AAPG ROCKY MOUNTAIN SECTION MEETING
Billings, Montana, September 18-21, 1983
Abstracts of Papers

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Minnelusa Depositional Cycles and Erosional Topography, Rozet Fields Area, Powder River Basin, Wyoming

Marine cyclic deposition is very apparent in cores of the upper Minnelusa Formation in the Rozet fields area, Powder River basin, Wyoming. A complete cycle from bottom to top is comprised of (1) subtidal facies of dolomicrite or dolomitized packstone that sometimes contains fusulinids or crinoid fragments, (2) intertidal facies of algal-laminated or layered dolomicrite which is, sometimes, desiccated and slightly brecciated, and (3) supratidal facies of anhydrite marked by "chicken-wire" structure. However, complete cycles are interrupted by exceptionally clean, well sorted quartz sandstone units that may have been deposited in a variety of closely related, coastal environments, including very shallow subtidal, intertidal, beach, and eolian.

A Minnelusa cycle and its facies have close counterparts in the Holocene sabkhas in Abu Dhabi. In addition, mapping of Minnelusa sabkhas reveals that they are very narrow, trend in the same direction, and are separated by quartz sandstone buildups that may represent eolian dune trends. A Holocene analog of the Minnelusa sabkha-eolian dune complex is seen in the area southeast of Abu Dhabi where narrow sabkhas are separated by eolian dune ridges. Thus, it appears that Minnelusa anhydrites formed in a sabkha setting very similar to the modern sabkha-eolian dune complex southeast of Abu Dhabi.

Erosional topography at the top of the Minnelusa Formation plays a prime role in the entrapment of hydrocarbon in the Rozet fields and, apparently, in many other fields that produce from the Minnelusa.

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Roosevelt Hot Springs Unit Development

The Roosevelt Hot Springs Unit, Beaver County, Utah, was unitized in April 1976, and was the first geothermal unit approved by the United States Department of the Interior. Current plans call for start-up of a 20 Mw geothermal power plant in April 1984, with the Roosevelt Hot Springs Unit producing 2.5 million pound-mass/hr (172,500 bbl/d) of fluids. This paper outlines the various steps taken during development of the resource from 1976 to the expected 1984 start-up. The topics briefly discussed will consist of a geologic description, exploration review, testing and data collection, resource and reservoir evaluation, and the 20 Mw geothermal plant.

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Structural and Sedimentologic History of Nesson Anticline

The Nesson anticline extends for 75 mi (120 km) and is the most prominent surface structure in the North Dakota portion of Williston basin. First mapped in 1918 by A. G. Collier, its description was published in a bulletin of the U.S. Geological Survey. Its axis trends north-south and is crossed by several northeast-southwest and northwest-southeast subsidiary anticlinal folds. Oil was first discovered in commercial quantity in North Dakota on the Nesson anticline in 1951. Since that time, hydrocarbons have been produced from Cambrian, Ordovician, Silurian, Devonian, and Mississippian strata.

Available well control indicates that the Nesson anticline was initiated during the Precambrian. Indications are that the structure probably was normally faulted on the west margin. Structural deformation was episodic, with recurrent motion along the same fault system through time. Cross sections and isopach and structure maps document the changes in fault motion and basin communication with open marine waters.

Continuing movement of the border faults of the Nesson anticline probably have enhanced porosity development by fracturing and by creation of sedimentary and diagenetic environments which favor porosity development.

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Structural Influence on Lower and Middle Cretaceous Sedimentation, Northern Great Plains

Sedimentation during the Lower and middle Cretaceous in the northern Great Plains (eastern Montana, North Dakota, South Dakota, and northeastern Wyoming) was influenced by recurrent movement of basement fault blocks. Regional thickness variations of four time-stratigraphic intervals are linear and have dominant orientations of northeast and northwest. Regional distribution of porous and permeable sandstone in the Muddy-Newcastle formation and equivalents (Albian), and in the Inyan Kara Group and equivalents (Aptian-Albian) are also linear and have dominant orientations of northeast and northwest. Similar thickness variations and directions of Lower Cretaceous units on the southwest flank of the Black Hills have been described in detail by Weimer and others in 1983.

A depositional model, incorporating structural and sea level changes, shows that marine and nonmarine units thicken in structurally low areas and thin over structurally high areas.

A tectonic model to account for the linear orientations, illustrates the effects of simple and pure shear stress systems. The stress systems were formed from the recurrent movement of basement faults possibly caused by movement of the North American plate during the Cretaceous.

Major surface expressed folds and faults and surface lineaments have dominant orientations of northeast and northwest. These features either overlap or are parallel to linear thickness trends of Cretaceous rocks. Both surface and subsurface features are thought to have resulted from common basement fault block movement.

Sedimentation and tectonic models can be used to predict vertical and lateral distribution of marine and nonmarine rocks. When integrated with these models, orientation of fractures and routes of fluid migration can be predicted by paleostructure analyses.

