A comparison of the present data and previous work shows that the greatest occurrence of extinctions is found at the Paleocene/Eocene boundary with a lower number o extinctions at the middle/late Eocene and Eocene/Oligocene boundaries. The lack of a major catastrophic change at the Eocene/Oligocene boundary may be a result of previous faunal events at the Paleocene/Eocene and middle/late Eocene boundary eliminating stenothermal species, leaving environmentally tolerant species in the late Eocene that were largely unaffected by the 3°C (37°F) temperature decrease at the Eocene/Oligocene boundary.

CORNELL, WILLIAM C., Univ. Texas, El Paso, TX

Some Permian (Leonardian) Radiolarians from Bone Spring Limestone, Delaware Basin, West Texas

A sample of the deep basinal Bone Spring Limestone (Leonardian) has yielded a diverse and superbly preserved assemblage of spumellarian radiolarians, associated with siliceous sponge spicules, and conodonts. Radiolarians include typically Paleozoic paleoactinommids, entactiniids, and rotasphaerids; Permian albaillellids and parafollicucullids; and triradiate spongodiscids or hagiastrids. Triradiate forms, which include approximately 60% of the shells in the sample, have not previously been reported to be abundant in pre-Mesozoic rocks. Albaillellids and parafollicucullids are similar to forms reported from the Permian strata of Japan, but the Bone Spring forms do not fit in the biostratigraphic zonation proposed by Japanese workers. This may be due to gaps in the Japanese stratigraphic sections or to provincialism in radiolarian faunas.

Diversity in the Bone Spring assemblage is higher than in other Permian assemblages. Most reported Permian radiolarians have been recovered by HF extraction of cherts, while the Bone Spring specimens were extracted from limestone with acetic acid. Thus, diversity differences can be partly attributed to fortuitous preservation.

CRAWFORD, F. D., C. E. SZELEWSKI, and G. C. ALVEY, Home Oil Co. Ltd., Calgary, Alberta

Geology and Exploration in Takutu Basin, Guyana

The Takutu basin is an intracratonic graben 280 km (174 mi) long and 40 km (25 mi) wide in northern Brazil and adjoining Guyana, lying entirely within the center of the early Precambrian Guyana shield. Acidic metavolcanic rocks and thick Proterozoic quartzite lie to the north of the basin. Granulite, gneiss, and granite border the graben to the south and east. High mountains arise along the south-bounding fault whereas more subdued topography flanks the north side of the basin. Triassic basalt forms a wide band of outcrop along the southern and eastern margins of the rift. There are very poor and sparse outcrops of the basin fill. The graben is filled with up to 4,000 m (13,123 ft) of Cretaceous and Jurassic sedimentary rock underlain by 1,500 m (4,921 ft) of mafic volcanics of Triassic age and possibly older (i.e., Proterozoic).

The geologic history of the Takutu graben is interpreted to extend back into Precambrian time because it occupies an ancient suture zone in the Guyana shield. Renewed rifting and major subsidence occurred in Mesozoic time resulting in the deposition of thick nonmarine clastics, evaporites, and carbonates. A basal(?) Jurassic clastic-carbonate sequence overlies the eroded basalt. It is overlain by thick Cretaceous Aptian salt and interbedded shales that were deposited over most of the basin and contain good oil source rocks. The only indication of a marine environment is found within the subsurface post-salt clastics in Brazil. Lacustrine an deltaic depositional processes were dominant as indicated from well and seismic data.

Two main structural styles, namely pre-salt and post-salt, occur in the basin. The former is characterized by block faulting and horst and graben development. Non-piercement halokinetic forms swells and ridges in the post-evaporite Takutu Formation. Wrenching and salt solution are interpreted on seismic records. A large, cross-basin arch is present in Guyana where at least six undrilled prospects have been mapped.

Three widely spaced exploratory wells have been drilled down to the mafic volcanics. The wells are located on structures near the rift margin or in areas of thinner basin fill. Two of the tests were dry and abandoned while Home Karanambo #1 was classed as a noncommercial oil discovery in fractured basalt. Several clastic depocenters have been interpreted and delineated from the seismic and drilling results. They lie near the southern and eastern unexplored basin margins, distant from the wells drilled to date.

