and bottom reflection loss associated with long range sonar systems has emphasized the necessity of ascertaining the degree and delineating the areal extent of sea floor roughness. Previous work done at this Observatory has been confined to the North Atlantic Ocean (Bryan, 1964; Bryan and Ewing, 1964; Markl, Ewing, and Bryan, 1967). The purpose of this study has been to produce a preliminary roughness chart of the North Pacific Ocean.

ROUGHNESS CHART

Fig. 1 shows the amount of track surveyed thus far. Continuous seismic reflection records along these tracks were used to estimate the relative degree of roughness and define its extent. Fig. 2 shows the boundaries drawn from these data.

As in previous work in the North Atlantic, areas of the sea floor are indicated by A, B, and C designations based principally on bottom roughness and texture.

Examples of A, B, and C types are shown as Fig. 3; the types have been defined as;

A Locally and regionally smooth (abyssal plains)

B Locally smooth but regionally rough

C Locally and regionally rough (usually areas where basement crops out)

AB and BC symbols normally imply intermediate degrees of roughness; however, in this preliminary chart A has been lumped together with AB. The A, B, and C designations correspond to low, medium, and high bottom loss. No quantitative loss figures are available yet for the north Pacific; however, it is expected that losses should correspond to measurements made over equivalent topography in the North Atlantic (Bryan and Markl, 1967).

It may be noted that major structural trends known to exist are frequently not reflected in the roughness pattern. This is not surprising considering the overall paucity of data and frequent large "holes" in the coverage. No attempt has been made to delineate roughness associated with individual islands and small island groups. Even with close control the chart should reflect only the trends of structures exhibiting significantly rougher topography than surrounding regions. Since many major trends are largely of a regional bathymetric nature with no marked change in roughness, they may not be reflected in Fig. 2. It should be mentioned, however, that in some areas where the control is minimal the boundary lines have been influenced by the known bathymetric and structural trends. In general, the validity of the boundary lines shown in Fig. 2 is best judged by a comparison with the control shown in Fig. 1.

The relief of the Pacific basin has been drastically influenced by vulcanism. It has a very thin sediment cover by comparison with other ocean basins. It is known that a very large proportion of the basin is characterized by abyssal hills - usually covered by a thin layer of unconsolidated sediment. Though the origin of these hills is still in doubt, it is related to the formation of the seismic second layer and the widespread vulcanism which prevailed (Menard, 1964). Whatever their origin, these hills are important because they are quite extensive and quite rough (typically BC).

SEDIMENT THICKNESS

The degree of roughness of the sea floor is dependent to a large extent on variations in the thickness of the sediment cover. Thus if we assume an ocean basin in which the basement surface is uniformly rough, the regions with thick sediment cover could be expected to be smoother at present than those with thin cover.

J. Ewing, et al (in press) have distinguished two major sedimentary sequences in the North Pacific on the basis of acoustic character - one is opaque, the other transparent to vertically incident sound at about 150 cycles. Their isopach map, in which the transparent layer thickness is indicated by 100 meter contours, is presented as Fig. 4 of this report. It shows that the opaque layer is recognized only in the western half of the North Pacific basin, attaining a maximum thickness in the western equatorial region. The transparent sediments which lie above this layer and extend up to the water-sediment interface also reach a maximum thickness (about 1000 meters) in this region and are quite thick all along the equator as well as in the Gulf of Alaska and along the continental margin between the Kamchatka Peninsula and Japan. On the other hand throughout the entire central portion of the Pacific basin there is less than 100 meters of this transparent material.

According to this pattern of sediment distribution one could expect the western half of the basin proper to be smoother than the eastern - this is indeed the case. The equatorial zone also should be quite smooth. Although it shows no significant AB areas a shift from BC to B can be ascribed to the smoothing effect of the thick sediments present in this region. The Gulf of Alaska is also quite smooth as might be expected from the great thickness encountered there.

Of course, this is a somewhat oversimplified approach. We are not considering the tectonic history of the basin. The basement is never uniformly rough and is frequently even difficult to define. In addition, we are not considering the type of sedimentation which has occurred or such things as the local effect of bottom currents. Nonetheless, it is still true that the principal effect of sedimentation is to smooth a rough surface on which accumulation takes place.

Since variation in sediment thickness alone cannot account for many observed variations in sea floor roughness, a closer look at portions of the Pacific Basin and local factors affecting roughness and sediment distribution is necessary - we shall begin with the Gulf of Alaska and proceed in a clockwise manner.

