processes in solitary and colonial radiolarians have begun to elucidate some of the adaptive mechanisms that may account for the remarkable success of these holoplankters in diverse oceanic environments. The diversity of algal symbionts including dinoflagellates, prasinophytes, and a brown-pigmented alga has been documented by light and electron microscopy, and the role of the symbionts in host nutrition has been determined for some solitary and colonial species using cytochemical and radioisotopic techniques. Fine structure analysis of predatory behavior and food vacuole contents shows that some larger solitary spumellarian species are omnivores consuming crustacean prey and other microzooplankton in addition to algae. This is in contrast to prior assumptions that most solitary radiolarians are microherbivores and therefore changes our conception of their niche in oceanic environments.

Fine structure examination of skeletal morphogenesis in a number of solitary and colonial species has clarified the mechanism of skeletal deposition and pattern of skeletal ontogeny. These studies contribute to our understanding of cellular specialization in radiolarians, their physiological adaptive mechanisms to a holoplanktonic existence, and the biological factors correlated with patterns of skeletal morphogenesis that may be useful in interpreting radiolarian evolution and paleoecology.

ARCHER, ALLEN W., DePauw Univ., Greencastle, IN

Trace Fossils of Middle Mississippian Carbonates, South-Central Indiana

Middle Mississippian (Meramecian) predominantly carbonate units of south-central Indiana, which include the Harrodsburg, Salem, St. Louis, and Ste. Genevieve Limestones, included the following environments: (1) sabkha (supratidal flats); (2) lagoons; (3) oolitic- and calcareous-sand bars and shoals; and (4) deeper shelf impure carbonates. Probably as functions of salinity and rate of deposition, these rocks range from being intensely bioturbated to a lack of recognizable bioturbation. Although several of the trace fossils cannot be currently assigned to recognized ichnogenera, the following forms have been recorded: *Chondrites*, *Cylindrichnus*(?), *Planolites*, *Teichichnus*, and a *Rhizocorallium*-type trace.

Degree of weathering exerts a considerable control on field recognition of the various forms. Intense weathering obliterates the slight tonal differences that aid in identification of traces in the fine-grained carbonates. However, in some calcarenites, certain taxa are only recognizable in weathered material and are nearly impossible to discern in polished slabs.

Factors related to episodic influx of fine-grained terrigenous detritus exert a considerable control on preservation of the various forms. Field exposures of carbonates that contain shale partings commonly exhibit abundant traces that are only apparent in polished slabs of more massive carbonates. The similarity of trace-fossil assemblages from these shallow-water carbonates with traces of deeper shelf Cretaceous chalks of the U.S. Western Interior further supports the contention of a high degree of preservational control.

ARMENTROUT, JOHN M., Mobil Exploration and Producing Services, Inc., Dallas, TX

Eocene-Oligocene Boundary Problems, West Coast, North America

Correlation of the international Eocene-Oligocene boundary with the provincial biostratigraphic framework of the northeast Pacific margin has been and continues to be controversial. The controversy centers about historical nomenclature and correlations, and current correlations based on planktonic fossil group.

The Geological Society of America's C. E. Weaver Committee published the first interdisciplinary correlation chart for the Cenozoic rocks of the western United States in 1944. The committee placed the Eocene-Oligocene boundary at the base of the "Keasey" Molluscan Stage and Refugian Benthic Foraminiferal Stage. These correlations were based on faunal similarity between Pacific Coast and European assemblages.

The most useful provincial boundaries of Late Eocene to Oligocene age are the Narizian-Refugian and Refugian-Zemorrian Benthic Foraminiferal Stage boundaries. Reevaluation of the Refugian Stage has recently been completed. The stage boundaries have been correlated to the international geologic time scale using planktonic microfossils.

Rigorous stratigraphic superposition of planktonic floras and faunas from continuously deposited foraminiferal-rich rocks results in correlation of the Narizian-Refugian Benthic Foraminiferal Stage boundary with the calcareous nannofossil zonal boundary NP18/NP19, and with planktonic foraminiferal Zone P15, in California, Oregon, and Washington. Thus, the Narizian-Refugian boundary represents a provincial chronostratigraphic datum of early late Eocene age.

Planktonic assemblages are rare in samples from above and below the Refugian-Zemorrian Benthic Foraminiferal Stage boundary. In California this boundary is commonly at an unconformity or without superposition of diagnostic faunas. In southwestern Washington the Refugian-Zemorrian boundary occurs in continuously deposited and foraminiferally rich sections. Nannofloras assigned to Zone NP22 and planktonic foraminifera assigned to the interval of Zones P17 to P20 occur in strata containing foraminifera assigned to the Zemorrian Benthic Foraminiferal Stage. Nannofloras assigned to the intervals of Zones NP20 and NP21, and Zones NP19 to NP21, and planktonic foraminifera assigned to the intervals of Zones P16 and P17, and Zones P15 to P17 occur in strata containing foraminifera assigned to the Refugian Benthic Foraminiferal Stage. Therefore, the Refugian-Zemorrian boundary occurs within planktonic Zones NP21 and P17, roughly correlative with the international Eocene-Oligocene boundary.