CREAMER, ELIZABETH A., Univ. Maryland, College Park, MD

Surface Expression of a Deep Mafic Pluton in Kentucky and Tennessee

The density and orientation of lineaments have been mapped from Landsat imagery in a 30,000 km² (11,583 mi²) area in central Kentucky and central Tennessee to determine whether known lower crustal intrusion is expressed on the surface through anomalous lineament patterns. A seismic refraction line through northern Tennessee and southern Kentucky indicates an anomalous region approximately 200 km (125 mi) long and 70 km (43 mi) wide where the upper crust is less than 10 km (32,808 ft) thick. The anomaly is coincident with a magnetic high seen on aeromagnetic surveys and with a Bouguer gravity high. Satellite magnetic surveys indicate a high in the general region of the anomaly. A basement core in the southern part of the anomaly is composed of peralkaline riebeckite syenite, a rock characteristic of a rift tectonic environment.

Lineaments were mapped as alignments of morphologic features such as streams, escarpments, mountain ranges, and tonal features on 1:500,000 scale multispectral scanner images of Bank 6. Winter scenes were chosen for a lower sun angle for better lineament mapping. The location of the anomaly was not revealed until lineament mapping was completed. Density and orientation of the mapped lineaments were then analyzed.

The following conclusions were reached from these data. (1) The lower crustal structure has no apparent expression through anomalous direction of lineaments over the structure. (2) The lower crustal structure is expressed on the surface through an increase in density of lineaments over the structure. (3) Aeromagnetic and satellite magnetic highs coincident with lineament density highs suggest correlation with deep crustal intrusive structures.

CROSS, AUREAL T., Michigan State Univ., East Lansing, MI

Plants of Devonian-Mississippian Black Shales, Eastern Interior, U.S.A.

Macrofossils of the New Albany shale and equivalents of Late Devonian of Early Mississippian age in the east-central United States are known from three main "floras" or assemblages. One "flora" is almost entirely composed of *Callixylon* logs, slabs,

and slivers, presumed to be driftwood permineralized after burial. *Callixylon* fossils are most abundant in the upper part of the Clegg Creek Member of the New Albany shale ()Famennian) and equivalent strata in western New York, Ohio, and contiguous areas, perhaps because these Progymnosperms reached the zenith of their development at that time. They also occur sporadically throughout the New Albany shale and equivalent strata. The principal geographic concentration of *Callixylon* is in western New York, principally in marine sediments, and on the west side of the Cincinnati arch. *Callixylon* is also sparsely and sporadically distributed in nearly all areas of outcrop of the Devonian black shales including the New Albany, Antrim, Kettle Point, and Ohio shales, and is found in Kinderhookian age shales from Illinois and Tennessee.

A second, and later, flora consists principally of permineralized wood pieces (phosphatized free-wood or concretions) of stems, rachises, petioles, and possibly even mid-veins of pinnules of diverse members of the Lycopsida, Sphenopsida, Cladoxylales, Coenopteridales, Progymnospermae, and Pteridospermae. A few of these disjunct pieces have been reconstructed into more complete plants known from the Catskill delta in western New York, Pennsylvania, and West Virginia. The principal concentration of these stem and petiolar segments is in the Falling Run Member of Sanderson Formation of the New Albany shale on the west side of the Cincinnati arch in southern Indiana and Kentucky, and in central Kentucky in the low saddle between the Cincinnati arch proper and its southward extension as the Nashville dome. This abundant distribution of minute stem axes and other such small plat fragments strongly suggests the source of these palnts to be a nearby island (Cincinnatia?). Alternatively, it is proposed that they have been concentrated by currents on a very shallow choal on or near a structurally positive submarine rise of the Cincinnati arch, or by floating algal mats in which the waterworn wood and leaf fragments became enmeshed as flotsam near some shore and were transported by these mats to more distant sites before the disintegration of the mats.

The third type of macrofossil palnt assemblage is constituted of *Foerstia*. These plants are considered to be algal in origin and indicate no clear relationship either to distance from shore or depth of water. The main concentration is in middle and lower New Albany shale and equivalents. It is also found sparingly in West Virginia and Michigan and much farther west (one specimen from the Exshaw shale of Montana).

