ment surfaces. The Tertiary depocenter, adjacent to this fault, shifted from west to east with continued slippage through time, the greatest movement occurring in Miocene and post-Miocene. In the strike direction, the valleys are separated into at least two subbasins by an east-west structurally high axis. The axis is postulated to be the result of a tear fault associated with movement along the listric normal fault.

Tertiary stratigraphy varies between valleys and between subbasins in a given valley. All the valleys contain Miocene and younger rocks; however, not all subbasins contain the pre-Miocene section suggesting a complex scheme of structural development.

EKDALE, A. A., Univ. Utah, Salt Lake City, UT

Trace Fossils and Stagnation of Deep-Sea Basins

The patterns and intensity of bioturbation of marine sediment are useful indicators of the response of benthic organisms to fluctuating oxygen levels in the bottom water. Trace fossil assemblages in mid-Cretaceous (Barremian-Albian) DSDP core sections from the central and southern Atlantic were examined to document the activities of burrowing infauna relative to episodes of stagnation in deep Atlantic basins during that time.

The mid-Cretaceous anoxic horizons in DSDP cores typically are dark, homogeneous or laminated, organic muds, which alternate with moderately to heavily burrowed facies containing less organic carbon. Bioturbation intensity and trace fossil diversity appear to correlate inversely with the amount of unoxidized carbon in the sediment, suggesting that the more organic-rich facies were deposited under conditions where oxygen was a limiting factor for benthic macro-organisms.

The ichnogenus *Chondrites* commonly occurs, sometimes to the exclusion of all other kinds of burrows, immediately above and/or below unburrowed, laminated mud. It also occurs in heavily burrowed limestones containing rich trace fossil faunas, including *Zoophycos*. Therefore, mid-Cretaceous *Chondrites* apparently were created by animals possessing broad oxygen tolerances; the presence of *Chondrites* alone in an organic-rich deposit probably indicates dysaerobic conditions.

ELLIOTT, DAVID, Johns Hopkins Univ., Baltimore, MD

How do Thrust Belts Form?

Thrust belts form at converging plate margins and straddle both sides of a hinterland occupied by a calc-alkaline arc. There are two competing theories for thrust belts and each implies a distinctly different behavior at the plate margins. The two theories, stated in oversimplified form, claim that thrust belts are created by either a horizontal push, or by the gravity-driven spreading of an elevated hinterland. In response to modern geometrically based structural interpretations the two theories have changed and developed over the past decade. Thrust toes are clearly dominated by a compressive push from the rear, but for larger parts of a thrust the gravitational terms are more significant. However, on the scale of an entire thrust belt, are rocks sufficiently weak for the gravitational terms to dominate? One of the principal differences between the two theories boils down to the question of rock strength. Certain simple structures provide a key to this impasse. One is listric normal and growth faults which develop without any push from the rear. Because of their high degree of symmetry, opposed-dip thrust complexes, such as triangle zones and pop-ups, also provide information. By working on these structures with limit analysis, a method recently developed in soil mechanics, we can estimate upper and lower bounds which bracket rock strengths under long term geological conditions. These bounds to rock strength can be directly applied to the two theories for the formation of thrust belts.

ERTEL, JOHN R., and JOHN HEDGES, Univ. Washington, Seattle, WA

A Test of the Melanoidin Hypothesis

Marine and terrestrial humic acids are thought to differ in structural composition owing to differences in precursors and formation pathways. It has been proposed that marine humic acids are formed by the polymerization of sugars and amino acids (the melanoidin pathway) while terrestrial humic acids result primarily from the condensation of lignin-derived phenols and amino acids. In this study, four marine and three terrestrial humic acids have been isolated, and a series of polymers have been made by the reaction of either glucose or catechol with alanine or ammonia. Chemical and spectroscopic measurements of the natural and synthetic polymers have been made, including elemental analysis, carbon isotope ratios and IR, UV-visible, UV-fluorescence, and ESR scans. In addition, degradative analyses of marine and terrestrial humic acids together with the synthetic polymers have been performed to determine (1) if characteristic structural differences exist between marine and terrestrial humic acids and (2) if similarities between the degradative products of synthetic and natural polymers reflect biologic precursors and reaction pathways.

FAIRBANKS, RICHARD G., Lamont-Doherty Geol. Observatory of Columbia Univ., Palisades, NY; JEAN CLAUDE DUPLESSY, Centre des Faibles Radioactivites, Laboratoire mixte CNRS-CEA, Gif-sur-Yvette, France, JOSEPH T. DURAZZI, et al, Lamont-Doherty Geol. Observatory of Columbia Univ., Palisades, NY

