The southeastern Absaroka volcanic sequence consists mainly of middle Eocene (50 to 43 m.y.B.P.) epiclastic rocks with minor pyroclastic rocks and lava flows near vent areas. The Wood River–Greybull River volcanic center is a major source of reworked material. From oldest to youngest, moderately colorful tan, brown, green, and maroon volcanic claystones, siltstone, and sandstones predominate in the Aycross Formation (1,000 ft, 305 m, thick); olive-drab volcanic sandstones and breccias predominate in the Tepee Trail Formation (2,500 ft, 760 m, thick); and light gray volcanic conglomerates and tuffaceous sandstones are most common in the Wiggins Formation (2,000 ft, 600 m, thick). The Aycross Formation contains abundant bentonitic material, forms a perched water table, and is probably an effective caprock. The Blue Point marker, a distinctive sequence of white bentonite beds, separates the Aycross and Tepee Trail Formations and is the best horizon for structural contouring within the volcanic rocks.

Broad gentle folds and horst blocks within Aycross, Tepee Trail, and lower Wiggins strata indicate movement on "Laramide structures" until approximately 45 m.y.B.P. However, several episodes of large-scale Eocene detachment faulting and mass movements locally obscure this relationship. Domal features beneath the volcanics and stratigraphic traps at the volcanic-nonvolcanic contact are the primary exploration targets, but significant traps related to the volcanic activity may be present locally.

THRASHER, LARRY, and F. D. HOLLAND, JR., Univ. North Dakota, Grand Forks, ND

Macrofossils of Bakken Formation (Devonian and Mississippian), Williston Basin, North Dakota

Results of this study of the macrofossils of the Bakken Formation in North Dakota have reinforced the suggestion, based on previous paleontological work in Saskatchewan, that the Bakken is of both Devonian and Mississippian age, rather than being entirely of Lower Mississippian age as originally considered. Increased drilling and coring activity in the North Dakota part of the Williston basin has provided the opportunity for acquiring a larger fauna than was previously available. Most of the fossils were obtained from the middle part of the Bakken Formation.

Based on lithologic character, the Bakken has been divided into three informal members. These consist of a calcareous siltstone unit between two lithologically similar units of carbonaceous shale. These black shales contain similar faunas distinct from that of the middle member. The black shales contain inarticulate brachiopods, conchostracans, and rare cephalopods and fish remains as well as more abundant conodonts, ostracods, and palynomorphs. The middle siltstone unit contains a more abundant and diverse fauna consisting of inarticulate and articulate brachiopods together with corals, gastropods, cephalopods, ostracods, echinoderm remains, and trace fossils. This is the first report of cephalopods, conchostracans, ostracods, corals, trace fossils, and some of the brachiopods in the Bakken, although all, except the gastropods, have been reported from stratigraphic equivalents (Exshaw Formation of Alberta, the Sappington Member of the Three Forks Formation of south-central Montana, the Leatham Formation of northeastern Utah, and the middle member of the Pilot Shale in western Utah and eastern Nevada). The Bakken macrofauna adds another dimension to interpretation of the depositional environment and paleoecology of offshore, sediment-starved, basinal units.

TILLMAN, RODERICK W., Cities Service Research, Tulsa, OK, and RANDI S. MARTINSEN, Consultant, Laramie, WY

Possible Tectonic Influence on and Facies Distribution of Shannon Ridge Sandstones, Wyoming

In the Powder River basin of Wyoming, Upper Cretaceous Shannon Sandstone shelf sand ridges are formed along the crest of a broad, subtle, southwest to northeast-trending paleoarch. During Shannon deposition, relief on the arch was great enough to alter shelf energies and cause sand ridges to develop within a predominantly silty shale interval.

