(and migration direction) and the resultant effective wind vector may have significant implications for paleowind analysis in the geologic record. In this instance, the structure reflects only west-southwest (July-December) winds, owing to a southwest-northeast imbalance in sand movement. This imbalance is due mainly to the effect of sand-trapping by vegetation on northeast slopes, as well as to seasonal differences in sand mobility, the latter correlating partly with the semi-annual shift in the wind regime.

CASEY, RICHARD E., and CYNTHIA R. WIGLEY, Rice Univ., Houston, TX

Neogene Deep-Living Radiolarian Zonation and Its Uses

A Neogene radiolarian zonation using deep-living radiolarians has been developed. This zonation consists of 6 radiolarian zones with the nominant taxa of each zone first occurring at the base of its zone, and that nominant taxa running throughout its zone. These zones are the *Eucyrtidium cienkowskii* (22.5-19 Ma), *Siphocampe arachnea* (19-14 Ma), *Oroscena* with digitate spines (14-11 Ma), *Botryostrobus bramlettei* (11-6 Ma), *Clathrocyclas bicornis* (6-2.5 Ma), and *Cycladophora davisiana davisiana* (2.5-0 Ma) Zones. These zones were developed by using Antarctic, equatorial, and North Pacific Deep Sea Drilling Project holes, and are believed to be cosmopolitan zones due to their being based on deep-living radiolarians. These zones are dated by correlating the first occurrences of the nominant taxa with warm-water radiolarian datums that have been paleomagnetically dated. These zones are not designed for routine use, but rather for tying together other more provincial zonations, and for comparing oceanographic phenomena on global datum planes. To date, this zonation has been used to correlate Antarctic zonations intra- and inter-regionally and to study the evolution of radiolarian lineages.

CASTANO, JOHN R., Shell Development Co., Houston, TX

Uses of Vitrinite Reflectance in Determining Thermal History in Sedimentary Basins

Vitrinite reflectance (VR), adapted from coal petrology, came into routine use in the petroleum industry in the late 1960s. Initially, the principal goal was to help establish the VR limits for oil and gas generation. Subsequently, VR has become accepted as the most useful measure of burial history and paleotemperature, largely because VR affords the most practical means of measuring the progression of organic metamorphism. VR is used to correlate other measures of thermal history such as chemical maturity parameters, Rock-Eval t_{max}, and burial-history reconstruction. VR can aid in identifying unconformities, geopressured sections, and thermally altered zones. Combined with good temperature data, the determination of VR equivalents from temperature and burial time are used to evaluate the relationship of depth to log VR obtained directly. The time and temperature required for maturation in Tertiary basins stresses the interplay of both factors in the maturation process. Reflectance has been employed in deciphering the burial history and tectonic evolution of many areas, including structurally complex regions as the Alps and the Wyoming Overthrust belt.

Interpretational problems that arise include: (1) VR can be altered by the absorption of hydrogen-rich materials, oxidation, and natural coking; (2) the presence of reworked and caved organic matter produces multiple reflectance populations; and (3) vitrinite is sometimes difficult to distinguish from solid hydrocarbons and some inerts if the particle size is small. Most of these problems are resolved at the microscope. Interpretation is improved significantly by analyzing a series of samples rather than an isolated sample.

CHANG, HUNG K., and RENATO O. KOWSMANN, PETROBRAS, Rio de Janeiro, Brazil

Thermal Subsidence of Santos and Sergipe-Alagoas Basins, Brazil—Application to Hydrocarbon Exploration

A uniform lithospheric extension model has been applied to the subsidence and thermal history of the Santos and Sergipe-Alagoas basins. Thermal subsidence curves were derived from more than 40 exploratory wells, complemented by seismic and gravity sections.

In the Santos basin, the region landward of the hinge zone is dominated by Tertiary marine onlapping sediments. Seaward, rift (continental) and postrift (transitional and marine) sequences are present with predominance of the latter. Crustal thinning by 35% exists just east of the hinge zone and increases to 70% at the shelf break.

Likewise, the hinge zone in the Sergipe-Alagoas basin overlies the largest gradient in crustal thinning, but unlike the Santos basin, rift-stage sediments dominate landward of this hinge zone. Seaward, the ratio of rift to postrift sediments is larger than in the Santos basin. Crustal thinning ranges from 20% to 60%, but this transition occurs over a short distance.

Thermal and burial histories were used to estimate oil windows for potential source rocks in various parts of these basins. Maturation profiles are in good agreement with observed vitrinite reflectance and hydrocarbon maturity data. The areal distribution of maturation stages through time is variable and largely controlled by crustal thinning. Information on timing of hydrocarbon generation was applied to the prediction and evaluation of hydrocarbon accumulation.

CHAPMAN, JOHN J., Western Carolina Univ., Cullowhee, NC

Uniformitarian Hypothesis to Explain Permian-Triassic Life Extinctions

A uniformitarian hypothesis is possible to explain the great Permian-Triassic life extinction event. Unlike the recent "catastrophic" explanations for the Mesozoic-Cenozoic extinctions, this hypothesis does not depend upon extraterrestrial intervention.

