on the petroliferous Mississippian Heath limestone they became potential hydrocarbon reservoirs.

Jim Coulee and Little Wall fields are in Ts10 and 11N, R27E, Musselshell County, Montana. These two fields are productive from six different point-bar sandstones which were deposited within one of the Pennsylvanian channel systems. Both productive areas were discovered in late 1969 and field developments still are continuing.

Jim Coulee has 25 productive wells within its present field boundaries. The average net pay is 18 ft (6 m) at a depth of 3,550 ft (1,082 m). Ultimate oil recovery is placed between four and five million bbl.

Little Wall field has eight productive wells with an average pay thickness of 30 ft (9 m) at a depth of 3,600 ft (1,097 m). Ultimate oil recovery should be in the range of 2 ½ million bbl.

The dipmeter has been used extensively throughout the area to determine water-transport direction, direction of channel center, and the type of bedding within each sand lens. This tool, coupled with other subsurface information, has helped in orderly field development and stepout extensions.

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Field Evidence for Structural Style of Laramide Traps in Rocky Mountain Forelands

By comparing many structures that crop out on the margins of the intermontane basins in the Rocky Mountain forelands, certain generalities can be made concerning structural style. Whether or not the layered rocks fault or fold is partly a function of the angle at which the deepest fault cuts the basement sedimentary rock interface. How much folding occurs and what shape it takes is a function of the sedimentary section involved.

Further, there are certain characteristics of these structures which are related uniquely to their overall geometry so that sometimes shape can be predicted from very limited data. These interrelated parameters can be carried into seismic interpretations to determine characteristics of buried structures.

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Multi-Dimensional Seismic Displays

Explorationists daily are required to interpret ever-increasing volumes of multidimensional data. Greater efficiency is available if data are presented to the interpreter in a graphically concise form.

Evaluation of seismic variables such as reflection strength, frequency content, phase, and interval velocity is simplified greatly by displaying these variables in color on the seismic sections. These displays take an even greater meaning when displayed in a 3-dimensional isometric form.

The reduction of complex data to a single display allows greatly enhanced decision-making by removing the problems of extrapolation, allowing the explorationist to concentrate on the kernel of the problem, i.e., the geologic implications of the data.

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Raft River, Idaho, Geothermal Wells: Siting, Drilling, and Testing

The area of southern and eastern Idaho is one of the most promising regions in the United States for near-surface, economically recoverable geothermal energy. This part of the state is divided between two physiographic regions. The Snake River Plain is typical of the volcanic-rift regions of the United States where approximately 8 percent of the hot wells, geothermal springs, and geysers in the western United States are located. South of this region is the Basin and Range province which covers Nevada, the western half of Utah, the southwestern half of Arizona, as well as parts of California, New Mexico, Colorado, and Montana, in addition to parts of southern Idaho. In this province are located more than a third of the known hot wells, geothermal springs, and geysers in the western United States.

In 1973, the Idaho National Engineering Laboratory (INEL) was funded by the Energy Research and Development Administration (ERDA) to pursue a program of research and development into the geothermal potential of the Raft River Valley, Cassia County, Idaho. A cooperative effort then was undertaken involving Aerojet Nuclear Co., U.S. Geological Survey, State of Idaho, and Raft River Rural Electric Cooperative. The objective of this effort is directed toward evaluating the possibility of establishing a geothermal plant in the area for the production of electricity.

The first step toward this objective, the drilling of two wells and their evaluation, has been partly completed during this last year. A review of the problems and experiences during the siting, drilling, and testing of these wells is very appropriate at this time.

The siting phase was completed with an evaluation of all geologic and geophysical data gathered, primarily by the U.S. Geological Survey, during a 1 ½-year field study. The drilling phase was conducted by INEL with a drilling rig from Reynolds Electric and Engineering Co., another ERDA contractor of Las Vegas, Nevada. The testing phase involved both INEL and the University of California Lawrence Berkeley Laboratory personnel.

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Proposed Geothermal Circulation Pattern, Corwin Springs–Gardiner Area, Montana

Hot-spring activity has persisted in the Corwin Springs–Gardiner area since the Pleistocene. The only active hot springs, LaDuke and Bear Creek, emerge at opposite ends of a 2-sq-mi (5.2 sq km) Pleistocene travertine deposit. The hot springs and travertine lie along the northwest-trending Gardiner fault, a Laramide high-angle reverse imbricate fault zone, which bounds the Beartooth crystalline rock uplift on the southwest. The post-Laramide Reese Creek and Mammoth faults are graben-forming normal faults that extend from the park upland northward into the hanging wall of the

Gardiner fault. The local thermal features lie on or between the intersections of these faults with the Gardiner fault zone. More than 10,000 ft (3,050 m) of Paleozoic and Mesozoic sedimentary rock is preserved within the graben in the footwall of the Gardiner fault. From a structural high within Yellowstone Park, the sedimentary units dip gently into the Gardiner fault zone, where they are dragged up and overturned locally to form an asymmetric syncline striking northwest. These structural relations suggest that ground waters flow down permeable sedimentary units within the graben from the Yellowstone upland to great depth under the Gardiner fault zone. Waters are heated at this depth and ascend through fractures to the surface. The cavernous Mississippian Madison Limestone, lying near a depth of 10, 000 ft (3,050 m) under the Gardiner fault zone, may be the principal aquifer and produce the high calcium content of the active hot springs. A normal thermal gradient could cause significant heating at this depth.

