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Classifications of Submarine Physiography in the Gulf of Alaska[1]

Soundings in the Gulf of Alaska have been made systematically since the middle 1920's. On the basis of these soundings certain areas of similar topographic relief have been defined as physiographic provinces and placed into a physiographic classification. As the data have increased and as new sounding techniques have been developed, the province boundaries have been altered and even the classification system has been changed. Although these modifications in approach to research on submarine physiography are apparent in studies of each ocean, an excellent illustration is provided by the Gulf of Alaska because of its small size and diversified physiography.

Nonprecision Echo Sounding

Murray (1941) presented a summary of the topographic data available for the Gulf of Alaska through 1939, although he did not recognize physiographic provinces. The sounding lines were located by astronomic fixes and dead reckoning, and the soundings were recorded on the average at intervals of 1 nautical mile (Murray, 1941). The topographic chart of the data showed a continental shelf and slope and the Aleutian Trench. The floor of the Gulf of Alaska, however, was depicted as a rather smooth region with several large seamounts. The major part of the floor, having relief too small to be measured by the existing equipment, was not considered so important as the more obvious and easily measured seamounts. Consequently, topographic description emphasized the seamounts of several hundred fathoms relief.

Eardley (1951) used the data reported by Murray (1941) as the basis for identifying a Region of Great Seamounts in the Northeast Pacific, as outlined in Figure 1. By transferring the boundaries of Eardley's region to the most recent general topographic base chart of the Gulf of Alaska (Hurley, 1960), the inclusion in the region of most of the seamounts and ridges known today is revealed. No attempt was made by Eardley to determine the physiographic significance of the region, because topographic data were scant and other types of data were practically nonexistent.

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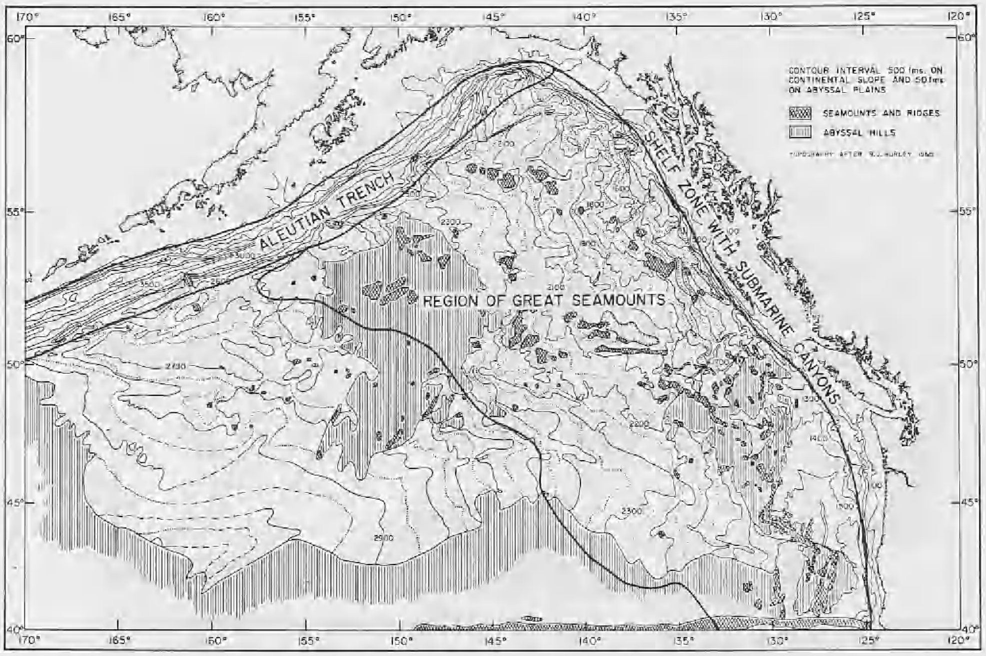

Figure 1. Physiographic regions in the Gulf of Alaska according to Eardley (1951). Most of the seamounts discovered since 1951 are in the Region of Great Seamounts.

The first association of types of bottom relief into physiographic provinces was made by Menard and Dietz (1951) in their description of a Gulf of Alaska Seamount Province and a Ridge and Trough Province (Figure 2). This work was based on some of the earliest continuously recorded echo-sounding profiles in the region. The previous, discrete-soundings data were thereby supplemented by continuous data in the form of graphic profiles. The small size of the recording paper and the nature of the echo-sounding system prevented resolution of features having relief of tens of fathoms, so that emphasis remained on the positive relief features of hundreds of fathoms relief—the seamounts and ridges.