The large areas of AB in the Gulf of Alaska are a consequence of the presence of relatively thick sediment cover, principally turbidite deposition. These areas should offer high reflectivity. The C areas here are caused by the Alaskan seamount group. To the south the sediment cover thins markedly, the sea floor is in abyssal hills and is riven by a series of east-west fractures including the Mendocino and the Murray zones; these are evidenced by C and in part hidden by the overall BC topography. The East Pacific Rise, the crest of which is almost devoid of sediment (probably because of sea floor spreading), is indicated by C and BC zones in the lower right corner of Fig. 2. In the eastern equatorial region the predominant roughness type is B, surrounded by BC; this is an area in which high biological productivity has caused a great thickness of calcareous and siliceous sediments to accumulate, smoothing the regional topography considerably. Farther west along the equator it is more difficult to generalize - the effects of the many island groups and the effect of the ancient Darwin Rise on the topography and sediment distribution is quite complex. As previously stated, the greatest thickness of both transparent and opaque sediments occurs in the western equatorial region. To the north, relatively large expanses of AB and B topography are separated by features such as the Marcus-Necker Ridge and Hawaiian Ridge, shown as C and BC respectively - farther north, the Emperor Seamount chain stands out within the predominantly B-type topography. The AB zones (which include genuine A-type) are ordinarily the result of turbidite deposition originating near the continental margins. Ewing, et al, have suggested that the Darwin Rise was the source of much of the pre-Cenozoic sediment in the western half of the Pacific Basin.

SEDIMENT TYPES

In the preceding section the sediment cover was considered primarily from the standpoint of its smoothing effect on the sea floor; only the total thickness of sediment, regardless of type, was considered. Although the immediate purpose of the present work is to describe bottom relief in the North Pacific the ultimate goal is to predict bottom loss on the basis of all pertinent geophysical parameters: topographic relief of bottom and sub-bottom interfaces and the material properties of the sediment layers. It is therefore quite relevant to mention a few important acoustic aspects of the sediments found in the North Pacific.

As indicated in the previous section, Ewing, et al, have identified two major sediment layers on the basis of their acoustic character as seen on seismic profiler records. These were designated "opaque" and "transparent". The transparent layer lies upon the opaque layer and extends upward to the sea floor itself. Although the profiler cannot resolve the sub-bottom structure of the upper 100 meters of sediment in great detail, the 3.5 kHz echo sounder, with which Lamont ships are equipped, provides a very detailed display of structure down to a maximum of about 150 meters. Fig. 5 shows that the transparent sediments are also transparent to 3.5 kHz and, in addition, demonstrates the advantage of the 3.5 over the 12 kHz echo sounder. The 12 kHz usually sees only the water-sediment interface; in Fig. 5a.it is quite smooth and flat, suggesting an area of high reflectivity. The 3.5 kHz echo sounder not only shows the bottom, but displays the transparent layer and, in addition, discloses the presence of microtopography in the interface underlying the transparent layer - this rough surface can be expected to increase bottom loss significantly.

The role of the transparent layer in determining bottom reflectivity is therefore crucial. Preliminary analysis of sonobuoy data suggests that the transparent layer has a relatively low sound velocity and gives a poor impedance contrast at the water-sediment interface.

Ewing, et al, point out that the transparent layer isopachs shown in Fig. 4 include two areas, the northeastern and northwestern corners, where especially thick patches of transparent sediment are interbedded with many strong reflectors resembling turbidites. This seismic evidence, involving hundreds of meters of sediment, is nicely paralleled by detailed analysis of the upper few meters of sediment as sampled by the piston corer. Horn, Horn, and Delach (1967) have defined provinces off Alaska and Japan where cores are rich in turbidites and ash layers respectively and where high reflectivity is therefore expected. A third zone in the central North Pacific yielded cores of homogeneous, low velocity sediment. The boundaries of the Alaska and Japan provinces follow the general shape of the isopachs of Fig. 4 within the limits of the available control. Thus there is considerable evidence that in these two strategically important provinces the detailed physical properties determined from core analysis can be tied in with the detailed topographic relief of the bottom and sub-bottom interfaces seen on 12 kHz and 3.5 kHz records and possibly even to the deeper sedimentary structure seen by the seismic profiler.

