VOLK, R. W., Nelson, Leonard, Marchetti, Leonard and Tate, Denver, Colo.

Future Petroleum Potential of Pre-Cretaceous Rocks of Eastern Colorado

Throughout Permian time, eastern Colorado, like western Kansas, was on the shelf area of the Anadarko basin; and the Las Animas arch, as reflected on top of the pre-Pennsylvanian unconformity, was a south-trending nose in the north part of the Anadarko basin. This relation was very similar to that of the Central Kansas uplift, from which over 2 billion bbl of oil has been produced from pre-Cretaceous rocks. Many other geologic similarities can be discerned between the Las Animas arch and the Central Kansas uplift. The two most dissimilar factors are (1) that the pre-Pennsylvanian unconformable surface on the Central Kansas uplift is underlain chiefly by Cambro-Ordovician rocks, whereas on the Las Animas arch, Mississippian rocks underlie most of the area; and (2) that the dip of the pre-Permian beds in northeastern Colorado was reversed during the Laramide orogeny.

The entire pre-Pennsylvanian sequence in eastern Colorado and western Kansas demonstrates a very subnormal but continuous pressure system. Over most of eastern Colorado, the Mississippian is the porous and permeable stratigraphic unit of this very low-pressure system. Fluids will migrate from the higher energy Pennsylvanian system to the lower energy Mississippian. Thus, the Mississippian is capable of deriving hydrocarbons transversely as well as laterally.

Since 1965, exploratory interest has been primarily in Mississippian reservoirs, although some Pennsylvanian oil and gas fields also have been found. Since 1965, 20 Mississippian and Pennsylvanian oil and gas fields have been found and over 200 wildcat wells have been drilled. The data from these wells have resulted in new interpretations of hydrocarbon accumulations. Early Pennsylvanian growth strongly influenced Mississippian accumulations, and recent refinements in seismic techniques have allowed definition of these growth features. By incorporating recent subsurface interpretations with the extensive seismic control available, numerous prospects are being defined and doubtless will result in additional pre-Cretaceous discoveries.

WALL, J. H., and C. SINGH, Geol. Div., Research Council of Alberta, Edmonton, Alta.

Paleogeographic Significance of Late Cretaceous Microfossil Assemblage from Buffalo Head Hills, Northern Alberta

A small isolated outcrop of shale in the Buffalo Head Hills of north-central Alberta has yielded forams, radiolarians, and dinoflagellates. The assemblage is of Senonian, and most probably of Campanian age. The foraminiferal fauna, including *Haplophragmoides fraseri, Verneuilinoides bearpawensis, Praebulimina carseyae,* and *Cassidella tegulata,* suggests correlation with the upper Campanian Bearpaw Formation of southern Alberta. The radiolarian assemblage includes *Spongurus (Spongurantha)* sp., *Spongodiscus* cf. *S. renillaeformis, Spongostaurus* sp., *Sethocyrtis* sp., and *Dictyomitra multicostata,* all forms illustrated by H. R. Bergquist from the Schrader Bluff Formation of northern Alaska, for which a middle Senonian age is designated. Essentially the same assemblage is known from the Bearpaw Formation in the Cypress Hills of southeastern Alberta. Among the dinoflagellates are *Deflandrea victoriensis, Dinogymnium longicornis,* and *D. sibiricum*—forms which are restricted to the Senonian.

The stratigraphic position of this outcrop is from 100–200 ft above the Cenomanian Dunvegan Formation. The Senonian, or more specifically, the likely Campanian age of the outcrop suggests at least a marked condensation, if not a pronounced unconformity, in the area. The microfossil assemblage may be construed as evidence in support of J. A. Jeletzky's 1971 hypothesis that a connection existed between the Arctic and western interior regions through northern Alberta during the Santonian and Campanian.

WARTERS, H. R., Trend Exploration Ltd., Denver, Colo.