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Paleotectonic Control of Pennsylvanian Sedimentation in Paradox Basin

The Paradox basin of the east-central Colorado Plateau province is an elongate rhombic evaporite basin of Middle Pennsylvanian age. It is bounded on the northeast by the Uncompahgre and San Luis segments of the Ancestral Rockies. The northwest-trending basin sagged along preexisting basement rifts by strong east-west extension during Desmoinesian time. The dominant zone of weakness was the northwesterly Olympic-Wichita basement lineament that lies along the eastern margin of the salt basin and the southwestern front of the Uncompahgre and San Luis uplifts. Less prominent northwest and northeast shear zones are ubiquitous, but are especially well developed in basement and Paleozoic rocks underlying the San Juan basin and the southwest shelf of the Paradox basin. It is a classic pull-apart basin developed along anastomosing wrench faults which first developed at about 1,700 m.y.B.P., and were rejuvenated repeatedly throughout the Paleozoic.

Initial subsidence and associated sedimentation occurred in the southeastern divergent termination of the basin in Atokan and early Desmoinesian time, when the Grenadier and Sneffels horst blocks were elevated to form the San Luis uplift. The quartzite-dominated horsts shed large volumes of relatively nonfeldspathic quartzose sediments into shallow seaways of northern New Mexico and southwestern Colorado. By mid-Desmoinesian time, the true Uncompahgre uplift was elevated to the north, and shed vast accumulations of arkose into the eastern margins of the basin. Meanwhile, cyclic evaporites, dominated by salt, accumulated in the structurally restricted basin. The southwestern shallow shelf of the basin developed along a broad zone of basement rifting, extending across the northern San Juan basin, the Four Corners platform, and northwest to beyond the Henry Mountains. The Four Corners lineament served to terminate salt deposition along the structural shelf and create local shoaling conditions to host myriad algal bioherms that would become prolific petroleum reservoirs. These fields include the giant Aneth field and the recently developed Bug field complex. Unlike the dramatic events along the eastern Paradox basin, tectonic involvement of carbonate sedimentation on the southwest shelf was very subtle. Sea-floor topography of a few feet over deep-seated faults would have been sufficient to localize biohermal development. Subtle tectonically induced topography on the present Monument upwarp and San Rafael swell limited sedimentation along the western basin margin.

The northwesterly rift fabric of the basin is transected by the conjugate northeast-trending basement fractures of the Colorado lineament. The most important of these underlies the length of the Colorado River, and terminates or offsets the major salt diapirs of the eastern basin. Northwest of the structure, the Paradox basin becomes compressional rather than extensional as to the south, due to convergent termination of the pull-apart basin; and marine sedimentation becomes rapidly limited to the narrow Oquirrh sag between the Emery and Uncompahgre uplifts. Also, the large influx of arkose from the Uncompahgre becomes much younger (Early Permian). Every aspect of sedimentation (clastic, evaporite, and carbonate) in the Paradox basin was greatly influenced by contemporaneous rejuvenation of the basement tectonic fabric.

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Hydrocarbon Accumulation in Pennsylvanian-Age Tensleep Sandstone: Trapper Creek Deposit, Wyoming

Preliminary investigations indicate a potential hydrocarbon accumulation in the Trapper Creek, Wyoming, deposit of more than 2.13 million tons of mineralized material with a yield of 0.92 bbl per ton of 5.2° API oil for an approximate resource of 1.96 million bbl of recoverable petroleum. Remote sensing data suggest that the accumulation is in part controlled by two major and four minor lineaments which traverse the area. Stratigraphic and lithologic criteria can be used to infer a "Minnelusa-type" model of occurrence. Ancillary stream sediment and outcrop geochemistry yield locally anomalous, but uneconomic concentrations of magnesium, calcium, titanium, manganese, silver, copper, molybdenum, vanadium, potassium, and silicon, which may have significance in the identification of similar hydrocarbon accumulations along the west flank of the Bighorn Mountains.

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Winnipeg Formation (Middle Ordovician), Williston Basin

Although the Winnipeg Formation has long been of interest to the oil and gas industry, little has been published on it. This study established a regional correlation of the Winnipeg Formation members by using mechanical well logs, Amstrat lithologic logs, and North Dakota Geological Survey Circulars. A regional cross section was constructed establishing the correlation markers. Data collected were used to divide the Winnipeg into three members: an upper transitional member, the Winnipeg shale, and the basal Winnipeg Sandstone. Isopach maps of the shale and sandstone members and a structure contour map were also made.

The Winnipeg Formation is Middle Ordovician in age. It lies unconformably over Lower Ordovician–Cambrian sediments or Precambrian basement rock and is conformably overlain by the Red River Formation.

The Winnipeg shale, a greenish gray calcareous shale, develops a sandstone lens in northwestern North Dakota called the "Middle Sand Member" in the literature. The shale isopach shows the thickness varying from approximately 90 ft (27 m) along the Cedar Creek anticline to over 200 ft (61 m) in the southeastern corner of North Dakota.

