LUMSDEN, DAVID N., and MICHAEL T. LEDBETTER, Dept. Geol., Memphis State Univ., Memphis, TN 38111

PENNSYLVANIAN-PERMIAN MIOGEOSYNCLINE TO NEARSHORE SHELF CARBONATE FACIES TRANSITION, CLARK COUNTY, NEVADA

Pennsylvanian and Lower Permian carbonates of Clark County, Nevada, were studied at Arrow Canyon (AC), Frenchman Mountain (FM), and Azure Ridge (AR). Distinct facies changes are observed from the AC section (2,193 ft, Bird Spring Group, restricted, miogeosynclinal) where limestones are 65.5% micrite to FM section (1,055 ft, Callville Formation, outer shelf) where limestones are 57.2% pelsparites, biosparites, or oosparites to AR (779 ft, Callville Formation, inner shelf) where limestones are 50.9% pelsparites, biosparites, and oosparites. The marked change in facies provides evidence for support of a dual terminology, Bird Spring Group for the basin facies and Callville Limestone for the shelf.

The Bird Spring-Callville interval is subdivisible into a lower eastward thinning member (1,634 ft, AC; 634 ft, FM; 322 ft, AR) characterized by abrupt vertical fluctuations in facies (AC 14.3, FM 8.0, AR 15.2 fluctuations per 100 ft) causing the steplike outcrop appearance characteristic of the interval. Gray to buff weathering and lack of quartz silt distinguish the lower member from the arenaceous buff to brown upper member. The latter contains several quartz sandstone units (zero AC, 41.7% FM, 51.1% AR) in which the size of the fine (<0.1 mm maximum apparent diameter in thin section) angular grains increases eastward. The upper member ranges from 559 ft at AC to 421 ft minimum at FM (491 ft maximum depending on contact position in a covered interval) to 457 ft at AR. A relatively small number of fluctuations in facies (8.4 AC, 5.2 FM, 3.9 AR) produces a uniform outcrop appearance.

MABERRY, JOHN O., and CHARLES L. PILLMORE, U.S. Geol. Survey, Denver, CO 80225

ASPECTS OF TRACE FOSSIL OCCURRENCE IN TRINIDAD SANDSTONE (CRETACEOUS) OF NORTHERN NEW MEXICO

The Trinidad Sandstone was deposited near the shoreline in a marine-to-continental transition during the last retreat of the Cretaceous sea from northern New Mexico and southern Colorado. The Trinidad primarily was deposited in shallow neritic and beach environments. It lies conformably on mudstone of the Pierre Shale and consists successively upward of mudstone with siltstone interbeds, interbedded siltstone and sandstone, and sandstone; inorganic structures include ripple marks, crossbedding, channel-fill structures, parting lineation, and crumpled and contorted bedding. These linear directional structures indicate that the paleoslope of deposition and the direction of sea withdrawal were toward the east-southeast.

Rhizocorallium, Ophiomorpha, Aulichnites, Asterosoma, Teichichnus, Desmograpton, and a yet-unidentified trace similar morphologically to a spiny echinoderm, as well as other tracks and trails, were found in the Trinidad in outcrops from Cimarron northeastward to Raton, New Mexico. These trace fossils indicate that the Trinidad environments dominantly were shallow neritic, littoral, dune, backshore, and in small areas, estuarine.

Amount of carbonaceous debris decreases upward in the stratigraphic section, and the fauna changes correspondingly from scavengers to domicile-building organisms. Dune sediments contain very few trace fossils, but overlying backshore sediments contain a large biota.

The Trinidad is overlain by very carbonaceous to coaly sediments of the Vermejo Formation. The Vermejo was deposited on an alluvial plain, behind the Trinidad beach, and contains only *Planolites* and shipworm-type traces in carbonaceous rocks.

