COMPACTION PHENOMENA IN GYPSUM AND ANHYDRITE

Anhydrite can be precipitated from natural brine in the presence of gypsum in the temperature range of 60°–70°C. Below this temperature range and within the anhydrite stability field, the rate of growth is extremely slow. Growth of gypsum in brine in the presence of anhydrite within the gypsum stability field is rapid. Recent anhydrite in the Persian Gulf in general occurs above the free-water level in supratidal sediments. It is postulated that this anhydrite is formed in the dark sediments during the hottest summer days and is preserved throughout the year in the partly dry sediments because of lack of water. However, at temperatures below approximately 23°C. in the presence of sea water which has been evaporated to precipitate halite, or at higher temperatures in less concentrated brine, the anhydrite will be dissolved and gypsum will precipitate. Thus, with burial of a few feet below the free-water level, any surface anhydrite should be dissolved easily and gypsum precipitated, at least during winter, at any known mean annual temperature. Only gypsum would be carried into the subsurface, despite the fact that anhydrite may have formed at or near the surface. This gypsum, and all original gypsum, will be replaced by anhydrite with burial to a depth of 500–2,000 feet, depending on the salinity of the subsurface water and on the geothermal gradient. During this stage, there will be at least a 38-per cent volume reduction of the solid. It is unlikely that this volume will be compensated by addition of anhydrite from an outside source because of the generation of abnormal fluid pressure and, thus, outward water flow during the gypsum-anhydrite replacement. Anhydrite in the subsurface commonly is devoid of pore space, indicating additional compaction. Therefore, ancient anhydrite sections must represent approximately one-third of their original depositional thickness. Because much of the volume reduction is delayed, the compaction and any dissolution of evaporites provide a mechanism for increasing and perpetuating the subsidence of an established evaporite basin in addition to and after its tectonic history.

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DIAGENESIS IN ESTUARINE SEDIMENTS

Diagenesis in estuarine sediments is affected by broad physical and chemical environmental patterns, the nature of which is becoming clear. The bottom environment is influenced most fundamentally by physical conditions, such as the pattern of water movements and the stability of the water column from place to place. Physical parameters are distinctly different in three major regimes of estuaries, the distributary reaches, the mixing zone, and the saline basin. Location and extent of each of these regimes are determined in any system by the interaction among fresh-water discharge, tidal range, channel geometry, and wind effects. The Rappahannock River estuary and the Po River delta illustrate contrasts in such physical differentiation.

In estuaries the environment for diagenesis is imposed by a determining physical background and the supplemental operation of chemical and biological processes. Variations in pH, Eh, and in dissolved silica and attainment of sulfide equilibrium illustrate the interaction between physical milieu and bottom chemistry. There is a class of chemical interactions (pH adjustment, ion exchange) which proceed instantaneously when fresh-water sediment enters the marine zone. There is another class that requires physical stability in the bottom sediments before equilibrium is approached (dissolution of silica, sulfide equilibrium). This latter class of reactions is the starting point for diagenesis. The initial stages of diagenesis begin just below the sediment-water interface in estuaries.

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PARACONFORMITIES

The stratigraphic succession is the net result of sedimentary deposition, non-deposition, and erosion within constantly changing environments. Consequently, rock strata are heterogeneous and interrupted by countless discontinuities, many of which are not readily apparent. The radiometric scale of geologic time firmly supports Joseph Barrell's theoretical conclusion that sedimentary rocks of any locality represent a small fraction of the time spanned by the formation of those rocks. Parallel evidence is supplied by the fossil record. In other words, the aggregate stratigraphic hiatus, recognized or concealed, greatly exceeds the preserved rock and fossil record.

The term *unconformity* (and its variants, disconformity and discordance) is employed generally for physically conspicuous stratigraphic discontinuities with inferred hiatuses. Existing confusion may be avoided if the antonym *conformity* is applied only to probably rare examples of strictly continuous deposits free from diastems, paraconformities, and disconformities. A preferred structural designation for indicating parallel bedding planes is *concordance,* whereas angularity of sedimentary contacts may be referred to as *discordance.*

The writer's observations of paraconformities in craton areas of the Colorado Plateau, Rocky Mountains, Mid-Continent, Mississippi Valley, Ohio Valley, Sweden, Andes of Peru, Salt Range of India, and elsewhere have led to the conclusion that present-day configurations of erosion and sedimentation do not yet provide an obvious explanation of ancient paraconformities. There is a surprising lack of evidence of protracted subaerial erosion such as soil profiles, sinks, and channels along paraconformities. This suggests extensive planar erosion or non-deposition near, or below, sea-level for long spans of time. Evidently, relative sea-level for long intervals rarely fell far below the land surface of the cratonal areas.

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CONODONT ZONES IN SALAMONIE DOLOMITE AND RELATED SILURIAN STRATA OF SOUTHEASTERN INDIANA[1]

Conodont zones recognized in the Brassfield Limestone and the Salamonie Dolomite (includes the Osgood and Laurel as members) in southeastern Indiana and adjacent Kentucky generally are comparable with Zone-I, the *celloni-* and *amorphognathoides*-Zones, and probably the *patula*-Zone established by Otto Walliser in the Carnic Alps. Differences in generic composition of the European and Midwestern faunas and apparent range extensions suggest a more complex zonation than that established by Walliser.

