of occurrence of the secondary structures, like the primary structures, varies with lithology. Crystal-growth disruption (sulfides and carbonate clots) in the oil shale increases with increasing organic content. In a vertical sequence of oil shale in the Parachute Creek Member, crystal-growth disruption of laminae increases upward through the section, and loop and fault structures decrease. Contortion of laminae is almost exclusive to the oil shale, and bioturbation is restricted to claystone and very limy claystone.

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DIPMETER INTERPRETATION OF STRUCTURAL AND STRATIGRAPHIC FEATURES IN ROCKY MOUNTAINS

No abstract available.

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ORIGIN OF Ca, Fe, AND Mg CARBONATES IN OIL SHALES OF EOCENE GREEN RIVER FORMATION IN COLORADO, WYOMING, AND UTAH

Calcium and magnesium carbonates are perhaps the most widespread minerals in the oil-shale sequence of the Green River Formation. Crystallography and chemical composition of the principal carbonate minerals in the oil shale indicate a wide range in mineral composition that includes calcite, Mg-calcite, dolomite which is iron-free and has normal 1:1 Ca:Mg, dolomite with low iron and excess Ca, ankerites with excess Ca, siderite, magnesiosiderite with low Ca, and aragonite.

Recognition of the ubiquitous presence of Mg-calcite in these rocks seems important in reconstructing a plausible depositional model for the sedimentary environment and origin of the kerogen-rich shales. Recent studies show the ability of algae and many invertebrates to precipitate high Mg-calcite in aqueous saline environments. Biogenic precipitation of calcite in the hypersaline waters of the Green River lake may account for the higher Mg-content of laminae adjacent to and within high-kerogen zones than in low-kerogen zones.

Subsequent to the inferred biologic precipitation or accumulation of high Mg-calcite in the upper levels of the lake, the Mg-calcite sank to a lower zone of extreme salinity after death of the organism. Postdepositional processes in the lower zone of accumulation may have converted high Mg-calcite to low Mg-calcite and dolomite, as suggested by the presence of this mineral assemblage in many of the samples studied. Development of ankerite, siderite, and magnesiosiderite is believed to be authigenic or diagenetic. Metastable carbonate minerals such as Mg-calcite plus dolomite with excess Ca, or Mg-calcite plus ankerite with excess Ca have been identified in a single polymineralic grain. This finding makes untenable an interpretation of the oil-shale mineral assemblage based on conventional equilibrium conditions for the system $CaCO_3$-$MgCO_3$-$MgCO_3$-$FeCO_3$ at 25°C.

We find no compelling mineralogic or chemical evidence that indicates precipitation of calcite and protodolomite at the basin margin followed by reworking and transport of the carbonate sediments to the basin center, as other workers have recently proposed for their playa-lake model.

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MINERALOGIC EVIDENCE FOR BURIED HYDROCARBONS—NEW EXPLORATION TOOL

Imperfect rock seals above petroleum deposits may allow large volumes of low-molecular-weight hydrocarbons to slowly leak and diffuse to the surface. The seeping hydrocarbons chemically alter and incorporate into near-surface and surface rocks as pore-filling cements that are isotopically and chemically distinctive and geographically identifiable because their compositions and densities markedly contrast with surrounding rocks. Strong empirical evidence indicates that gases diffuse directly through the overburden, and leakage of liquid hydrocarbons is controlled by salinity variations in formation waters which affects their solubilities and promotes chemical reactivity. Highly reducing hydrocarbons and associated compounds cause discoloration of surface strata by reduction and dissolution of iron. Near the surface, hydrocarbons are oxidized; expansion of depressurized gas evaporates ground waters concentrating and precipitating dissolved solutes with unique isotopic signatures.

Such alteration and mineralization phenomena have been documented in outcrops of a Permian redbed sequence overlying several prolific oil accumulations in southern and central Oklahoma, but especially at the Cement anticline. Recognition of similar phenomena elsewhere could lead to new discoveries.

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EVAPORITE DEPOSITS OF NORTHERN GREAT PLAINS: COMPARISON OF DEPOSITIONAL SETTINGS

The stratigraphic succession in the northern Great Plains is punctuated by many evaporite deposits of varying thickness and areal extent. They are most predominant in rocks of Paleozoic age and particular in the Devonian and Mississippian Systems. The youngest known deposits are associated with redbeds which have been assigned Late Triassic to Early Jurassic ages. Most of the evaporites in the northern Great Plains are composed of calcium sulfate; halite is somewhat less common, and there are small amounts of soluble potassium chlorides.

Recent geochemical investigations of the distributions of Sr^{+2} in modern evaporites and brines indicate that the mass ratios of Sr^{+2}/Ca^{+2} in calcium sulfate deposits may be employed to assist in the identification of the hydrologic environment in which an evaporite was precipitated and indirectly to distinguish depositional settings. The data from these investigations have been applied to selected evaporites in the northern Great Plains and corroborate the interpretations of the depositional settings as obtained from an examination of the lithologic associations.

The brines from which the evaporites in the northern Great Plains were precipitated may be thought of as having existed in one of two hydrologic environments: (1) interstitially in siliciclastic or carbonate sediments, or (2) as standing water in topographic depressions that underwent intermittent replenishment by less saline waters. The depositional settings as interpreted from lithologic associations and the results of geochemical analyses include: (1) arid supratidal flat, (2) barred-marine basins, ranging from structur-

ally controlled regional elements to restricted lagoons on the landward side of offshore barrier complexes, and (3) playa lakes.

