spread eastward to the inner craton margin. In southeastern Idaho, less detritus was available from the Antler highland in Early Mississippian time, and a starved basin developed between the foreland basin on the west and the inner craton margin on the east. Carbonate-bank deposition followed on both sides of the Snake River plain in Late Mississippian time, as the northern flysch basin ceased subsidence.

By Middle Pennsylvanian time, the flysch deposits rose to form a highland from which coarse detritus was shed west, east, and south to interfinger with the fine-grained craton-derived, in part subarkosic, sands of the Wood River and Sublett basins, which gradually deepened through Late Pennsylvanian into Early Permian (pre-Phosphoria) time. Carbonate-bank deposition continued into Early Permian time east of the Copper Basin highland.

The Lower and Upper(?) Permian Phosphoria Formation is recognized throughout southeastern Idaho and in south-central Idaho as far west as the Lemhi Range. West of the Lemhi Range, mollusk-rich fine-grained Phosphoria-equivalent rocks are known from one locality in the White Knob Mountains and from two localities in the Pioneer Mountains. Fine-grained, banded and graded siltites of Phosphoria age, which resemble continental-rise contourites, are present in the Boulder Mountains. Phosphoria-equivalent andesitic and dacitic volcanic rocks in western Idaho record a contemporaneous volcanic arc west of the continent.

SLOSS, L. L., Northwestern Univ., Evanston, IL, and LEON T. SILVER, California Inst. Technology, Pasadena, CA

Basins, Basement, and the Drill

Subcircular to broadly elliptical sedimentary basins of cratonic interiors remain among the more enigmatic elements of continental geology. Such basins may be characterized by significant, preserved sediment thicknesses (approaching 4 km); long subsidence history ($>100 \times 10^6$ year); non-systematic but, commonly, globally synchronous variation in subsidence rates; and obscure relation to anomalies of the magnetic or gravity fields or of crustal thickness. Mechanisms involving thermal contraction and/or loading of the crust appear inadequate to explain subsidence history and amplitude. Lacking new, critical data, progress toward rational concepts is slow.

Deep drilling of basement rocks of sedimentary basins, including adequate sample recovery and measurement of thermal, magnetic, density, and stress parameters, holds the exciting promise of providing essential information for testing concepts. It is held, for example, that basins lie along ancient continental margins or at the triple junction of sutures. Remanent magnetism and petrologic and structural data from oriented cores could be definitive.

The basement rocks of the continent hold the keys to many fundamental earth science problems. The early history of the planet, the mechanisms of continental development, the nature and timing of pre-Mesozoic global tectonics, and the sources of many materials essential to society, are examples. The drill can probe the third dimension of the basement, interpolate through cover between surface exposures, extend basement data to outer continental margins, and target critical features. Measurements of the dynamic state of the crystalline crust can provide insights to seismic hazards, geothermal energy potential, hydrothermal ore-forming processes, and possible suitable settings for long-term toxic waste disposal.

A feasible basement drilling program, integrated with appropriate surface studies designed to achieve maximum scientific yield, can probe one of the great frontiers in the earth sciences.

SMAGALA, TOM, Pendleton Land & Exploration Co., Denver, CO, and MARY BETH COOPER, Kansas-Nebraska Natural Gas Co., Inc., Lakewood, CO

Cretaceous Niobrara Gas Play

The Upper Cretaceous Niobrara Formation has yielded natural gas of biogenic origin from structural closures on the gently dipping east flank of the Denver-Julesburg basin and the northern plunge of the Las Animas arch. Present production is from the Smoky Hill Member of the Niobrara Formation. The majority of fields located to date are in Colorado and Kansas; however, several new fields have been discovered in the Nebraska part of the basin. Potential for significant Niobrara gas production exists in the Kennedy and Salina basins of Nebraska, and from parts of South Dakota, North Dakota, Montana, and Canada. The formation has high porosity and low permeability and requires hydraulic fracture stimulation for economic production. Production depths range from 1,000 to 3,200 ft (305 to 975 m).

The chalk beds of the Niobrara were deposited in the deep, quiet water of the Cretaceous interior seaway.

SMITH, B. D., J. T. NASH, and J. KALLIOKOSKI, U.S. Geol. Survey, Golden, CO

Geophysical Exploration for Precambrian-Related Uranium Deposits

Genetic models for uranium mineralization found at Proterozoic unconformities between fluvial sandstones and crystalline lithologies include three general geologic features: (1) structural relief at the unconformity; (2) permeable zones controlled by lithology and faulting; and (3) graphitic and sulfide-bearing zones commonly associated with mantled gneiss domes. Though radiometric surveys have been successfully used where the fluvial rocks are thin or eroded away, non-radiometric geophysical methods are commonly used in the interior parts of the sedimentary basins to detect one or more of the above geologic features to define favorable areas for uranium. In the Athasbasca basin of Canada, airborne and ground electromagnetic (EM) methods as currently used are thought to have a depth of exploration of 200 m. Application of these non-radiometric geophysical methods to Precambrian sedimentary basins in the United States is not likely to produce as great a depth of exploration because the fluvial cover rocks are not as geophysically transparent as the Athabasca sandstone. We suggest that two approaches be used to improve the depth of exploration and resolution of non-radiometric geophysical methods. The first approach is to use EM methods that have not been commonly used such as the controlled-source or natural-field audiomagnetotelluric method which can have a depth of exploration of several kilometers. The second approach is to use advanced geophysical interpretation methods to define responses from the alteration halos around the uranium mineralization. Advanced Induced Polarization surveys may detect such halos as evidenced by applications in Tertiary sedimentary basins.

