anomaly maps, has been identified in the central part of the Powder River basin, Wyoming. By comparing productive areas and sandstone trends to the high, it is apparent that it has affected deposition of sedimentary units since at least Lower Cretaceous time and conceivably since marine foreland deposition began.

Sandstone sequences, such as the Muddy Formation, deposited in a primarily fluviodeltaic environment were deflected around the flanks of the high whereas units deposited in a predominantly marine system, such as the Shannon, had their best sandstone development on top of the high. Understanding the relations between the positive element and sandstone distribution is an obvious aid to exploration.

Similar highs in other Rocky Mountain structural basins are identified and exploration targets discussed. These highs provide early migration paths for hydrocarbons, platforms for the development of porosity in clastic rocks, and in some places, can be shown to be areas unfavorable for exploration because of the absence of sandstone.

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Oil Production from Fractured Cherts of Woodford and Arkansas Novaculite Formations, Oklahoma

The chert section of the Woodford Formation has been known to be productive of oil and gas for at least 30 years. However, little was known about the chert as a reservoir until 1969 when Jones and Pellow Oil Co. and Westheimer-Neustadt Corp. jointly developed the Northeast Alden pool extension in T7N, R13W, Caddo County, Oklahoma. Cores, thin sections, X-ray analyses, and combustion tube studies indicate that the Woodford Chert is a prime source bed for hydrocarbons, and when fractured is an excellent reservoir.

In February 1977, Westheimer-Neustadt Corp. drilled the No. 1 Wallace in Sec. 2, T8S, R5E, to test the Arkansas Novaculite, which is similar to the Woodford Chert, and completed the well for a potential flow of more than 1,000 bbl of oil per day. The significance of the discovery has not been fully realized by industry in that it may have opened a new petroleum province in the Ouachita facies that extends from southeastern Oklahoma in a broad arch for over 600 mi (966 km) to the Marathon Mountains near the Mexican border.

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Getting the Most Out of Radon Geochemistry

Radon and radium are specific indicators of uranium. Radon in particular is easily analyzed in the field or in a portable lab. For this reason and because of its mobility as a soluble noble gas, radon has received considerable attention in exploration. The mobility of radon is complicated by its short half-life (3.8 days) and by movements of earlier members of the decay series.

Claims of the successful application of radon geochemistry to detect uranium deposits beneath several tens of meters of cover (including shale and coal beds) seem extravagant but may warrant further study. In areas of shallow overburden, radon in soil gas can extend evaluation to depths beyond reach of the scintillometer. Radon to thoron ratios are useful in this work as well as radon content itself. Day-to-day variations of radon content in soil gas are confusing, but seldom obscure trends and anomalies.

Lake-water radon anomalies are associated with two recent major uranium discoveries in the Canadian Shield. In both discoveries, the radon anomalies were detected in the earliest stages of exploration in the area.

Radium, the parent of radon, also can be readily determined in a portable laboratory. In an example from southeast Texas, a dramatic reduction in radium values has been measured in groundwater within a few hundred feet of an orebody. Anomalous radium measurements other than those associated with uranium mineralization or geothermal waters are extremely rare.

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Cementation, Diagenesis, and Paragenetic Sequence in Biyad-Wasi Sandstones (Lower-Middle Cretaceous) of Central Saudi Arabia

Although most of the Biyad-Wasi sandstones are friable and poorly cemented, some specimens reveal some cementation principally by secondary silica (or quartz), carbonate, or ferruginous material. The Biyad-Wasi sandstones have undergone several important diagenetic changes during their postdepositional history. The full paragenetic sequences commence with primary partial silica cementation, which was followed by precipitation of iron solutions in the remaining pore spaces; both these stages involved quartz overgrowths, produced as a result of pressure solution. Later stages resulted in precipitation of iron-rich clays and carbonate in new pore spaces created by partial replacement and corrosion of detrital quartz grains. The lack of quartz overgrowths is believed to be due to inhibition of pressure solution in these stages. The final diagenetic stages include weathering, which has created new pore spaces, and precipitation of silica dust (probably of aeolian origin) in such pores, and the formation of secondary silica overgrowths in the form of microcrystalline quartz. This process gives rise to the "quartzitic" crusts developed on many elevated outcrops of the Biyad and Wasi sandstones.

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Evolution of Brooks Range Thrust Belt and Arctic Slope, Alaska

Rotation of a small continental lithospheric plate in Early Cretaceous time formed the southern part of the Canada basin of the Arctic Ocean and an Atlantic-style extensional plate margin underlying the continental shelf north of Alaska. Simultaneously a compressional margin formed to the south, causing over 500 km of crustal shortening and large-scale obduction of ophiolitic rocks over the leading edge of the Arctic alaska plate. An asymmetric foredeep north of the thrust belt is filled with Neocomian to Albian lithic flysch derived from the imbricated sedimentary and mafic-ultramafic igneous terranes. Middle and Late Cretaceous isostatic rebound of the depressed sialic crust resulted in several kilometers of vertical uplift in the southern Brooks

Range and extensive refolding and refaulting of the allochthons throughout the range. At the mountain front, autochthonous Triassic and older sedimentary rocks are at depths of over 8 km except in the northeast, where they are exposed by erosion of a regional Late Cretaceous and Tertiary vertical uplift centered in the Romanzof Mountains. North of the range an Albian and Late Cretaceous molassoid wedge derived from the south and west is deformed by decollement that dies out northward; the zone of detachment is incompetent Albian shale.