MACINTYRE, IAN G., Div. Sedimentology, Smithsonian Inst., Washington, DC 20560

SUBMERGED REEFS OF EASTERN CARIBBEAN

Submerged early Holocene or late Pleistocene reefs up to 90 km long and with bottom relief commonly about 20 m were established in relation to preexisting lower sea levels on outer edges of terraces at depths ranging from 30 to 80 m off most islands in the eastern Caribbean. They are far more impressive physiographic features than their modern counterparts. These reefs are distinguished from modern reefs in that they are present at depths greater (below about 15 to 20 m) than are commonly associated with present reef-framework construction by hermatypic corals. Data from echo-sounder profiles, rock dredging, bottom photographs, and first-hand observations indicate that off the Virgin Islands, St. Martin, St. Barthelemy, Montserrat, Guadeloupe, Martinique, St. Lucia, and the Grenadine Islands, submerged reefs are dead and covered by only a few scattered living corals. On these reefs, reef corals below 15 m cannot cope with skeletal destruction by boring organisms and cannot compete for substrate with other encrusting or attached organisms. Off the west coast of Barbados, however, reef-framework construction is still occurring below about 15 m. Although the age relations of these reefs are not known, they are probably no older than late Pleistocene, and have a minimum age for initial development of about 8,000 years B.P. The eastern Caribbean is characterized by living inner-shelf fringe reefs; however, the common occurrence of shelf-edge submerged reefs indicates that during the latter stages of the Holocene transgression, reefs in this area were generally adjacent to deep waters similar to the modern Pacific barrier and atoll reefs.

MACKENZIE, DAVID B., Marathon Oil Co., Littleton, CO 80122

PRIMARY STRATIGRAPHIC TRAPS IN SANDSTONES

Primary sandstone stratigraphic traps involve lateral termination of the reservoir as a direct or indirect result of factors related to the depositional environment; Burbank, Bell Creek, and Pembina are among the very few giant oil accumulations found in them. As these traps rarely can be detected by surface measurements, other discovery methods are essential. The understanding of depositional process and environment is a promising approach.

Primary sandstone stratigraphic traps occur in many facies, including fluvial, deltaic, shallow-marine, and deeper marine. The largest sizes and greatest number occur in shallow-marine and shoreline environments. Knowledge of sandstone models of all kinds may provide valuable clues in interpreting fragmentary well data in terms of size, shape, trend, and characteristics of the reservoirs being sought.

The distribution of many sandstone bodies may be controlled in part by underlying, commonly inconspicuous, erosional surfaces. Reconstruction of the paleotopography of the unconformity thus may commonly delineate prospective trends. The distribution of trap barriers may be controlled by environment. For example, discrete shoreline sandstone bodies replaced updip by lagoonal shales are better prospects than those replaced updip by sandy ("leaky") deltaic deposits. Such sandstones are more likely to be related to interdeltaic rather than deltaic areas.

Most progress will come from further development and refinement of depositional models. A greater understanding of shallow-marine sandstone bodies is especially needed. Moreover, as exploration emphasis shifts offshore, there will be a growing premium on one's ability to recognize depositional models in the absence of cores and outcrops.

MACKENZIE, FRED T., Dept. Geol., Northwestern Univ., Evanston, IL 60201, and ROBERT M. GARRELS, Scripps Inst. Oceanog., La Jolla, CA 92037

CHEMICAL HISTORY OF OCEANS

The reaction "igneous rocks plus acid volatiles to give sedimentary rocks plus seawater" has long been the basis for geochemical balance calculations, and also the basis for chemical arguments for the constancy of seawater composition. In most balance calculations based on continental igneous rocks as the sediment source, there is an unaccounted excess of iron and calcium in the sediments. This excess may well have come from submarine alteration of mafic volcanic rocks, a process shown to be important today by recent dredging and coring, and probably of greater relative importance in early earth history. Both subaerial and submarine weathering contribute to the mass of cycling sedimentary rocks and hence to oceanic composition.