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BRAIDED RIVERS AND RELATED TERRIGENOUS DEPOSITIONAL SYSTEMS—USEFUL BUT ENIGMATIC EXPLORATION MODELS

Closely related Holocene and Pleistocene braided-fluvial, eolian dune-sand flat, and playa-lake depositional systems in the eastern Texas Panhandle represent a useful but complex model for hydrocarbon exploration in ancient continental sediments. The modern South Canadian fluvial system and the Pleistocene Borger fluvial system are braided river deposits which are distinguishable from other sand bodies by multilateral sand-body geometry (high width/thickness ratio), low channel sinuosity, few sedimentary structure types, poor lateral and downstream continuity of individual depositional sequences, punctuations of these sequences by thin clay drapes, and a high sand/mud ratio. The main sand body of the South Canadian system averages two mi in width and 125 ft in thickness and cuts into the coarse-grained and sometimes conglomeratic sand of the Borger system. Fine to medium wind-polished sand of the Lake Marvin eolian-dune system and the older vegetated Nix Ranch eolian-sand system is deposited in thin plane-bedded sheets and strongly cross-stratified parabolic and longitudinal dunes. These eolian units are derived from, and often continuous with, South Canadian fluvial deposits of different ages. The strongly vegetated and older Pampa eolian-sand system is related similarly to the Borger fluvial system. In addition, the surface of the Pampa system is pockmarked by small pre-Nix Ranch playa-lake deposits consisting of organically rich and finely laminated beds of clay and sandy silt.

Hydrocarbon discoveries in fluvial and eolian sands illustrate the economic value of this depositional model. Among the many examples of production from fluvial sands are the Lower Cretaceous "J" sand bodies in Nebraska, lower Paleozoic Granite Wash in Alberta, and the Berea sand in Ohio. The Permian Queen sandstone in New Mexico produces from probable eolian deposits.

Limited subsurface information leads to difficulty in recognizing separate depositional systems in sands of similar size and texture. For this reason the explorationist must be careful in application of depositional models. Realization of possible variation in sand-body geometry in a particular type of depositional system is essential.

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CAMBRIAN AND LOWER ORDOVICIAN STRATIGRAPHY IN BIGHORN MOUNTAINS AND ASSOCIATED UPLIFTS IN WYOMING AND MONTANA

New information concerning Cambrian and Lower Ordovician stratigraphy in Wyoming and Montana is derived from 26 measured sections in uplifts along a 430-mi trend from the Rawlins uplift on the south, through the Ferris Mountains, Rattlesnake Hills, Bighorn Mountains, Prior Mountains, Big Snowy Mountains, and Little Rocky Mountains on the north.

Seas transgressed east-southeastward up a paleoslope of low regional relief but with several hundred feet of local relief. The sedimentary record consists of a series of lithotope belts each extending generally parallel with the shoreline. From the shore seaward the order is as follows: (1) sandstone, generally clean, medium- to coarse-grained, crossbedded and burrowed, deposited in beach, intertidal, and shallow subtidal zones; (2) sandstone, generally clean, fine-grained, crossbedded, laminated and burrowed, deposited in the shallow subtidal zone; (3) sandstone, the same as (2) except a glauconitic greensand and may be interbedded with siltstone and shale; (4) siltstone, may be interbedded with fine-grained sandstone and shale; (5a) shale, usually burrowed, with micrite beds and nodules, seaward from (4) in deeper water; (5b) shale and intraclast limestone conglomerates indicate shallower water and offshore intertidal zone environments; (6) laminated limestones, intraclast limestone conglomerates, and crinozoan calcarenites suggest an offshore shallow subtidal and intertidal environment.

The faunal record begins with the *Bathyuriscus-Elrathina* Zone of medial Cambrian age and ends with the *Bellefontia* Zone of Early Ordovician age. Trilobites and brachiopods dominate the faunas but conodonts assume major importance in latest Cambrian and Early Ordovician time. Both faunal-zone boundaries and key beds are isochronous surfaces that form planes of correlation within lithotopes and across facies boundaries between lithotopes.

The *Bathyuriscus-Elrathina* Zone and "lower" *Bolaspidella* Zone are of lithotopes (1) through (5). The "upper" *Bolaspidella* Zone reflects an abrupt east-southeastward shift in depositional environments and only lithotopes (3) through (5) are present. The *Cedaria* Zone is largely (4) and the *Crepicephalus* and *Aphelaspis* Zones are (5b). Seas withdrew after initial *Aphelaspis* Zone deposition and returned at about the beginning of the *Elvinia* Zone. *Elvinia, Taenicephalus, Idahoia,* and early *Saukiella* Zones are (5b) with the shale dominant at the base and limestone increasing upward. Late *Saukiella, Mississquoia,* and *Bellefontia* Zones are of lithotope (6).

An unconformity variably truncates the section and younger strata lie on rocks ranging in age from *Bellefontia* Zone limestones in the Big Snowy Mountains to *Bolaspidella* Zone greensands in the Rawlins uplift.

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DELTAIC SEDIMENTATION, SOUTH PLATTE FORMATION (LOWER CRETACEOUS), MORRISON AREA, JEFFERSON COUNTY, COLORADO

Previous workers have delineated deltaic sedimentation from a western source within the South Platte Formation. Outcrop studies in the Morrison-Deer Creek area provide a model for sedimentation within the region of maximum channel development of the South Platte Formation. The total thickness of the South Platte Formation is 170 to 245 ft.

The sequence at the base of the South Platte represents marginal marine deposits and alternate fresh to marine interdistributary bays.

Ten to 20-ft sandstones, approximately 300 ft wide are active or partly active fills of minor distributary channels, or crevasse-splay channels associated with delta-plain sedimentation of a major delta lobe. Major multiple distributary channels formed as the delta