The dominant worldwide event at the close of the Paleozoic was the formation of Pangea. The Mesozoic witnessed the sundering of this supercontinent and the formation of the modern continental masses and oceans.

The areas covered by the waters of the Paleozoic oceans surrounding Pangea either were incorporated onto the fringing continents or were subducted. New oceans, which became the present oceans, were forming in the Mesozoic in the areas where the combined continental masses were splitting apart.

If these 2 events were in part simultaneous and yet physically separated in such a way that the waters in the newly forming oceans did not connect with the water in the closing oceans, almost complete extinction of all earlier marine life forms would result.

Radioactive dating of the present ocean floor indicates that the Paleozoic floor was eliminated, and new ocean floor began to form in the Mesozoic. Chemical dating of present ocean water indicates that its time of origin is approximately the same as that of the present ocean floor.

CHAPMAN, WILLIAM H., Exxon Co., U.S.A., Houston, TX

Computer-Generated Reconnaissance Maps Using Commercial Data

Much well and production-history data are currently available in digital form from commercial sources. These data, when mapped using a computer, can quickly give valuable perspectives to the geologist developing new prospects.

A large data bank has been built from commercial well and production data that can be reported or mapped using either proprietary or commercially available software. Time and manpower reductions experienced using the computer-generated maps give the geologist the ability to evaluate large geographical areas before committing resources to potential prospects. These maps can include not only conventional geologic maps, such as isopach and structure maps, but also maps of abnormal pressure, bottom-hole temperature, or any geologic parameter contained in the data bank.

CHIA, YEE-PING, ARCO Oil & Gas Co., Dallas, TX

Numerical Simulation of Subsurface Flow in a Sedimentary Basin

Pore water in sedimentary rocks is normally in motion. In general, gravity-induced flow driven by the elevation gradient predominates in a basin with orogenic deformation; however, in a basin with continuous deposition, compaction-induced flow driven by the excess fluid-pressure gradient predominates. Subsurface water flow is considered to have a controlling influence on the migration of widely dispersed petroleum. Therefore, the analysis of a basin-wide flow system, particularly its paleohydrogeologic conditions, is essential for understanding the history of petroleum migration and entrapment.

The nonlinear finite element method has been used to simulate coupled processes of sediment deformation and fluid flow in sedimentary

sequences. By activating and deactivating elements at various stages in the computation process, the sequential deposition and erosion during evolution of a sedimentary basin can be modeled. Simulated results indicate that excess fluid pressure occurs when a basin is progressively loaded by overlying sediments. An excess pressure gradient will cause pore fluid to flow vertically and horizontally, depending upon the regional stratigraphy and structure, toward the sediment surface. In sandstone-shale sequences, pore fluid in shales tends to flow toward adjacent sandstones, increasing the effectiveness of petroleum accumulation. The downward flow from overlying shales to sandstones, plays an important role in providing resistence to the upward migration of petroleum. The concentrated fluid flux in sandstones tends to flow parallel to the bedding plane toward highest positions of permeable strata, such as crests of anticlines, pinch-outs, or outcrops. Although the orogenic deformation further compresses sediments initially, the subsequent erosion rapidly reduces excess pressure and causes the invasion of meteoric water.

This study suggests that numerical modeling is an effective technique in evaluating histories of subsurface flow, sediment compaction, and petroleum accumulation.

CHIBURIS, EDWARD F., Arabian American Oil Co., Dhahran, Saudi Arabia

Analysis of Amplitude Versus Offset to Detect Gas/Oil Contacts in Arabian Gulf

The theoretical behavior of P-wave reflection amplitude as a function of incidence angle (offset) indicates that diagnostic changes should be spatially observable when crossing boundaries between different formation fluids. In particular, when free gas is present in porous sand, Poisson's ratios are known to be abnormally low (usually <0.1-0.2), whereas for oil and water the ratios are usually much greater than 0.3. If the overlying layer has an impedance and Poisson's ratio greater than the target layer, the reflection amplitudes will increase with offset, thereby producing bright spots in stacks.

The problems in analyzing seismic amplitudes are well known. The distortions produced in the recorded amplitudes owing to the effects of sources and receivers, instrumentation, processing, attenuation and absorption, layer tuning, multiple interference, and noise can render the measurements meaningless unless corrected for, which would be difficult. However, by using relative instead of absolute amplitudes and by applying suitable analysis techniques, most of these effects can be virtually eliminated. The resulting amplitude behavior can then be properly interpreted in terms of changes in formation properties.

