tary history on either side of it and internal changes of formations extending into it.

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ASMARI OIL FIELDS OF IRAN

The Asmari oil fields of Iran are truly giants, most of them having recoverable reserves greater than 1 billion bbl, in many fields much more than that. The fields are closely packed in a region of relatively constant stratigraphy and structure, and have a common genetic relationship. The individual accumulations occupy very large rock volumes in large-amplitude folds and, although the reservoir properties of the Asmari are poor in terms of porosity and matrix permeability, very high production rates are possible because of extensive reservoir fracturing. These rates can be maintained for very long periods because of the great vertical extent of the oil columns. The Asmari fields are prime examples of anticlinal traps and of the effect of fracturing on reservoir performance.

The Asmari reservoir is a limestone of Oligo-Miocene age and consists mostly of shallow-water but nonreefal carbonates with a significant sandstone member developing in the northwest part of the area. The Asmari is the uppermost wholly marine unit in a sequence of shelf carbonates interspersed with shale which was deposited, with only minor interruptions, from Carboniferous through Oligo-Miocene time. At the end of the time of Asmari deposition, increasing tectonic instability caused more varied sedimentation; this phase of instability terminated in a strong orogeny which formed the enormous anticlinal traps in this thick sequence of sediments.

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ALTERNATE MODELS OF COMMUNITY VARIATION

Much ecological and paleoecological work is based on a quantitative study of the relative abundance of species. Such studies attempt to interpret geographic or stratigraphic trends in terms of ecologic gradients. If the trend for each species is considered separately, interpretations relatively are straightforward. It is advantageous commonly, however, to search for patterns of covariation among species; if present, they sharpen and simplify environmental interpretation, and provide some basis for synecological reconstruction.

Discovery and description of covariation patterns are not straightforward, and it is helpful therefore to have available several alternate models of community structure along an ecological gradient. One may consider a sampling traverse along which species abundances may reflect the direct *in-situ* operation of environmental factors, as well as the indirect influence of water-mass biogeography. Four simple models are postulated. In Model A (Random Fluctuation), species abundances are random with respect to traverse position. In Model B (Staggered Peaks), species have narrow, overlapping ranges and optima staggered along the traverse. In Model C (Simple Covariance), reaction groups consist of two or more species having the same optimum and exhibiting proportional variation; groups overlap, but no species belongs to more than one group. Model D (Complex Covariation) is like C, except that species may belong to more than one group. Numerical examples are given for each model. By inspecting species plots and treating data by *R*- and *Q*-mode factor analysis, criteria are developed for recognizing model situations. Study of natural data suggests that real community variations are mixtures of the four model types.

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GROWTH AND DOLOMITIZATION OF SILURIAN REEFS, ST. CLAIR COUNTY, MICHIGAN

Pinnacle reefs in eastern Michigan were formed during a period of cyclic carbonate-evaporite deposition in uppermost Niagaran-lower Salinan time. At present, reef sequences have salt beds as their lateral equivalents. Restoration of evaporite sequences to their relative positions during deposition demonstrates, however, that this is due to differential compaction of carbonate beds, rather than contemporaneous deposition of reef rock and evaporites. Compaction of carbonate muds during lithification, rather than cementation, also accounts for the majority of porosity loss in the area. Where porosity is preserved, compaction-resistant framework is present with the resulting porosity directly proportional to quantity of framework.

The reef and surrounding carbonates are dolomitized. The pattern of dolomitization, quantity of dolomite in relation to bed thickness, position of the dolomites in relation to evaporite beds, and time of dolomitization suggest that dolomitization was caused by a continuous movement of large quantities of normal connate waters through the sediments. It cannot be shown that refluxion by highly concentrated brines during periods of evaporite deposition contributed substantially to dolomitization. Evaporite sequences overlying bodies of carbonate mud prevented the vertical escape of water during compaction, forcing this water to flow laterally to the reefs, and then vertically through them to the surface. This very large quantity of water was forced through a relatively small volume of rock in the nearby reef area, supplying the magnesium for dolomitization. The outflow of water continued during intensely evaporitic cycles, altering evaporite deposition in the reef area, and preventing heavy brines from entering the porous reefs and destroying porosity

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PETROLOGY AND STRUCTURE OF A SALINA (SILURIAN) DOLOMITIZED ALGAL STROMATOLITE COMPLEX, NORTHWESTERN OHIO

A unique algal stromatolite complex is located southwest of Maumee, Ohio, on the Niagaran reef-bank system that contributed to the isolation of the Michigan basin during the Cayugan Epoch. Overlying strata have been eroded so that the individual features of the complex may be studied in essentially their original paleogeographic setting. Major features in the study area include tidal channels, natural carbonate levees, algal mounds, scour channels, laminations, ripple marks, desiccation cracks, and gypsum and anhydrite molds

The dolomite rocks in the area may be subdivided into eight microfacies as follows: (1) mound; (2)

mound scour channel; (3) mound transition; (4) intermound; (5) blanket; (6) laterally linked hemispheroid; (7) mud flat; and (8) tidal channel. Each of these microfacies is characterized by a particular algal mat frequency, the degree of development and the nature of laminations, and by the amount of mechanically deposited sediment.