CURRAN, H. ALLEN, Smith College, Northamption, MA

Ichnology of Pleistocene Carbonates on San Salvador, Bahamas

Trace fossils, well preserved and in full relief, occur sporadically in Pleistocene carbonates of intertidal and shallow subtidal origin on San Salvador, Bahamas. Most prominent are irregular boxworks of *Ophiomorpha* sp., which occur in a subtidal, current-bedded, medium to coarse skeletal calcarenite facies associated with an underlying coral-algal reef facies. *Ophiomorpha* sp. also occurs in the form of more isolated shaft an dtunnel systems in cross-stratified, coarse *Halimeda*-rich calcarenites deposited in a tidal delta paleoenvironment. Burrow tues have thick walls (2 to 3 mm, .08 to .1 in.) of micritic material and distinctly mammillated to rugose exterior surfaces; tube outside diameters are 1 to 2.5 cm (.4 to 1 in.). Although *Ophiomorpha* sp. exhibits an obviously pelleted exterior surface, the pattern of pellet arrangements is not nearly as regular or distinct as that normally found in *Ophiomorpha nodosa* preserved in siliciclastic sediments. Occurring with *Ophiomorpha* sp., commonly in abundance, are vertical burrow tubes less than 1 cm (.4 in.) in outside diameter and with lengths of up to 15 cm (6 in.). These tubes are assigned to *Skolithos*, and two or more types are present.

Rhizocretions formed of calcrete and presumably initiated by the action of plant roots occur commonly in most facies on San Salvador, and they can easily be mistaken for trace ffossils of invertebrate origin, particularly *Ophiomorpha* sp. Criteria for distinguishing *Ophiomorpha* sp. from rhizocretions include the following. (1) *Ophiomorpha* sp. has a distinct lining of regular thickness, and individual segments of the burrow system have consistent diameter; rhizocretions do nto have a distinct lining and are irregular in diameter. (2) The interior surface of *Ophiomorpha* sp. is smooth and the exterior surface distinctly mammillated; rhizocretions have highly variable interior and exterior surface. (3) *Ophiomorpha* sp. compelxes have much more consistent patterns of shaft/tunnel arrangement than exhibited by rhizocretion systems.

Calcarenites of beach facies are widespread along the coastline of the island, but these facies do *not* contain *Ophiomorpha* sp. In few places, these facies have unlined vertical burrows of variable diameter and trails, both attributable to the activity of crabs. The modern marine carbonate environments surrounding SanSalvador exhibit much trace-making activity and provide analogs for further interpretation of the Pleistocene trace fossils and their associated paleoenvironments.

DAHL, H. M., C. A. CALLENDER, and P. A. SCHROEDER, Texaco, Inc., Bellaire, TX

Geologic Factors Influencing Reservoir Performance at Texaco's Salem Tertiary Recovery Project, Marion County, Illinois

A detailed lithologic reservoir study was conducted to aid Texaco personnel in designing and monitoring an experimental surfactant-polymer flood in the Mississippian Benoist Sandstone, one of several producing formations in the Salem field of south-central Illinois. Twelve elongated five-spot patterns are distributed over the 60-acre (24 ha.) project area. The Benoist Sandstone averages about 49 ft (15 m) of net pay at a depth of about 1,800 ft (550 m). Cores from eight wells were studied in detail. Particular attention was paid to variations in sedimentary structures, lithology, and mineralogy that could influence reservoir performance. Techniques employed in this study included examination of slabbed cores, thin-section petrography, X-ray diffraction (XRD) mineralogy, and scanning electron microscopy/energy dispersive spectrometry (SEM/EDS).

The Benoist Sandstone is one of several Late Mississippian deltaic sandstone units deposited in the subsiding Illinois basin. These sandstones are bounded above and below by fossiliferous marine limestone and shale. Delta-front sandstones, hereafter referred to as bar-finger sandstones, comprise the bulk of the formation. Channel-fill deposits are found near the base of the unit and nonreservoir, tidal-flat deposits near the top. The bar-finger deposits are moderately to well-sorted, fine to medium-grained sandstones with horizontal to inclined planar bedding and some ripple and planar cross-bedding. The planar bedding is accentuated by clay and mica-rich layers, one millimeter to several centimeters thick. These shale layers increase and thicken upward, and separate the bar-finger sands into several reservoir units.

The Benoist sandstones are quartzose, containing 70 to 98% monocrystalline and polycrystalline quartz and small amounts of detrital feldspar and shale clasts. Cement is predominantly quartz in the form of syntaxial overgrowths, with minor calcite. Small amounts of clay occur as detrital laminae, authigenic pore fillings, and sand-grain coatings. The percentage of detrital and authigenic clay increases near the top of the bar-finger sandstone and significantly reduces permeability. Illite, the dominant clay,