Carbon Flux from Ocean to Biosphere—Chemical Evidence from Deep-Sea Cores

The ocean is the major carbon reservoir in the ocean-atmosphere-biosphere system. Depending upon the demands of the biosphere, the ocean alternately acts as a source or sink of carbon. Because organic carbon has a δC^{13} composition of approximately -25 ppm (PDB), a 15% variation in the size of our modern biosphere (living and humus) would result in a 0.2 ppm δC^{13} variation in the CO_2 of the world ocean. A -0.4 ppm δC^{13} variation in modern surface water has been measured in a 200-year-old coral. Carbon-14 measurements in the same coral confirm that the cause of the δC^{13} variation

during the past century is the burning of fossil fuel. The carbon isotopic composition of certain species of planktonic foraminfera accurately reflects the C-13 composition of CO_2 in the ocean surface water, and also records the −0.4 ppm change in surface water. This change was measured by comparing living planktonic foraminifera C-13 composition with the C-13 values measured in fossil planktonic foraminifera from core tops. During deglaciation periods in the Pleistocene, certain species of planktonic foraminifera and benthic foraminifera record synchronous global C-13 fluctuations of approximately +0.8 ppm which indicates a flux of 1.2×10^{18} g carbon from the ocean to the biosphere. These figures suggest that the biosphere doubled in mass in less than 10,000 years, presumably owing to rapid climate change. We can extrapolate these findings in modern and Pleistocene planktonic and benthic foraminifera to measure carbon fluxes in the Tertiary and Late Cretaceous. How well periods of rapid organic carbon production correspond to periods of significant carbon burial and maturation is not yet known.

FANG, J. H., T. H. STARKS, and JOE MATTERN, Southern Illinois Univ., Carbondale, IL

Geostatistical Approach in Coal Resource Estimation

The conventional reserve/resource estimation methods (triangular, polygonal, and isopach) are briefly described and then compared against a new geostatistical approach. The comparison is based on estimates using real-world data from southern Illinois. The geostatistical procedure employed is a kriging technique called the intrinsic random functions of order k, using spherical covariance models. While the intrinsic random function approach is usually considered to be a local estimation procedure, the introduction of sampling methodology allows its extension to global estimation problems without excessive cost for computation. The major advantages of the geostatistical approach are that it provides a built-in measure of the precision of its estimates, thus allowing the determination of confidence limits, and also gives additional insight into the spatial variability of coal seams. The estimates are improved as more geological information of the coal deposits becomes available.

FEINSTEIN, SHIMON, Univ. Oklahoma, Norman, OK, WILLIAM E. HARRISON, Oklahoma Geol. Survey, Norman, OK, THOMAS L. THOMPSON, Univ. Oklahoma, Norman, OK, et al

Subsidence and Thermal History of Southern Oklahoma Aulacogen—Implication for Petroleum Exploration

Evolution of the southern Oklahoma sedimentary basin has been constructed from the stratigraphic record in deep wells, using the back-stripping method, and by analysis of the rate of subsidence. For this analysis, rate of subsidence has been considered a significant recorder of the cumulative effect of the factors which control basin subsidence. Similarity of subsidence curves constructed in this study to other models indicates, in general, the application of the concept of thermally-controlled isostatic subsidence for the evolution of the southern Oklahoma basin.

Two distinct mechanisms of subsidence are proposed for the evolution of the basin. First, elastic flexure of the lithosphere controlled the initial 20 m.y. of subsidence. Second, reactivation of aulacogen boundary faults may account for differential subsidence.

An anomaly in the rate of subsidence curve suggests a short phase of sediment compaction and fluid migration near the termination of the subsidence stage. This compaction might be a sensitive indication of change in the state of stress from extension to compression, possibly related to the regional tectonic setting.

FERREIRA, JUSTO CAMEJO, and PAULO CESAR GAGLIANONE, PETROBRAS, Sergipe, Brazil

Sergipe-Alagoas Basin, Brazil—Source-Rock Characterization and Evaluation

Cores, drill-cuttings, and oil samples from the Sergipe-Alagoas basin were studied in detail to characterize and evaluate the source rocks of the area and correlate the oil with the probable source-rocks.

The content of organic matter was determined by conventional Leco analyses. The types of organic matter in each sample were determined qualitatively by visual microscopic examination. The thermal maturity was ascertained by light hydrocarbons (C_1 to C_4) analyses, organic extract composition, character of the C_{15+} saturated hydrocarbons, thermal alteration index (TAI) and, in a few places, by measurements of vitrinite reflectance.

The results of the study indicate that source rocks are present in stratigraphic sections belonging to three depositional cycles: nonmarine, transitional (evaporitic), and marine. Source rocks from each cycle yield oils of distinct character. Three oil systems were distinguished: (1) Barra de Itiuba/Serraria, (2) Carmópolis, and (3) Calumbi.

The source rocks of the Sergipe-Alagoas basin are of good quality but the total volume of hydrocarbons that might be expelled is probably not very large, since the source beds are relatively thin and probably discontinuous.

This study also indicates that entrapped hydrocarbons of the Sergipe-Alagoas basin have migrated short distances.

FERTL, W. H., Dresser Atlas, Houston, TX

Geothermal Resources Evaluated by Well Logs

Well logging in the petroleum industry developed over five decades into a mature industry, whereas geothermal well logging is a relatively new enterprise.

The present discussion focuses on the types of geothermal reservoirs encountered, geologic and reservoir engineering objectives, and qualitative and quantitative interpretive formation evaluation techniques based on geophysical wireline logs.

Specific field case studies illustrate the state-of-the-art technology, including examples from the Geyser dry