where the number of intervals is less than 20% of the total number of identified units. Best results are obtained if coincident layers of identical lithology are treated as a unit facies rather than as multistory facies. The effect of varied identification of lithologies is critical. For example, grouping clay and shale gives markedly different results from cases in which they are distinguished. It can be concluded that (1) Markov tests support current beliefs in that they indicate relative lack of memory in shelf sediments indicating many breaks in sedimentation, and (2) consistent evaluation of facies is critical, as different labels for the same lithology cause large-scale variation in numerical results.

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### Diagenesis of Shaly Rocks

Argillaceous rocks show major chemical and mineralogic trends as a function of geologic age. If the trends are compared by eras, they are of global significance. The ratios of the various metal oxides to $Al_2O_3$ plotted against geologic age form 3 distinct behavioral groups and oxide–$Al_2O_3$ ratios, except those of $K_2O$ and FeO, diminish with increasing rock age.

The first group, water $(-H_2O)$, CaO, and $CO_2$, decreases with rock age from high to very low values. The covariance of $H_2O$ with CaO and $CO_2$ is consistent with a gentle water leach of shale and loss of original calcium carbonate through time. MgO, $Na_2O$, and $SiO_2$ form a second group, but change with geologic age much less than the first group. The chemical trends of these second group oxides, along with $K_2O$, reflect the differences in shale mineralogy as a function of age. The increase in illite percentage in older rocks results in a slight "relative" enrichment in $K_2O$ whereas the abundance of expanded clays in younger shales gives rise to Mesozoic-Cenozoic shales of higher $Na_2O$, MgO, and $SiO_2$ content. This interpretation requires that reactions of the following type obtain within shales in the first few hundred million years after burial: (low silica) kaolinite + (high silica) expanded clay + potassium = (intermediate silica) illite + MgO, $Na_2O$, and $SiO_2$ (lost from shale).

The third group includes FeO and $Fe_2O_3$. There is a reciprocal relation between these oxides; young rocks are high in oxidized iron, old rocks low, but the total iron oxide concentration in shale is almost constant with geologic age. This trend partly reflects the postdepositional oxidation of organic matter and attendant reduction of iron in shales as they progressively age.

These time-dependent chemical and mineralogic trends are in harmony with the general concepts of differential sedimentary cycling and chemical uniformitarianism; concepts that predict approximately the kinds of long-term, postdepositional, selective changes expected in argillaceous rocks as a function of geologic age, and that help to discriminate between primary and secondary chemical and mineralogic features.

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### Sable Island Deep Test of Scotian Shelf

Mobil Oil No. 1 Sable Island was drilled to a total depth of 15,106 ft on the Scotian shelf of the Canadian Atlantic offshore. It was the first deep test in the region. The well, on the outer shelf, 190 mi east of Halifax, Nova Scotia, used historic Sable Island as a drilling platform.

The exploratory test was drilled into the Lower Cretaceous; thus, it not only documented the extension of the submerged Atlantic coastal plain south of Nova Scotia, but also indicated the presence of a thick Cretaceous sedimentary succession in the region.

The well section is predominantly marine clastic rock composed of 4,050 ft of Tertiary and Quaternary, and 11,056 ft of Cretaceous strata. These sequences can be subdivided into 11 units on the basis of sandstone percentage, paleontologic data, and other lithologic criteria. These units indicate the occurrence on this part of the Scotian shelf of fluctuating, mainly marine Cretaceous and Tertiary deposition in littoral to bathyal water depths.

Encouraging but noncommercial gas shows were tested in several zones, particularly in the Lower Cretaceous. A trace of oil was recovered on a test at total depth. Porous sandstone is abundant through most of the section.

The discovery by the Sable Island well of a thick, marine, Cretaceous-Tertiary section with indications of hydrocarbon generation and potential reservoir beds greatly enhances oil and gas prospects in the Canadian Atlantic offshore and the Scotian shelf in particular.

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### Critique of Membrane-Filtration Concepts as Applied to Origin of Subsurface Brines

Membrane-filtration processes capable of filtering dissolved inorganic salts from water have been well documented in the laboratory and in industrial applications (desalination). Application of such processes to earth (sedimentary-basin) models, however, is inadequately documented and subject to several difficulties. These difficulties include the facts that (1) natural pressure gradients adequate to overcome the osmotic pressures required to separate salt from water do not appear to be available or reported in sediment-sedimentary rock environments, and (2) salt exclusion properties of membranes correlate inversely with permeability. To achieve geologically significant enrichment of salts in subsurface fluids requires that large volumes of fluids pass across what would normally be regarded as aquicludes and nonreservoir rocks under relatively leak-free conditions. No proof of such massive movements has been offered. In fact, the consequences of such movements, consistently applied to sedimentary basins, would negate much of the existing principles and practice of petroleum geology and petroleum engineering.

Recent pore-fluid studies from ocean drilling operations show no evidence of membrane filtration in deep-ocean sediments or in geosynclinal sediments from the Gulf of Mexico. These factors contribute to the conclusion that membrane filtration concepts as presently formulated have little importance in enriching subsurface waters in salt, and probably have only minor influence on the ionic composition of subsurface fluids.

