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

and retrieval, this approach has potential value for future planning of regional subsurface stratigraphic studies.

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MARINE GEOLOGY OF EASTERN CONTINENTAL MARGIN OF CANADA

The outer continental shelf of eastern Canada, from Georges Bank to Ellesmere Island, is mainly smooth compared with most of the land on the west. This submerged "prairie" ranges from 10 to 300 mi wide. It is the northern extension of the coastal plain of the United States that is partly exposed on land as far north as Long Island. North of Long Island there are no documented marine fragments of plain sediments on land. The depth of water on the banks south of 48°N lat. is about 200 ft. In contrast, north of the 48° parallel, the average water depth is about 450 ft. The shelf is partly covered with Pleistocene ground moraine. Cenozoic and Mesozoic rocks crop out or are close to *in-situ* positions along some of the submerged valleys.

It has been known for decades that most of the submerged coastal plain is underlain by fairly low-velocity sediments up to 25,000 or more ft thick. It can be speculated that these fairly soft strata (low velocity) are not older than Triassic because drifting and rifting probably started to make basins available to be filled at that time. The beds are mainly sandstone and shale. The source areas on the west are Precambrian and the folded Paleozoic rocks of the Appalachians. One speculation is that the Precambrian perhaps yielded a sandier section than the Paleozoic rocks because of the dominance of carbonates, volcanics, and shales in the Appalachian area.

Drilling on the Grand Banks and Sable Island has shown that hydrocarbons are present. It is known that almost all the stages are present from Pleistocene to Upper Jurassic. Salt is present but its age is still only assigned to the Jurassic or earlier. It is tempting to speculate that the salt is Permian and a western segment of the North Sea salt.

Salt dome structures are present as are "basement" features.

This large frontier area is an attractive place to look for large petroleum reserves.

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SEDIMENTOLOGIC MODELS FOR CARDIUM OF SOUTH-CENTRAL ALBERTA

The Cretaceous Cardium Formation, throughout 10,000 sq mi of the Alberta basin, is composed of almost contemporaneous, noncontiguous sandstone bodies which are present as far as 100 mi east of the maximum regression of fluvial and lagoonal lithofacies.

Individual bodies are separated by marine shale and consist of 1 or more linear bars, which abut abruptly against shale on the basinward flank. The sandstone is coarser and cleaner toward this flank, which is fringed by conglomerate in many places. The base of the sandstone is transitional with the underlying shale through a sequence that becomes coarser toward the top. These gross features of Cardium stratigraphy are unlike a normal cycle of shoreline regression.

Comparison is made with models based on 4 basic variables: vectors of sediment supply and dispersion, void space due to subsidence, and volume filled by sediment accumulation.

Models representing delta progradation and turbidity-current deposition are characterized by continuity of supply and dispersion and gradational relations between sandstones and basin shales. Models representing shoreline progradation have discontinuity between supply and dispersion resulting in abrupt basinward contacts, but require juxtaposition and diachroneity of continental, littoral, and basinal lithofacies. Reworking on transgression results in a regional disconformity of which there is no evidence in the Cardium.

A model representing vertical accretion (shoaling) on a shallow stable shelf with localized sand accumulation satisfies all critical observations.

Comparison with appropriate modern areas of sedimentation indicates that the post-Pleistocene rise of sea level has imposed limitations on uniformitarian analogies.

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BED THICKNESS IN EXPERIMENTAL TURBIDITES

Turbidity currents were produced by releasing suspensions of glass beads from a lock into a horizontal, water-filled channel. The channel was 15 cm wide and 6 m long. Two sizes of mixing chamber were used with lengths of 29 and 59 cm. Other variables were grain size, d; concentration by volume in the original suspension, C; depth of suspension and water in the channel, H; and sorting of the sediment. These variables were related to the thickness of the bed close to the release gate, t.

For nearly uniform grain sizes, the results may be summarized by a series of power equations: $t = k_1 d$; $t = k_2 C^{0.7}$; $t = k_3 H^{0.4}$; $t = k_4 L^{0.5}$ (L is the length of the mixing chamber). The relation between t and d differs from that in natural turbidites, where the exponent of d is generally less than unity. Preliminary results with sediment mixtures indicate that poor sorting changes the shape of the bed to a more tapering profile, and results in transport of coarse particles farther down the channel.

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INTEGRATED EXPLORATION ECONOMICS IN WYOMING: VIEWPOINT OF GEOLOGIST

Wyoming's general economy is dependent on its exploration geologists and the half-billion-dollar productivity of its minerals industry. Extraordinary uranium discoveries in sedimentary rocks, broad-scale leasing for coal, and an abnormally high, record-setting, wildcat success ratio of 10:1 in the petroleum industry have been contributing factors.

Integration of mining and petroleum activities in Wyoming have prompted modifications in exploration programs and resulted in improved evaluation techniques. Increased intercompany communication and improved industrial-related services have helped to broaden the economic perspective.

Although economics continues to influence the ebb and flow of exploration at the individual company level, it plays only a subordinate role in the overall statewide picture. Geologic prospects rejected by 1 company as not economic are quickly absorbed by another. Marginal prospects have become successful ven-