CONCLUSION

The preliminary chart of roughness in the North Pacific should be suitable for making rough estimates of expected bottom loss. Two major limitations should be kept in mind: first, the control at present is quite marginal, and the boundary lines are therefore very uncertain. Second, the existence of large areas of low-velocity easily-penetrated sediment suggests that sediment properties will play an unusually important role in bottom loss in the Pacific. Thus while sea-floor relief can indicate areas which are too rough for good reflection regardless of sediment type, there is no assurance that smooth topography will give good reflection. Major improvements in bottom loss prediction will be possible when enough 3.5 kHz records are available, particularly in areas in which the structure of the upper few meters can be correlated with core samples.

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Fig. 1 Track chart of Lamont Geological Observatory surveys in the North Pacific.

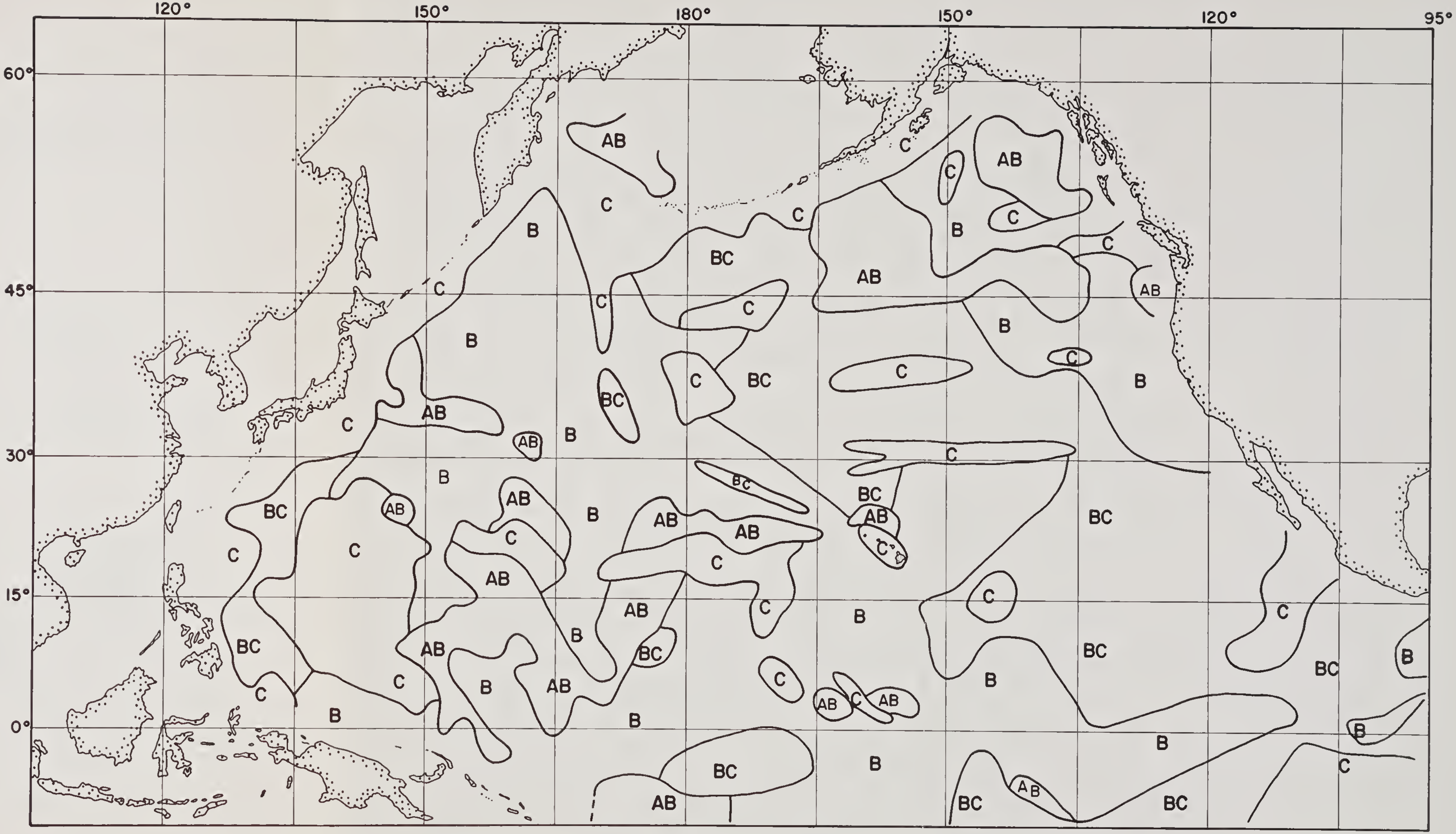

Fig. 2 Overall distribution of bottom roughness in the North Pacific. AB = relatively smooth; B = intermediate; C = rough; BC = a category between B and C which includes abyssal hill topography.

