able stratigraphic units. The enclosed units represent longer intervals of time, and their lithologic gradations represent the diluted total environmental impress.

Markers represent (1) widespread, essentially contemporaneous deposition of thin lithologic components, and (2) virtually contemporaneous contact phenomena resulting from halmyrolic chemical alteration, replacement, and syngenetic emplacement proximal to the sediment-water interface during times of non-deposition. Time markers may indicate such short-interval lithologic inflictions as changes in water depth, climatic variations, migration of shoreline, and influx of suspensoids with chemical or physical character sharply differing from that of sediments within the body of the marker-bounded unit. Unit thickness of sediment deposited at any locale is dependent on sediment availability, fluxes of the scattering agent, rate of regional variation in chemical impress of depositing medium, and amplitude of local and regional structural change.

Lithologic variations occur in any unit, but the mechanical-log characters of the units are remarkably consistent through an entire sedimentary basin. If log character of unit sequence is similar, one may consider the unit to be areally equivalent not only in duration but in simultaneity. Log character is a function of space and environment, and the time markers signal massive changes in the vertical continuity of these environmental controls.

Stratigraphic analysts are able to use these "time slices" to create isopachous and lithofacies maps of short-interval synchronous units. These maps are rigidly controlled for unit initiation, termination, and time span. Thickness variations represent a measure of competitive sedimentation resulting from an interplay of environmental factors which involve the allogens and syngens in sedimentary prisms of a marine basin. Paleontologic and sedimentologic characteristics in these geosynchronous units yield environmental and geographic patterns important in the delineation of porosity trends. Geosynchron maps permit analysis of intra-basin structural growth which influences first-phase oil migration. Time-length vacuity becomes susceptible to quantitative analysis.

If the generally accepted concepts of uniformitarian geology are approximately correct, these maps systematize haphazard lithologic patterns into geographic- and time-controlled stratal units whose internal characteristics make it possible to determine rates of sedimentation, facies gradation, lateral intensities of environmental impress, origins of sediments, depth of water, distance to shore, and a host of other sedimentational variables not otherwise easily susceptible to quantification.

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Dish Structure, a Primary Sedimentary Structure in Coarse Turbidites

Some clean but poorly sorted sandstone beds in California contain vertical progressions of thin lens-shaped structures, here termed *dish structures*. Individuals are 4–50 centimeters long, 1 to a few centimeters thick, oval in plan, and are oriented parallel with bedding. Each dish has a fine-grained, slightly clayey lower surface that is concave-up, and from which clay content decreases and sand size increases upward to a coarse, clay-free top. The size of the structures decreases and the concavity of their bottoms increases higher in the bed. The margins of each dish are truncated by adjacent and overlying dishes, except where they occur along individual horizons with their joined margins forming upward-pointing peaks. Steeply oriented elutriation columns lacking clay and finer sand commonly accompany dish structure. They disrupt or turn up dish surfaces through which they pass, and terminate beneath overlying dishes.

Typical sandstone beds containing dish structure are about 1 meter thick and progress upward from a base of coarse, structureless sand (interval *a* of Bouma, 1962) through flat lamination, dish structure, and overlying flat lamination (*b*), to a top of very fine-grained sand containing convolute lamination (*c*). Dish structure also occurs as a central interval within an otherwise nearly structureless, very thick bed.

Antidunes may produce simple dish structure by alternate scour, and by breaking and deposition in the troughs during aggrading suspension flow in a turbidity current that has declined from dispersion flow (after Bagnold). Middleton (1965) reports structures similar to some dish structures in size and shape resulting from antidune flow. Some characteristics, possibly including clay distribution, may result from sporadic water expulsion, related sediment flowage, and general de-watering of the bed. Dish structure between structureless intervals would require dispersion flow to progress to antidune flow, then revert to dispersion flow.

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Columbia River Sand Waves

Large-scale sand waves (dunes) occur over much of the Columbia River bottom from near the mouth at Astoria, Oregon, upstream to The Dalles (including Bonneville Reservoir), a distance of 280 kilometers. The waves range in height from less than a meter to 7 meters, but most are 2–2½ meters high. Common lengths are 40–60 meters. Virtually all waves are asymmetrical, with steep slopes facing downstream. The mean particle size of bottom sediment is in the range of fine to very coarse sand. The migration rate for a group of waves in Bonneville Reservoir was approximately 0.6 meter/day during a 2-week period of high water in mid-June, 1966 (average current speed, 0.7 meter/second), decreasing to 0.3 meter/day in the following month at lower stages of the river.

Sand waves are not uniformly developed throughout the river. Within Bonneville Reservoir the location of waves apparently is determined by the availability of sand-size sediment and the river's flow characteristics. Just below Bonneville, the patchy wave distribution may be caused by coarse sediment (gravel) and (or) high current speed; near the mouth, waves apparently are not well developed because of variable directions of current flow during the tidal cycle. Water depth has no consistent effect on the location or size of the waves.