CHRISTIE, P. A. F., Schlumberger Technical Services, London, England, and J. A. DANGERFIELD, Phillips Petroleum Co., Tanager, Norway

Bore-Hole Seismic Profiles in Ekofisk Field

In October 1983, a major bore-hole seismic survey was carried out in the Ekofisk oil field in the Norwegian sector of the North Sea on behalf of the Phillips Petroleum License 018 group of companies. A conventional deviated well VSP and 3 multilevel walkaway seismic profiles were acquired in an area showing poor surface seismic returns owing to gas charging in the overlying sediments.

Processing the data through to a series of conventional common-midpoint sections permitted detailed interpretation of the top of the Ekofisk formation and the top of the Tor formation away from well control. Both formations are producers separated by a tight zone. The Tor formation is the primary zone to waterflood, and information about its lateral continuity is important in the location of proposed water-flow injector wells.

A probably fault-controlled lineation subparallel to the bore hole was detected by the surveys. Reflections from below the reservoir formations are evident, and a by-product from the survey is strong evidence for the existence of apparent anisotropy in velocity or lateral velocity gradients.

CHUNG, GONG SOO, and ROBERT N. GINSBURG, Univ. Miami, Miami Beach, FL

Siliciclastic Incursion in Southern Florida and Development of Florida Reefs During Late Cenozoic

Only one major interruption has occurred in the long history of shallow-water carbonate deposition that has prevailed in southern Florida since the Jurassic. This break resulted from a substantial incursion of the finer siliciclastic sands interbedded or mixed with surprisingly coarse quartz sands during the late Cenozoic. Along the southeastern margin, this influx was succeeded by the development of reefs during the Quaternary.

The siliciclastics occur in the subsurface beneath a section of Pliocene to Holocene shallow-water carbonates. Recent study of well samples shows that these sediments are thickest (120-200 m) along a north-south trend that extends from the central part of southern Florida to the upper Florida Keys. These sediments are largely composed of quartzose grains ranging in size from very fine sand to granule (0.06-4 mm), with minor proportions of calcareous clays, phosphatic grains, and marine faunal fragments. The medium sand to granule-sized sediments are composed of well-rounded quartzose grains and occur either interbedded or mixed with finer fractions.

The sudden influx of siliciclastics in southern Florida beginning in the Miocene is quite unexpected considering the remoteness of the Appalachians, the postulated source. This southward transport may have been accomplished by rivers and/or longshore currents. The siliciclastic section extends southward slightly beyond the curving arc of Quaternary reef deposits. The coincidence of the southeastern edge of siliciclastics with the arc of Quaternary reefs suggests that reef development may have been localized on the siliciclastic margin.

CHURKIN, MICHAEL, JR., WESLEY K. WALLACE, and THOMAS E. MOORE, ARCO Alaska, Inc., Anchorage, AK

Alaska—an Explorationist's Jambalaya

Seaward growth of Alaska since Jurassic time has resulted from terrane accretion and deposition of thick clastic sequences in successor basins. Post-accretionary strike-slip faulting and rifting have fragmented both newly accreted terranes and older continental rocks. Accretion and dispersion have resulted in a jambalaya of geologic units that may be viewed in the context of terrane analysis. This offers a spectrum of opportunities and problems for exploration.

Large continental fragments (e.g., North Slope, Nixon Fork, and Tatonduk terranes) consist predominately of Paleozoic rocks with relatively continuous stratigraphy and the greatest potential for regional source and reservoir trends. Other exploration targets may include continental rocks beneath oceanic terranes (e.g., Kagvik, Angayucham, Innoko, and Tozitna terranes), which occur as extensive, relatively thin thrust sheets. An island-arc terrane, the Peninsular terrane, has acted as a source both of hydrocarbons from its organic-rich oceanic sediments, and of reservoir-quality deposits shed into the Cook Inlet successor basin. Post-accretionary rifting and strike-slip dispersion of the growing continental framework of Alaska have resulted in formation of a series of basins filled with clastic sediments, including the Bering Sea and Interior basins, which are current targets for hydrocarbon exploration.

CICCARONE, MITCHELL and WARREN NORTON, Kent State Univ.–Stark Campus, Canton, OH

Thickness Trends and Structure of Berea Sandstone (Mississippian) in Washington County, Ohio

The Berea Sandstone has been a drilling target for hydrocarbon production in Ohio for over 100 yr. Although extensively produced, the Berea still rewards the driller with new commercial production. Due to its shallow depth and low cost of completion, the Berea has undergone a renaissance in interest in recent years. This paper presents the results of a study of more than 3,500 geophysical and driller's logs in Washington County in southeastern Ohio. Structure contours show major trends, such as the Burning Springs anticline and the Cambridge arch, trending almost north-south. In the western third of the county, structural trends change, however, to a more complex, less continuous pattern with a predominant northeast-southwest trend. Isopach trends delineate a system of channel sands trending roughly east-west with sandstone thicknesses ranging from 0 to greater than 25 ft (8 m). Both structures and thalwegs are relatively narrow and thickness changes rapidly, both parallel to and normal to the thalweg. Although no new interpretations of Berea struc-