all the basin's oil in addition to having its own potential carbonate reservoirs. The faulted margins of the basin fed a system of alluvial fans, sand flats, and mud flats. Alternating dry and rainy periods regulated the size and nature of contemporaneous basinal alkaline lakes. Dry periods corresponded to contracted playa lakes with ostracod carbonates and euxinic shales; rainy periods corresponded to expanded pluvial lakes with pelecypod banks. Subaqueous intrusions of basaltic magma generated hyaloclastites with kerolitic ooids and hyalotuffs.

Petrographic analysis reveals 5 diagenetic stages: (1) syndepositional alteration of lithoclasts to trioctahedral smectites; (2) early dolomitization, early silicification, and cementation by bladed-rim calcite and zeolites; (3) freshwater-vadose dissolution of bioclasts and lithoclasts, freshwater-phreatic sparite cementation, and neomorphism; (4) mixed saline-freshwater silicification; and (5) burial with compaction, late dolomitization, and partial conversion of smectites to illite.

Pelecypod limestones with primary interparticle, secondary intraparticle, moldic, and moldic-enlarged porosities are the potential reservoirs. Ideal conditions for porosity generation and preservation were subaerial exposure followed by rapid lake expansion and burial.

BIEBER, DAVID W., Independent Geologist, Englewood, CO

Exploration Model for Unconformity-Related Hydrocarbon Accumulations in Cherokee Group of Western Kansas

The sandstones of the Desmoinesian Cherokee Group in western Kansas are important hydrocarbon producers. The Start oil field in Rush and Ness Counties is an example of an unconformity-related Cherokee accumulation from which an exploration model can be made. In this field, the upper Cherokee member is economically important and is interpreted to be a marine unit deposited on the distal portion of an alluvial plain. Traps and reservoirs in this unit were formed by winnowing of clay and silt-sized material from sediments deposited on the crests of paleohighs.

Four maps are useful in exploring for upper Cherokee hydrocarbon accumulations such as Start. An isopach map of the Cherokee Group is useful for locating thins that coincide with paleohighs on the basal Pennsylvanian unconformity. An isopach map from the Cherokee top down to the first sandstone porosity is useful. "Thins" of this interval define areas where wave and current action have winnowed finer material from sands. Closed anticlines on a Cherokee structure map are areas where Cherokee reservoirs are likely to be oil bearing rather than water bearing. An isopach map from the Cimarronian Stone Corral anhydrite top down to the Missourian Lansing Group top is also useful. "Thins" of this interval correspond to paleohighs on the basal Pennsylvanian unconformity. This interval can be picked from seismic records. Prospective areas occur where isopach thins of Stone Corral to Lansing, of Cherokee Group, and of Cherokee top to first sandstone porosity coincide with Cherokee anticlinal structure.

BINDER, ALAN B., NASA, Johnson Space Center, Houston, TX

Lunar Resources—Enabling Factor in Industrialization of Near-Earth Space

The industrialization of near-earth space has already begun during the last few space shuttle flights and will continue at an ever-accelerating pace as the first United States space station is built in the next 8 yr. However, the economic return from near-earth space industry is limited by the high cost per kilogram of launching into orbit the structural elements needed to build the space stations and the raw materials that are to be made into products in them. This limiting factor can be overcome if the moon is used as a source of the material needed to build the space structures and as the source of the raw materials needed in the processing. First, O, Si, Mg, Fe, Ca, Al, and Ti are the major constituents (>1% by weight) in lunar rocks, and can be obtained directly from them by one of several proposed processes. Of these, O is needed as a rocket fuel, Si for making solar cells to generate space-station electricity, and light weight Mg, Al, and Ti to make structural elements for the space stations. Second, the rocket fuel per kilogram of payload needed to reach low earth orbit from the moon is 68% of that needed from the earth's surface, assuming that decelerating into earth orbit is achieved by a rocket maneuver. The amount of fuel is reduced to 15% if orbit is achieved by aero-braking. If the payload is launched from the moon by a "mass driver" and aero-braking is used, the cost in the rocket fuel needed to reach low earth orbit is reduced to nearly zero.