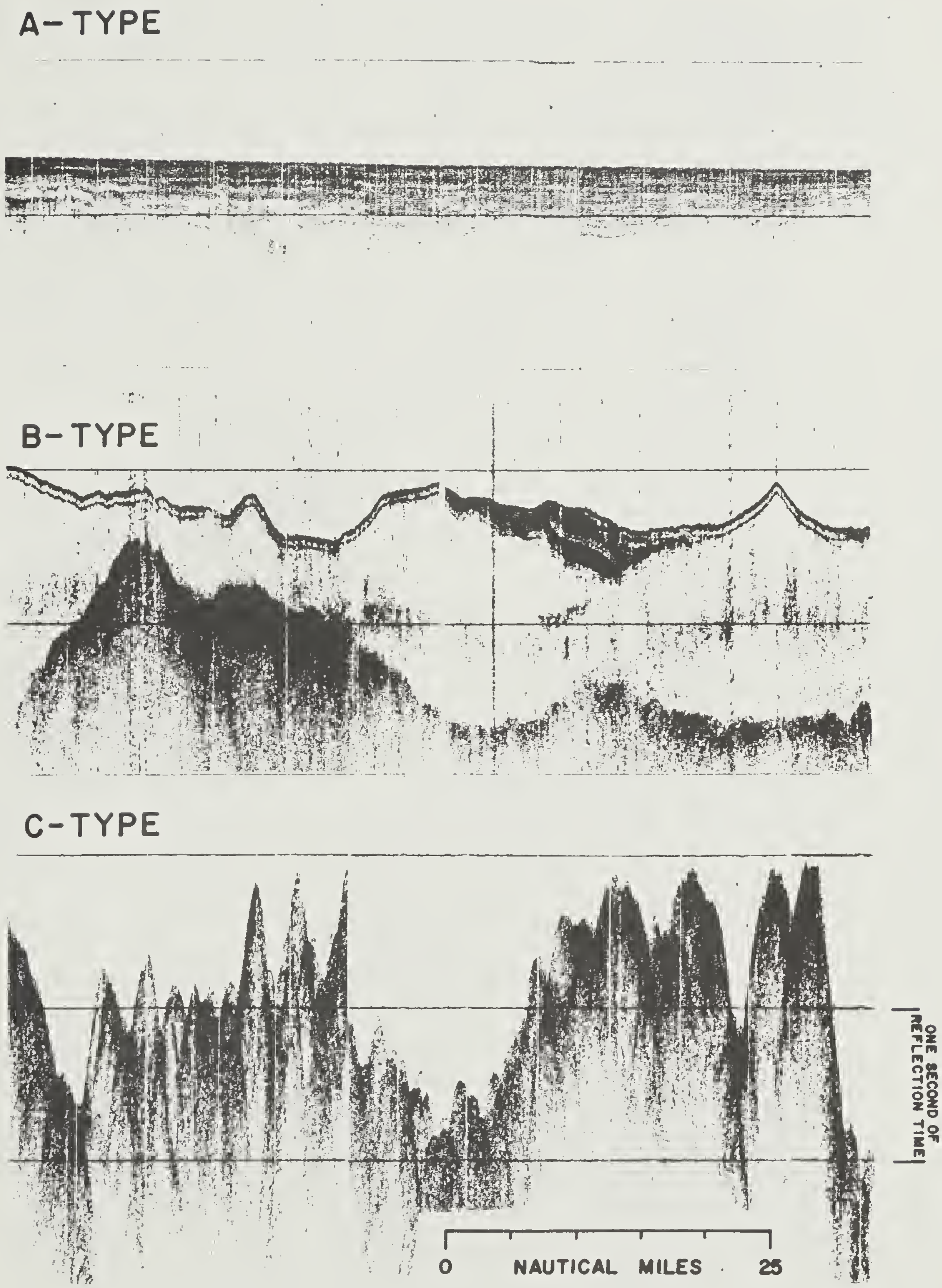

Fig. 3 Seismic Reflection profiles illustrating typical A, B, and C-type topography. vertical exaggeration = 25:1