The basic characteristic upon which the provinces were identified was the shape of the most common positive relief feature in each province. In the Gulf of Alaska Seamount Province these features were large, isolated, conical seamounts having summits a few hundred fathoms beneath the water surface. In the Ridge and Trough Province, on the other hand, the most common positive relief features were clusters of quasi-parallel ridges supporting a few peaks that extended almost to the sea surface. A more generic distinction was made by assigning a volcanic origin to the features in the seamount province and a fold or fault mountain origin to those in the Ridge and Trough Province. The latter province was considered a submarine continuation of the Pliocene-Pleistocene orogenic zone in California and southern Alaska.

A later and more complete description by Menard (1955a) of the characteristics of these two provinces based the distinction between them on the greater age of the

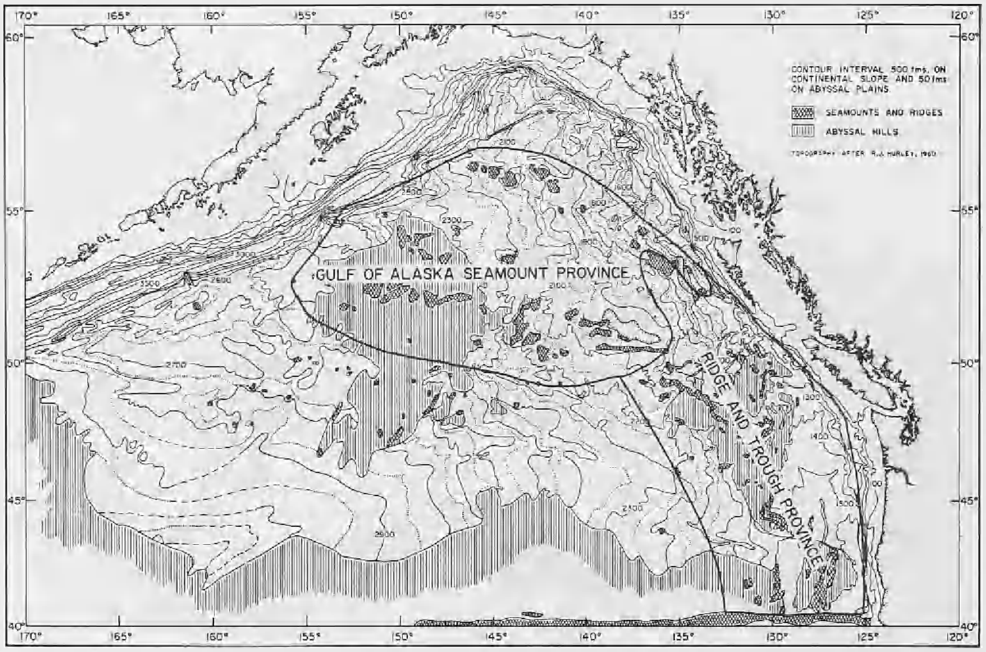

Figure 2. Physiographic provinces identified by Menard and Dietz (1951) and Menard (1955a). The provinces are separated on the criteria of type, age, and origin of the large positive relief features.

topography in the Gulf of Alaska Seamount Province, where a thick apron of sediment extends out from the base of the continental slope, truncated seamounts have sunk, and recent seismic and volcanic activity is unrecorded. In contrast to this, the Ridge and Trough Province was considered a more youthful topography, as evinced by seismic and volcanic activity, the proposed block-fault origin of the ridges, and the numerous seamounts rising to within only a few fathoms of the sea surface. A thick apron of sediment, extending outward from the base of the continental slope off the northwestern United States, however, indicates the elapse of sufficient time for the formation of a thick sequence of terrigenous sediment. This smooth apron-like part of the Ridge and Trough Province was delimited by Menard (1955b) as a separate area, the Great Trough. The development of the Great Trough was thought to have been caused by the damming effect of the rough topography in the Ridge and Trough Province to the west, which prevented the terrigenous material from continuing as turbidity currents into the deeper part of the North Pacific.

Gibson (1960) also recognized the Ridge and Trough Province and the Great Trough, but he subdivided the Gulf of Alaska Seamount Province into the component ranges of submarine mountains (Figure 3). The topographic data used by Gibson (1960) represent soundings taken by U.S. Coast and Geodetic Survey ships during the period 1925-1957. His more recent data were continuous echo-sounding records, and the horizontal positioning of the ship by this time was based on the more accurate system of LORAN. Still, the emphasis was on the large positive relief features.

