to a much lesser role than formerly, applying only to blocks of *unfractured* rock a few kilometers on a side, if such exist.

The studies to date indicate that the basement fracture sets formed in orthogonal, *i.e.*, right angle, patterns; that the fractures of different sets trend through one another with little or no displacement, and hence resulted from vertical, rather than horizontal forces; and that they are very old. One key study of aeromagnetics on the Colorado Plateau indicates that the minimum age of the fracturing is 1.7 billion years. Several mechanisms for the formation of these sets have been proposed.

GLASS, GARY B., Wyoming Geol. Survey, Univ. Wyoming, Laramie, Wyo.

CONTRASTING THE EFFECTS OF COAL MINING IN WYOMING AND PENNSYLVANIA

Acid mine water and increased stream siltation are both attributable to Pennsylvania's coal mining and are significant polluters of their water resources. Coal mining affects Wyoming's waters minimally because there are no acid water and very little siltation of permanent streams. In Wyoming coal mining can improve groundwater recharge and store much needed water.

Pennsylvania's coal-mined land is adversely affected by (1) subsidence; (2) total disturbed, surface-mined acreage (350,000 acres) and its rate of increase (12,000 acres in 1971 for 27 million tons of coal); and (3) slides on hillsides. Wyoming's sparse population makes subsidence effects minimal. Disturbed surface land effects are minimized by the (1) small total acreage (3,936 acres) and small annual increase (averages 170 acres for 8 million tons); (2) low-relief, flat, basinal rangelands mined; (3) remoteness from population centers; and (4) similarity of mine spoils with some natural landforms.

Wind-blown dust and fumes from burning culm banks and mine fires are accentuated in Pennsylvania because of their closer proximity to populated areas.

Although at least 80% of the disturbed surface acreage in Pennsylvania is recreational woodland, most disturbed acreage is remote, sparsely vegetated rangeland in Wyoming. Although vegetation in both states can be reestablished by planting or more slowly by natural revegetation, toxicity of mine wastes in Pennsylvania commonly retards its reestablishment and kills vegetation adjacent to the mine as well.

In Wyoming, the adverse effects of coal mining other than subjective, esthetic criticisms of temporary surface land disturbances are less damaging than in Pennsylvania.

GOODWIN, JONATHAN H., Dept. Geol. and Geophys. Sci., Univ. Utah, Salt Lake City, Utah.

SALT DEPOSITION IN NORTH ARM, GREAT SALT LAKE, UTAH

Construction of a semipermeable, rock-fill railroad causeway across the Great Salt Lake has caused a severe imbalance in concentrations of lake brines north and south of the causeway. Ninety percent of freshwater inflow enters the lake south of the causeway. South arm brines are becoming progressively fresher as salts are deposited on the floor of the north arm where there is no freshwater inflow other than rainfall and minor springs. The water surface of the south arm is as much as 40 cm higher than the surface of the north arm.

Logging of 38 cores up to 1.5 m long drilled on a 4-mi grid shows a maximum salt thickness of about 1.5 m and an average thickness of more than 0.6 m covering 1,250 sq km of the north arm. Nearly 2 billion tons (metric) of salts have been deposited in the north arm since the causeway was completed 13 years ago; a rate of 150 million tons per year.

X-ray diffraction analysis of more than 150 samples shows that the salt in the north arm is almost entirely halite. Minor amounts of sylvite are present in some samples, but it is uncertain whether it was deposited in the lake with the halite or from occluded brines partly evaporated from the core tubes during prolonged storage. Preliminary electron microprobe studies indicate that potassium occurs in local concentrations within halite crystals and not along crystal boundaries, suggesting that the sylvite may be primary.

GWYNN, THOMAS A., Montana-Dakota Util. Co., Bismarck, N.D.

ENVIRONMENTAL IMPLICATIONS OF DEVELOPING COAL RESOURCES

There are new things in reclamation but mostly there are just increased awareness and better performance by industry. Most of us in this business consider ourselves good citizens and dislike the label of a "despoiler of America's pristine beauty." Yet we are torn between that which is desirable and that which is economically feasible.

In approaching the subject of reclamation the problem must be put into perspective. It is established that the United States will approximately double its present consumption of minerals and mineral fuels each 15 years. During the past 30 years the United States has used more minerals and fuels than did the entire world in all previous history.

There is increased demand for great amounts of energy from oil, natural gas, coal, and hydroelectric power, not to mention atomic energy and solar energy. Shortages in some of these areas are already appearing with the discovery of natural gas and oil now falling behind the consumption. Present estimates by the industry are that 6 million bbl of this oil must come from synthetic sources including coal and oil shale.

