munity patterns. Tidal flat and lagoonal communities (Walker and Laporte) and an offshore cystoid-ectoproct community (Anderson and Goodwin), which are both recognized in Ordovician rocks, persist into the Devonian and coexist with the Devonian brachiopod communities. Restricted subtidal and barrier communities are absent from progradational Helderbergian rocks. This pattern is analogous to Bretsky's three-community sequence of the Late Ordovician.

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GEOLOGY AND HYDROCARBON POTENTIAL, DEEP GULF OF MEXICO

The results from the deep drilling program in the central basin of the Gulf of Mexico provide convincing evidence that the Sigsbee Knolls are salt domes. This evidence raises many questions concerning the origin of the Gulf of Mexico and the possibility of vast hydrocarbon reserves beneath the deep-water areas. The fact that the Sigsbee Knolls are salt diapirs has led to the implication that buried Mesozoic salt is present across the entire basin. This concept has led to arguments concerning basic, worldwide, geologic processes. For instance, Belousov, who doubts the possibility of deep-water salt deposition, claims the presence of salt in deep-water areas validates his arguments for "basification"—making oceans from continents. However, the genetic model for deep-water salt deposition presented by Schmalz has made it possible to reconcile the hypothesis that the Gulf represents an ancient ocean basin which has been at oceanic depths at least since Mesozoic time with the presence of salt in the basin.

The basic premise in both these arguments is that salt is continuous across the deep basin and this may be invalid. The data available at present indicate that Mesozoic salt deposition was restricted to the margins of the western Gulf of Mexico and the presence of salt on the basin edges has been caused by the seaward migration of buried salt. The data also favor the hypothesis that whatever the origin of the Gulf of Mexico—foundered and oceanized continental crust or rifted ocean basin—it is a relatively old, undisturbed feature with great prospects for vast reserves of hydrocarbons in the southwestern section. This region includes the Sigsbee Knolls and their southwestern extension to the deep-water salt diapirs of the Bay of Campeche, adjacent to the Saline basin of Mexico. Petroleum prospects are suggested by the drillhole into the Challenger Knoll from which salt-dome caprock saturated with oil, gas, and sulfur was recovered and from short piston cores into knolls in the Bay of Campeche which contained either layers or scattered inclusions of solid hydrocarbons.

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PRE-PENNSYLVANIAN PALEOTECTONIC FRAMEWORK OF ANCESTRAL ROCKIES OF COLORADO

The tectonic framework that controlled the locations of the late Paleozoic Ancestral Rockies was well established in pre-Pennsylvanian time.

The Uncompahgre uplift in southwestern Colorado arose along tectonic lineaments that originated in the late Precambrian. Recurrent movements along the fault system continued through early and middle Paleozoic time and the resulting submarine topography controlled the sedimentation of reservoir facies in the adjacent Paradox basin.

The Front Range and Wet Mountains uplifts of central Colorado were apparently low and inactive prior to Late Devonian time; at least, evidence is lacking that they were source areas during the early Paleozoic. The relation between basement tectonic trends and the location of the Permo-Pennsylvanian uplifts is obscure.

The first demonstrable uplift of the Front Range element occurred in Late Devonian time when coarse clastic material was shed into the Parting sea from the west flank of the uplift and a satellite structure in the northern Sawatch Range. Uplift of these source areas recurred in Early Mississippian time and produced limestone conglomerates in the basal Leadville Formation.

The Wet Mountains lay dormant until Early Mississippian time, and a broad lowland occupied the general region in the Late Devonian. Local deposits of limestone conglomerates in the Leadville Formation attest to the Early Mississippian time of uplift.

Continued detailed petrologic and paleotectonic studies in the 1970s will lead to new petroleum discoveries in the related Paradox and Eagle basins by establishing favorable reservoir facies trends, paleohydrodynamic patterns, and times and paths of petroleum migration.

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CHEMICAL ASPECTS OF CRUDE OIL PRESERVATION

Previous studies indicate that although thermal maturation is an overwhelming control on petroleum composition within the deeper and hotter regions of the Western Canada basin, other processes significantly affect the quality and preservation of crude oil in areas where the burial is less deep. The objective of our study was to investigate, with as many analytic tools as possible, the nature of those processes which alter and degrade petroleum in less mature settings.

The Mississippian oils of Saskatchewan provide an excellent opportunity for isolating and examining those processes which might result from chemical interaction between oils and formation waters. Along the entire subcrop trend, only 3 geologic parameters change significantly; formation waters become less saline from east to west, and oils become heavier and more sulfurous and eventually disappear on the west.

Methods used include chemical analyses of formation waters followed by isotopic determinations of S, C, O, and H. Crude oils were analyzed for individual gasoline-range hydrocarbons, normal paraffins to n-C^{35}, sulfur, and API gravity. In addition, C and S isotope measurements were made on saturate, aromatic, NSO, and asphaltene fractions of selected crudes. The critical environments also were checked for direct evidence of microbiologic activity.

Preliminary results suggest that the western part of the study area was invaded by fresh meteoric water which resulted in the degradation of crudes through two processes. The disappearance of light hydrocarbons toward the zone of freshwater invasion indicates removal of these more soluble compounds by water washing. Light normal paraffins disappear much faster than expected from their relative solubility, and extended range chromatograms show that heavy, insolu-

ble, normal paraffins also have disappeared in the degraded zone. Biodegradation may be a plausible explanation for this additional phenomenon.