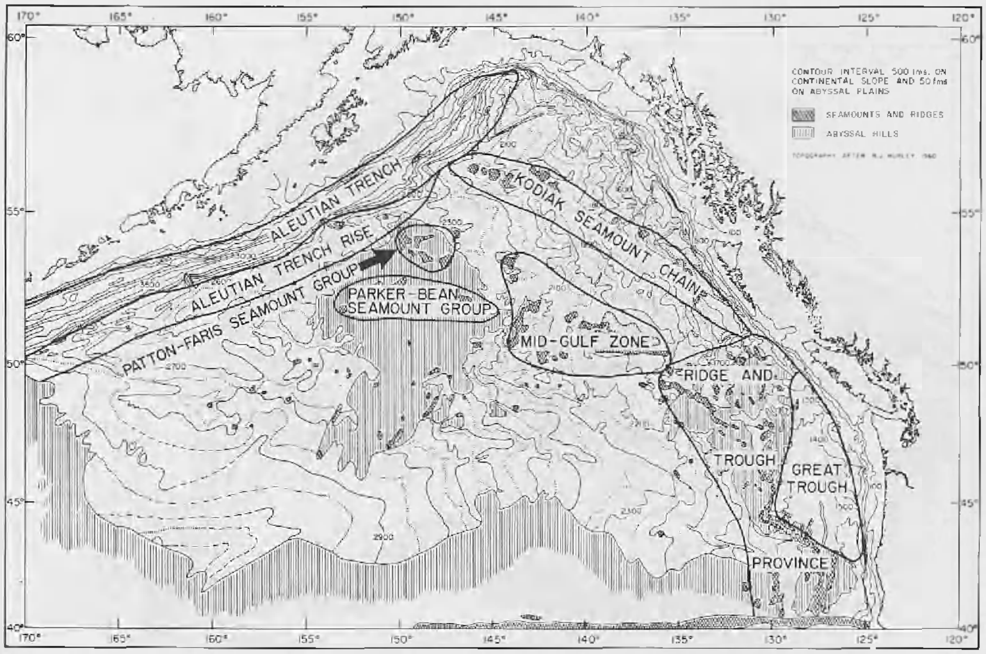

Figure 3. Physiographic divisions proposed by Gibson (1960). Emphasis is placed on the large, positive relief features, which are grouped into northwest-trending fracture zones.

The significance of the provinces identified by Gibson was thought to be their expression as, or relation to, fracture zones in the sea floor. The large east-west fracture zones in the eastern Pacific, such as the Mendocino Fracture Zone, had been described by Menard (1955a). Gibson considered northwest-southeast fracture zones in the Northeast Pacific to be represented by the submarine mountain systems which he assumed were formed of volcanic material from fissures or isolated vents. The north-northeasterly trending features within the Ridge and Trough Province and Mid-Gulf Zone were considered to be significantly different from the northwesterly trending features forming the three seamount areas and to represent a different stress pattern in the earth's crust. Gibson also discussed the Aleutian Trench as a geosyncline and the outer ridge, which he referred to as the Aleutian Trench Rise, as an anticline. No emphasis, however, was placed on the areas of smooth floor or minor relief.

Precision Echo Sounding

In the early 1950's the inadequacy and errors of the standard, small-size, continuous-recording echo sounder were overcome by the development of an expanded-scale, precision recorder (Luskin *et al.,* 1954). The precision recorders permitted far greater resolution of the bottom topography. As a result, large areas of ocean bottom covered with abyssal hills of a few tens of fathoms relief were surveyed. Also recorded on this high-resolution instrument, however, were smooth, flat floors, which were delimited as areas called abyssal plains and explained as representing accumulations of turbidity current deposits (Heezen *et al.,* 1954).