Possible recurrent movement in the Salt Creek anticline created a paleohigh which strongly localized development of thick sand ridge complexes in the Shannon Sandstone. During Shannon deposition, relief on the paleohigh apparently was strong enough to cause ridges to build laterally as well as vertically. Shannon ridge complexes at Salt Creek are more oblate, bigger, thicker, and more closely spaced than most central Powder River basin ridges. Also, there are two vertically stacked ridge systems developed within the Shannon Sandstone. While the lower ridge system is coeval with the Shannon ridge system in the central basin, the upper ridge system is only developed locally and, we believe, is related to active growth on the paleohigh during Shannon deposition. At no time, however, did the paleohigh cause ridges to be subaerially exposed.

Eleven Shannon shelf ridge and ridge-associated facies were defined in outcrops on the Salt Creek anticline. Vertical and lateral changes in facies are relatively abrupt where observed in closely spaced outcrop sections and, in general, facies are stacked in coarsening-upward sequences with central bar facies commonly immediately overlying interbar sandstone facies. Porous and permeable potential reservoir facies include: central bar facies, a clean, cross-bedded sandstone; bar margin facies (Type 1), a highly glauconitic, cross-bedded sandstone containing abundant shale and limonite (after siderite) rip-up clasts and lenses; and bar margin facies (Type 2), a cross-bedded to rippled sandstone. These facies were formed by sediment transported and deposited in the form of medium to large-scale troughs and sand waves on and across the tops of ridges by moderate to high-energy shelf currents.

TONNSEN, JOHN J., General Hydrocarbons, Inc., Billings, MT

Influence of Tectonic Terranes Adjacent to Precambrian Wyoming Province on Petroleum Source and Reservoir Rock Stratigraphy in Northern Rocky Mountain Region

The perimeter of the Archean Precambrian Wyoming province can be defined generally. A Proterozoic suture belt separates the province from the Archean Superior province to the east. The western margin lies under the western Overthrust belt and extends at least as far west as southwest Montana and southeast Idaho. The province is bounded on the north and south by more regionally extensive Proterozoic mobile belts. In the northern belt, Archean rocks have been incorporated into the Proterozoic rocks, but the southern belt does not appear to contain rocks as old as Archean. The tectonic response of these Precambrian terranes to cratonic and continental margin vertical and horizontal forces has exerted a profound influence on Phanerozoic sedimentation and stratigraphic facies distribution. Petroleum source rock and reservoir rock stratigraphy of the northern Rocky Mountain region can be correlated with this structural history. In particular, the Devonian, Permian, and Jurassic sedimentation patterns can be shown to have been influenced by articulation among the different terranes comprising the ancient substructure. Depositional patterns in the Chester-Morrow carbonate and clastic sequence in the Central Montana trough are also related to this substructure. Further, a correlation between these tectonic terranes and the localization of regional hydrocarbon accumulations has been observed and has been useful in basin analyses for exploration planning.

TROMP, PAUL L., Mitchell Energy Corp., Denver, CO

Depositional Environments of Middle Minnelusa "Leo" (Middle and Upper Pennsylvanian), Wyoming, South Dakota, and Nebraska

The informal middle member of the Minnelusa Formation, commonly known as Leo, consists of a spectrum of sediments including sandstone, dolomite, anhydrite, bedded chert, limestone, and radioactive carbonaceous shale. Deposition within the upper Paleozoic Alliance basin of the present day tri-state area of South Dakota, Wyoming, and Nebraska occurred in sabkha, tidal flat, and shallow subtidal environments. Major and minor cycles of eustatic sea level changes are manifest by the Leo section. Eolian sands, organic "black shales," supratidal to subtidal carbonates, and evaporites are intercalated in close vertical and lateral proximity.