We will be disturbing ever-increasing areas of the earth's surface to recover the fuel we need and surface mining must of necessity increase many fold. Therefore, we must expect increasing pressure from citizen's groups, sportsmen's organizations, environmental study groups, newspapers, and state and federal governments.

It is incumbent on us as an industry to actively and accurately tell our story to the public, so that every citizen in the states where we operate realizes that we are doing more than just making money—we are also providing them with needed electric power with fuel for the many industries that give them the civilization they demand; we are contributing substantially in taxes to provide schools, hospitals, and other civic benefits; and we provide the base for a thousand and one other products and services used in everyday life.

Because laws are obviously going to come, it is only sensible that the mining industry take a heavy part in drafting them so that insofar as possible they not be restrictive or punitive or otherwise unfavorable to such an extent that mining operations are curtailed or placed in a poor competitive position with other fuels.

Reclamation must be a part of our every day mining operation and must be an anticipated expense. This reclamation must be the result of combining the best technical assistance we can get to the hard economic facts of the coal mining business. This reclamation must be carried on with sensitivity to the needs of the area we are mining and to the feelings of the residents of the area. As increased federal interest in spoils reclamation is a certainty, we must ask companies to participate aggressively in establishing just and realistic reclamation laws. We must overcome the ostrich attitude our industry has had in the past because the conservation movement and increased awareness by the public of our environment are here to stay.

HEACOCK, ROBERT L., Shell Oil Co., Denver, Colo.

PYROLYSIS AND THIN-SECTION EXAMINATION OF PETROLEUM SOURCE ROCKS

The lack of rapid, but geochemically sound, methods for identifying organic-rich rocks in small samples (potential petroleum source rocks) was a major obstacle to the application of petroleum origin and migration concepts in oil and gas exploration. More than 4,000 ft of near-surface stratigraphically continuous core, primarily shales, was obtained from the marine Cretaceous of central Wyoming by use of a variety of geologic, mineralogic, paleontologic, petrophysical, and geochemical techniques. Extractable heavy hydrocarbon and organic carbon contents were used as standards to which the other techniques were compared. It was found that lithic characteristics, particularly sedimentary structures and thin-section properties, correlate quite well with the standards. Test-tube pyrolysis, followed by careful measurement of the amount of fluorescence produced by the condensed liquids, was the most useful method developed.

JACOB, ARTHUR F., Dept. Geol., Univ. North Dakota, Grand Forks, N.D.

ELONGATE CONCRETIONS AS PALEOCHANNEL INDICATORS, TONGUE RIVER FORMATION, NORTH DAKOTA

Two types of sand bodies occur in the nonmarine Tongue River Formation (Paleocene) of western North Dakota, linear and tabular. The tabular sand bodies have sharply scoured bases, become finer upward, and the vertical sequence of sedimentary structures shows a decrease in the flow regime upward. These bodies are overlain by gray lignitic silts and clays, and they are interpreted as high-sinuosity stream deposits.

Linear sand bodies are the most common type in the Tongue River Formation. They are usually straight and have deeply channeled bases and flat tops. Vertical changes in grain size show no consistent pattern, but the upper parts become finer upward in many places. Sedimentary structures are about 60 % planar (omikron) cross-stratification, 25% horizontal or low-angle planar laminae (plane bed) with parting lineation, and 15 % small-scale ripple cross-stratification. Paleocurrent indicators parallel the axes of these bodies, which are interpreted as low-sinuosity stream deposits.

Elongate concretions, up to about 15 ft wide and hundreds of feet long, occur only in the linear bodies. They consist of calcite-cemented sandstone, and they usually occur at or near the tops of the bodies. They help to protect the bodies from erosion so that in places the bodies exist as exhumed paleochannel systems that form an inverted topography. The axes of the concretions parallel both paleocurrent indicators and the axes of the sand bodies. The concretions are clearly visible on air photos and can easily be used to map paleochannel patterns either on the air photos or in the field.

JAMIESON, E. R., Union Oil Co. Canada, Ltd., Calgary, Alta.

SILURIAN CARBONATE RECYCLING: EXPLANATION FOR ANOMALOUS SUB-DEVONIAN UNCONFORMITY IN WILLISTON BASIN

Conventional electric-log correlations of the lower Paleozoic sequence in southern Saskatchewan express the sub-Devonian boundary as a major unconformity which has traditionally been interpreted as an erosion surface involving the removal of large volumes of Interlake carbonate rock between Late Silurian and Middle Devonian times. The amount of sediment removal invoked by this concept seems anomalous for the Williston basin, in terms of the short timespan involved.