Pinnacle Reefs of Middle Devonian Onondaga Limestone, Upstate New York and Northern Pennsylvania

The Onondaga Limestone was first named by James Hall in 1839 for exposures in Onondaga County, New York. It was also Hall who in 1859 recognized that the facies of the lower part of the Onondaga (Edgecliff Member) originated through the accumulation of coral skeletons and wrote of the occurrence of "coral reefs" in many places.

It was not until 1967, 128 years after Hall's initial work, that the first hydrocarbon-productive Onondaga reef was entered in the subsurface with the drilling by the Wyckoff Development Company of the Douglas Cornell No. 1 well in Steuben County, New York. The well, which was to test a structural prospect in the underlying Oriskany Sandstone, quite unexpectedly found 148 ft of gas-productive Onondaga reef. Since that time, intensive seismic and subsurface work by Trend Exploration Limited, Anderson Oil, and Cabot Corporation has resulted in the discovery of additional gas-productive pinnacle reefs in the area. These reefs are approximately 200 ft high, have initial flow rates of 15 million cu ft/day and calculated open flow approaching 30 million cu ft/day.

A consideration of the regional paleogeology, as derived primarily from well-sample examination, mechanical well logs, and the integration of detailed seismic data, leads to the conclusion that the gas-productive area is part of a much more extensive potentially productive pinnacle-reef basin. The occurrence of pinnacle reefs within the basin is controlled by change of lower Onondaga (Edgecliff) reef-platform facies to nonreefal basinal facies accompanied by subsidence. The subsidence at reef growth time is extreme in some areas of the basin indicating that many reefs substantially taller than those already found are present.

WEBB, J. E., Phillips Petroleum Co., Bartlesville, Okla.

Relation of Oil Migration to Secondary Clay Cementation, Cretaceous Sandstones, Wyoming

Thin section, sieve, and clay-mineral analyses indicate that many of the clay-rich sandstones in Wyoming were deposited as clean, well-sorted sands. After deposition and burial these sands were filled with either hydrocarbons or secondary clay cement. It is proposed that hydrocarbon migration took place shortly after burial. Those sands not filled with hydrocarbons were subjected to continued precipitation of clay from the formation waters until all effective porosity and permeability were eliminated. Later tectonic movements may position these "sealed traps" in an off-structure position. A thorough understanding of the geologic and tectonic development of the basin is necessary to prospect for this type of trap.

WEEKS, L. G., Lewis G. Weeks Assoc., Westport, Conn.

WORLD PETROLEUM EXPLORATION

Of the 135 countries of the world whose current status of petroleum exploration was reviewed, 65 are producing oil and gas (including 2 about to have production); in 70 countries activity is confined to exploration or preparations to explore. About 90% of the petroleum exports from the noncommunist world flows from Arab or closely affiliated countries.

At least 75% of the world's proved and potential petroleum reserves exist beneath the continental terrace, which includes the coastal plain, the continental shelf and slope, and also many partly enclosed seas, gulfs, bays, deltas, estuaries, straits, *etc.*

Most of the available basins of the world, as well as some nonbasin areas, including the offshore shelves, *etc.*, have been leased for petroleum. There is a wide tendency in area selection to overvalue the less attractive and commercially submarginal areas, and to underestimate the potential of the much smaller percentage of bonanza class areas. The greater part of the leased area of the world is of the former type.

World production has more than doubled in each of the last 2 decades to 48 million bbl/day in 1970. If production merely doubles in each of the next 2 decades a minimum of 22 trillion bbl of new oil must be added to meet the production demands of the period and leave a 20-year supply ratio (15 trillion bbl to leave a 10-year supply ratio). The current year's supply ratio is 31; also 15 to possibly 25 trillion bbl of oil is the range of estimates by informed geologists of recoverable liquid oil (proved plus potential) remaining in the world. By any reasonable projection, the years of the petroleum age are finite.