BINGHAM, M. P., ARCO Exploration Co., Denver, CO, and R. H. BAILEY, Northeastern Univ., Boston, MA

Depositional Environment of Lower Cambrian Limestones, Nahant, Massachusetts

About 130 m (427 ft) of Lower Cambrian Weymouth Formation is exposed at Nahant, Massachusetts, 11 km (7 mi) northeast of Boston. Several beds of white to light-gray, fossiliferous limestone, up to 3 m (9.8 ft) thick, occur in a sequence of dark, very thinly bedded argillite. Portions of the argillite contain altered and chertified carbonate nodules. Limestone beds contain irregular, very thinly laminated chert layers with structures characteristic of silicified laminate stromatolites.

The limestone is comprised of 4 microfacies: (1) thinly bedded unfossiliferous micrite, (2) irregular intraclasts surrounded by sparry cement or biomicrite, (3) biomicrite (wackestone to packstone) containing small shelly fossils, primarily hyolithids, and (4) biosparite (hyolithid grainstone).

Conoidal hyoliths do not show a strong preferred current orientation on slabs and peels, but are often irregularly disposed with long axes at high angles to bedding. Biomicrites (packstones) and biosparites occasionally overlay irregular scour surfaces. Irregular bioclastic-rich pockets are surrounded by and grade into micrite or biomicrite.

A shallow subtidal, partially protected shelf of platformal environment best explains the textural and bedding characteristics of limestones. Storm events are recorded as bioclastic-rich and intraclastic sediments over scour surfaces. Irregular cyclic repetition of microfacies and lack of progressive shoaling or deepening during carbonate deposition suggest that limestones represent periods of stillstand at relatively low sea level positions. Carbonate deposition ceased when extrabasinal mud input increased, possibly during episodes of rapid sea level rise.

BISHOP, WILLIAM F., Tenneco Oil Exploration and Production, Houston, TX

Eocene and Upper Cretaceous Carbonate Reservoirs in East-Central Tunisia

Regionally, well-defined belts of lowest Eocene (Ypresian) Metlaoui carbonates trend northwest-southeast. On the northeast is an open-marine, basinal facies of planktonic foraminiferal micrite and marl. Thick bars of shallow marine nummulitic wackestone, packstone, and grainstone trend northeastward at an angle to the paleoshelf. Lagoonal or supratidal carbonates are widespread between the shelf deposits and thick evaporites that crop out in intermontane basins.

The reservoir is confined largely to nummulitic packstone, and visible effective porosity is best developed between forams in zones filled with sand-size debris where secondary solution-enlargement has occurred. Porosity within nummulite chambers, while abundant, is ineffective, although a few open fractures were observed in cores. This lithology tested oil in 2 recent wildcats and is a commercial reservoir at Sidi El Itayem and Ashtart fields.

Distribution of Zebbag carbonates of Late Cretaceous (Turonian) age is more complex. A northwest-southeast-trending platform is bounded on 3 sides by basinal shale and micrite with planktonic forams which grade into a transitional facies of micrite and wackestone that shows some evidence of shallow-water deposition, such as dolomitization, bioclasts, rare ooliths, etc. Predominately back-reef and lagoonal bioclastic wackestones and packstones occur in narrow belts, apparently controlled at least locally by block faulting. The rest of the platform lithology comprises mostly dolomite and dolomitic limestone.

The most significant porosity is interparticle (generally solution-enlarged) in foram packstones, but intraparticle porosity in forams and rudists commonly enhances the reservoir. Intercrystalline porosity in dolomitized zones is common, and fenestral porosity occurs in a few places. All are modified by nonfabric-selective channel and vuggy porosity and in some instances by fractures.

