values of pH not only does calcite cement tend to be precipitated, but also quartz particles tend to be peripherally corroded and ultimately replaced. Such cementation and replacement of quartz by calcite have been observed in subaerially exposed sandstones <10,000 years old, in subsurface reservoir rocks, and in modern beachrocks. Other bacteria form $CO_2$ from methane, such as that found in lagoonal sediments or tidal marshes, and this $CO_2$ can trigger precipitation of carbonate cement in sediments lying on the sea floor or occurring in the subsurface.

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PRACTICAL CLASSIFICATION OF REEFS AND BANKS, BIOHERMS, AND BIOSTROMES

Reefs and banks form stratigraphic traps which account for more than 40 percent of the total petroleum production of the world. Yet there is much confusion concerning the classification and terminology of these skeletal deposits. Following Lowenstam and Nelson *et al.*, I apply the terms "reef" and "bank" to denote the origin of the structures, whereas I use the terms "bioherm" and "biostrome" to designate the shape of the structures and their relations with the associated layered facies.

A reef is a structure built by the *in-situ* growth of organisms which have the ecologic potential to act as frame-builders. It is a wave-resistant, prominent structure on the sea floor and will, therefore, influence and modify the sedimentation in its vicinity.

A bank, however, is made up of organisms which did not have the ability to act as frame-builders. Banks may be formed in place or by mechanical accumulation following transport of the skeletal remains. Banks are also wave-resistant. They may or may not be prominent structures on the sea floor. Correspondingly, they may or may not influence the sedimentation in their surroundings.

According to the mode of their formation, banks may be further subdivided into mechanical aggregational banks and biogenic banks. The biogenic banks result from (a) biogenic baffling of sediment; (b) biogenic sediment binding; (c) biogenic accretions of cementing organisms; and (d) local gregarious growth of organisms which did not cement themselves to one another or to the substratum.

Thus, reefs and banks represent distinctly different biogenic structures. A reef is a structure in which the *in-situ* growth of organisms is more important than sediment trapping and binding. In banks the sediment-baffling and binding functions of the organisms are the predominant source of sediment accumulation. In a reef, the organic productivity of the frame-building organisms is by itself sufficient to elevate the structure above the surrounding sea floor. Frame-builders in general are organisms which cement themselves to the substratum and form a rigid reef mass.

According to their shape and geologic settings, biogenic buildups may be subdivided into bioherms and biostromes.

A bioherm is a massive, mound-shaped structure which is in discordant relationship to the surrounding layered facies of different lithology. A biostrome is coarsely layered and grades concordantly into the associated layered sediments.

According to the foregoing definitions, a reef represents a bioherm in shape and geologic setting. A bank, however, may appear in the form of a bioherm or a biostrome. Mechanically accumulated banks and biogenic banks resulting from the sediment-baffling activity of organisms usually are found in the form of bioherms. Banks resulting from biogenic binding of sediment may represent bioherms or biostromes. Local gregarious growth of organisms usually leads to accumulations of biostrome type.

Examples of various types of recent and ancient reefs and banks emphasize the fact that structures which superficially appear to be similar may be quite different in their genetic and environmental interpretation.

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BASEMENT TECTONICS AND FOLD PATTERNS—KINEMATIC-MODEL APPROACH

In the study of fold patterns in relation to basement tectonics, the experimental-model approach followed by Mead, Cloos, and others has been elaborated in the development of relevant kinematic models. These models are displayed in motion and have the advantage of arbitrary mechanical reversibility, as well as the capability of showing the effects of deformational influences in both the "before" and "after" stages.

In the application of model results to field examples, the influence of transcurrent basement shearing is invoked to explain the development of extensively repetitive folding over large areas of layered rocks. Thus, pervasive shearing, rather than the application of external lateral stress at a distant point, produced the widely distributed deformation. In this context the kinematic models demonstrate "skin tectonics" and "wrinkle folds."

Various effects in fold patterns can be explained in terms of the varying ratio of horizontal to vertical movement in the shear systems. If the resistance of flexible layers to ductile compression is considered, it may be demonstrated that dilatational areas tend to develop at points of maximum flexure, particularly at crests and troughs of folds. Gravitational stress then augments crestal dilatations and depletes or prevents corresponding dilatations in troughs.

If differential movements occur unevenly within a wide zone of shearing, the effect will be *relative* reversals of movement (or of shear sense) that would not necessarily involve any *actual* reversals in the direction of material movement relative to geographic coordinates. This circumstance would be analogous to the manner in which a body may undergo both positive and negative accelerations while maintaining positive velocity.

The effect of relative reversals of movement is equivalent to that of oscillatory shearing, for which the terms "forward" cycle and "reverse" cycle may be used to describe the *relative* differential movements. A succession of oscillations results in the superimposition of two approximately orthogonal deformation ellipsoids. The ellipsoid generated by the forward cycle maintains a degree of unrecovered strain on which the cross-deformation ellipsoid of the reverse cycle is then superimposed. This process is advanced as an explanation of cross-fold phenomena in which dilatational maxima are located at the tops of domes which mark the intersection of structural cross-trends, or which are aligned *en échelon* along one particular trend. Where layers are steeply dipping as in an isoclinal sequence, the cross-deformation effect is expressed in the form of steeply plunging buckles and "drag folds" with intervening tensional ruptures.

