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 lobes developed and prograded. These lenticular sandstone units, such as the Kassler sandstone are 20-40 ft deep and 1,500-2,800 ft wide. Active channel fill is 50 to 90%. Similar major channels are developed within the upper part and at the top of the South Platte ("J" sandstone interval). One channel at Turkey Creek is oil saturated.

Minor penecontemporaneous faulting within the South Platte Formation produced offsets of 0.5 to 7 ft, with reconstructed strikes of the faults being perpendicular to and parallel with major channel trends. The faults may have been caused by rapid sedimentation and compaction or by minor offsets above basement-fault systems.

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DEVELOPMENT AND ECONOMIC IMPLICATIONS OF PALEOKARST, MOLAS PASS AREA, SOUTHWESTERN COLORADO

With the emergence of the Mississippian Leadville Limestone, a climatically specific subaerial tower-karst surface developed in the Molas Pass area, with 80 ft of local relief. Much of this surface is buried under different thicknesses of the Early Pennsylvanian Molas Formation, in part a regolith of siltstone and residual clays from the limestone solution.

Rising like small peaked knobs from a plain are three examples of the tower karst found near Molas Pass, the Molas Lake tower, Waterfall tower, and Sultan Creek tower. These illustrate the relatively low limestone solubility, strong fracturing, both joint and fault, and high water-table variations conducive to both tower and the related Kegelkarst formation. Folding may produce adverse conditions for the karst tending to hasten cavern integration and limestone removal.

Tower karst and the predominance of kaolinite in the lower Molas, together with silica and hematite produced from soil ferralitization, suggest a subtropical to tropical climate with heavy rainfalls followed by rapid evaporation. The modern localization of this type of karst to areas below 30° of latitude implies a northward migration of the Molas Pass area since the Early Pennsylvanian.

The complex stratigraphic relations between the fine-grained Leadville Limestone and the underlying Ouray dolomitic grainstone have made their field separation difficult and may indicate which areas were above and below sea level during the karst formation. This suggests a relative elevation of 100-200 ft for the Leadville at the time of the maximum tower-karst formation.

The geologic controls on tower-karst development as observed in the Molas Pass area correlate well with the climate and geologic controls in a modern tower-karst analogue, central Jamaica.

An understanding of the mechanisms of tower-karst formation and burial is directly applicable to petroleum stratigraphic trap location as in the Elk Basin field of northern Wyoming-southern Montana, and the localization of base metal sulfide ore deposits as at Gilman, Colorado.

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EVIDENCE OF SUBSURFACE WATER IN EQUATORIAL REGION OF MARS

Possible stream channels in the equatorial region of Mars are associated with chaotic terrain boundaries. Scalloped edges and slump features at the edge of chaotic terrain in the Chryse region of Mars indicate that the relatively smooth "upland" areas have collapsed to form chaotic terrain that has been further modified in part by both eolian and fluvial processes.

Circular depressions near chaotic terrain could result either from impact or collapse (or both). Eolian infilling may have modified impact craters to the extent that they do not resemble terrestrial or lunar counterparts. However, the dominance of fractures originating within circular depressions may indicate an internal source of heat. Collapse of the surface because of local heating, either internal or external, would provide a mechanism for both the subsidence responsible for chaotic terrain and the release of subsurface water leading to channel formation.

Analyses of *Mariner 9* imagery and ERTS photographs show that drainage basins on Mars and earth have similar characteristics, but both sets of photographs have fewer small tributaries than are actually present in terrestrial drainage basins. On earth, small tributaries are not observed because of the resolution of ERTS cameras. On Mars, both resolution and eolian infilling may account for this characteristic. There is evidence of the effects of both surface and subsurface water on Mars, but erosional characteristics of Martian channels show a closer relation to formation by subsurface water than to formation by rainfall.

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DISCONFORMITIES IN ROCKS OF EARLY LATE CRETACEOUS AGE IN SOUTHEASTERN WYOMING AND NORTH-CENTRAL COLORADO

Upper Cretaceous strata of marine origin, which are commonly called the Frontier and Niobrara Formations in southeastern Wyoming and the main body of the Benton Shale and the Niobrara Formation in north-central Colorado, enclose two widespread disconformities. The position of these disconformities and the duration of the two corresponding hiatuses in this sequence are interpreted from lithologic logs of outcrops and invertebrate fossils collected in the region. The lower unconformity separates a dominantly shale unit of Belle Fourche and Greenhorn age from an overlying dominantly sandstone unit of Carlile age. The hiatus indicates progressively less erosion in a southeasterly direction. From central Natrona County, Wyoming, where the magnitude of the lower hiatus is greatest, to eastern Larimer County, Colorado, where the magnitude is least, the age of the rocks directly below the unconformity decreases and the age of the rocks directly above the unconformity increases. The upper unconformity is generally at the contact of the Frontier or Benton and the overlying calcareous shale and limestone of the Niobrara (between beds of Carlile and Niobrara ages, respectively). The corresponding hiatus indicates more erosion in the southeastern part of the region. In contrast to the lower hiatus, the upper hiatus may be absent in central Natrona County and northwestern Carbon County, Wyoming, and seems to be greatest in eastern Larimer County, Colorado. In Natrona and Carbon Counties, the beds underlying the Niobrara are much younger and the basal strata of the Niobrara are older than rocks below and above the unconformity in Larimer County. The variation in the