binding processes appear to be involved: (1) crusts of organic origin, commonly concentrically layered deposits of red algae, Foraminifera, and Bryozoa, and (2) thick, laminated, lithified, micrite crusts with a smooth to nodular surface, preferentially accreted upward and not clearly associated with any calcareous taxa. The organic crusts commonly occur just under the reef surface, whereas the hard concretionary crusts are common deeper within the reef, lining the numerous channels and cavities that permeate the framework.

Many of the reef pores (both the primary inter- and intra-framework pores and also cavities produced secondarily by boring organisms such as *Cliona*) are filled with lithified sand, micrite, or acicular crystalline cement. Just beneath the reef surface is extensive lithification of poorly sorted micritic sediments between and within the framework. Sand trapped in inter-framework cavities is consolidated by drusy cements. In many places, the lithified material is bored by *Cliona* and the resulting cavities are refilled and relithified, indicating that these processes occur at a rapid rate.

Similar features are recognized in Pleistocene reefs on the north coast of Jamaica. This observation suggests that the lithification processes are common in time as well as in space.

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Paleozoic Carbonate Facies of Central Appalachian Shelf

The central Appalachian shelf, which received sediments discontinuously throughout the Paleozoic, is bounded on the north by the Precambrian crystalline rocks of the Adirondacks, on the west by the Cincinnati arch and on the east by geosynclinal basins. Major carbonate sequences were deposited during the Late Cambrian-Early Ordovician (Conococheague, Beekmantown), Middle Ordovician (Black River, Trenton), Middle Silurian (Lockport), Late Silurian-Early Devonian (Tonoloway, Keyser, Helderberg), and Middle Devonian (Onondaga). Minor, but equally interesting, carbonate units were deposited during the Middle Devonian (several thin limestones within the Hamilton) and Late Devonian (Tully).

Recent environmental stratigraphic studies of these carbonate rocks show a great variety of lithofacies and biofacies. Despite this great diversity, four major facies complexes can be characterized.

Tidal flat deposits, consisting of laminated, dolomitic, mud-cracked, intraclastic rocks with low faunal diversity and algal structures, are well developed in the older carbonate units (Conococheague, Beekmantown, Black River, upper Lockport, Tonoloway, Keyser, and lower Helderberg). These rocks were formed in supratidal and intertidal environments.

Shallow subtidal deposits, consisting of biomicrite (generally well burrowed), biosparite (in many places current stratified), and some oösparite with relatively diverse and abundant biotas, are particularly common in the middle part of the Cambrian-Devonian carbonate sequence (upper Black River, Trenton, middle Lockport, Keyser, Helderberg, and Onondaga). These rocks record restricted- to open-marine environments above, or slightly below, effective wave base.

Deeper subtidal deposits, consisting of well-burrowed impure biomicrite with less abundant and less diverse biotas, are more typical of the younger part of this interval (Onondaga, Portland Point, and Tully). These strata formed in open-marine environments below effective wave base.

Carbonate buildups are found throughout the Cambrian-Devonian either as small algal mounds (Conococheague, Beekmantown, Lockport), tabulate or stromatoporoid biostromes (Black River, Lockport, Keyser, Helderberg, Tully), or as bioherms dominated by rugose and tabulate corals (middle Lockport, Helderberg, and lower Onondaga). Fossil diversity and abundance are greatest within the biostromes and bioherms.

As might be expected, the temporal distribution of these broad facies complexes parallels the Paleozoic tectonic history of the central Appalachians. Thus, during times of tectonic stability carbonate tidal-flat and shallow subtidal deposits were abundant. As tectonism increased in the eastern geosynclinal terranes, the nearshore areas of these environments were flooded by land-derived terrigenous clastics. Greater subsidence of the shelf areas also seems to have been general, with the result that deeper water carbonate became more common. Carbonate buildups seem to occur in a wider variety of environmental situations. Although related to the general tectonic regime, they also were dependent on good marine circulation and local paleogeography.

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Markov Forecasting Techniques in Exploration

When preceding events influence succeeding events, a certain probability can be calculated for the process, which is said to possess the Markov property. An increasing number of geologic processes have been described that demonstrate this property, and the behavior of exploration geologists frequently is no exception. Markov methods allow a reasonably limited number of exploration factors to be considered together on a probability basis. A particular advantage is that factors having different dimensions, such as barrels of oil, the density of seismic coverage, or the cost of drilling, can be evaluated together for forecasting purposes.

Small Markov studies can be undertaken without a computer, but for larger models it is both simple and desirable to use a computer. A forecasting model should include consideration of environmental conditions (the historical events), the alternative choices (the possible outcomes from which the optimum forecast may be derived), and the weight attached to each factor.

Forecasts can be made for two general areas. Within a company, the exploration environment conducive to success is worthy of investigation, as is the efficiency of the exploration process. From a competitive viewpoint, the behavior of other companies is of interest as advantage can be taken of any known Markov tendencies in their exploration policies. Geologists should use Markov methods to reduce the uncertainty of decision making to finite probability. This will result in an increased success ratio.

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Practical Computer Usage for Subsurface Geologists

Techniques for proper utilization of the computer need to be developed by experienced subsurface geologists thoroughly familiar with the computer programs used in solving exploration problems. Output from the computer is not the end result, but is the beginning point for the exploration geologist. The "geology" of 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