BLACKWELL, DAVID D., Southern Methodist Univ., Dallas, TX

Measurement of Contemporary Thermal Properties in Sedimentary Basins

Searches for new and innovative ways to explore for hydrocarbons have included consideration of various thermal techniques possessing the possibility of making significant contributions to exploration technology. The recognition of hydrocarbon maturation as basically a thermal process has made the relatively accurate determination of sedimentary-basin temperature history important. Whereas many thousands of bottom-hole temperature measurements have been made in hydrocarbon exploration holes in sedimentary basin, the necessarily marginal quality of these data has limited the application of heat flow, geothermal-gradient, and temperature techniques to hydrocarbon exploration and to the investigation of thermal properties of sedimentary basins.

There is no substitute for detailed and accurate temperature-depth logs made in holes that have reached thermal equilibrium. From these measurements, a large amount of thermal information can be determined, such as the effective in-situ thermal conductivity of the units encountered by the drill and evaluation of active migration phenomenon in the vicinity of the drill hole. Correlation of thermal conductivity with log properties can be used to extend throughout a sedimentary basin the detailed information from the few holes suitable for equilibrium temperature measurements. Actual logging experience and comparison of relative in-situ thermal-conductivity values with values in equivalent units measured in the laboratory demonstrate major discrepancies and emphasize the need for, and importance of, in-situ data.

BLOCH, JOHN D., Washington Univ., St. Louis, MO

Fluid Inclusion Analyses of Detrital Quartz Grains—New Provenance Tool

Preliminary analyses by microthermometry of fluid inclusions in detrital quartz of the Upper Cambrian Lamotte Sandstone revealed the occurrence of 2 distinct groups of aqueous fluid inclusions. Specific salinity signatures and homogenization temperatures may be used to distinguish specific granite types of the source rock terrain. The inclusions chosen for analysis occur in isolated clusters or are randomly distributed within a grain, commonly in association with mineral inclusions of zircon, sphene, rutile, and/or tourmaline. Secondary inclusions are present in the Lamotte but are not included in this study.

The first group of inclusions is characterized by low salinities (< 1.0-8.0 wt. % eq. NaCl), the second by high salinities (12.1-29.6 wt. % eq. NaCl). Final melting temperatures as low as −30.6°C indicate the presence of divalent ions in these inclusions. Both groups yield homogenization temperatures of between 150°C and 220°C. The low-salinity inclusions occur predominantly in subrounded to well-rounded sand less than 1.0 mm in size that is derived from a distal source. The brine inclusions occur exclusively in subangular to angular gravel 2.0-3.0 mm in size, implying a more proximal source area.

A comparison of these inclusions with inclusions found in the granites of the apparent source terrain indicates that a medium-silica amphibole-orthoclase granite (Slabtown type) or a low-silica amphibole-plagioclase granite (Sivermines type) or both are the primary source rocks for this quartz. These granite types have limited areal distribution in the present-day St. Francois mountains and the identification of these granite types as the source rock for the locally derived quartz has broad implications for reconstructing Cambrian depositional environments and paleostructure of the ancient St. Francois mountains.

BLODGETT, ROBERT H., Ohio State Univ., Columbus, OH

Paleovertisols as Indicators of Climate

Clay-rich paleosols are common in the rock record in upper deltaplain, fluvial floodplain, marginal lacustrine, and playa deposits. In environments characterized by a marked seasonality of precipitation, these soils are generally Vertisols. Modern Vertisols contain over 35% clay, predominantly smectite, have a distinctive slickensided ped structure, and locally develop surface microrelief and carbonate nodules.

The optimum development of Vertisols is in subtropical to tropical monsoonal climates. Surface microrelief (gilgai) is common in subhumid and semiarid, but not arid, climatic regimes. Carbonate nodules are common in both drab and pigmented Vertisols in semiarid climates. In the transition to subhumid regimes, carbonate nodules are likely to be either absent or restricted to drab Vertisols. Vertisol pigmentation appears to be a function of inherited color or the development of organic complexes, and thus only indirectly controlled by climate.