Block tectonics may be simulated by introducing discontinuities of shape and viscosity into kinematic models. In this way, oscillatory shearing may be seen to generate "intracratonic mobile belts" in which successive shear cycles produce repeated increments of unrecovered strain which are compounded within the belt. This compounding gives the effect of a deformation that is disproportionately large for the evident amount of net movement between blocks.

The worldwide prevalence of conjugate systems of crossing shear zones or cross-dislocations that lie in the quadrantal northeasterly and northwesterly directions is seen as a result of accelerations and decelerations in the rotational movement of the earth. The effects may be simulated in the appropriate kinematic model.

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GEOLOGY OF WESTERN CANADIAN CONTINENTAL SHELF

This paper deals primarily with the stratigraphy of the Tertiary sediments in the Tofino and Queen Charlotte basins of Canada's Pacific shelf. Information is included from Mesozoic and Tertiary outcrops along the shoreline margins of the basins; from the six Richfield Oil Corporation wildcats on the Queen Charlotte Islands; from Shell Canada's aeromagnetic, reflection, and refraction seismic surveys; and from 14 offshore wildcats drilled between May 1967 and May 1969.

The pre-Tertiary framework of the shelf consists of a thick and complex sequence of Mesozoic sedimentary, metamorphic, and intrusive and extrusive igneous rocks. Little is known about the early Tertiary history, but data from the Tofino basin suggest widespread early-middle Eocene submarine volcanic activity, initial uplift followed by subsidence in late Eocene time, distinct transgressions of Oligocene-early Miocene seas, followed by a middle Miocene period of crustal deformation, uplift, and regression. There was a major transgression in late Miocene and a lesser one in early Pliocene time, followed by a regressive phase in late Pliocene-Pleistocene time.

The early Tertiary volcanism in the Tofino basin spread northward and continued, at least sporadically, in the Queen Charlotte basin into the Miocene. Tertiary sedimentation in the Queen Charlotte basin did not begin until the Miocene and, although interrupted by perhaps two periods of uplift and erosion, continued through the Pliocene into the Pleistocene.

The maximum thickness of Tertiary sediments is more than 15,000 ft. Depositional environments range from deep-water, open-marine sequences of shales, siltstones, and sandstones in the Tofino basin, through both deep- and shallow-water marine sediments in the Queen Charlotte basin, to a thick nonmarine sequence of sandstone, shale, siltstone, and coal in Hecate Strait and the Queen Charlotte Islands. The sands in both basins are composed primarily of feldspars and quartz, and those of the Queen Charlotte basin are characterized by high porosity and low permeability.

There is a wide variety of structural styles including areas of numerous large anticlines with multiple unconformities and complex growth and fault histories; areas of small, gentle, low-relief anticlines; and areas where the Tertiary sediments onlap older volcanics with little or no folding of the sediments. There are insufficient deep seismic reflections to interpret and understand properly the structural style of the Tofino basin, but at least two basic mechanisms must be considered: (1) simple compressional folding with detachment from the basement, and (2) flowage of the overpressured shales into the cores of the anticlines. At various times in different places in the basin, each of these mechanisms might have been dominant.

Both oil and gas shows have been encountered, but no commercial accumulations have yet been found.

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MODERN AND ANCIENT HURRICANE DEPOSITS—THEIR GEOLOGICAL SIGNIFICANCE

The shoreline sands along the coastlines of the northern Gulf of Mexico offer excellent examples of the varying processes that have created them and determine their distribution. Sands of such varying origin as eolian sands of the south Texas sand sheet, the barrier islands of the Central Texas Bay-Barrier Island province, the chenier sands of southwestern Louisiana, the channel sands of the active and inactive passes of the Mississippi River delta complex, the reworked sands of the old distributary channels of the Mississippi delta, and the Mississippi-Alabama barrier island chain, are well documented in this almost unique basin of deposition. These sands are "made" by nearshore processes from other sand-containing sediments and are not deposited as such from their source. They, in essence, are all multicycle sands.

The "normal" shoreline and nearshore processes maintain these sand deposits in their present environments. Major storms, however, completely disrupt these processes and cause unusual sand distributions. Many of the storm-caused distributions are repaired by the "normal" processes shortly after they are formed. Some, however, remain as a permanent distribution and probably are included in the geologic record as such.

Many examples of sand bodies in the subsurface Tertiary of the Gulf Coast geosyncline are directly analogous to modern "normal" and "abnormal" sand bodies available for study in the northern Gulf of Mexico. For example, the Oligocene "Frio barrier" in South Texas is associated with probable storm deposits.

## ERRATUM

AAPG *Bulletin*, v. 56, no. 3 (Mar. 1972), p. 653, right column, the name of R. A. Soeparjadi should be added as co-author with R. C. Slocum of the abstract, "Oil Boom in Indonesia—Too Optimistic?"

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma 74101. (Names of sponsors are placed in parentheses.)

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