Early Desmoinesian (lowermost Leo) sediments are open marine, upper subtidal limestone interbedded with restricted marine upper subtidal dolomite, anhydrite, and radioactive organic-rich dolomite. During the upper Desmoinesian and lower Missourian, most of the Alliance basin was a restricted carbonate tidal flat. Throughout the remainder of the Pennsylvanian, the prevalent environment was a restricted coastal to inland sabkha with episodic inundations intercalating intertidal dolomite and lagoonal "black shale" with the sabkha sediments. Prolonged periods of exposure allowed migration of eolian dunes across the region. The broad sabkha surface was an area of eolian bypass with only isolated patches of dunes being trapped by rare topographic relief. The bulk of the migrating sand was transported south and west into the sand seas of the Tensleep, Weber, and Casper Formations. Sand was supplied from the north probably by eroded Tyler and older Paleozoic sandstones. In the present-day Hartville uplift area, an Upper Pennsylvanian trough known as the Lusk embayment modified Leo sedimentation. This trough introduced open marine waters into the southwestern corner of the Leo region, resulting in deposition of crinoidal limestone (in lieu of evaporites and carbonaceous shale) interbedded with eolian dunes.

Criteria suggesting windblown deposition of the majority of Leo sandstone include deflationary lag surfaces, low-amplitude ripples, subcritically climbing translatent cross-stratification, and sand-flow toes. Isolated eolian sandstones provide excellent stratigraphic traps for hydrocarbons generated in the organic-rich shales. The current flurry of Leo drilling that began in 1978, has affirmed the inherent potential of this play. Definition of paleodepositional trends and seismic recognition of isolated dunes are the keys to Leo exploration success.

VERPLOEG, ALAN J., and RODNEY H. DEBRUIN, Wyoming Geol. Survey, Laramie, WY

Trapper Canyon Deposit, Eastern Big Horn Basin, Wyoming: Tar Sand or Heavy Oil?

The Trapper Canyon Deposit (Battle Creek Deposit in U.S. Bureau of Mines Monograph 12) is located on the western flank of the Bighorn Mountains approximately 30 mi (48 km) east of Greybull, Wyoming. The petroleum occurs in the upper eolian sequence of the Pennsylvanian Tensleep Sandstone which dips from 5° to 8° to the southwest. The deposit was initially reported by N. H. Darton in U.S. Geological Survey Professional Paper 51 in 1906. A characterization study was made on the deposit which included mapping the deposit and surrounding area, measuring three stratigraphic sections in the Tensleep Sandstone, and sampling 13 outcrop localities. Thickness of the deposit ranged from 0 to 22.5 ft (6.8 m) in the 13 sample localities. Preliminary analyses of outcrop samples indicate API gravities and viscosities consistent with the definition of a tar sand. Oil properties are similar to those published for Phosphoria-sourced oils produced from the Tensleep Sandstone in fields to the west. Lateral pinch-out of the deposit, tight characteristics of upper and lower bounding units, and the lack of any apparent structural controls in the area, are all evidence for a stratigraphic trapping mechanism. Recoverable reserves are estimated at 1.96 million bbl over a 67-acre (27 ha.) area.

VICE, D. H., Independent, Billings, MT, J. P. CROWLEY, Crowley Environmental and Planning Assocs., Calgary, Alberta, Canada, and M. A. VICE, Independent, Billings, MT

Thermal Infrared Survey of Sunlight Basin, Park County, Wyoming

Thermal infrared surveys were flown over the Sunlight mining region and Sulphur Camp area of the Sunlight basin to substantiate whether reported fumaroles are indicative of contemporary geothermal activity in the area.

Thermal infrared imagery shows areas of warm ground along and warm water discharge into Sunlight Creek and Sulphur Lake. Sulphur deposits are found on north- and south-facing hill slopes associated with a second warm ground anomaly adjacent to Gas Creek. Warming is also manifested in the thermal characteristics of vegetation, and several fumaroles are identifiable. Aeromagnetic data show a 200 gamma low at Sulphur Camp which cannot be explained topographically.

Major northeast-trending lineaments provide potential conduits for thermal fluids from the magma plume in Yellowstone National Park, 50 km (30 mi) to the southwest. The floor of the Yellowstone caldera is topographically higher and could provide the necessary hydraulic head to move the fluids outward. Other geothermal resources may exhibit the same characteristics. This example suggests that geothermal resources may occur at considerable distances from a heat source.

