Structure, litho-orogenic units, and postorogenic basin fill by reflection profiling

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5. Although the eustatic sea-level changes of Pleistocene times have produced spectacular worldwide changes in the regimen of the continental margins, these same changes may be brought about locally and regionally through tectonism.

SUMMARY

Introduction

The purpose of this investigation has been to utilize a group of modern continental margin submarine basins with known physiography, and oceanographic characteristics and with known sediment source areas, as a natural sedimentological laboratory. Measurement of sedimentary fill of these basins and its internal structure by continuous reflection profiling, for comparison to source, distance from shore, and other variables in an analysis of marine processes has been the primary objective. The region selected for these studies is the California Continental Borderland which lies between the shoreline and the continental slope off southern California, U.S.A., and the northern part of Baja California, Mexico (Fig. 1). This complex physiographic area about equivalent in size to the Adriatic Sea contains 18 major basins, 20 to 80 nautical miles in length and 5 to 22 in breadth, with depths to more than 1600 fathoms and distances to sources of sediment supply varying from zero to more than 110 nautical miles (Fig. 3).

Data for the study have been collected during the period March 1963 to January 1966 utilizing high-powered, low-frequency continuous-reflection profiling equipment which produces graphic recordings of subbottom structure to depths of more than a kilometer beneath the sea floor.

Basis of Profile Interpretation and Format of Presentation

Structural data from interpretation of the profiles are dependent on acoustic discontinuities across geological surfaces.

The collected data have been interpreted on the basis of structure, topography and localities of known lithology into units of volcanic or basement rock, preorogenic sedimentary rock and postorogenic sediments. The term "preorogenic sedimentary rocks" implies that they were deposited prior to the time of last orogenic activity which formed the major topography of the present basins. A combination of photographs (Figs. 6-10), simplified line tracings (Fig. 11), and detailed line tracings (Fig. 16) of the records is used to show both large scale features and details of structural types.

Regional Geologic Setting

The California Continental Borderland is near the center of a region of topographic and geologic diversity. It is bounded on the north by the Transverse Range Province, on the east by the Peninsular Ranges Province which forms the backbone of Baja California, and on the west and southwest by the submarine Baja California Seamount Province (Fig. 12). The most profound event in the geologic history of the region was the post-Triassic, pre-Late Cretaceous diastrophism, plutonic intrusion, and metamorphism which produced the basement complex of much of the area.

Rocks of the Baja California Seamount Province are largely basalts of submarine volcanic origin. The rocks of the rest of the region can be assigned to two major divisions: basement and pre-batholithic rocks and, separated by a profound unconformity, the post-batholothic marine and nonmarine strata of Late Cretaceous, Tertiary, and Quaternary age and volcanic rocks of Tertiary and Quaternary age. Rocks of Miocene age form the most common sedimentary strata of the Borderland and adjacent areas of the northern margin, whereas Cretaceous marine and nonmarine sediments are most common in the southern terrestrial margin.

Structure and Litho-Orogenic Units of the Continental Borderland

A structural map of the Borderland is compiled on the basis of interpreted reflection profiling traverses. Locations and apparent displacements of features interpreted as faults and axes of anticlines and synclines were used in constructing the map. Connections of the points is on the basis of topography and regional structural patterns. Analysis of the reflection profile sections (Fig. 11) and the structural map (Fig. 13), leads to the conclusion that the Continental Borderland may be divided into five integrated structural zones: (1) the part north of and including the channel islands Transverse Range structure, (2) the southern Borderland area of predominant northwest trending faults terminated on the north by the major left lateral displacement of the Santo Tomás Fault and, in the central Borderland between these first two, (3) the outer fault zone primarily associated with the continental slope fault (the Patton Escarpment), (4) the inner fault zone; an extension of northern Peninsular Range structure bounded on the west by the San Clemente-Agua Blanca and associated faults, and (5) the oval shaped central region of probable en echelon oriented major folds. This latter region is of greatest significance in setting the Borderland apart as a distinct province unlike those it adjoins. Although the Continental Borderland has commonly been referred to in the past as similar to the Basin and Range Province covering much of southwestern United States, it is in many respects more like the southern Coast Ranges.

A regional primary fault system affecting the Continental Borderland, as well as adjacent provinces, comprises deep seated, right lateral faults trending northwest-southeast exemplified by the San Andreas fault, and east-northeast trending faults of left lateral displacement. Components of the latter primary fault system are represented in the Borderland by the right lateral San Clemente-Agua Blanca fault, possibly by the continental slope fault forming the Patton Escarpment and by the left lateral faults of the Transverse Range system in the north and the very active Santo Tomás fault to the south.

