shaped masses (swamp). Although hardness tends to increase with increasing burial depth and age, some nodules in relatively young deposits are very hard. Preliminary chemical analyses and X-ray diffraction studies indicate that they are composed of various carbonates, mainly calcium, manganese, magnesium, calcium-magnesium, and iron. Iron carbonates are abundant and appear to be more common in the older deposits. The change in proportion of the various carbonates presently is being investigated but this change must be abrupt. Other inclusions, such as iron oxides. iron hydroxides, *etc.*, also are abundant.

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SEDIMENTATION IN MALAYSIAN HIGH-TIDE TROPICAL DELTA

The Klang-Langat delta empties into the Straits of Malacca at 3° N. lat. along the west coast of the Malay Peninsula. Both the delta and its catchment basin are located in the wet tropics with mean annual rainfall ranging from 80 to 140 inches. The subaerial delta occupies about 160 square miles. Wave energy levels along this coast are low to moderate; the range of mean spring tides is 15 feet. Tidal processes dominate sediment dispersal patterns and control delta form. An extensive tongue-shaped sand bank or shoal (Angsa Bank) is down-drift from the delta. The subaerial delta displays a maze of criss-crossing tidal channels separating mangrove islands. Although the system has the configuration of an estuary, it is in reality a complex delta of the Klang and Langat Rivers.

Six major environments and facies are recognized in the active delta. The most seaward of these consists of well-sorted medium-grained sand deposited on extensive shoals or banks. Sorting reflects intensity of tidal currents. Local concentrations of shell and transported organic debris also are characteristic. This marine sand forms the bulk of the subaqueous delta deposits. Fringing the subaerial delta are broad low tidal flats composed of irregular-bedded, fine-grained sand, silt, and clay. Networks of small tidal creeks dissect the flats; shellfish and other burrowing organisms abound. Bottom sediment in major tidal channels is predominantly clayey sand with local concentrations of shell and transported organic debris. Mangrove-covered islands constitute most of the active subaerial delta. Although organic production is high, it is overshadowed by fine-grained detritus resulting in accumulation of organic clay, rather than peat. On the margins of the islands small sandy accretion beaches border channel mouths. Central parts of large islands and backswamp areas between major channels in the older parts of the delta are occupied by large fresh-water jungle-covered swamps. These are the sites of woody peat accumulations which attain thicknesses of 20 feet or more.

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ATLANTIC COASTAL PLAIN TERRACES AND TERRACE FORMATIONS

The relation between coastal-plain terraces and their underlying formations has long been obscure. Atlantic coastal-plain terraces are underlain by "cyclic formations" in the sense proposed by Stephenson (1928). They consist of continental and marine contemporaneous cyclic sequences. The continental sequence consists of stream, fresh-water, marsh, lacustrine, estuarine, and deltaic sedimentary facies. The marine cycle consists of littoral, sublittoral, bar, barrier island-lagoon, and barrier-island tidal-marsh sedimentary facies. The two sequences are gradational within estuarine facies and disconformable along former strandlines.

The cyclic formations overlie an unconformity that has been cut into older stratigraphic units. Landward the unconformity surface consists of stream valleys and divides over which the continental sequence was deposited during a rise in sea-level. Seaward the unconformity has been modified by marine scour. The marine sedimentary sequence occurs on this scoured surface. Initial marine erosion proceeds landward during a rise in sea-level until estuaries are filled and sediments supplied to the ocean balance sediments being eroded. From this stage onward, during slow transgression through subsequent regression, coastal-plain accretion takes place seaward with construction of one or more barrier-island and tidal-marsh stages and seaward growth of deltas.

The terminal surface of the cyclic formation is the terrace which contains both continental and marine land forms representing the last processes operative in the area during regression. Thus geomorphology and pedology reflect the terminal nature of the underlying litho-, bio-, and environmental facies. The underlying stratigraphic facies illustrate the cyclic sequence of environmental stages necessary to develop the terminal land form.

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RECONSTRUCTION OF AN ANCIENT SHALLOW-WATER MARINE ENVIRONMENT*

It is commonly possible to decide that an ancient body of rock was laid down in a shallow-water marine environment but in many cases it is impossible to determine precisely which shallow-water marine environment.

The Ordovician Stairway Sandstone, a shallow-water marine formation of the Amadeus basin, central Australia, contains appreciable, though so far non-commercial, quantities of oil, gas, and phosphate. It is therefore desirable to have a detailed knowledge of the depositional environment of this formation. For this reason, extensive field and laboratory studies were undertaken.

These studies have revealed that the sedimentary rocks, mainly orthoquartzite and phosphatic shale, were deposited during a regressive-transgressive cycle which resulted in the migration of a single shallow-marine depositional environment across at least 40,000 square miles of the basin. This has profoundly influenced facies distribution. Using a detailed graphic-log approach, the numerous sedimentation units in the Stairway Sandstone can be grouped into six composite units. These, in turn, comprise a single compound sedimentation unit whose characteristics are the result of a particular depositional environment.