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Microfacies and Sedimentary Structures in Deeper-Water Lime Mudstones

Limestone deposited in downslope or in basinal positions possesses several distinctive criteria based on microfacies, bedding, and fauna. The microfacies include (1) homogeneous lime mudstone, (2) millimeter-laminated lime mudstone, and (3) common micro-pelletoid lime grainstone (calcisiltite). The latter may show fine ripple cross-lamination. These rock types may occur in graded sequences but non-graded alternations are also common. Several kinds of minor sedimentary rhythms are recognized. The limestone types generally are dark, but light colored and even pink or red varieties are known. Distinctive monotonous bedding, consisting of planar relatively thin (½- to 2-foot) limestone beds interlayered regularly with thinner beds of dark shale, is common. Chert beds may be intercalated in such sequences. Spectacularly large cut-and-fill structures (stretching more than 100 yards) and presumably caused by submarine penecontemporaneous sliding are seen in places. Convolute bedding and flame structures indicative of soft sediment slumping are scarce.

Distinctive faunal assemblages exist in these beds. Siliceous and calcareous microplankton (radiolarians, diatoms, calcispheres, and tintinnids), sponge spicules, graptolites, pelagic or nektonic pelecypods, pelagic Foraminifera (globigerinids), pteropods, and certain ammonoids are especially characteristic.

Field observations of this limestone type show that it commonly forms a sort of apron down very gentle slopes from typical carbonate shelves and in many places regionally is peripheral to a depositional basin, the center of which contains a thin section of dark shale. Recognition of this facies permits one to predict proximity to a carbonate-shelf margin. In several locations lime mudstone mounds are seen slightly upslope from basinal lime mudstone. Both the even and regularly bedded lime mudstone and calcisiltite and the mudstone mounds contrast with characteristic limestone turbidite (allodapic limestone) which probably represents accumulations down from relatively steeper slopes, in more tectonically active environments, and perhaps downslope from shelves with higher water agitation. Numerous examples of "deeper-water" but non-turbiditic limestone are discussed from basins and geosynclinal troughs in the late Paleozoic of the western United States, the Cretaceous and Jurassic of Mexico, the Middle East, and Europe.

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K-Ar Mineral Age of Ash Bed in Pico Formation, Ventura Basin, California

A widespread volcanic ash layer, 1–4 inches thick, in the Pliocene Pico Formation (Wheelerian microfaunal stage) has been dated radiometrically. Twenty-five-pound samples of ash were taken from each of two localities. Each sample yielded about 4 grams of sanidine and 1 gram of biotite. These minerals are unaltered and show euhedral grain boundaries; some sanidine crystals have rims of glass. The glass matrix, comprising 95 per cent of the sample, is isotropic and apparently unaltered. Radiometric ages follow.

	West Bank of Ventura River (Million Years)	*South Side of South Mountain (Million Years)*
Sanidine	8.4±1.3	9.2±1.4
Biotite	9.3±0.9	10.2±2.1
Glass	<0.4	<0.2; 1.1

All ages were run at Shell Development Company except the biotite from Ventura River, which was run by John Obradovitch, United States Geological Survey, Denver, Colorado. The mineral ages are consistent within the range 8.4–9.7 m.y. The glass ages are discordant, apparently because of argon leakage; the glass is therefore useless in radiometric dating despite its unaltered appearance.

The upper part of the Pico is divided into two molluscan zones, a lower warm-water zone, and an upper zone containing a molluscan assemblage resembling that living today in Pacific Northwest waters. The temperature shift from warm to cold previously was correlated with the onset of Pleistocene glaciation and, because beds containing the cold-water mollusks are folded, the age of folding (Coast Range orogeny) traditionally has been considered to be intra-Pleistocene.

R. F. Meade has shown that the base of the cold-water molluscan zone is just below the ash bed near South Mountain; it is possible that the molluscan shift is not caused by glaciation but by a pre-Pleistocene change in oceanic current patterns accompanying a general late Tertiary cooling. The new radiometric age and the invalidation by Durham, Jahns, and Savage (1954) of mammalian evidence for a Pleistocene age of folding suggest that both the molluscan temperature shift and Coast Range orogeny occurred in Pliocene time.

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Railroad Gap Area—New Reserves in Old Province

The Railroad Gap area, consisting of the Railroad Gap field and the deeper pools at Northeast McKittrick and McKittrick Front, is on the west side of the San Joaquin Valley near McKittrick, Kern County, California. The discovery of the Railroad Gap field in February, 1964, by the Standard Oil Company of California led to the deeper-pool discoveries at Northeast McKittrick and McKittrick Front by the same operator during the ensuing 1½ years.

Anticlinal closure traps most of the reserves in each field. The folds differ considerably in size, configuration, and orientation. Normal and reverse faults are common, and cause differences in oil-water interfaces within the same accumulation.

Nearly all stratigraphic units from the Eocent Point of Rocks Sandstone Member to the Pleistocene Tulare Formation are productive in the area. The primary objectives and most prolific reservoir rocks are the Oligocene Oceanic and the lower Miocene Phacoides and Carneros Sands. The massive Phacoides and Oceanic Sand units differ considerably in thickness and reservoir quality from place to place. The Phacoides permeability variations are particularly surprising, because initial completions range from 100 to 9,000 BOPD at similar structural positions within the same accumulation.

The Railroad Gap area was known to be anticlinal, but conclusive evidence of critical closure on the northwest could not be documented by conventional structural studies or geophysical methods. Regional isopachous studies of the middle and upper Miocene, however, indicated the existence of thickness variations of a sufficient magnitude that potential northwesterly closure could be inferred to be present in the underlying lower Miocene sediments. The isopachous contours reflect middle and late Miocene structural growth along the trend, suggesting a favorable geologic history for the area. The lower Miocene and Oligocene, from nearby well data, were known to contain excellent clastic reservoirs, thus completing the knowledge necessary to justify an exploration program.