The demand for petroleum energy has been growing at a rate 3 to 5 times the rate of population increase, and over the present decade will more than equal that of the 112 prior years following Col. Drake's discovery. The rate of finding giant and supergiant fields does (or soon will do) no more than keep pace, and then only briefly, with the years supply ratio. The time required to find and develop the main crop of fields in new producing basins has very rapidly and greatly decreased. Some geologists have looked unduly to the stratigraphic trap, greater depths of drilling, and the deeper ocean bottom areas as the answers in meeting the petroleum demands of the future.

Worldwide oil occurrence studies indicate that the temperature gradient varies greatly over the world's basin areas, and from basin to basin, depending on the geologic background. They also indicate that the gradients have a strong influence both on the incidence of petroleum occurrence and on the initial and optimum depths of such occurrence. This apparently explains in a large and often critical measure many of the unanticipated exploration disappointments as well as successes.

WEIMER, R. J., Colorado School Mines, Golden, Colo.

DELTAIC SEDIMENTATION AND GROWTH FAULTING, UPPER CRETACEOUS, COLORADO

The upper Pierre, Fox Hills, Laramie, and Arapahoe Formations in the western Denver basin record deltaic sedimentation during the final regression of the Cretaceous sea from eastern Colorado. Prodelta shales and siltstones (Pierre Formation) are overlain by delta-front sandstones (Fox Hills), and delta-plain sandstones, claystones and coals (Laramie Formation). The younger conglomerates of the Arapahoe Formation are braided channel deposits of the fluvial system.

Two types of penecontemporaneous (growth) faulting are recognized in 5 mi of outcrop from Golden south to Interstate 70. One type of faulting cuts delta-plain sediments, resulting in a thickness increase of the Laramie Formation from 330 to 530 ft in a horizontal distance of 800 ft. By normal fault movement at the time of sedimentation, an extra 200 ft of lower Laramie sandstone, with minor claystone and thin coal, was deposited on the downthrown side of the fault. The northwest-trending fault plane curved downward toward the south from a dip of about 60° to a low-angle bedding plane fault.

A second type of faulting records slumpage on oversteepened prodelta slopes created by seaward progradation of the shoreline. One slide block of shallow-water distributary-mouth sandstone (Fox Hills) about 100 ft thick moved southward down the prodelta slope into water depths estimated to be from 100 to 175 ft and was subsequently buried by prodelta clays (Pierre).

The geographic position of these growth faults in the delta sequence appears to have been controlled by recurrent movement of deep-seated faults in the Precambrian basement which at the time of Laramie deposition was at depths in excess of 10,000 ft. Growth faulting, heretofore unrecognized in the Cretaceous of the Rocky Mountain area, may be a common occurrence in the areas of deltaic sedimentation. Some abrupt thickness changes may be explained more readily by this process than by the commonly invoked theories of facies change or unconformities.

WENGERD, S. A., Univ. New Mexico, Albuquerque, N.M.

PRESIDENTS, PRECEDENTS, PROVOCATION, AND PREROGATIVE—ARE GEOLOGISTS SCIENTISTS?

It is the prerogative, in fact the duty, of a president of a scientific society to break precedents, at the certain risk of provocation of society members. Utilization of the exploration geologist as a decision maker and representative of industry in the development of natural resources has led some geologists who search the earth's crust for enormously valuable fossil fuels and minerals to downgrade themselves as scientists. Because profit is involved, some academic colleagues and administrators assume that our application of geology is an impure utilization of pure scientific principles.

Industrial administrators, clients, and geologists themselves have noted that obsolescence comes quickly to anyone whose scientific work becomes routine rather than an exciting adventure in continuous learning. To break this insidious syndrome of security, the exploration scientist must fight apathy, lethargy, and inertia. At every turn, it is the geologist with pride in his work who must reestablish the fact that he is a true scientist *first, a professional second, and a dedicated member of* his scientific associations third.

The American Association of Petroleum Geologists, classed as a learned professional society, is also a business league made up of scientists. As such, all petroleum geologists and geophysicists can be willfully provocative, must break hampering precedents, and should assume their rightful prerogatives as pure scientists. We