The characteristics of this compound unit, compared with those of modern sediments, show that the modern lagoon-barrier and intertidal-flat sediments

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are very similar in both lithologic character and sequence to those of the compound sedimentation unit of the Stairway Sandstone. However, because of the many thousands of square miles covered by the facies of the Stairway Sandstone, both modern models are considered to be inadequate. Therefore a more hypothetical model of epeiric-sea sedimentation also is considered. Though having the disadvantage that there is no known present-day counterpart, this model nevertheless warrants some consideration. It is possible to explain many of the features of the Stairway Sandstone (and perhaps other formations) by its use.

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PALYNOMORPHS AS INDICATORS OF NEARSHORE AND OFFSHORE FEATURES IN MODERN SEDIMENTARY BASINS

Distribution of pollen, spores, cuticles, tracheids, as well as dinoflagellates, hystrichospheres, microforaminifers, and certain other microplankton, may be used within certain limitations to identify or assist in determining sedimentary environments and ancient paleogeographic patterns.

Special consideration is given to the modifying influence of marine circulation, currents, tides, *etc.* on patterns of distribution. Configuration and restrictions of basin and shorelines, patterns of surface or near-surface circulation resulting from prevailing wind regimes (resulting in localized areas of upwelling in different seasons), submarine canyons, and other such agencies and features cause significant modifications on distribution patterns of palynomorphs.

Direction, strength, and season of prevailing winds and storms exert some control in distribution of pollen and spores. Down-wind distribution areas show decreasing frequency from source areas.

Dilution of palynomorph concentrations in the vicinity of deltas and channels, where an abundant supply of terrigenous sediments is accumulating, seems to lower absolute frequencies of palynomorphs only in main channels and very near the shore.

Differential susceptibility to decay, which characterizes these entities, makes it difficult to depend on the presence or absence of particular pollen of plants which make up the communities on the coastal plains to identify nearshore position.

Use of total number of spores and pollen in sediments, to determine positions of former shorelines, should be amplified with a consideration of type of sediment at the sampling site and the nature of thanatocoenoses of marine faunas and algae.

Cuticles and tracheids are extremely abundant in fine sediments near the shore and decrease offshore. Cuticular fragments greater than 1 millimeter in diameter usually are not carried or are destroyed within a few miles of shore; tracheids greater than 50μ and finer cuticles are deposited in decreasing numbers 50–100 miles offshore.

Some kinds of palynomorphs increase in relative frequency, compared with total pollen and spores, with increasing distance offshore. Mangrove and pine are typical of this group. Herbaceous pollen generally is more abundant near the shore.

Comparison is made of results of studies of palynomorphs in modern bottom sediments in the Gulf of California, Gulf of Paria, Mediterranean Sea, Sea of Okhotsk, and Gulf of Mexico for the purpose of indicating proximity to shorelines and deltas.

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THEME: STRATIGRAPHY GUIDES STRUCTURE: (A) INTERRELATION BETWEEN STRATIGRAPHY AND STRUCTURE (*Crowell*); (B) VENTURA BASIN, EXAMPLE OF THEME (*Paschall*)

INTERRELATION BETWEEN STRATIGRAPHY AND STRUCTURE

Earth deformation initially delineates basins and, together with climate and provenance, guides the distribution of sediments. In geosynclines and mobile belts the rise and fall of welts and troughs influence the facies sharply. Even in cratonic regions, tectonic control of sedimentation is clear. Crustal deformation also occurs after deposition, and the positionings and geometric details of structures are controlled by the mechanical properties and inhomogeneities of the strata. In such cases stratigraphy clearly has guided structure. In many regions, however, deformation and deposition have occurred together, and an interplay continues intermittently for long periods of time. As a result, deformation guides deposition which in turn guides deformation *et cetera*. Such an interrelated continuum regulates the movements of fluids, including oil and gas, within the strata.

Modern analysis of basin history requires a careful reconstruction of the interplay between deformation and deposition. The analysis is most effective if one begins with the present and works backward in time, sorting out the geological events and their effects one by one. Knowledge gained recently of modern depositional environments and the geometry and distribution of sedimentary facies within them provides the geologist with reference models of the appearance of his study area in the past. It is not sufficient to visualize static strata as having been deformed suddenly after deposition and lithification. Instead the geologist must find techniques which permit him to reconstruct the panorama of continuous changes not only of the stratigraphy through time, but also the folding, faulting, and movements of fluids within the strata. (*Crowell*)

VENTURA BASIN, EXAMPLE OF THEME

The sediments of the Ventura basin are more severely deformed than those of most oil-producing provinces. This circumstance, in combination with the narrow linear aspect of the basin and the abundance of outcrops, yields more conspicuous examples of structural-stratigraphic relations than usually are encountered.

The basin's early history reveals a characteristic common to all depositional areas, *i.e.*, the manner in which basin and basin-margin structure affected sedimentation. A second feature of basin history that is not so conspicuous elsewhere is the manner in which stratigraphy affected later deformation of the basinal sediments, as well as oil accumulation in them.

Major high-angle reverse faults now exist locally along the north and south boundaries of the main Pliocene basin. The very thick (world-record) Pliocene section not only thins toward these faults, but also typically has a notable decrease in permeable sandstone percentage.

The fault zones contain fine-grained terrigenous clastic rocks and siliceous shale, which served as a lubricant for fault movements. The fault zones proba-