The Winnipeg Sandstone, a blanket marine sandstone, shows the thickest sandstone along the Nesson anticline and is absent along the southern end of Cedar Creek anticline. The Winnipeg Sandstone's lithology is similar to the Deadwood Sandstone of Cambrian age, suggesting that the Deadwood Sandstone may be a source for the Winnipeg Sandstone.

The transition zone represents a transgressive facies change. The consistent distinctive gamma ray kick used as the transition zone correlation marker was used as datum point for the cross sections and structure contour map.

Problems encountered included scattered well control, difficulty determining the bottom of the sandstone interval, wells not penetrating the entire section, difficulty determining the top of the shale interval, and difficulty in correlating old electric logs.

Recent gas and oil discoveries in the Winnipeg Formation have renewed interest in its economic potential. Several fields in North Dakota produce from the Winnipeg Sandstone. In Montana, good gas shows have been found in the middle sand member.

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Exploration for Oil and Gas in Flathead Region, Montana and British Columbia, 1892 to 1983

Oil seeps had long been known and used in the Flathead region, but after official reports in 1892, all areas around known seeps and supposed seeps were staked with claims. By 1910, several wells had been drilled with oil shows in the Waterton area, two at Akimina Creek in British Columbia, four in the Kintla area (with oil and gas shows) in Flathead County, Montana, and a small, short-lived, producing field on Swiftcurrent Creek in Glacier County, Montana. The creation of Glacier National Park in Montana (1910) and Waterton Lakes National Park in Alberta (1911) ruled out exploration in those areas.

Exploration continued in the Flathead region of British Columbia, especially at Sage Creek, with the discovery of numerous oil and gas seeps. Drilling in the vicinity of the seeps never achieved production but almost always had numerous oil and gas shows in holes that were terminated because of equipment or hole problems. The prolific occurrences of oil and gas in lost holes was usually enough for new promoters to find new investors to spend their money on new wells. All drilling was in rocks of the Precambrian Belt Supergroup and was very difficult with cable tool rigs. Crow's Nest Glacier Oil Co. 1 spudded in 1918 and terminated at 3,265 ft (995 m) in 1932. Columbia Oils Ltd. attempted to penetrate the Lewis thrust but quit after 5 years in 1938 at 8,000 ft (2,438 m) when it found that the hole had gone horizontal. Flathead Petroleum finally penetrated the thrust plate in 1951 at 4,400 ft (1,500 m). It tested the Mississippian Rundle Group (Madison equivalent) and found only carbon dioxide gas. The Sage Creek seeps and old open wells are still producing a fine light 42° oil as well as flammable gas from some as yet undetected source.

Several wells have tested the Tertiary Kishenehn Formation. Drilling began in 1902 when Kintla Lake Oil Co. drilled two wells, 1,290 ft (393 m) and 1,000 ft (305 m), based on oil shales from which oil was distilled. Two old wells in Canada had oil and gas shows in the Tertiary as did the recent Nyvatex Mueller 1 (test) in Flathead County, Montana, which was drilled to 800 ft (244 m). Other more recent wells in the Flathead region of British Columbia have had noncommercial shows of gas. The complex structure of the region combined with the surface exposures of Precambrian Belt Supergroup rocks have greatly hindered exploration in the past and caused current explorationists to have second thoughts. The prolific gas fields of the foothills of southern Alberta, and the fact that significant oil and gas occurrences in the region do exist, continue to draw interest to the area. The current and latest exploration effort will finally begin to truly assess the petroleum potential felt to exist by the petroleum pioneers who broke their bits in the region.

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Petroleum Potential of Winnipeg Sandstone in South Dakota

The term "Winnipeg Group" includes all strata which underlie the Red River Formation and overlie the Precambrian basement complex. The upper unit, a greenish-gray, noncalcareous marine shale, is called the Icebox Shale or Winnipeg shale in the Williston basin, and it ranges from 0 to more than 100 ft (30 m) in thickness. Outcrops in the Black Hills contain Middle Ordovician fossils. The lower unit consists mainly of quartzose sandstone ranging from 0 to 465 ft (141 m) or more in thickness. In the northern Black Hills, most of the sandstone is included in the Deadwood Formation and is Late Cambrian in age, but the uppermost beds are Early and Middle(?) Ordovician. In the Williston basin, the terms Black Island and Winnipeg Sandstone have been used to denote the sandstones which underlie the Icebox or Winnipeg shale. The disconformity which separates Black Island and Deadwood sandstones cannot be traced with confidence into the subsurface of South Dakota, where the entire sequence appears to be a blanket of sandstone containing only thin interbeds of dolomite and shale. Therefore, the term Winnipeg Sandstone is used to denote all the sandstone between the Winnipeg shale and the Precambrian basement.