jectively and with any desired degree of precision.

For example, if a rock (population) is "massive" then no structure is apparent and various sampling patterns will yield equivalently unbiased estimators; on the other hand if the structure is layered, orthogonal patterns, with one parallel and the other perpendicular to the layers, will yield significantly different estimators unless the parallel pattern achieves correct weighting of the layers. In layered populations, patterns perpendicular to layers (channel sampling) will yield unbiased estimators of the population mean and variance; adjusting the parallel sampling pattern to equivalence with the perpendicular supplies information on the weighting, i.e., on the variation within and between layers and hence an estimate of the number of different layers. This then leads to an objective definition of layering.

In practice, when the internal structure is initially unknown, it is necessary to use different sampling patterns to decide whether the population (rock) is structured or massive.

The achievement of random sampling in various "populations," from testing techniques to deciphering "natural" variability, indicates that this procedure is a useful tool in defining the patterned variability or "structure" of a population. It appears to be invariant to change in variate (*e.g.*, measurement or counting) or change in scale (*e.g.*, from an electron micrograph to an outcrop).

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ENERGY SOURCE OF INTRUSIVE MASSES

Textbooks of geology generally fail to discuss the motivating force of intrusive masses. Texture, composition, and shape are dealt with in detail, but the mode of emplacement is ignored. It is here postulated that the energy is almost entirely derived from the geostatic load of the overburden and that the mechanics involved in the emplacement of igneous dikes, volcanic plugs or necks, stocks, etc., is essentially the same as that involved in salt and ice piercements, and even the "frost boils" on northern roads. The mechanics of large basin downwarps is also discussed.

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MATHEMATICAL SIMULATION OF SEDIMENT ORGANISM COMMUNITY INTERACTIONS WITH AN IBM 7090 COMPUTER

An ALGOL-58 computer program has been written by the authors for IBM 7090 or 7094 computers for simulating the interactions of combined sediment-organism communities through geologic time. Although the program is based on a mathematical model applicable to various sea-floor communities, the program has been developed with carbonate sediment-organism communities in mind.

The mathematical model considers the sea floor at a given "instant" in time to consist of a large number of discrete elements arranged on a grid of arbitrary dimensions. Each grid element may be thought of as a square containing a single community and is symbolized by an integer number in a two-dimensional array. Successive "time planes" (sea-floor surfaces) are generated in which the distribution of communities for each discrete instant is printed out using various symbols to identify different communities.

The program employs feedback control loops in which the geographic distribution of communities on preceding sea-floor surfaces influences, but does not rigidly control, the geographic distribution of communities that develop subsequently. The selection of a community element occupying a particular square at a particular moment is treated as a random process influenced by conditional probabilities. The program makes extensive use of pseudo-random number generation methods for selection of individual elements.

The program is being used to study the development of Devonian coral-stromatoporoid reefs, as well as idealized modern sediment-organism communities. Adaptive learning techniques are used to adapt the model to real data. Mathematical simulation should be a powerful oil-finding tool in some regions by yielding greater insight into the behavior of reefs and other sedimentary features and providing improved means of prediction.

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DISEQUILIBRIUM PRECIPITATION OF MOLLUSCAN SKELETAL MATERIAL AND ITS IMPLICATIONS REGARDING THE USE OF TRACE ELEMENTS IN FOSSIL SHELLS AS PALEOECOLOGICAL INDICATORS

An investigation of the distribution of magnesium, iron, manganese, and strontium in the skeletal carbonate of twenty-five specimens of *Crassostrea virginica* and coexisting sea water, supplemented by a compilation and analysis of published and unpublished data on trace element distributions in other marine mollusks, indicates that molluscan skeletal material is not precipitated at equilibrium with coexisting sea water. Calculations demonstrate that the partitioning of minor elements between carbonate and sea water does not follow the Nernst distribution law. It is suggested that during shell construction the growing skeletal crystallites are either (a) at equilibrium with fluids in the depositional tissues whose composition is determined by organic processes, or (b) at complete disequilibrium with surrounding fluids. The results of this investigation explain the poor correlation observed in previous studies between skeletal chemistry and environmental factors, such as water temperature and salinity, and indicate that the trace element content of fossil skeletal material cannot be used for detailed paleoenvironmental reconstruction.

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SEDIMENTS OF THE GULF OF MAINE

The Gulf of Maine is a rectangular depression on the continental shelf about 180 miles long and 120 miles wide. Georges Bank, Browns Bank, and the Nova Scotian Shelf, all shallower than 100 meters, separate the Gulf from the Atlantic Ocean to the southeast. Glacial scouring has accentuated the highly irregular bottom topography, and numerous basins 200 to 377 meters deep are present. Large areas between shallow bedrock ridges and the large flat-floored basins are veneered by poorly sorted mixtures of clay, silt, sand, and gravel, probably derived with very little change from glacial till and outwash. These sediments contain moderate amounts of layer silicates but less than 2 per cent organic matter. The sand-size fraction contains 3 to 10 per cent rock fragments and 10 to 15 per cent dark minerals.

Post-Pleistocene reworking of poorly sorted glacial material by wave and current action near the coast and on the shallow banks flanking the Gulf has produced relatively well-sorted sand, low in layer silicates and organic matter. Some well-sorted material has also been deposited on the flanks of Georges and Browns Banks and in some coastal areas.