Oil and gas potential is greatest to the north, where Cretaceous sedimentary rocks truncate and prograde over the rifted plate margin. At Prudhoe Bay, northward onlapping Carboniferous to Jurassic platform sedimentary rocks are truncated by organic-rich Cretaceous shale beds, which are the hydrocarbon source and part of the trap. Southward the basin is dominantly a gas-prone stratigraphic trap province; however, potential reservoirs are limited. In the Brooks Range, reservoir potential exists in only a few areas of Carboniferous carbonate rocks that have extreme structural complexity.

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Nodular Submarine Cementation on Bahamian Slopes—Possible Model for Origin of Some Nodular Limestones

Submarine cemented nodules (< 6 cm across) floating in a muddy matrix have been recovered by piston coring from carbonate slopes (depths 300 to 800 m) in the northern Bahamas. These nodular units are usually associated with peri-platform oozes, and range in thickness from 9 to 345 cm. Petrographic data indicate that the nodules are multi-generation, deep-water, grain-supported intramicrites to intramicrudites cemented by pelloidal high-Mg calcite. Carbon-14 activities indicate that the nodules are 4 to 5 $\times$ 10^3 years younger than surrounding sediment. Carbon and oxygen isotopes plus paleotemperature data suggest that the nodules were cemented in situ near the sediment-water interface.

The origin of these nodular units involves a complex interplay of physical, biologic, and chemical processes that act concomitantly above the permanent thermocline. Bottom currents play a key role in the cementation of the nodules by controlling the permeability of the sediment via winnowing and thus the degree of interstitial circulation. Burrowing organisms may enhance submarine cementation by "irrigating" the shallow subsurface, and may be responsible for the vertical mixing of nodules. On the slope north of Great Bahama Bank facies transitions from hardgrounds at depths < 375 m, to nodular sediment at depths of 375 to 500 m, to soft, unlithified peri-platform oozes at greater depths correlate with a downslope decrease of bottom current strength. These observations suggest that bottom currents in conjunction with bioturbation may have major influences on the degree of early diagenesis and thus facies relations. Recognition of similar facies in the rock record may be useful in interpretation of open-marine carbonate slope deposition, synsedimentary submarine cementation, deposition above the permanent thermocline, and the existence of contour-following currents.

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Origin of Subsurface Fracture Systems—Example from Altamont Field, Uinta Basin, Utah

The Altamont field is a major, naturally fractured, overpressured oil reservoir situated on the gently northward-dipping flank of the asymmetric Uinta basin. Low porosity Tertiary clastic and carbonate rocks form a stratigraphic trap beneath thick Green River Formation carbonate mudstones. The reservoir occurs at depths between 2,450 and 5,200 m, and thickness of the producing interval commonly exceeds 700 m. Permeability is derived mainly from vertical fractures in sandstones and carbonate rocks.

Joints in surface rocks within the basin occur predominantly as orthogonal sets whose orientations correlate with major tectonic features bordering the basin. Fractures in oriented core of reservoir rock exhibit a single dominant north-northwest trend. Rock mechanics tests on samples from the core indicate anisotropy coincident with the trend of microcracks.

Timing of subsurface fracture development relative to basin subsidence and uplift is interpreted from fluid-inclusion thermometry conducted on quartz and carbonate crystals which line open fractures. Results indicate that fractures opened when strata were near their maximum burial depth. The fracture system became more extensively developed as uplift and erosional unloading continued.

Various geologic processes interact during the burial, diagenetic, tectonic, and unloading history of rocks in a sedimentary basin. Their combined effect determines the state-of-stress in stratigraphic units. At Altamont the effect of overpressuring has been critical in fracture genesis. Thorough evaluation of the relative influence of individual geologic processes on the stress history of rock units in a basin can be usefully applied in exploration for fracture reservoirs.

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Uranium Occurrence in Leadville Dolomite at Pitch Mine, Saguache County, Colorado

Uranium ore in the Pitch Mine occurs chiefly in brecciated Mississippian Leadville Dolomite along the Chester upthrust zone and, to a lesser extent, in sandstone, siltstone, and carbonaceous shale of the Pennsylvanian Belden Formation and in Precambrian granitic rocks and schist. Uranium mineralization is generally thicker, more consistent, and of higher grade in dolomite than in other hosts; roughly 50% of new reserves are found in dolomite. Most ore distribution is controlled by dolomite and probably by brittle behavior (pervasive faulting and brecciation) in a "forced fold" environment during Laramide basement uplift.

Leadville Dolomite in the ore zone is bounded by faults and its maximum known thickness in the area is about 17 m. The Leadville is predominantly dolomicrite