The main period of folding in the early Paleozoic has resulted in cross-sectional exposures of several diapirs. Bald cap structures and interdigitation of conglomerates with basin sediments along the flanks of the domes indicate repeated phases of diapir movement. Adjacent diapirs show evidence of uplift at widely different times from the glacial phase of the Late Proterozoic to the Early Cambrian.

Boulder trains derived from the core of one diapir (Enorama) successively onlap along the flank of the structure and the unconformity may be traced for several miles. The same stratigraphic units (Umberatana Group) on the opposite flank, are truncated by subsequent movements of the core.

An example of a structure of irregular form is the Arkaba diapir, which shows control over facies and thickness from the top of the Umberatana Group through the Wilpena Group to the Lower Cambrian.

Other structures (Frome and Wirrealpa diapirs) exist on an important hinge zone which controlled Lower Cambrian deposition. The Frome diapir shows repeated intervals of erosion near the Adelaide System-Cambrian boundary and offers exposures of both diapiric and depositional contacts. The Wirrealpa diapir and associated faults separate a Lower Cambrian sequence to the south, comprising two formations (2,000 feet in thickness) from an equivalent section to the north, of seven distinct units totalling 10,000 feet in thickness. The diapir core was eroded during this interval.

Exposed is a cross section of a graben which developed during the early Cambrian above a diapir (Oraparinna), the bounding faults of which controlled the development of an *Archaeocyatha* biohermal bank which intertongues with basinal facies.

Diapiric structures which affected late Proterozoic and early Paleozoic deposition have been recorded 750 miles to the northwest of this province from the Amadeus Basin in central Australia. Evaporitic deposits there are reported within the Bitter Springs Limestone which occurs below a late Proterozoic glacial unit.

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### Bathyscaph Observations in the La Jolla Submarine Fan Valley

Observations, made from the bathyscaph *Trieste* during six dives to depths ranging from 1,800 to 3,000 feet, reveal that submarine erosion is actively modifying a series of step-like terraces forming the internal walls of the La Jolla Submarine Fan Valley. The innermost terrace is cut by a narrow, steep-walled, flat bottomed channel that forms the longitudinal axis of the valley. Beneath a thin mud cover, the channel contains sand and plant fill that is entirely different from that found on or forming the internal terraces. The steep slopes (up to 70 degrees), found where the innermost terraces lead down to the inner channel, have slump scars, striations, and fresh burrows that indicate they are presently being eroded by marine processes. Terrace sediments are bedded and semi-consolidated and do not appear to have been deposited in the present erosional environment of the canyon. On one of the dives, large rounded rock boulders, up to 3 feet in diameter, were found scattered through the interbedded sand, mud, and plant material found in the inner channel. The nearest possible source for these large erratics is more than one-fourth of a mile from their present location.

The following characteristics are arguments against dense, high-velocity turbidity currents as agents of erosion or transportation in the present day La Jolla Fan Valley: (1) the lack of scour depressions around large man-made objects found in the sands of the inner channel, (2) the sinuous course of the inner channel, (3) a low axial gradient, (4) a lack of inner channel sediment on terraces 10 feet above the channel bottom, and (5) the heterogeneous mixture of fragile sea-grass mats, large boulders, and micaceous sands.

Pulsating bottom currents with velocities up to 0.45 knots have been measured. These currents were observed to have sufficient strength to transport fine micaceous sand and unconsolidated clay-sized particles along the bottom of the inner channel. However, the large boulders associated with sands and organic debris, foreign to the surrounding sea floor, must have been transported by another mechanism; gravity creep and progressive slumping of the entire fill of the erosion channel are suggested agents.

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### Vadose Pisolite in the Capitan Reef

New evidence on the origin of the pisoliths of the Permian Capitan Reef Complex indicates that they are not of lagoonal algal-nodule origin, but are early vadose concretions and probably Permian pisolitic caliche. If the reinterpretation is valid, the pisolite implies that (1) the climate was dry, (2) the reef complex was subaerially exposed repeatedly during its growth, with attendant opportunities for diagenetic alteration of porosity and for "inorganic binding," and (3) the paleotopographic crest on the complex was not in the so-called organic reef-rock, that is, in the sponge-bearing lime wackestone of the Capitan facies, but instead was in the dolomitized grainstone of the Carlsbad facies.

Basic to the older interpretation is the requirement that the pisoliths rolled about during growth. [Algae cannot grow downward so as to encrust the bottom side of objects at rest, due to their need for light and to the resistance of the substrate.] Evidence of *in situ* downward growth (consisting of fitted polygonal structure, downward elongation of pisoliths, and inclusions of silt perched in the upper parts of concentric growth layers), together with the lack of admixed sediment and of sedimentary structures characteristic of gravel-size deposits, indicate that the pisoliths are not algal nodules, nor even transported sediment, but are concretions.

Evidence that the growth of pisoliths was commonly interrupted by leaching and nontectonic fracturing and was closely associated with cementation and internal sedimentation of silt requires that the concretions grew in a diagenetic environment characterized by complex variability and by water moving rapidly enough to transport silt. The vadose zone alone seems to meet this requirement. The Permian pisoliths significantly resemble known vadose concretions, especially those of pisolitic caliche.