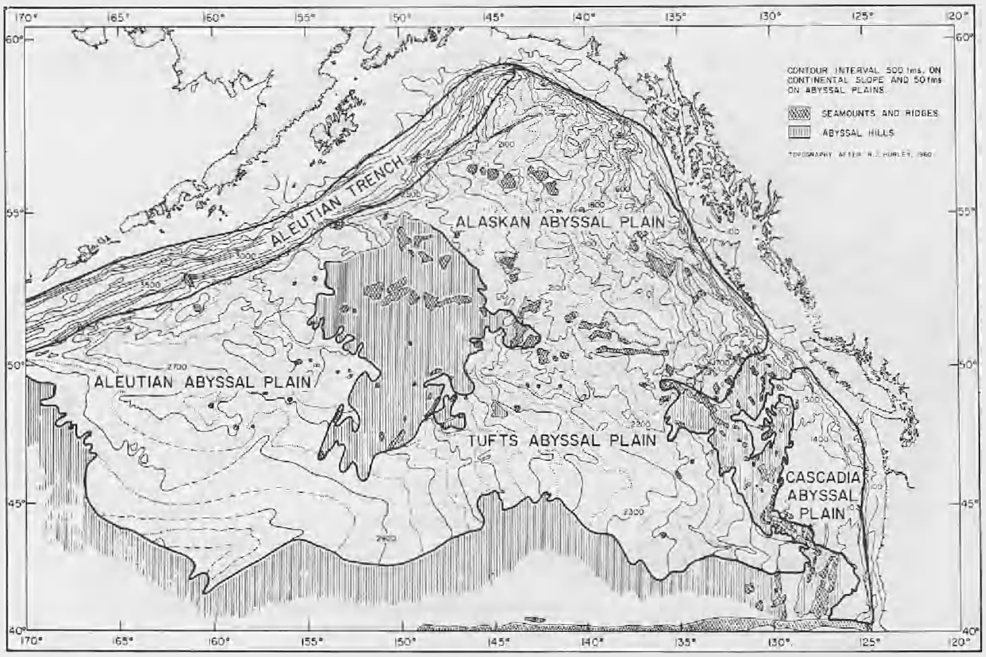

Figure 4. Physiographic provinces identified by Hurley (1960) on the basis of the extent of low-relief plains and hills. Improved instrumentation permitted emphasis on the plains of presumed turbidity current origin.

The new instruments and the emphasis on features of low relief were applied to the Gulf of Alaska by Hurley (1960). The stressing of the importance of abyssal plains in a classification of submarine physiographic provinces and the stressing of the significance of turbidity currents to the development of abyssal plains relegated the seamounts to secondary status as a basis for delimiting provinces. Consequently, the outlines of the provinces identified by Hurley (1960) are very different from those drawn by previous workers (Figure 4). The abyssal hills are considered to represent the original topography not covered by turbidity current deposits creating the abyssal plains.

Although Hurley described features such as the continental rise (the intermediate gradient between the steep continental slope and the gentle abyssal plain) and the outer ridge of the Aleutian Trench (the Aleutian Trench Rise of Gibson, 1960), he did not distinguish them as physiographic types differing from the abyssal plains. Also, although the Ridge and Trough Province was recognized by Hurley (1960), he assigned to it no more major a role in the classification than that of any other area of abyssal hills.

Since the time of Hurley's work, the main changes in the classification have dealt with delimiting the continental rise as the wedge of sediment at the foot of the continental slope and with the recognition of the Ridge and Trough Province as part of the worldwide oceanic rise system. The physiographic provinces delimited by the writer are outlined in Figure 5.

The delimitation of the continental rise has reduced the size of Alaskan Abyssal Plain and eliminated Cascadia Abyssal Plain. The area formerly considered as Cascadia