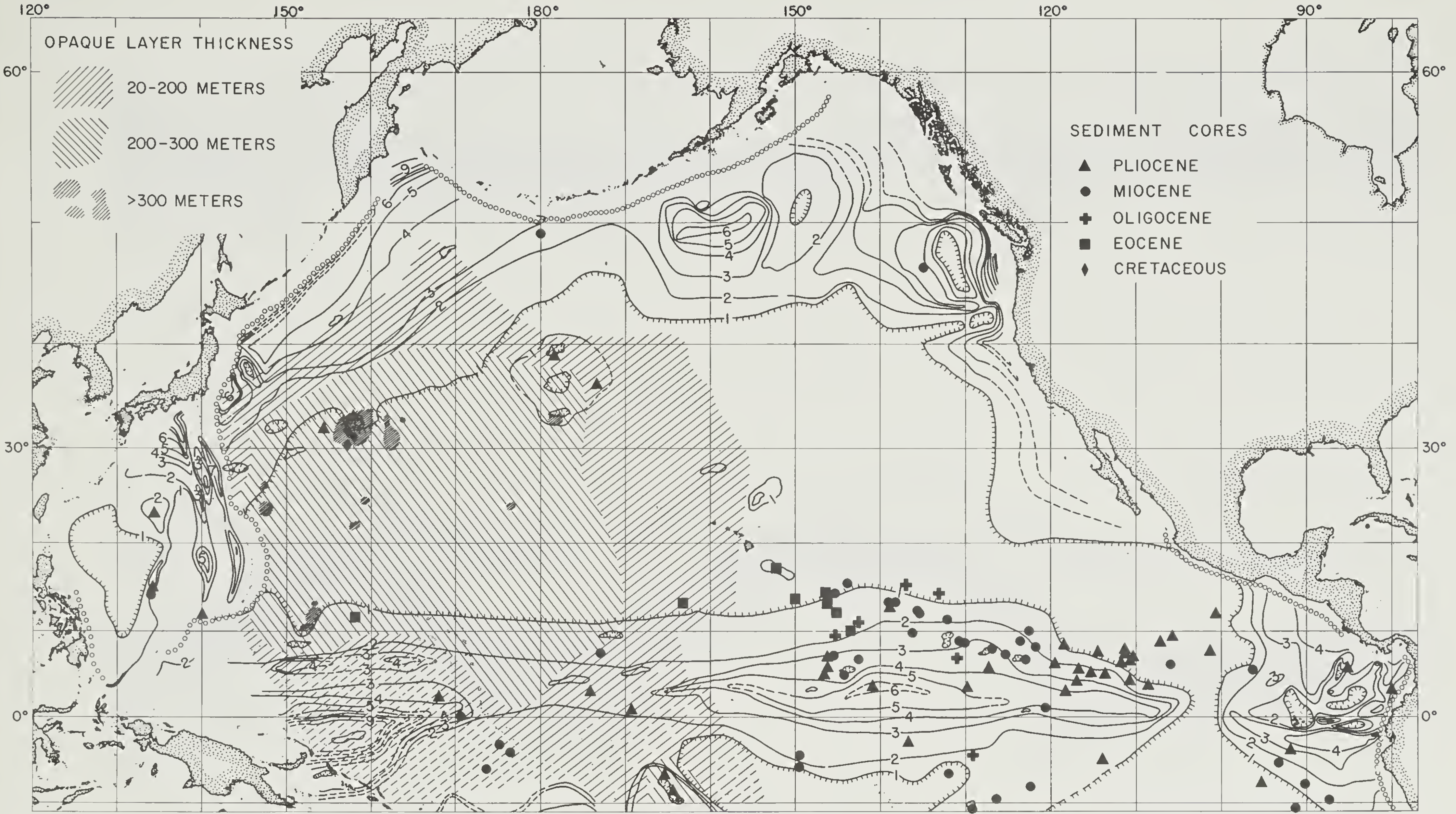

Fig. 4 Isopach map of the "opaque" and "transparent" layers in the North Pacific (Ewing, J.I., et al, in press). Interval of transparent layer isopach lines is 100 meters.