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### Uplifts, the Primary Structures of Deformation in the Shelf and Miogeosyncline of the Western United States

The large asymmetrical and elongate domes that constitute the basic structure of the ranges of the shelf province of Montana, Wyoming, Colorado, New Mexico, and the Colorado Plateau of Utah and Arizona are depicted as primary structures with the flanking thrusts as secondary gravity slide phenomena.

The miogeosyncline of western Utah and eastern Nevada is analyzed for its pre-Basin and Range and pre-volcanic structures, and an outcrop pattern arrived at that shows uplifts similar to those of the shelf. A number of thrusts are believed to be gravity slide structures on the flanks of the uplifts, and most of the folds and associated thrusts are squeeze structures between the uplifts. These latter compose synclinoria with thick Pennsylvanian and Permian sections.

The uplifts, including those of the Ancestral Rockies as well as some in the miogeosyncline, have had a history beginning with the Pennsylvanian. Vigorous uplifting reached a climax in the Late Cretaceous and Early Tertiary. All of the uplifts owe their existence to magmatism, in which basalt from the mantle has risen to the interface between the granitic and basaltic layers to form megalenses or blisters.

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TATUM DOME, MISSISSIPPI, SITE OF ATOMIC EXPLOSION, PROJECT DRIBBLE[1]

Tatum dome, Lamar County, Mississippi, site of the *Salmon* atomic explosion of Project Dribble, is a roughly cylindrical salt stock having a slight overhang in the upper 2,500 feet. Diameter of the stock at 2,500 feet subsea is about 4,200 feet; top of the stock at 1,230 feet subsea is nearly flat. The salt consists of alternating bands of halite and anhydrite-rich halite; the bands are nearly vertical and several inches wide. In the upper 50 feet, banding is less steep, and the halite is purer and very coarsely crystalline.

Anhydrite caprock, extending umbrella-like over the salt stock, is almost entirely dry hard rock containing some fractures; its upper few feet is gypsiferous. Cavernous, brecciated, calcite caprock containing strontianite and celestite overlies the anhydrite; it contains comparatively fresh water.

Above the caprock is "false cap"—thin calcareous pyritized sandstone and fossiliferous limestone (probably early Miocene)—overlain by slightly arched beds of unconsolidated silty clay and sand (Miocene), 450 feet thick.

Data indicate that artesian water moves into the calcite caprock from the abutting Vicksburg Group (Oligocene); it then percolates slowly upward into shallower fresh-water aquifers.

Beds flanking Tatum dome are structurally disturbed. Tertiary beds in the shallow rim syncline have normal regional thickness. Aquifers around the dome contain fresh water as deep as 2,000 feet; saline water occurs in the Eocene Cook Mountain Limestone and in beds below.

*Salmon* was a 5-kiloton coupled atomic detonation centered at a depth of 2,700 feet in the northeastern quadrant of the dome.

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QUARTZ CONTENT—GRAIN SIZE RELATIONSHIPS AND LOCATION OF SOURCE TERRANE

With other factors held constant, quartz content is a positive function of grain size. Examination of changes in this relationship among critically chosen samples can determine the location of source terrane and direction of sediment transport. Sediments deposited near the source terrane resemble the parental material more closely than those subjected to degradational processes associated with longer transport. In general, sediments become more quartzose in the silt and sand sizes as these processes proceed.

This approach has discriminated between the bordering Appalachian and Ouachita fold belts as sources of the Upper Carboniferous detritus of the Black Warrior basin of Alabama. If an Appalachian source is postulated, all samples taken proximally to the folded zone should be quite similar, being at the same time less quartzose for their grain size than samples collected farther to the west. Conversely, a southern, Ouachita source would yield increasing quartz contents from south to north. Experimental studies indicate the latter condition, with no perceptible Appalachian contribution.

These results form a basis for predicting the character of these rocks beneath the mantling sediments of the Mississippi embayment, as well as clarifying the order of tectonic events of the southeastern United States.

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CYCLEOLOGY—A DISCIPLINE CONCOMITANT TO PALEOECOLOGY

The subject of cycleology is the detection and study of cyclicity in geological and paleontological phenomena, whereas paleoecology is concerned with the establishment and interpretation of ancient facies, and of the evidences of ancient life entombed in them.

Phase is the fundamental unit in cycleology, and recognition of a geological (or paleontological) cycle is based on the establishment of two or more successive orderly sequences of phases, be they lithological, paleontological, or a combination of both. Phase is analogous to paleoecological facies, but the two are not identical concepts. Part of a facies, or even all of it, may become a phase in a geological cycle.

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DISTRIBUTION OF SEDIMENTS IN THE WORLD OCEAN

Sediment stratification and thickness have been measured by a seismic reflection profiler along many traverses in each of the oceans. Sediment thickness is less than 40 meters over a large fraction of the area but there are deposits, mostly level bedded and always adjacent to continents, in which it ranges up to 3 km. The sediments are generally completely undisturbed. The age and mechanism of transport of these sediments are discussed in the light of several tectonic theories. The facts mentioned argue for sediment transport along or near bottom by a process controlled mainly by gravity, and against continental drift.

The sediment fill-in of a number of deep sea trenches is described and its implication for mode and date of formation of the trenches is discussed. There is very little sediment in most of the trenches, and that present is usually in horizontally stratified deposits in rift-like depressions in the trenches. This fact is considered to indicate that most of the trenches are very young. All of these observations indicate that pelagic sedimentary processes contribute very little to the totality of deep-sea deposits.

[1] Approved for publication by Director, U. S. Geological Survey.