pore pressures. Because of their polygenetic origin, breccia masses have diverse orientations paralleling bedding or fracture/fault systems.

In conclusion, fracturing and brecciation of the Monterey Formation reflect the interplay between processes of diagenesis, deformation, and fluid dynamics. The most important features of the reservoir in the area of the present study are: (1) vertical fractures oriented normal to the structural trends and inferred to be favorably oriented (to remain open) with respect to the regional minimum horizontal stress; and (2) breccias that are both stratigraphically and structurally controlled and inferred to be related to the interaction of rock stress and fluid dynamics.

BELITZ, KENNETH, U.S. Geol. Survey and Stanford Univ., Menlo Park, CA, and JOHN BREDEHOEFT, U.S. Geol. Survey, Menlo Park, CA

Hydrodynamics of Denver Basin, An Explanation of Subnormal Fluid Pressures

Anomalously low fluid pressures are found in the Lower Cretaceous, Mesozoic, and Paleozoic rocks of the Denver basin. Drill-stem test data and published hydrogeologic information are used to construct a potentiometric map for the Lower Cretaceous sandstones in the area. Normally, one expects the potential surface to be at or near the land surface (0.43 psi/ft). However, the potential surface for the Lower Cretaceous sandstones and underlying Paleozoic rocks is up to 2,500 ft (762 m) beneath the land surface (0.35 psi/ft) in parts of the Denver basin in Colorado and the Nebraska panhandle. The low pressures seem especially anomalous considering the elevation of the outcrops along the Rocky Mountain Front and the Black Hills.

The hydrostratigraphy is defined based on the known regional geology. Structure, isopach, and lithofacies maps are used to estimate the hydraulic characteristics of the rocks in the basin. A numerical model is constructed, based on the hydrostratigraphy, which simulates the regional flow system. Both transient and steady-state flow regimes are simulated. The interaction of the Lower Cretaceous sandstones with overlying and underlying hydrostratigraphic units is investigated. The significance of recharge in the outcrop areas is evaluated. The model is used to define the conditions under which subnormal fluid pressures may occur. The subnormal fluid pressures are reasonably explained as a consequence of regional ground-water flow.

BENNISON, ALLAN P., Geological Consultant, Tulsa, OK

Importance of Shelf to Trough Black Phosphatic Shales in Mid-Continent

Pennsylvanian black shales containing radiolarian-rich phosphatic nodules, such as are now accumulating on outer shelves and upper slopes of modern tropical seas, are widespread throughout much of Kansas, Oklahoma, and other Mid-continent states.

Conodonts, inarticulate brachiopods, conularids, fish teeth, and radiolarians constitute the main biota of these black shales. Such shales characterize about half the 60 or more known Pennsylvanian cyclothems of Oklahoma and Kansas. These shales, individually approximating about 1 m (3 ft) in thickness in the extensively mined limestone and coal sequences of eastern Kansas and northeastern Oklahoma, have been described by Moore, Branson, Heckel, and others. However, much thicker, up to 8 m (26 ft), coeval zones in the deep Arkoma and Anadarko basins are surprisingly under-reported considering that such highly organic shales may have been the prime source of commercial oil and gas. Furthermore, those coeval black shale wedges that interfinger southward from the Arkoma trough into the red bed- and conglomerate-dominated sequences flanking the southern tectonic borderlands are virtually unreported.

These are the "core shales" of Heckel, the deep stillstand or maximum transgressive facies. Representative black phosphatic shales crossing two or more tectonic provinces include the Desmoinesian sub-Verdigris, Anna, and Nuyaka Creek beds, and the Missourian Mound City and Stark beds.

Dysaerobic (low oxygen) and supposedly slightly shallower water, dark gray concretionary shales adjoin these black phosphatic shales. In many cyclothems the dysaerobic facies represent the deep stillstand facies where the latter is missing. Typically, it features a middle to outer shelf diverse molluscan community, including rapidly evolving goniatites useful for correlations.

These deep-water stillstand indicators are more useful for regional correlations than those for the low water stillstand that include coals, coaly shales, red beds, and paleosols. Carboniferous sea level fluctuations at times probably exceeded 200 m (656 ft), arising from interacting tectonic pulses and glacial-eustatic changes. Recent findings indicating that Carboniferous glacial maxima in southern Pangea exceeded Pleistocene maxima may account for the numerous regressive events on a global scale at that time.

BENSON, RICHARD H., Smithsonian Inst., Washington, D.C.

Changes in Deep-Sea Ostracode Fauna from Eocene into Oligocene

A major change in deep-water oceanic circulation occurred near the end of the Eocene forming the present psychrosphere and basic two-level water-mass system. This event is especially felt in the South Atlantic and Indian Ocean as shown by ostracods found in DSDP cores. Faunas traceable back to the Cretaceous rapidly evolved into the modern deep-sea faunas at this time. Several important ornate genera undergo diachronous changes suggesting that the flooding of the world ocean basins with colder waters happened in stages. The displacement of Tethyan water masses coming from the north by newly formed Antarctic bottom waters can be followed by changes in the ostracods.

BERG, R. R., Texas A&M Univ., College Station, TX

Abnormal Pressures and Their Relation to Oil and Gas Migration and Accumulation

Subsurface water exists in a dynamic state, and the condition of hydrodynamic flow, or potential for flow, is indicated by abnormal fluid pressures. Excess pressures indicate updip flow of water and transfer of hydrocarbons from source rock to reservoir in stratigraphic or structural traps. Deficient pressures most commonly indicate downdip flow, reinforcement of capillary-pressure barriers, and enhanced oil columns in stratigraphic traps. The principles of hydrodynamic flow can be applied in either case for prediction of sites for petroleum accumulation; furthermore, a quantitative estimate can often be made of the amount of oil or gas trapped.

Excess pressures in the Gulf Coast Tertiary section are generated by several mechanisms: (1) nonequilibrium compaction, (2) clay transformation, (3) aquathermal pressuring, and (4) hydro-