The submarine alteration branch of the sedimentary geochemical balance may be written: mafic volcanics + volatiles = greenstones + cherty iron formations + carbonate rocks. No major differences in oceanic composition have been deduced as stemming from early greater relative submarine alteration, but the sedimentary mass is predicted to have been richer than now in carbonate rocks, chert, and iron minerals. Most of the early carbonate rocks, because of selective cycling, now exist as Phanerozoic deposits.

MALEK-ASLANI, M., Tenneco Oil Co., Houston, TX 77001

DEPOSITIONAL ENVIRONMENT OF MISSION CANYON (MISSISSIPPIAN) OIL FIELDS IN NORTH-CENTRAL NORTH DAKOTA

Three fourths of the oil fields in the Mission Canyon carbonates of north-central North Dakota are stratigraphic traps. The hydrocarbons in the Mission Canyon carbonates occur in 6 marker-defined beds, each representing a generally regressive off-lap carbonate cycle which is capped with the supratidal evaporite facies. Two types of depositional cycles are recognized: those formed when the shelf was stable and those which developed when the shelf was structurally deformed. The vertical patterns of the facies changes have been analyzed in the context of these 2 types.

The deepest part of the Williston basin during Mission Canyon deposition was in the northwestern corner of North Dakota. A broad open shelf extended eastward, where marine water circulation was sufficient to support bottom-dwelling and skeletal-producing organic communities. A trend of oolitic bars separated the open shelf from a restricted lagoon farther east. The lagoon was an area of nonskeletal carbonate sedimentation which changed facies eastward to tidal flats and supratidal "sabkhas" where evaporite deposition occurred.

The stratigraphic traps are related to the tidal flat facies. The reservoir rocks are covered by evaporites and are best developed where lobes of shelf carbonates extend eastward into the predominantly evaporite areas. Locally, traps also were formed within the structurally controlled mud islands. The preferential dolomitization of tidal-flat and mud-island facies resulted in good reservoirs.

Prolific growth of blue-green algae on the tidal flats probably provided the organic source material for petroleum within the stratigraphic traps.

MARTIN, WAYNE D., Dept. Geol., Miami Univ., Oxford, OH 45056

PETROGRAPHY OF COMPOSITE VERTICAL SECTION OF CINCINNATIAN SERIES LIMESTONES, SOUTHWESTERN OHIO AND ADJACENT AREAS

An offshore, shallow-water environment was in existence during the accumulation of the major part of the Cincinnatian Series, Eden to Saluda. The upper part of the section, Saluda and Whitewater, was formed under nearshore, subtidal, and lagoonal conditions.

The average limestone, Eden to Saluda, is a biocalcirudite, an autochthonous coquinoid rock. It is coarse-grained, poorly sorted and contains approximately 38% fossil allochems which were originally deposited with ooze. The carbonate mud of the limestones has been recrystallized almost completely and many fossil allochems have undergone recrystallization as well. Coarse pseudospar forming 40% of the rock is about equal in abundance to allochems with microspar (5–30 μ) forming the remaining 20%. Chemically precipitated sparry calcite is uncommon and apparently exists only in fossil cavities and under umbrellas.

Bryozoa are slightly more abundant than brachiopods through all of the units and each of these phyla exceeds echinoderms by 3 to 2 and trilobites by 3 to 1. Pelecypods, gastropods, and ostracods are minor constituents. The relative order of abundance of phyla holds through all of the formations.

Allochems average about 28% of the upper part of the series; microspar forms about 55% of the average rock and pseudospar forms about 15%. Micrite is minor but more abundant than in the lower, thicker part of the series. The major fossil phyla have the same relative order of abundance, but bryozoans exceed brachiopods by 10%. Ostracods, algal products, and coral become very conspicuous and are the only allochems in some beds. Dolomite is abundant in many beds of the upper Cincinnatian.

MASTERS, C. D., West Georgia College, Carrollton, GA 30117

"MUDDY" MISSISSIPPI

The application of geologic science to oil exploration requires achievement of sufficient understanding to make predictions. One of the most important predictions geologists are called upon to make is the distribution of rock stratigraphic units. Prediction may be enhanced by interpreting the vertical profile of associ-