Major rock types are stromatolite-constructed dolomite mudstone, wackestone, and packstone. Nearly all samples are characterized by the partial or pervasive development of a filamentous (and presumably algal) microstructure. Burrows and pellets are uncommon in all of the microfacies. Ostracods are common. Laminations are well developed in all of the microfacies except the mound microfacies. Breccias are common especially in algal mounds and are due to mineralization by sulfate minerals, and dedolomitization, desiccation, and solution collapse.

The general sequence of mineralization was: (1) formation of microcrystalline xenotopic dolomite, probably by replacement of an initial $CaCO_3$ mud, accompanied by the formation of gypsum and anhydrite; (2) dedolomitization, primarily in the mound microfacies; (3) partial replacement of calcite and dolomite by celestite; (4) replacement of some calcite, dolomite, and celestite by fluorite; and (5) limited formation of medium crystalline, idiotopic, and hypidiotopic dolomite by a process of local source dolomite crystallization and recrystallization.

Comparison with several Recent carbonate analogs in the Persian Gulf and Bahamas suggests that most of the eight microfacies were formed in a supratidal environment.

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Clay Minerals as Cumulative Records of Their Environments

The environmental aspects of clay minerals include relations of clay minerals to two environments that may differ radically from each other: the environment of origin (where *formed*) and the environment of deposition (where *found*).

Environmental aspects are viewed as parts of geologic history and change. Three components constitute geologic history and change: (1) earth materials that undergo the changes and simultaneously serve as substantive records of the geologic changes, (2) the energies (climate, weathering, sedimentation, *etc.*) that effect the changes on the materials, and (3) the flow of time through which the energies act on the materials.

Parent materials of clay minerals are argillaceous and nonargillaceous parent rocks, plus ions added minus ions removed during genesis. Energies effecting argillation include activities of the H^+ (protons), other cations (notably K, Mg, Ca, Na, Fe) and anions (carbonate and silica complexes), oxidation potential (electrons, e^-), and organisms. Geological terms for these agents are fresh rain water, alkaline ocean water and brines, and hydrothermal solutions, but they can be quantified with the equilibrium diagrams and thermodynamic calculations of the geochemist. Time in geology correlates with kinetics of geochemistry.

In the environment of deposition the already formed clay minerals may respond to (1) mechanical energy of sorting, (2) colloidal effects of flocculation or dispersion with consequent modification of surface areas and surface chemistry, ion exchange, dialysis, and the probably important but poorly understood interactions with organic materials, and (3) reaction with the ions of the aqueous medium in which deposition occurs.

Following deposition, the clay minerals respond to the energies of mechanical compaction and mechanical dehydration, further thermal dehydration that is significantly important near the temperature of boiling water, activities of ions of concentrated brines accelerated in reactivity by high temperatures, and decrease in oxidation potential of surroundings.

A cumulative record of events is imprinted on clay minerals insofar as changes are produced in the minerals. A specimen of clay minerals extracted from a core of shale from a 3-mi depth may have an exceedingly complicated genealogy, not completely interpretable. Its interpretation is a function of both the fidelity of the mineral record, and the competence of the interpreter.

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Submarine Channel and Fan Deposits, Silurian of Central Wales, United Kingdom

Mapping and detailed sedimentological study of a group of geosynclinal formations of Llandoverian age (Lower Silurian) around Rhayader, central Wales, have been undertaken jointly by the writer and M. A. Woollands (University College, London). These formations occur near the southeastern margin of the Welsh trough and consist essentially of bodies of sandstone and conglomerate, lenticular through distances of several kilometers, and enclosed within a framework of graptolite-bearing argillaceous sediments.

Marked lateral and vertical variations in the geometry, internal features, and transport patterns of the coarser intercalations may be demonstrated and are attributed to differences in the mechanisms and sites of deposition. On the southeast, an argillaceous facies with a few thin, laterally derived tractional sandstone beds and calcareous bands, displaying slumps, is interpreted to represent a slope environment. This facies contains a few longitudinally derived distal turbidite units which appear in more profusion on the northwest in an argillaceous facies of inferred basin-plain origin.

Mantling the pelagic sediments are broadly lenticular bodies of coarse sandstone interpreted as proximal turbidites. Sole marks in these sandstone beds present a complex but essentially longitudinal transport pattern but ripple marks and other depositional features indicate modification of the northeast-southwest longitudinal pattern by lateral tractional currents (from the southeast). Such proximal turbidites grade both laterally and vertically into more distal turbidites and into coarse granule-gritstone and boulder conglomerate.

The rudites occupy successive, steep-sided channels excavated in the pelagic basin floor and slope sediments, and display features characteristic of fluxoturbidite associations. The orientation of channels, sole marks, ripples, and pebble imbrication consistently indicates current movement toward the north-northwest whereas the internal features and fabric of the coarse sediments suggest emplacement by a sand-avalanche