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QUATERNARY PALEOCLIMATIC VARIATIONS

Ratios of Antarctic radiolarians, *Spongotrochus glacialis* and *Lithelius nautiloides,* to the subantarctic radiolarians, *Lithamphora furcaspiculata* and *Theocalyptra bicornis,* define at least 4 major cold intervals within the Brunhes Normal Magnetic Epoch, with a temperature range from less than 0 to about 5°C. In tropical areas, cooler temperatures of the Brunhes are suggested by the marked decline of *Sphaeroidinella dehiscens* and an increase in temperate species.

In the Antarctic area, temperate species of radiolarians such as *Eucyrtidium acuminatum, Lamprocyclas maritalis,* and *Saturnulus planetes* reflect generally somewhat warmer conditions in the Matuyama than during most of the Brunhes; variations in their abundances suggest perhaps 5 warmer cycles above the base of the Gilsa event with a range between about 5 and 15°C. In tropical areas, warmer temperatures are indicated by the common occurrences of *Sphaeroidinella dehiscens* and the absence or very uncommon occurrences of temperate species.

In temperate parts of the circum-Pacific area, the origin and development of *Globorotalia truncatulinoides* and the extinction of discoasters occurred long before the influx of polar populations of *Turborotalia pachyderma.* Thus, the base of the Pleistocene as defined by these events indicates that the Pliocene-Pleistocene boundary must be within the upper part of strata previously referred to as upper Pliocene in California. It is postulated that the subsequent major cooling indicated by the influx of sinistrally coiled populations of *Turborotalia pachyderma* is near the Brunhes-Matuyama boundary and may be near the base of the classic glacial Pleistocene.

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DEPOSITIONAL ENVIRONMENTS OF MUDDY RESERVOIR SANDSTONES (LOWER CRETACEOUS) IN POWDER RIVER BASIN, MONTANA AND WYOMING

Lower Cretaceous Muddy Sandstone forms stratigraphic traps in the northeast Powder River basin. The most productive reservoirs are local concentrations of clean, quartzose sandstones deposited in linear bodies as marine bars. Sediment supply to the bars was accomplished by transverse sedimentation from associated fluviodeltaic environments.

Two distinct marine bar types may be recognized: (1) regressive, interdeltaic barrier bars, and (2) transgressive, delta-destructional bars. In regressive bars, grain size increases upward, and subenvironments which may be recognized include, in ascending order, lower shoreface, middle shoreface, upper shoreface-beach, and eolian. In transgressive bars, the vertical sequence of grain size and subenvironments is reversed with grain size decreasing upward, and subenvironments generally commencing with middle shoreface and succeeded upward by lower shoreface. Both bar varieties have prominent lagoonal or tidal-flat deposits as lateral equivalents. These fine-grained, back-bar sediments act as effective barriers to updip petroleum migration.

Transgressive bars are associated closely with typical fluviodeltaic deposits which they may succeed, laterally or vertically, in close succession. Therefore, they are interpreted as delta-destructional bars. Regressive bars, however, are laterally and vertically removed from the main sites of delta construction, and are interpreted to be typical coastal, interdeltaic deposits.

Although fluviodeltaic sandstones are local sources for bar sands, they are mineralogically quite distinct. Significant quantities of rock fragments and clay-rich matrix reduce the relative quartz content. Therefore, porosity and permeability values are low and, despite the fact that the fluviodeltaic sandstones are locally thick, they form less productive reservoirs.

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EXPANDED NEED FOR MINERAL ECONOMICS IN EXPLORATION FOR METALS

One of the most prominent manifestations of changing trends in exploration for metals is a more common participation by the geologist in mineral economics. There are at least three new aspects of exploration in which this involvement is expressed. 1. Increased competition and new entries in mineral exploration are challenging the traditional conservative approach to exploration by mining companies. A new philosophy introduced primarily by oil companies tends to increase costs and accelerate the tempo of exploration thereby changing the total economics of many programs of mineral exploitation. 2. The broadening commodity interests of many companies have utilized the varied backgrounds of exploration geologists in preparation of commodity evaluations and forecasts. Many geologists are now providing advice and background to guide corporate decisions regarding new commodity ventures. 3. The mining industry is confronted with a new set of costs that are now part of the economics of any operation. These may be considered to be environment-control factors and are related to restoration of mined-out areas and water- and air-pollution controls.

To function efficiently in mineral economics, the geologist must establish and maintain a flow of communication with all subdivisions of his company and with people in other professions and disciplines, such as engineering, accounting, sales, metallurgy, chemistry, and economics. It is also vital that he present his ideas and conclusions in a manner meaningful to management.

Finally, one of the major needs of the exploration geologist is the availability of educational facilities in mineral economics.

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PETROGRAPHY AND ORIGIN OF KROL SANDSTONES AROUND SOLON, NORTHWESTERN HIMALAYA, INDIA

The area around Solon (lat. 30° 55′; long. 77° 07′) in northwestern sub-Himalaya, India, is the type area of the Krol Group (Permo-Carboniferous?). Petrologically the Krol sandstones may be designated as coarse- to medium-grained sandstone: mature quartz and carbonate-cemented quartz arenite (Folk, 1966). Conspicuous presence of round grains of quartz led earlier workers to conceive of an eolian origin for these sandstones. Petrologic examination of the sandstone