ages of 2,670 and 3,310 years, confirming that the dolomitization is a penetemporary phenomenon related to the present sedimentary environment.

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SEDIMENTARY STRUCTURES IN MODERN CARBONATE SANDS OF THE BAHAMAS

Sedimentary structures of carbonate sand bottoms near Bimini, Sandy Cay, and the Berry Islands have been examined in depths ranging to 10 ft. below MLW. Box cores with a vertical face 18 in. high and 12 in. wide were impregnated in the field with epoxy resin to preserve and accentuate the structures.

Four distinct types of internal structures occur in contrasting depositional environments. *Type I*, characterized by 3–10 cm.-thick sets of cross-strata and either horizontal or curving truncation surfaces, is found in intertidal, rippled, oölite shoals. *Type II*, with 20–40 cm.-thick sets of tabular cross-strata and horizontal truncation surfaces, is found in intertidal-subtidal, unrippled, grapestone bars. *Type III*, with even, parallel laminae inclined at low angles to the horizontal, is found in the backshore and foreshore of beaches. *Type IV* is mottled, lacks stratification, and is found in unrippled level bottoms.

Bahamian field observations confirm pertinent hydrodynamic conclusions of J. R. L. Allen, H. W. Menard, and D. B. Simons. Type I is observed to form by small ripple trains induced at low flow intensities by tidal currents. Type II is judged to form by a large-scale ripple induced at high flow intensities by rare storms. According to M. M. Ball, deposits with similar structure were formed by Hurricane Donna in Florida Bay. Type III is observed to form from swash and backwash currents on beaches. Type IV reflects an environment in which organisms destroy stratification as fast as it is produced.

These four types should be considered as end-members representing hydrodynamically pure situations. Many actual sites represent alternating conditions (beach-shoal, beach-bar, etc.), as is clear from preserved structures.

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SEDIMENTARY STRUCTURES IN LAYERED ULTRABASIC ROCKS*

Many igneous intrusions show layering formed by gravitational accumulation of crystals that is, both in variety and detail, remarkably similar to the bedding of sedimentary rocks. Such layering occurs in most compositional types of intrusions but especially in mafic and ultramafic bodies. The examples considered specifically are from the Duke Island ultramafic complex in the Alaskan panhandle; the rocks are composed of olivine and clinopyroxene but, where layered, look much like graded bedded turbidity current deposits. The intrusion is composite, and the layering, which has been tilted and folded, has two ages—thus, layered blocks and fragments of olivine pyroxenite are included in stratified peridotite. Over-all, stratification is developed intermittently through an original vertical thickness of 2 miles. Individual layers have been traced for 300 feet, and one continuously layered section is 1,500 feet thick and extends 1,000 feet.

A typical layer is 2 inches to 2 feet thick and is graded from grain sizes of 2–10 mm. at its base to 0.1–1 mm. at its top; some mineralogical sorting results because the olivine crystals are generally finer and thus concentrated upward. The base of a layer is sharp; the top may terminate against the next stratum or may pass into an intervening zone of thin laminae. Some of the layers of younger age resemble graded beds of slide conglomerate, their lower part being largely olivine pyroxenite fragments.

Other layering features include: cross-layering, slump and deformation concurrent with accumulation, streamlining of layers over irregularities, load casts, general correlation between layer thickness and particle size, lateral grading, and "diagenetic" recrystallization.

The layering has undoubtedly formed because of magmatic currents during extremely unstable conditions. The currents were probably a convective type of overturn marked by the descent of dense, crystal-laden magma from the cooling roof and wells of the pluton, and it is likely that they were initiated and perpetuated by repeated slumping. The described phenomena illustrate that features of water-laid sediments can form in a vastly different environment in terms of the specific gravities of particles and transporting liquid, and the viscosity of the liquid.

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PERMIAN CALCAREOUS ALGAE FROM NORTHWESTERN WASHINGTON AND SOUTHWESTERN BRITISH COLUMBIA

Limestone units of the Tethyan Permian eugeosynclinal sequences of northwestern Washington and southwestern British Columbia contain abundant specimens of calcareous algae. The limestone bodies are mostly lenticular in shape and range from a few inches to approximately 1,000 feet thick. They are interbedded with volcanic flows and breccias, tuffs, ribbon cherts, argillites, conglomerates, graywackes, and lithic sandstones which may reach a thickness of 10,000 feet or more.

Limestones of Wolfcampian age on Orcas Island, Washington, contain *Mizzia* in association with bryozoa and the fusulinids *Schwagerina* and *Pseudofusulinella*. Limestones of probable early Guadalupian age on the south side of Mount Pilchuck in Snohomish County, Washington, contain *Mizzia* and *Gyroporella* associated with the fusulinids *Cancellina* and *Schubertella*. Upper Guadalupian age limestones of San Juan Island and western Snohomish County, Washington, contain *Mizzia* and other green algae associated with fusulinids of the *Neoschwagerina-Verbeekina* zone. The youngest Permian limestone, containing the *Yabeina* fusulinid zone (Ochoan?), near Granite Falls, Washington, and near Ashcroft, British Columbia, contains *Mizzia* and several other dasyclads.

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STRATIGRAPHY OF THE STEEP ROCK GROUP, STEEP ROCK LAKE, ONTARIO, AND EVIDENCE FOR EVOLUTION OF THE PRECAMBRIAN ATMOSPHERE

Knowledge of the stratigraphy has provided the surest guide in iron ore exploration and development at Steep Rock Lake. Most and possibly all of the 33 million tons produced has come from a single stratigraphic member.

