an area can be displayed in a form acceptable and familiar to the experienced geologist. The amount and quality of the displayed information will give the geologist more information, in an objective form, than has ever been available previously. This information, interpreted by the experienced geologist, will result in a higher quality of "decision making" than has been possible previously. Use of a computer will not enable the reduction of an exploration staff, but properly used, will increase the need for experienced geologists and increase the "success ratio."

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DETRITAL DOLOMITE IN ONONDAGA LIMESTONE (MIDDLE DEVONIAN) OF NEW YORK: IMPLICATIONS TO "DOLOMITE QUESTION"

Dolomite occurs in the matrix of the Onondaga Limestone (Middle Devonian) in New York as scattered grains ranging in size from 4 to 150 μ. Detrital quartz is associated with the dolomite. Study of etched and stained thin sections shows a correlation between grain size of the dolomite and quartz. Limited data show a correlation between grain size of dolomite, quartz, and detrital calcite (silt to fine sand) matrix. In addition there is a correlation between abundance of dolomite and quartz, where high dolomite values occur with high quartz values.

These data suggest that dolomite in the Onondaga is detrital. Source of the dolomite is uncertain, but reworked, penecontemporaneous supratidal sediments and older (for example Silurian) dolomites are possibilities. Wind is a likely mechanism for transport of the detritus.

Deposition of detrital dolomite, followed by later diagenetic overgrowths on the detrital nuclei is suggested as a mechanism for "dolomitization." This process is compatible with the following phenomena observed in dolomitic rocks: (1) association of insoluble detritus with dolomite, (2) occurrence of dolomite in fine-grained limestone, and (3) dolomite interpreted as "primary" (being fine grained) and dolomite interpreted as "replacement" (being coarse grained). Two models for the origin of dolomitic rocks are proposed.

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PALYNOLOGY OF KAIPAROWITS FORMATION, GARFIELD COUNTY, UTAH

The Kaiparowits Formation is the youngest Cretaceous unit in central-southern Utah. One 2,750-ft-thick section of the formation was measured, described, and sampled in the type locality, The Blues, Garfield County, Utah. Palynological documentation is based on the study of 15 samples distributed throughout the formation. Palynomorphs assignable to 80 species in 41 genera were described. One genus and 36 species are believed to be new.

The Kaiparowits Formation is equivalent to the upper Lance or Hell Creek. *Aquilapollenites* spp., *Azolla cretacea* Stanley, and *Proteacidites* spp. proved to be of greatest significance for correlation and dating purposes. Comparisons of the entire flora also indicated that the Kaiparowits Formation is Late Cretaceous.

The lower 2,200 ft of the Kaiparowits Formation was deposited as a delta in a rapidly subsiding basin. The sediments indicate a western provenance—probably central or western Nevada. The Blues was in the fluvial part of the delta with low, marshy or swampy topography. Uplands and semi-arid to arid areas also were present within the drainage basin. Sedimentation of the upper 550 ft of the formation was probably similar to that of the lower 2,200 ft, but is incompletely understood. Considerable volcanic activity in the region is indicated by the presence of large volumes of bentonitic material within the formation. No evidence was observed to indicate that any of the Kaiparowits Formation in this area was deposited under marine conditions.

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RECOGNITION OF EVAPORITE-CARBONATE SHORELINE SEDIMENTATION

Evaporitic-carbonate shoreline sediments are deposited in an arid or semiarid climate by tidal currents which transport the sediment from the marine environment to the shore. The sediments accumulate primarily as tidal-flat deposits which prograde seaward producing a vertical sedimentary sequence from marine to supratidal. The supratidal sediments are the most easily recognized. They are characterized by irregular laminations, desiccation features, lithoclasts, and a general lack of fossil material. The intertidal sediments are more difficult to identify. They commonly are pelleted carbonate mud with burrows and a restricted fossil assemblage. Gastropods are dominant in many places. The vertical sedimentary sequence is the most useful tool to identify intertidal sediments. The sediments just below the supratidal are generally intertidal sediments.

The arid or semiarid climate allows seawater to evaporate and become saturated with respect to gypsum or anhydrite when the water circulation is sufficiently restricted from the open ocean. Primary bedded gypsum is precipitated in shallow lakes in the tidal-flat environment. In order for gypsum to be deposited in lagoons connected to the open sea by a channel, the ratio of the surface area of the lagoon to the cross sectional area of the channel must be about 10^6. Most gypsum or anhydrite associated with shoreline sediments is present as nodular, replacement, or pore-filling crystals. This type of evaporite is secondary and crystallized from hypersaline interstitial water. The hypersaline interstitial water is the result of evaporation at the sediment-air interface. Bedded gypsum or anhydrite, then, indicates the existence of a hypersaline lake or lagoon environment whereas nodular, replacement, or pore-filling gypsum or anhydrite is secondary and is found in marine, intertidal, and supratidal sediments.

The precipitation of gypsum or anhydrite from seawater produces a dolomitizing fluid according to the reflux dolomitization theory. This type of dolomitization starts in the supratidal sediments and spreads into the underlying sediments. Therefore, extensive dolomitization associated with tidal-flat sedimentation indicates evaporitic shoreline sedimentation.