Changing precipitation patterns can cause the production or destruction of evaporites or carbonates in a Vertisol profile. In contrast, the slickensided ped structure has a high preservation potential and is probably modified little during changes in climate and subsequent burial. Unlike marine and profundal lacustrine clays, Vertisols have a high bulk density and appear to be affected little by burial compaction. Syndepositional cementation, in the form of veins and nodules of low-Mg calcite (i.e., calcrete), is common. However, major changes in the clay mineralogy of these paleosols may occur during diagenesis, including the transformation of smectite into mixed-layer clays, illite, or kaolinite.

BOLLER, KIMBERLY ANN, Texas Tech Univ., Lubbock, TX

Ostracode Distribution in Late Pennsylvanian Finis Shale Cyclothem

Four successive intergrading ostracode biofacies characterize the Finis Shale cyclothem (Cisco Group, Virgilian) near Jackboro, Texas. Composition of the ostracode biofacies parallels the distinct megafaunal assemblages ascribed by Boardman et al (1983) to changing oxygen concentrations, water depths, and salinity.

Black, organic-rich, noncalcareous, fissile shales occur near the base of the Finis. This lithofacies is barren of ostracodes and megafauna, and is interpreted to represent a "deeper" water, anoxic environment. The overlying dark-gray, phosphatic shales contain a diminutive pyritic molluscan fauna with abundant ammonoids and a low-diversity ostracode assemblage dominated by *Healdia*, indicating a dysaerobic environment. The overlying lithofacies is a medium-gray, clay-rich, calcareous shale.

The megafauna is dominated by a brachiopod-bryozoan assemblage, and a diverse *Amphissites-Kirkbya* ostracode association occurs. This fauna represents a "shallow" depth, aerobic environment. The *Amphissites-Kirkbya* biofacies is overlain by a dark-gray calcareous shale with abundant megafossils of the fusulind-bryozoan facies of Boardman et al. This interval is dominated by a *Bairdia-Amphissites-Kelletina* ostracode assemblage, indicating a shallower aerobic environment. The shale is interrupted by the Jacksboro Limestone Member, an algal limestone deposited at or near wave base, which is covered by a thin intertidal sandstone. The cyclothem is capped by noncalcareous, brown silty shale. It contains a low-diversity ostracode assemblage dominated by *Cavellina* and a megafaunal assemblage characterized by *Myalina*, which represents a shallow, brackish water environment.

BOSTROM, ROBERT C., Univ. Washington, Seattle, WA

New Vista of Crustal Architecture—High-Order Geoidal Images

Altimeter-bearing satellites produce images of the earth's gravity field in unprecedented detail. The images reveal crustal architecture in scale intermediate between lithosphere plates and local fault blocks. Geoidal images provide a preview of the architecture of remote regions prior to conducting ship or airborne operations, and provide interpretive background for regional exploration already in progress.

Altimetric satellites provide data primarily of water-covered areas. The geoidal images avoid assumptions inherent in the preparation of Bouguer, free-air, and isostatic gravity maps. Oceanic data combined with continental gravimetric data are displayed as contour maps.

The synoptic view provided by high-order geoidal images makes it possible to trace crustal features such as fracture zones to the margin of continents. The images are of sufficient detail as to cast doubt on many correlations deduced on the basis of the oceanic magnetic anomalies. Crustal stretching and intraplate deformation may be more common than supposed.

BOYD, RON, Dalhousie Univ., Halifax, Nova Scotia, Canada

Quaternary Stratigraphy of Sable Island Bank, Nova Scotia

Over 300 m of Quaternary sediments are preserved on the Sable Island Bank section of the Scotian Shelf off Atlantic Canada. Most of these are interpreted as Pleistocene glacial sediments. However, a Holocene sandbody over 50 km long, 4 km wide, and 50 m thick occupies the Sable