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Depositional Environments of Oil Shale

Oil shale in the Green River Formation of Wyoming and Colorado is associated with domal stromatolites, cross-bedded ooliths and pisoliths, ostracodal lag deposits, flat pebble conglomerates, bedded saline minerals, and barren marlstones with flute casts. In addition, some oil shale units contain mudcracks, breccias, and saline mineral nodules. Obviously neither the depth of water, nor the presence of bottom currents in the depositional environment, is a limiting factor relative to oil shale deposition.

On the other hand, the influx of detrital sediments is a serious constraint on oil shale deposition. Kerogen content of oil shale drops drastically near clastic deltas and prograding clastic shorelines. Much of the oil shale in the Green River Formation was deposited in an environment characterized by shallow water, periodic desiccation, high organic productivity, and a very low sediment influx. These conditions are well satisfied by a playa-lake complex, or in other words, a shallow-water lake surrounded and protected by a broad playa fringe.

Kerogen-rich laminae of the oil shale are the result of a relatively continuous deposition of algal mats and oozes, whereas the carbonate-rich laminae are derived from at least two sources: (1) clastic transport and (2) chemical precipitation. Seasonal flooding of the playa lake with fresher water contributes not only detrital carbonates washed into the lacustrine environment from the playa fringer, but also contributes carbonate as a chemical precipitate.

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Source Beds of Petroleum in Denver Basin

Crude oil and shale samples from the Denver basin were analyzed by organic geochemical techniques to determine oil-source-bed relations. Infrared spectrophotometry, gas chromatography of the $C_{15}+$ saturates, mass spectrometry, and carbon- and sulfur-isotopic ratios were used to characterize both the crude oils and the extractable organic matter in shales. The oils were characterized further by gas chromatography of the C_4-C_7 fraction and optical rotation measurements.

In general, oils in Cretaceous rocks are compositionally similar, and they can be distinguished from oils in the Permian Lyons Sandstone. The Cretaceous oils were compared with extractable organic matter in Cretaceous shales to determine the regional and stratigraphic occurrence of petroleum source beds. The results show that most Cretaceous shales are thermally immature over a large part of the basin. In areas where the Cretaceous section has had a thermal history sufficient to cause generation of petroleum like hydrocarbons within the shales, many potential source beds exist. The geographically limited occurrence of source beds and the occurrence of oil in thermally immature areas suggest that extensive vertical and lateral migration has occurred.

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Corwin Springs Known Geothermal Resources Area, Park County, Montana

The Corwin Springs Known Geothermal Resources Area is contiguous to Yellowstone National Park along a part of the northern boundary of the park near Gardiner, Park County, Montana. The area contains two known sites of hot springs activity—LaDuke Spring, 2.8 km southeast of the small resort community of Corwin Springs, and Bear Creek Spring, 2.6 km east of Gardiner. LaDuke Spring issues from brecciated quartzite and has a flow rate of 380 l/min, a surface water temperature of 65°C, a silica-geothermometer temperature of 66.9°C, and a Na-K-Ca geothermometer temperature of 77°C. Bear Creek Spring issues from limestone and has a flow rate of 4 l/min, a surface water temperature of 32°C, a silica temperature of 44.8°C, and a Na-K-Ca temperature of 87.3°C. The springs, which are actively depositing travertine, are on or near the trace of the Gardiner fault, a high-angle reverse fault which forms the southwestern boundary of the Beartooth uplift.

Interesting features of this potentially significant geothermal area include: (1) the proximity of the Corwin Springs area to the intense geothermal activity and significant Pliocene and Pleistocene volcanism in Yellowstone National Park; (2) the Sepulcher graben, a potential geothermal reservoir and major geologic structure extending from the Corwin Springs area into Yellowstone National Park; (3) the Gardiner fault and its role in localizing thermal activity in the Corwin Springs area; (4) the negative gravity anomaly centered over the northern terminus of the Sepulcher graben; (5) the negative magnetic anomaly in the area; (6) the location of the area within the Intermountain seismic belt; (7) the existence of recent tectonism within the area, as demonstrated by Pleistocene and Holocene faulting; and (8) the observed surface and estimated geochemical temperatures of the two known hot springs—features which do not indicate high subsurface temperatures.

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Sedimentation and Multiple Coal-Seam Correlations in Upper Cretaceous Swamp Complex, John Henry