Evaporites are removed easily by shallow groundwater. They are not well preserved in outcrops, and most commonly they are absent. Comparisons of subsurface anhydrite and outcropping shoreline sediments show that, in many places, the anhydrite or gypsum has been leached from the outcrop samples leaving molds and in places producing solution collapse breccias. Calcification of anhydrite or gypsum and dolomite is common. The recognition of evaporitic shoreline sedimentation from outcrop samples commonly makes it necessary to establish whether dissolution of evaporites and calcification of dolomite and anhydrite or gypsum have occurred.

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PALEOECOLOGIC ASPECTS OF TRACE FOSSILS[1]

Many physical aspects of the depositional environment in which some rocks are formed may be reconstructed with the aid of trace fossils such as tracks, trails, borings, or other evidences of organism activity. Trace fossils are extremely abundant in sedimentary rocks of all ages, but commonly have not been used by geologists as an aid in paleoecologic interpretation. Water depth, salinity, current action, relative acidity, kinetic energy of the depositional environment, rate of sedimentation, and mode of life of the organisms may be deduced by using trace fossils as an interpretation tool.

Orientation of trace fossils in beds may indicate approximate directions of current action, whereas the type of trace preserved connotes the habitat preferred by the organism. Vagile, benthonic, filter-feeding organisms commonly build nearly vertical burrows; detritus-feeding organisms tend to burrow horizontally. Filter-feeders live in an environment where the current velocity is sufficient to winnow fine particles; detritus-feeders live where fine-grained sediments and finely divided organic matter slowly settle from the water. Delicate tracks and trails preserved in rocks are indicators of a calm environment and slow sedimentation rate, whereas tubes, burrows, and borings are built and preserved in current-activated waters.

In sedimentary rocks that are lacking skeletal or body fossils, trace fossils are valuable aids for use in reconstructing the physical history of the depositional environment.

[1] Publication authorized by the Director, U.S. Geol. Survey.

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UPPER DEVONIAN AND LOWER MISSISSIPPIAN SEDIMENTARY RECORD, WESTERN CANADA SHELF

Western Canadian Upper Devonian and Lower Mississippian shelf rocks, several thousand feet thick, are characterized by three sedimentary domains: a carbonate-evaporite area on the southeast (Saskatchewan), a central area dominated by carbonates (Alberta), and a terrigenous clastic and argillaceous carbonate area on the north (northeastern British Columbia). The carbonate-evaporite and carbonate domains include sabkha-type microdolomite-evaporite cycles, as well as barriers and blankets of skeletal and nonskeletal limestones. Although many of these rocks compare closely with sediments of certain Holocene carbonate settings, the makeup of these fossil sediments tends to be distinctive at various stratigraphic levels.

To illustrate: within the carbonate domain (Alberta), the Frasnian Stage contains wave-resistant organic reefs in which stromatoporoids and colonial corals are abundant. In contrast, reefs, stromatoporoids, and colonial corals are almost unknown in Fammenian strata, most of which form an extensive blanket of nonskeletal limestone with evaporites and redbeds on the east. A widespread black shale unit caps the Fammenian. Kinderhookian rocks are argillaceous carbonates in which echinoderm detritus increases upward. Although colonial corals reappear in the Kinderhookian, the Mississippian lacks organic reefs. The Osagian is distinguished by an explosive and geologically unique development of echinoderms—the main source of the enormous volumes of skeletal sands of this age which cover much of the area—and also contains well-developed cyclic lagoon-sabkha sediments.

Two dominant factors that influenced Late Devonian–Early Mississippian sedimentary patterns on this continuous shelf are oscillatory variations in water depth (probably tectonically controlled) and change in composition of the dominant fauna and flora from frame-builders to sediment-contributors.

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FORAMINIFERAL TEST AS AN ENVIRONMENTAL BUFFER

Despite many studies of foraminifers, very few suggestions have been made concerning the function of the test. If the adaptive significance of the test were known, this would provide a theoretical basis for understanding the ecological importance of test shape and construction.

Observation of the behavior of many shallow-water species in response to environmental changes indicates that the test may function as a chemical and physical buffer between the organism and the environment. Shallow-water foraminifers construct a test of much larger volume than needed merely to house the living protoplasm. Under conditions of stress, *Sorites, Planorbulina, Bolivina, Discorbis,* and miliolids occupy only the inner chambers of the test; the outer chambers may be filled with a less dense, highly vesiculate cytoplasm, or may be empty. If the individual chambers of the test are connected only through one or a few small openings, adverse osmotic effects produced by changes in salinity can affect the protoplasm only slowly. Complex tests may thus serve as a baffle to reduce the rate of chemical diffusion.

Some chambers are sites of concentration of symbiotic algae. In *Elphidium,* algal-filled chambers are in communication with each other, but the apertures of the final chamber are sealed. The foraminifer communicates with the outside only through the tortuous passageways of the canal system except during relatively brief intervals of chamber addition. The test functions as a protected greenhouse for the foraminifers' symbiotic algae.

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ENVIRONMENTAL INTERPRETATION OF UPPER PART OF MESAVERDE FORMATION, NORTHWESTERN COLORADO, FROM OUTCROP, CORE, AND SUBSURFACE STUDY

Various lines of evidence, such as the vertical succession of gross lithologic character, textures, and sedimentary structures, the fauna, and the geometry of rock stratigraphic units, indicate that the upper part of the Hayden Gulch outcrop section of the Mesaverde Formation in northwestern Colorado is a sequence of former barrier islands and lagoons intertonguing with overlying offbeach marine shale of the Lewis Formation. The collective criteria used to recognize the different depositional environments at the outcrops were readily apparent in a core taken along depositional