A map of litho-orogenic units (Fig. 14) is based on the classification of reflection records as showing lithology in terms of stratified and non-stratified rocks and on the association of these rocks with orogenic features. Stratified rocks are, in turn, subdivided into preorogenic sedimentary rocks and postorogenic sediments. The map of litho-orogenic units amplifies the data of the structural map in showing a large central region of preorogenic sedimentary rock (largely Miocene in age) flanked on either side by topographic and structural highs of volcanic and basement rocks. The extensive areal continuity and relative simplicity of internal structure within the rocks of the central folded area together with paleogeographic considerations suggest that their origin was by deposition on an open continental terrace or in a simple broad basin rather than in isolated block faulted basins.

Postorogenic Sediments

The principal aim of this investigation has been to differentiate between sequences of folded and faulted preorogenic rocks which form the present topographic basins and the postorogenic fill of the basins. The thickness of sediments accepted as postorogenic are plotted areally (Fig. 15) to define volumetric distribution and its relationships to potential controlling factors such as coastal sediment sources, currents and bathymetry. Internal structure of postorogenic sediments is used as a basis for their division into turbidity-current and hemipelagic deposits, assuming that hemipelagic, particle-by-particle deposition will result in sedimentary fill largely conformable to underlying topography; whereas sequences of turbidity-current origin will terminate abruptly against topographic barriers.

The time and rate of deposition of the basin fill is estimated on the basis of calculated uncompacted thickness of the deposits and total weight of terrigenous detritus as compared to independent estimates of these factors. If it is assumed that one million years can be allowed for total deposition, the resulting rates of 4 to 160 cm/1000 years are compatible to those based on radiocarbon dates, and the total weight of sediment is comparable to the independently estimated total weight which should be introduced to the area from the coastal drainage basin system in one million years.

It is concluded, on the basis of volumetric distribution, internal structure, and time and rate of deposition, that deposition by turbidity currents has been of paramount importance, virtually masking any hemipelagic deposition in the basins. Because fine-grained sediments (clayey silts and silty clays) have been previously estimated to constitute an important part of basin fill, this conclusion is incompatible with earlier theories on the origin of the basin sediments, which have classified only the relatively coarse-grained layers as turbidites.

Processes of Transportation to and Deposition in Basins

A system of processes to bring sediments to the basins and to satisfy the structural and distributional requirements brought out by this study together with those of topographic and lithologic data resulting from previous studies is presented as a working hypothesis. Within this transportation deposition system, it is proposed: (1) that the fine turbidites are deposited from flows of a very low-density, low-velocity variety; (2) that these flows are initiated at shelf depths from wave-generated bottom turbid layers; (3) that the turbid layers travel across the shelf into deeper water at a low angle to the shoreline under control of down-slope-gravity flow, orbital or to-and-fro motion, and local tidal and offshore currents; (4) that the turbid layers commonly intercept previously formed canyon and gully systems where they then become channelized and flow long distances down distributary systems to basin floors and basin slope aprons where gradual dissipation and deposition occur; and (5) that they do not erode or carry shallow-water microfaunas into the deep basins, but are deposited slowly and gently enough to incorporate the indigenous benthonic microfaunas.

Within the transportation-deposition system it is further proposed that the well developed network of canyons, fan valleys, and apron and basin-floor distributary channels of the affected basins are formed by denser, higher-velocity turbid flows into the basins. These carry and deposit sands, introduced at canyon head near shore, as well as silt and clay-sized sediment. Thus the lithology and structure of the basin floor sediments are to a very great extent controlled by shore and near shore processes.

General Significance of Postorogenic Basin Fill Processes

Acceptance of the proposed transportation-deposition system involves broad geological implications concerning processes of sediment transport, deposition, and erosion of the continental margins in general. This section summarizes these implications. It (1) reaffirms glacial periods of the Pleistocene as times of submarine canyon formation and deposition of much of the known deep-sea turbidites; (2) reaffirms the corollary that pre-Pleistocene continental terraces were, in general, in the process of progradation of shoreline and continental slope; (3) downgrades hemipelagic deposition to a position of little importance with respect to its volumetric contribution to slope progradation and basin fill, and substitutes, instead, shelf-generated, low-density, low-velocity turbidity currents flowing diagonally away from the shoreline as the primary constructional process; (4) suggests that regional stream discharge during Pleistocene time was the major contributor of sediment rather than wave erosion of shelf sediments; (5) postulates that stratigraphically thick sections of coarse grained turbidites are strong evidence favoring the existence during deposition of one or more feeder submarine canyons or gullies with heads in either the near shore sand transport zone, in the delta front of a major river, or an active estuary; and (6) proposes that the system of distributaries supplying these coarse turbidites will act also to intercept and funnel to turbidite basins large volumes of bottom turbid layers carrying silt and clay-sized particles.

REFERENCES

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