SMOSNA, RICHARD, West Virginia Univ., Morgantown, WV

Carbonate-Sulfate Mineral Replacements in Diagenesis of Peritidal Limestone

Petrographic study of crystal textures and fabrics, both original and replacement, has revealed the postdepositional history of carbonate and sulfate minerals in the Silurian Tonolway Limestone. Crystal forms, assumed to have been gypsum originally, are locally common in supratidal facies; they occur as coarse euhedral needles, randomly oriented to bedding, and commonly in clusters. When this gypsum precipitated interstitially in the lime sediment, micrite was often incorporated into the crystals; organic matter, concentrated on side faces, may have blocked nucleation, causing the fibrous crystallization texture. As a consequence of the changing chemistry of pore fluids, a series of mineral replacements began within these crystal forms. Gypsum was first replaced by celestite, as evidenced by its pseudomorphism. The enclosing aragonite sediment inverted to calcite, and strontium was thus freed for the making of celestite. Afterwards, calcitization of the sulfates took place, i.e., each crystal was replaced by a mosaic of very finely crystalline calcite. Calcitization began around inclusions of micrite within the crystal forms. Presumably, decomposition of algal material produced carbon dioxide that was used for the calcitization reaction. Sulfate ions released by this last replacement inhibited the growth of calcite, resulting in its very fine crystallization fabric. Lastly, these calcite "pseudomorphs" were themselves partly replaced by limpid dolomite.

SNEDDEN, JOHN W., Mobil Oil Corp., Houston, TX, and DAVID G. KERSEY, Texas A&M Univ., College Station, TX

Coastal Swamp Origin of San Miguel Lignite Deposit, Jackson Group, South Texas

The environments of deposition of the San Miguel lignite, a commercial quality deposit in a 4.5 by 0.3-km area in Atascosa and McMullen counties, Texas, was determined through analysis of nearly 122 m of continuous core and over 600 electric and radiation logs. The lignite is in the Jackson Group and is part of the south Texas Eocene lagoonal-coastal plain system.

The lignite is overlain and underlain by a unit of gray-green bioturbated siltstone and claystone 33.9 m thick. The lack of body fossils and abundance of root structures indicates this unit was deposited in a coastal grass-flats environment.

Below the bioturbated unit is a unit of massive green claystone 3.4 m thick, which contains abundant macroinvertebrate fossils. The fossils indicate this unit was formed in an open bay or lagoon.

Below the green claystone is a coarse, carbonaceous sandstone 3.6 m thick. Sedimentary structures and petrographic trends of this unit are analogous to those of modern back-barrier flats deposits.

The lignite interval is composed of lignite and carbonaceous clay partings of 4.2 m average thickness. The lignite interval has an overall strike-trend with local dip-trending segments. The lignite represents the accumulation of plant matter in a coastal swamp behind a lagoon. The clay partings formed during occasional flooding of the swamp by coastal streams.

Analysis of sedimentary structures, petrography, and paleontology from continuous cores is considered essential to oil and gas exploration. This study demonstrates these techniques are also important in lignite exploration.

SPIRAKIS, CHARLES S., U.S. Geol. Survey, Denver, CO

Anomalous Thermoluminescence Around Uranium Deposits

Radiation damage to crystal structures may be detected using thermoluminescence (TL). Quartz and feldspar grains separated from rocks that were once mineralized with uranium display an anomalous TL characterized by an increase in high-temperature TL relative to low-temperature TL. This anomalous TL may be detected by either examining the ratio of low-temperature TL to high-temperature TL or a graph of TL intensity versus temperature. One of these methods of comparison must be used to normalize the variation in the susceptibility of the samples to TL. Without this normalization, the variation in the susceptibility could mask the anomalous TL caused by mineralization. After a uranium-mineralized rock has been leached of uranium, this type of anomalous TL persists for geologically significant lengths of time. Consequently, TL may be used to identify formerly mineralized rocks. Studies of TL around uranium deposits indicate that this type of anomalous TL is present in rocks updip from migrating roll-type deposits (one in Texas and one in Wyoming), around the margins of a partly leached tabular deposit in Utah, and in leached outcrops above a vein-type deposit in Colorado.

TL may be a very practical prospecting guide; it is inexpensive, fast, and easy, requires little sample, and is a direct indicator of uranium mineralization rather than of a concomitant process. Further, Tl samples are less susceptible to contamination than other types of geochemical samples.

STANLEY, DANIEL J., Smithsonian Inst., Washington, D.C., and ANDRÉS MALDANADO, Univ. Barcelona, Barcelona, Spain

Depositional Models for Fine-Grained Sediment in Western Hellenic Trench, Eastern Mediterranean

Sediments in tectonically active, topographically re-