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The Steep Rock group lies unconformably on a granite complex. The basal unit is a conglomerate succeeded by the Dolomite, Orezone and Ashrock formations. Intense deformation is indicated by steep dips, brecciation, shear folds, and numerous faults and dikes, but thermal effects are negligible, and Precambrian limonite and bauxite have remained unaltered.

The Orezone formation has three members. The lowermost of these, the Manganiferous Paint member, is up to 1,000 feet thick, is mainly below ore grade, and represents a residuum derived from the Dolomite formation which it overlies disconformably. The middle, or Goethite, member is up to 300 feet thick, is dominantly goethitic iron ore, but includes minor aluminous and cherty sediments and, in a few places, lenses of ferruginous bauxite. The uppermost, or Pyrite, member occurs sporadically along and near the contact of the Orezone with the overlying Ashrock formation. Microcolloform structures in the pyrite, paucity of trace elements, and association with carbon and banded chert indicate a sedimentary origin for this member.

Valency changes in iron and manganese within the Steep Rock group suggest that deposition spanned a critical period in atmospheric evolution about 2 billion years ago.

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Size and Distribution of Oil and Gas Fields

In any decision concerned with the strategy and tactics of oil and gas exploration, a key variable is the *size* of hydrocarbon deposits in barrels of oil or in MCF of gas. The size of pool or field discovered in a particular wildcat venture determines the degree to which the venture is an economic success. Since the pool or field size that will be discovered is almost always unknown before a prospect is drilled, an important question is: What functional form should be used to characterize the probability distribution of field sizes in a petroleum province? By "functional form" we mean a mathematical formula which defines a family of distribution functions.

Two types of functional forms are particularly adapted to use in this context—the Lognormal and Pareto-Levy—for several reasons: (1) because they give a good empirical fit to histograms of reported field sizes in barrels of oil or MCF of gas; (2) because they are in concordance with some concepts of the origin of mineral deposits; (3) because stochastic models of the discovery process built on reasonable assumptions about the process lead to these functional forms; and (4) because the Lognormal distribution in particular is analytically tractable and rich enough to capture most reasonable oilmen's quantitative judgments about reported field size.

The Lognormal distribution is highly suited for use in analysis of exploration decision problems, for a particular Lognormal density function is fully specified by only two numbers.

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Primary Structures in the Middle Jurassic Great Oölite Series, Southern England

Primary structures observed in the Great Oölite Series include planar, wedge-shape and lenticular cross-stratification, current and interference ripples, micro cross-lamination, dunes, pseudonodules, loadcasts, graded bedding, mudcracks, groove casts, current lineation, prod marks, and bounce casts. These structures are grouped into two environmental and petrographic combinations.

High-energy, channelled, shelly-oölitic limestones (grainstones) are characterized by vertical sequences consisting of a basal zone of imbricated shell fragments, a middle zone of thick sets of planar and lenticular cross-stratification, and an upper zone of interference and current ripples and wavy beds. The cross-strata show two dip directional maxima which are 180° apart, possess a high dip angle (26° average) and contain thin (1–1.5 in.) graded beds. These graded cross-strata consist of a shell chip zone which grades upward into coarse-grained oölite and fine-grained oölite. The shelly base of such a graded bed thickens and increases in particle size downslope. The oölites were deposited by normal flow in a lower flow regime, whereas the shell chips were deposited by counter eddies eroding the basal channel shell lag concentrate. The primary structures in the channelled limestone were formed in a lower flow regime operating in intertidal zone channels.

Low-energy, even-bedded, oölitic clayey limestone (packestone and wackestone) are characterized by thick (1–5 ft.) graded beds, load casts and cross-stratified grainstone lenses. These cross-strata are low angle (average dip is 18°) and are current lineated if the limestone contains 15–25% quartz sand. The graded beds grade upward from coarse-grained oölite to clay-size carbonate particles. The top of each graded bed is bored and plastered with oyster shells in life position. These graded beds were formed by periodic sea-level oscillations which transgressed subtidal deposits across low and then high tidal flats. The cross-stratified grainstone lenses represent a beach or barrier bar marginal to the intertidal zone.

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Petrology of the Simsboro Formation (Eocene) of Northeast Central Texas*

The lower Eocene Simsboro formation of the Wilcox group, between the Trinity and Brazos Rivers, Texas, was deposited as a braided stream-floodplain complex. It consists of: (a) very fine-grained to medium-grained sand: immature, clay pellet-bearing subgraywacke bordering on an orthoquartzite; (2) illitic-kaolinitic, silty clay; (3) fine sandstone: siliceous, bimodally mature orthoquartzite; and (4) kaolinitic, silty clay.

The fine- to medium-grained, kaolinitic, clay pellet-bearing subgraywacke occurs as channel deposits and exhibits pronounced trough or festoon cross-bedding. The round kaolinitic clay pellets are detrital. The matrix consists of particles of kaolinite worn from the clay pellets and pellets mashed by the harder detrital grains. Thinly laminated (5–20 mm.) silty clay, in lenticular beds up to 20 feet thick, is laterally associated with the festoon cross-bedded channel deposits. Angular pebbles, cobbles, and boulders of this clay, derived from the nearby flood-plain, are locally incorporated within these channel sands. Hard, siliceous orthoquarzite, consisting of fine-grained quartz in a matrix of quartz silt, forms a massive ledge 2–20 feet thick throughout the area. The exact relation of the orthoquartzite to the rest of the Simsboro is not known. A persistent bed of thinly (1 mm.) laminated, white, kaolinitic, silty clay 20 feet thick occurs at the top of the formation.

Orthoclase and microcline grains severely weathered

* Publication authorized by the director of the Bureau of Economic Geology, The University of Texas, Austin.