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### CHEMICAL COMPOSITION OF OCEANIC WATER DURING TERTIARY TIME; EVIDENCE FROM PORE-WATER STUDIES ON JOIDES DRILL CORES

Chemical analyses have been performed on pore solutions from more than 25 drillholes in the North and South Atlantic Ocean. Several holes penetrated Tertiary-Mesozoic sediments and bottomed in basalt. The data indicate that in the central areas of the Atlantic Ocean the salinity and chlorinity of pore fluids approach the values for bottom waters and vary less than about 1–2% with depth, with a few exceptions. Diagenetic changes in major inorganic ions are relatively minor, regardless of depth, lithology, or proximity to basalt bottom. Significant effects include chiefly loss of magnesium, partial loss of sulfate, and corresponding increases in alkalinity. Nearer the continents, fluid compositions range over somewhat wider limits, especially in the direction of lower salinity. With due allowance for molecular diffusion and other disturbing effects, the data offer no evidence that the oceans varied appreciably in either chloride, salinity, or ionic composition during Tertiary time.

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### PROCESS APPROACH TO DIAGENESIS OF REEFS AND REEF-ASSOCIATED LIMESTONE

Geologic reasoning commonly is based on analogy rather than on process. In facies studies, geology by analogy generally works. Spatial distribution of sediment types is usually in accordance with a few general rules and is therefore repetitive in the geologic record. However, when one approaches diagenetic problems, geology by analogy runs amuck.

The diagenetic modification of a carbonate sediment is a composite of numerous biological, physical, and chemical processes separated in time. Each limestone unit results from a combination of several or all of these processes operating in varying degrees and in varying sequence. It is therefore proposed that a more fruitful approach to problems of carbonate diagenesis is to identify the processes that produce important diagenetic modification in the Holocene and Pleistocene where processes can be studied first hand, and in ancient rocks where late diagenetic processes can be strongly inferred. Then, systematically review this list of processes with regard to the rock units in question to discover which processes are potentially important in these rocks and which processes can likely be discounted for reasons of sedimentary facies, paleoclimatology, paleogeography, or sea level history.

One process approach to diagenetic problems in ancient rocks, is to study those processes which appear to produce significant modification in Holocene and Pleistocene materials.

Marine cementation is becoming well documented as an important void-filling process in certain environments. Certain generalities concerning the marine environment may enable us to predict the location and importance of submarine cements. Although seawater commonly is saturated with respect to calcium carbonate, the amount of calcium carbonate available from any 1 batch of pore water is small. If cement is to grow in the pore space of the submarine sediment, water must either be pumped through the pore space or calcium and carbonate ions must diffuse into the pore space. These requirements for a pump or a diffusion mechanism may grossly limit the environments in which we shall expect to find submarine cementation to be an important process.

The vadose environment (subaerial and above the water table) is the site of important solution and precipitation processes in Pleistocene rocks. The stabilization of aragonite and high-magnesium calcite to low-magnesium calcite provides a basic driving mechanism for both precipitation phenomena and selective solution. Availability and flow of water, combined with shape and mineralogy of sedimentary particles allow for a wide variety of diagenetic fabrics to be formed within the diagenetic environment. Further, carbonate equilibrium in this environment is a complicated composite of equilibrium between the rock and the water, the water and local $PCO_2$, and the local $PCO_2$ and a larger $CO_2$ reservoir. Finally, seasonal variation allows solution and precipitation phenomena to be superimposed although the sediment remains in essentially the same environment.

The freshwater phreatic environment (pore space completely occupied by fresh water) has several unique features primarily related to the fact that mineralogic stabilization occurs more rapidly in this environment than in the associated vadose environment. Because of the differences in solubility of the 2 mineral phases, massive precipitation commonly occurs when water from an aragonitic vadose environment enters a calcite phreatic environment. Solution processes may operate in close proximity to the phreatic environment attendant to $CO_2$ evolution as phreatic precipitation occurs.

Caution should be exercised in ascribing observed diagenetic modification to ill-defined "late diagenetic" processes where there are so many well-defined early diagenetic processes from which to choose.

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### PATTERN RECOGNITION AS GUIDE FOR ESTABLISHING MINIMUM SAMPLING REQUIREMENTS IN REGIONAL STRATIGRAPHIC STUDIES

The recognition of spatial order for facies defined within a sedimentary depositional framework has been accomplished traditionally by descriptive methods. This approach has limited the progress made at attempts to establish minimum sampling requirements necessary to delimit the major depositional patterns in regional stratigraphic studies. A more quantitative approach can be taken if one considers the spatial arrangement of facies as a problem in multivariate pattern recognition. This has led to the development of a statistical method for analyzing multiphase mosaics expressed in map form. Nearest-neighbor theory has been combined with cross-association analysis to provide estimates of geometric parameters defined for different classes of depositional environments. On the basis of areally sampled data, a derived pattern can be judged either as being random, in which more detailed sampling is indicated, or as being nonrandom, in which the observed pattern is compared with one of several reference patterns whose geometric parameters are specified. The sample size required to attain any desired level of correspondence for any given reference pattern can be established. The Mississippi deltaic plain was chosen as a test example of the method. Based on areal sampling, a 10% random sample is sufficient to delineate the major depositional framework, and a followup 30% systematic sample is sufficient to delineate the major facies trends. Considering the increasing cost of data storage