VUKE, SUSAN, Montana Bur. Mine and Geology, Butte, MT

Comparison of Western Facies of Thermopolis, Muddy, and Mowry Formations with Other Areas of the Early Cretaceous Seaway, Northern Rocky Mountains and Great Plains Region

The Thermopolis, Muddy, and Mowry formations were deposited in environments associated with an Early Cretaceous sea in the area of the modern Northern Rocky Mountains and Great Plains. The sea advanced into the western interior from the north temporarily joining a northward-transgressing Gulf sea. A regressive period followed, and the southern margin of the sea retreated at least as far north as Wyoming. Studies of depositional environments in the central and eastern parts of the seaway indicate that a second Early Cretaceous transgression followed. However, evidence for the second transgression is not apparent in the study area (Madison and Gallatin Ranges of southwestern Montana). Eastward progradation of marginal marine environments continued on the western side of the seaway despite the sea's second advance. Fluvially dominated delta systems developed on the western side with only minor reworking by marine processes. The western side also received significant amounts of volcaniclastics producing additional lithologic and environmental differences across the seaway.

Facies of the Thermopolis, Muddy, and Mowry formations on the western side of the seaway are compared with other parts of the seaway through compilation of regional paleogeographic maps for five Early Cretaceous episodes. These comparisons show that significant differences in sediment source, amount of sediment input, and tectonic setting existed from one side of the seaway to the other. The following are some of the changes in the Thermopolis, Muddy, and Mowry formations which occur across the Early Cretaceous seaway as a result of the following differences. (1) The lower, informally designated "rusty beds member" of the Thermopolis Shale is more calcareous on the western side of the seaway. Paleozoic carbonates provided sediment from the west while siliciclastic sediment was shed into the seaway from the east. (2) The Thermopolis Shale was subaerially exposed on the eastern side of the seaway is separated from overlying Muddy Sandstone by an unconformity. In contrast, the depositional sequence is continuous on the western side. (3) An unconformity separates lower, regressive Muddy Sandstone deposits from overlying transgressive Muddy Sandstone deposits in the central and eastern parts of the seaway. The Muddy Sandstone on the western side of the seaway is a continuous regressive deposit. (4) The transgressing sea reworked lower Muddy Sandstone into extensive winnowed bar deposits in the eastern and central parts of the seaway. These excellent oil and gas reservoirs apparently are not present on the western side of the seaway. (5) The Mowry Shale was deposited in offshore marine environments in most of the Northern Rocky Mountains and Great Plains region. However, in most of southwestern Montana, the Mowry Shale and equivalents were deposited in nonmarine environments. (6) Siliceous claystone is the dominant lithology of the Mowry Shale deposited in marine environments on the western side of the seaway. Much of the sediment on the western side was derived from volcanic sources. The Mowry Shale is less siliceous to the east, probably because volcanic sediment decreases eastward. Organic carbon content is higher to the east, increasing the petroleum source potential of the Mowry Shale on the eastern side of the seaway.

WALLICK, BRIAN P., Univ. North Dakota, Grand Forks, ND

Depositional Environment of Bullion Creek Formation (Paleocene) in Southern McKenzie County, North Dakota

The environment of deposition of the Bullion Creek Formation in western North Dakota has been variously ascribed to lacustrine, meandering fluvial, and marginal marine deltaic environments with the latter three being favored by most workers. The purpose of the present study is to evaluate these previous models through careful field observations on a local scale, more specifically T145 and 146N, R102W of McKenzie County, North Dakota.

The Bullion Creek Formation rests conformably atop the Slope Formation (nonmarine) in the southwest quarter of the state and is conformably overlain by the Sentinel Butte Formation. The Tongue River Member of the Fort Union Formation is the lateral equivalent of the Bul-