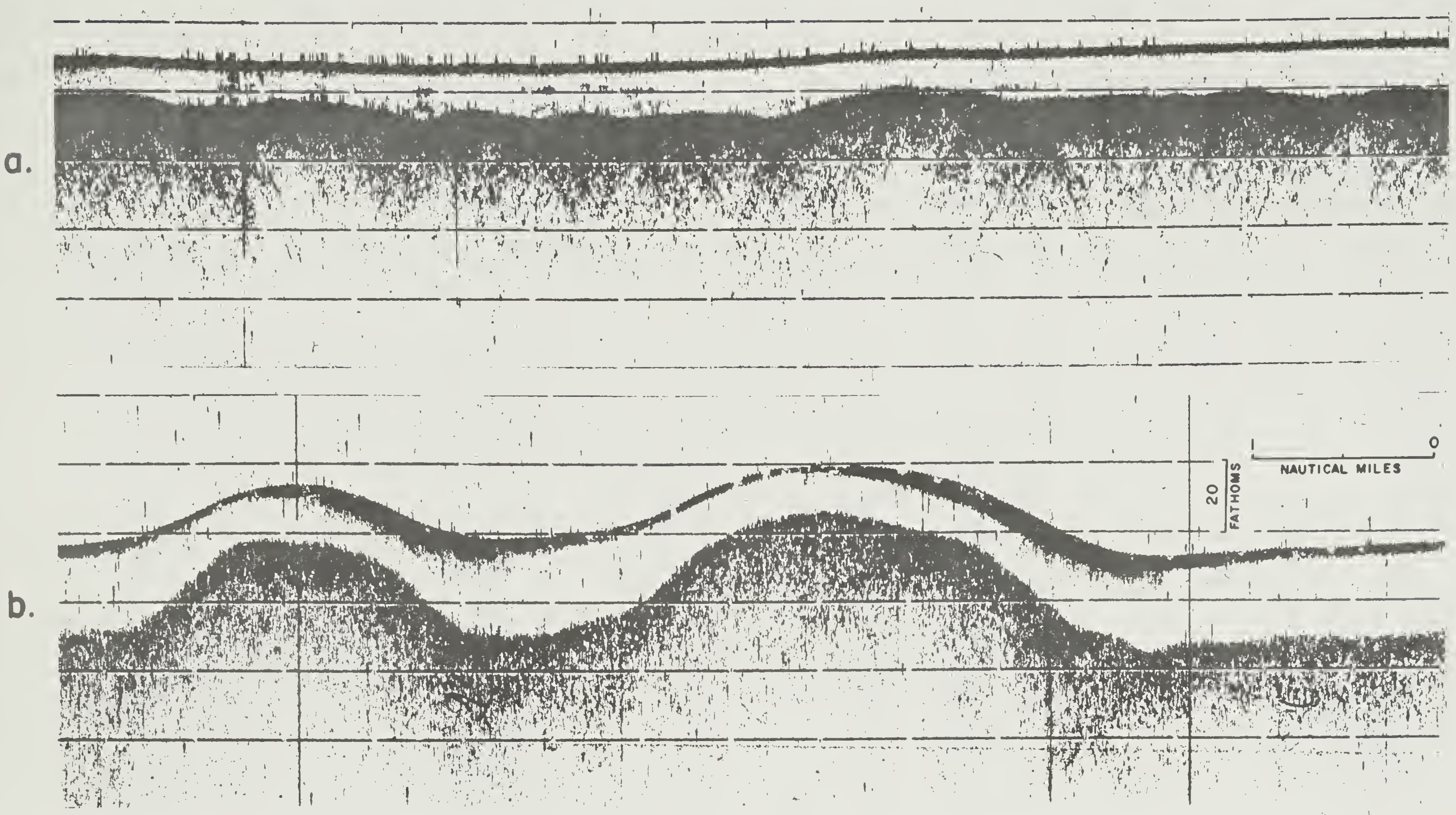

Fig. 5 Examples of 3.5 kHz echo sounder records from the North Pacific. Note the bottom echo and the transparent sediment blanketing a deeper reflector. The hyperbolae in (a.) indicate the presence of small-scale roughness at the interface.

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The roughness of the North Pacific sea floor has been assessed and subdivided, largely on the basis of seismic profiler data. A preliminary chart delineating the areal extent of the three major subdivisions has been made. The effect of sediment thickness on roughness is discussed.

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