[1] Published with permission of the State Geologist, Indiana Geological Survey.

Although the conodont fauna of the Brassfield Limestone conforms in general with that of Zone-I, it appears to be transitional with the *celloni*-Zone fauna in southeastern Indiana, where the formation is younger than in its type area in east-central Kentucky. Correlation with the European sections is made more difficult because specimens assigned by Walliser to *Icriodina irregularis* and considered by him to be indicative of the upper part of Zone-I may in fact belong to *Scyphiodus*, a genus that is present in beds as young as the lower part of the Clinton Group in Ontario. A new platform-type genus derived from *Spathognathodus* is first recorded in the upper part of the Brassfield.

Above the Brassfield Limestone in its classic concept is another lithologic unit, tentatively assigned to the Brassfield, that has a mixed conodont fauna. The conodonts considered indigenous include *Icriodina irregularis, Hadrognathus staurognathoides, Carniodus* spp., *Spathognathodus celloni, Pterospathodus amorphognathoides,* and new species thought to belong high in the *celloni*-Zone. Overlap of *S. celloni* and *P. amorphognathoides* shows extension of the known range of one or both species. The conodonts of this zone are morphologically unstable, but the thinness of the unit and admixed material, including Ordovician specimens, do not allow recognition as yet of precise evolutionary development and zonation.

The conodonts in the basal part of the overlying Salamonie Dolomite belong in the *amorphognathoides*-Zone and include *Pterospathodus amorphognathoides* and *Ozarkodina gaertneri.* In Europe the upper terminations of these two species and *Carniodus* coincide, whereas in the Cincinnati arch area the two extend considerably above the highest level of *Carniodus.* These facts suggest that an unconformity is present in the Carnic Alps between the *amorphognathoides*- and *patula*-Zones. If so, most of the Salamonie above the lower beds that contain *Pterospathodus* may represent an unrecorded time interval, but it is possible that the absence of *Kockella patula* reflects provincialism.

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CONSOLIDATION CHARACTERISTICS OF SELECTED NORTH PACIFIC SEDIMENT CLAYS

A recent theoretical analogy of the consolidation process of clay-type sediments, with reference to their viscous resistance to compression, indicates that engineering properties other than rheology can be determined from the consolidation test. A consideration of the lithology of selected north Pacific sediment cores, correlated with consolidation and other soil-mechanics test results, verifies this conclusion. In this circumstance the pore fluid functions as a highly viscous media which controls the deformation of such sediments under load. A mathematical statement of this viscous resistance to compression is combined with a new stress equation to present a statement which adequately expresses the consolidation process. Interpretation of consolidation curves using this approach enables prediction of viscous resistance to shear. This resistance is controlled primarily by stress level and to a lesser degree by compositional factors. These studies are supported by the conclusions of other researchers of the mechanical behavior of such materials.

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SEDIMENTOLOGIC PROCESS ANALOGIES BETWEEN EARTH AND MOON

(No abstract submitted.)

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PALEOGEOGRAPHIC AND PALEOECOLOGIC ANALYSIS OF PLANKTONIC FORAMINIFERA

Abundance studies of extinct planktonic Foraminifera are proving a fruitful method of paleogeographic and paleoecologic analysis. Population counts of species and genera in fossil faunal assemblages give approximate percentage figures for paleo-faunal studies. Comparison of population data between two or more stratigraphic sections can be used as an indication of paleo-faunal differentiation and can outline paleogeographic distribution of species. Abundance analysis based on faunal sequences appears to reveal patterns that are repeated within sections from the same faunal province.

Application of this method of analysis to planktonic foraminiferal faunas from Maestrichtian and Paleocene assemblage zones in selected sections of the Atlantic, Gulf, and Mediterranean regions indicates distinct paleogeographic and paleoecologic differentiation. Broad generic distributions are evident, whereas there are more distinct geographic limitations on species in the Maestrichtian and Paleocene. There also is some indication of possible geographic subspecies variation. The most marked differentiation occurs along lines of longitude with more favorable comparisons and less marked differences along lines of latitude. A greater number of genera and species are found in low latitudes than in high latitudes in rocks of the Maestrichtian and Paleocene.

Faunas from sediments deposited in shallow-water environments are characterized by a limited number of species. The species that do occur usually are the most abundant elements in the planktonic faunas found in sediments deposited in deeper-water environments.

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APPLICATION OF WATER-CLASSIFICATION METHODS TO WATERS FROM CARBONATE FORMATIONS

Many reports of formation-water analyses show determinations for only carbonate, bicarbonate, sulfate, chloride, calcium, magnesium, and sodium ions. An attempt to utilize these analyses has been made by using the methods of Palmer, Sulin, Schoeller, and Chebotarev to classify some waters from carbonate and other types of formations. The purpose of this study is to determine whether these methods effectively classify waters associated with petroleum formation and whether this information can be used in exploration or the identification of formations.

It was found that the more extensive water-classification methods of Sulin and Schoeller better classify waters associated with petroleum formation than the methods of Palmer and Chebotarev. In this study, waters that were classified by Sulin's method as chlo-