Based on facies analysis, an evolutionary model is presented involving marginal upwarp and erosion throughout the span of Interlake deposition, augmented by sediment recycling in the latter part of Interlake times. Marginal attenuation of Interlake units is coupled with the passage of normal marine to supratidal carbonate facies on a gradient which predicates the emergence of a broad surrounding hinterland at least by mid-Interlake time. This area emerged gradually and a corresponding regression of Interlake seas exposed increasingly greater surface areas of lithified carbonate sediment to subaerial processes. Chemical and mechanical erosion of this terrain caused a natural recycling of carbonate material toward the marine basin, both as clastic and dissolved particles. These were redeposited as part of a broad coastal plain complex which prograded into the shrinking marine area and eventually covered all of southern Saskatchewan. Hence, long before Interlake sedimentation had ceased, erosion had strongly beveled preexisting sediments around the Williston Basin margin, developing the unconformity which separates Silurian from younger rocks in this basin. Much of the sediment removed by this erosion was recycled during Late Interlake time and post-Silurian erosion caused only slight modification of the terrain.

Exploration of the Interlake Group for petroleum should be based on an understanding of the evolutionary changes accompanying Interlake sedimentation. Because the most favorable porosity occurs in dolomitized marine carbonates, exploration efforts should be directed toward southeastern Saskatchewan, where marine deposition prevailed over the longest period of time and accordingly potential reservoirs should be thickest.

JOHNSON, R. P., and V. B. CHERVEN, Dept. Geol., Univ. North Dakota, Grand Forks, N.D.

LOW- AND HIGH-SINUOSITY STREAM DEPOSITS OF SENTINEL BUTTE FORMATION (PALEOCENE), MACKENZIE COUNTY, NORTH DAKOTA

Low-sinuosity stream-channel sands in the study area are 8-20 m thick and up to 400 m wide. They are lens-shaped, with flat tops and concave-upward, deeply channeled bases. Paleocurrent directions are subparallel to sand-body axes. Epsilon cross-strata are rare, but numerous other types are common. The sands are fine- to very fine-grained and moderately sorted. Cross-stratification and grain size changes suggest one or more episodes of upward decrease in flow regime.

High-sinuosity stream-channel sands may also reach 20 m in thickness but may be a kilometer or more in width. They are tabular bodies with scoured bases. Paleocurrent directions are parallel to sand body axes. Cross-strata types are less varied than in low-sinuosity stream sands but epsilon cross-strata are more common. The high-sinuosity sands are generally coarser grained and better sorted than the low-sinuosity deposits, and grain-size changes along with cross-stratification changes show an upward decrease in flow regime.

Alternate thin beds of tan and rust-colored sands, silts, and clays in wedge-shaped bodies overlie the high-sinuosity sand, but occur adjacent to and slightly above the low-sinuosity sands. These characteristics, plus low organic content, numerous thick concretionary layers and abundant climbing ripples suggest that these are natural levee deposits.

The natural levee deposits grade laterally and vertically to the disturbed and dark-colored clays of the flood basin. These laterally extensive deposits commonly become fine upward and become organic, and are overlain by beds of lignite.

Thin, very fine-grained sands occur in either the natural levee or flood-basin deposits of the low-sinuosity streams. They have channeled bases, pinch out laterally, and show highly variable current directions. They are probably crevasse-splay deposits.

KENDALL, A. C., Dept. Mineral Resources, Regina, Sask.

LAMINATED ("VARVITIC") CARBONATES AND ANHYDRITES FROM ORDOVICIAN AND DEVONIAN OF SASKATCHEWAN

Bituminous-laminated (or "varvitic") carbonates, which grade upward into laminated anhydrites, are of particular interest to the petroleum geologist, because the carbonates may act as source, carrier, and reservoir rocks whereas the overlying anhydrites form impermeable caprocks. Commonly, such sediments exceed 10 ft in thickness and are traceable over thousands of square miles, but have been interpreted as of upper intertidal (algal mat) and supratidal (sabkha) origin.

Carbonate-anhydrite laminites occur as a basin facies of the Middle Devonian Winnipegosis Formation in Saskatchewan and are located on the basin floor between large carbonate banks. The laminites grade downward into a thin (1-10 ft) unit of black, highly bituminous, laminated mudstone containing a pelagic fauna. Near carbonate banks this mudstone thickens and includes carbonate beds interpreted as turbidites or mud-