Most winnowed fine detritus has accumulated on the flat floors of the deep basins. The sediment there is silty clay composed dominantly of mica, chlorite, and mixed layered mica-montmorillonite. Kaolinite occurs only as traces in a few samples. The minor amounts of sand-size material are composed predominantly of mica and of foraminiferal tests and other biogenic debris. Organic matter exceeds 4 per cent in some of the basins. The carbon/nitrogen ratio of the deposits tends to increase with distance from shore.

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CRETACEOUS DELTAS IN THE DENVER BASIN AND RELATIONSHIP TO PETROLEUM

Early Cretaceous and early Late Cretaceous deltaic sediments of the Denver basin include the oil-producing "D" and "J" sandstones (upper Dakota Group). The very fine- to coarse-grained quartzose sandstones are in part cross-bedded and ripple marked, in part marine, and in part nonmarine; contain coal and carbonaceous or lignitic beds, mud pellets, siderite concretions, interbedded claystones; and in some areas grade laterally and vertically through siltstone into marine shale.

Within the "J" sandstone there is a well-defined delta extending northwestward into the Denver basin in Colorado. There are smaller deltas in western Nebraska, and, between these two areas, there is a narrow marine embayment. A similar deltaic pattern is developed in the "D" sandstone. Petroleum is concentrated in the parts of the deltas that have the greatest interfingering of marine and deltaic deposits.

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ABYSSAL BASIN SEDIMENTATION

Clastic sands and silts transported and deposited by turbidity currents have created the vast abyssal plains of the ocean basins and have constructed the abyssal cones and natural levee systems of the continental rise. Clastic silts and lutites, largely transported by ocean currents, have created much of the continental rise and the outer ridges which parallel the continental margins. Biogenous sediment, resulting from near-surface productivity, more or less redistributed by currents, has created the rolling abyssal swales of productive mid-oceanic areas and has contributed to the continental rise and marginal trench sediments.

Although turbidity currents are responsible for the leveling of the abyssal plains, turbidites constitute less than one-third of the sediments beneath the plains. Horizontal size grading in turbidites away from source areas is detectable but small. Apparently a much more important control on size is imposed by the lower courses of the major rivers. Turbidity currents originate near the mouths of several major rivers at the rate of 50 per century but in many other likely areas none have occurred for thousands of years.

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SUBSURFACE STRATIGRAPHY OF COASTAL GEORGIA AND SOUTH CAROLINA

Sediments ranging in age from Pleistocene to Early Cretaceous (?) overlie metamorphosed basement rocks in most of coastal Georgia, but in southeastern Charlton County there are Paleozoic strata between the Lower Cretaceous (?) and the basement complex. The thickness of sediments ranges from 2,674 feet in Screven County, in the north, to 4,700 feet in Glynn County at the coast; the section thins somewhat toward Florida.

The Quaternary unit includes the surficial clastics of Recent to Pleistocene age. The Tertiary units include the predominantly clastic section of Miocene age; the Oligocene sandstones and their limestone equivalent, the Ocala Limestone; the Lisbon and Tallahatta clastics and their Avon Park-Lake City Limestone equivalents, the Wilcox clastics and their Oldsmar Limestone equivalent, all of Eocene age; and the Clayton and Tamesi Formations and their Cedar Keys Limestone equivalent of Paleocene age. The Upper Cretaceous units include the Lawson Limestone and the equivalent clastics of Navarro age; beds of Taylor and Austin age, both in clastic and limestone facies; and the clastic Tuscaloosa Formation. The oldest unit consists of clastics of Early Cretaceous(?) age; these sediments overlie metamorphosed basement rocks in the north and Paleozoics in the south. Two sections, one coastal and the other inland, show lithologic and faunal relationships which reflect changing depositional environments. Regionally, facies change from clastics in the north to limestones in the south with corresponding changes in microfossil suites. Tentative correlations of the clastic sections with their limestone equivalents are based on lithologic and fossil evidence.

There are no local geologic structures, but the sedimentary rocks of the area show the collective effects of the Carolina arch, the Southeast Georgia embayment, and the Ocala uplift.

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SEDIMENT DISTRIBUTION ON THE INNER CONTINENTAL SHELF, WEST COAST OF SOUTHERN AFRICA

"Sparker" surveys show that the inner continental shelf along a 400-mile stretch of the west coast of South and South West Africa (Olifants River to Luderitz) consists of large areas of virtually sediment-free bedrock and two well-defined elongate bodies of unconsolidated sediment of probable Late Pleistocene-Holocene age.

The sediment distribution pattern is dominated by a strikingly continuous wedge-like body of silts and clays that averages 7 miles in width. This wedge has a maximum thickness of about 80 feet along its inshore edge which lies approximately 3 miles offshore in 200–300 feet of water. Location of the wedge is controlled by a marked steepening in slope of the bedrock surface which coincides with the contact between the Precambrian basement and a sedimentary section of unknown age which dips gently seaward. At the Orange River, the wedge merges with and is overwhelmed by the river's submerged delta.

A second sediment body of lesser extent is the 1 to $1\frac{1}{2}$-mile-wide inshore lens which lies just seaward of the surf zone along a 90-mile stretch south of Luderitz. This inshore lens averages 20 feet in thickness and consists primarily of silty sand and shell material. Gravels, where present, are generally concentrated near the base of the section, and fill irregularities in the dissected bedrock surface. The inshore lens has accumulated shoreward of a series of low discontinuous ridges, and includes re-