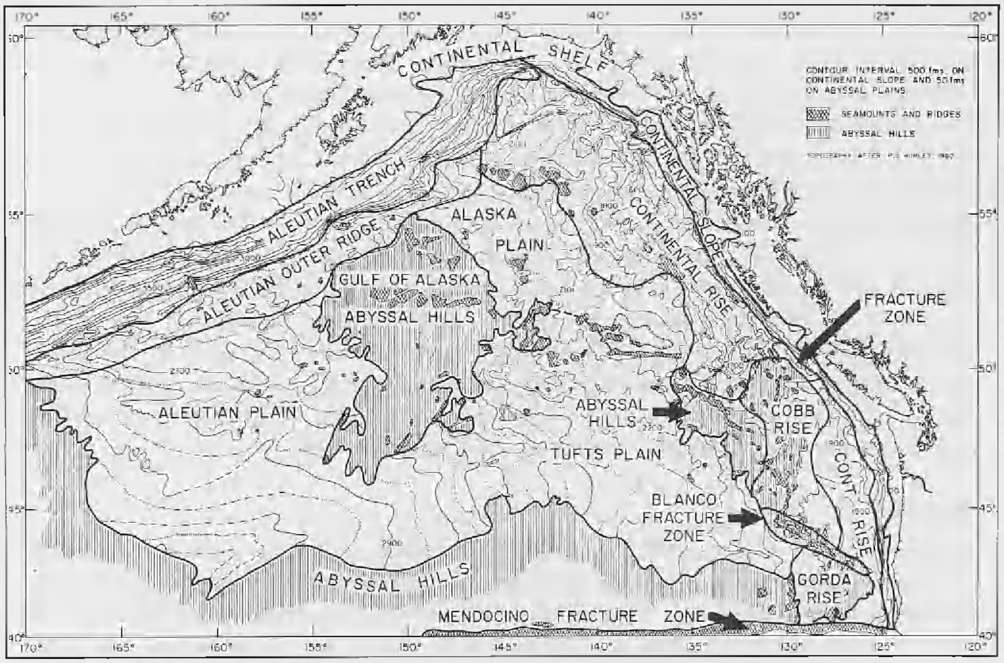

Figure 5. Physiographic provinces in the Gulf of Alaska as delimited in this paper. The continental rise and abyssal plains are mainly depositional provinces. The oceanic rises, fracture zones, and trench—outer ridge provinces are mainly of diastrophic origin. Volcanic ridges and seamounts are abundant among the abyssal hills.

Abyssal Plain actually represents in its eastern part the coalesced deep-sea fans forming the continental rise, as noted by McManus (1964), and in its western part it represents the flank of Cobb Rise, part of the oceanic rise system.

The Ridge and Trough Province, included by Menard (1960) as part of the oceanic rise system and labeled as part of the East Pacific Rise, has topography similar to that on the Mid-Atlantic Ridge, including a median valley, as shown by subsequent studies of the area (McManus, 1965; Talwani *et al.,* 1965). The rise is separated into two rises by the Blanco Fracture Zone (McManus, 1965), an area of large northwest-trending ridges and deep troughs. Another northwest-trending fracture zone separates Cobb Rise from the continent.

The present classification of physiography in the Gulf of Alaska consists of three groups of provinces: (1) the enigmatic abyssal hills provinces, (2) the provinces delimiting areas of dominant terrigenous sedimentation, and (3) the provinces delimiting areas of dominant diastrophism. The areas of dominant terrigenous sedimentation include the continental rise, and Alaska, Tufts, and Aleutian Plains. This designation, however, does not imply that present sedimentation in these areas is primarily terrigenous, since the surface sediment is principally pelagic as shown by Nayudu and Enbysk (1964). The importance of the terrigenous material is revealed in the cores from the areas, and it is to the terrigenous sedimentation that the smooth bottom is attributed.

The provinces in which the physiography is apparently dominated by diastrophism are Gorda Rise, Cobb Rise, Mendocino Fracture Zone, Blanco Fracture Zone, the unnamed fracture zone near Vancouver Island, Aleutian Trench, and the Outer Ridge. The significance of diastrophism in the development of the ridges, troughs, and hills of the oceanic rises and fracture zones is apparent, for the topography is formed on volcanic or sedimentary rocks having only a veneer of pelagic sediment. Thicker sections of pelagic sediment occur only in the intermontane basins. Terrigenous sediment forms the topography locally in small depressions where sediment has entered through a gap in the hills and ridges and has been ponded. Smoothing by terrigenous sediment also has produced a fill deposit in the bottom of the Aleutian Trench, and later studies may well identify a trench plain as a separate province. This combination of diastrophic and sedimentation controls has also played a major role in the development of the Outer Ridge, a feature considered to have a diastrophic origin, but which displays a smooth, undulating topography similar to that of the continental rise.

Summary

Early studies of physiography in the Gulf of Alaska used echo sounders that were adequate to identify only the large positive and negative relief features such as ridges, seamounts, and trenches. As a result of the limitations of instrumentation, emphasis was placed on the seamounts, ridges, and the trench as determining the physiographic classification. The classification, therefore, was based solely on features of volcanic or diastrophic origin. With the later development of precision echo-sounding recorders and more precise horizontal positioning came an emphasis on the low relief features such as abyssal hills and abyssal plains. Recognition of abyssal plains also produced emphasis on turbidity current deposition of terrigenous sediment as a factor in developing the submarine surface.

In the parts of the Gulf of Alaska where the sea floor is relatively smooth, the physiography is dependent mainly upon the processes depositing terrigenous sediment; the resulting provinces are the continental rise and abyssal plains. Where the sea floor is formed of rough topography, however, the physiography reflects either the surface of the poorly known abyssal hills or the diastrophic and volcanic effects of the development of oceanic rises, fracture zones, and the trench—outer ridge system. The present physiographic classification of features in the Gulf of Alaska places equal significance on surfaces developed by sedimentation, volcanism, and diastrophism, rather than solely on sedimentation or on volcanism and diastrophism.

Acknowledgments

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