The above correlations result in the reassignment of much of the 1944 Weaver chart's Oligocene to the Eocene: the "Keasey" and "Lincoln" Molluscan Stages and the Refugian Benthic Foraminiferal Stage are now recognized as late Eocene in age.

Radiometric calibration of the provincial boundaries is not yet possible. Whole rock potassium-argon and fission track dates are available but both have very large error bars or lack adequate biostratigraphic control to be useful.

Fossiliferous stratigraphic sections have rocks with sufficient remanent magnetism for magnetostratigraphic studies but to date only reconnaissance data are available.

ARMENTROUT, JOHN M., and ULRICH A. FRANZ, Mobil Exploration and Producing Services, Inc., Dallas, TX

Tectonic Control of Eocene Arkosic Sediment Deposition, Oregon and Washington

Chronostratigraphic and geographic studies of Eocene arkosic sandstones suggest deposition during a "volcanically quiet" interval resulting from the westward jump of the Farallon-Kula plate subduction zone in Oregon and Washington.

The Eocene arkosic sandstones were deposited as part of a broad fluvial plain-coastal plain-shelf margin basin complex extending throughout Oregon and Washington between uplands of Mesozoic rocks. Feldspathic-quartzose sediments were transported from the east by river systems draining granitic terrains perhaps as far away as the Idaho Batholith. Local volcanism within the drainage system, along the coastal plain, and on volcanic islands to the west, added variable amounts of volcanic rock fragments to the feldspathic-quartzose sediments.

Chronostratigraphic correlations suggest that the arkosic sandstones were deposited along the margins of the depositional system during the early Eocene, prograded westward during the middle Eocene, and then regressed during the latest Eocene and Oligocene simultaneously with the influx of abundant pyroclastic debris. The pyroclastic material was derived from ancestral Cascade Mountain Range volcanism. Onset of Cascade volcanism, and volcanic-lithic grain dilution of the feldspathic-quartzose sandstones, began in the south during the early middle Eocene and extended northward reaching Washington in the early late Eocene.

The Eocene tectonic history of western Oregon and Washington provides a framework for understanding the occurrence of the feldspathic-quartzose rocks in a dominantly "graywacke" fore-arc provinence.

During the early Eocene, a northwest-southeast seamount chain was extruded on the Farallon and Kula plates west of an eastward-dipping subduction zone. Subduction of the oceanic plates moved the seamount chain obliquely toward the subduction zone.

In middle Eocene time—49 to 40 m.y.b.p.—the seamount chain reached the subduction zone creating instability in the subduction system and resulting in the westward jump of the underthrust boundary between the Farallon-Kula and North American plates. The westward jump of the underthrust boundary resulted in both the accretion of the seamount chain as part of a newly formed fore-arc accretionary prism, and a decrease in magnetic arc volcanism. The relative decrease in arc volcanism occurred during the interval after the consumption of the detached eastern subduction plate and the onset of magma generation from the newly formed western subduction zone.

Coincident with and continuing after the subduction zone jump and seamount accretion, eastwardly derived arkosic sediments prograded across Oregon and Washington spilling into the new fore-arc basin and enveloping the seamounts. Basaltic intrusion within the fore-arc basin occurred along tensional fault systems within the accretionary prism.

As the western subduction zone developed, a new, more western magmatic arc formed along the axis of the modern Cascade Mountains. Beginning in the late Eocene, the fore-arc basin subsided and the sea transgressed eastward depositing fine-grained arc-derived tuffaceous sediment over the entire basin.

ARONSON, JAMES, Case Western Reserve Univ., Cleveland, OH, and ROGER L. BURTNER, Chevron Oil Field Research Co., La Habra, CA

K/Ar Dating of Illitic Clays in Jurassic Nugget Sandstone and Timing of Petroleum Migration in Wyoming Overthrust Belt

Authigenic illite is a prominent pore-fill in the Nugget Sandstone, the main reservoir rock of most fields in the southwest Wyoming Overthrust belt. Illite, a good K/Ar clock, was dated from several well samples, all from the Absaroka thrust sheet. This includes a producing well in the Clear Creek field where seven samples traverse the gas, oil, and water zones. The ages of the Clear Creek suite are virtually concordant at 110 ± 2 m.y. Assuming hydrocarbon emplacement would have arrested authigenesis in the oil and gas zones, the similarity of ages from the hydrocarbon zones with the water zone indicates hydrocarbon emplacement was post 110 m.y. ago (middle Cretaceous). Ages obtained from the other Absaroka sheet Nugget samples fall in the narrow range of 102 to 120 m.y.b.p. This indicates illite authigenesis was a relatively short-lived "event" for the Nugget in the Absaroka sheet.

The Wyoming-Idaho-Utah overthrust belt involves several thrust sheets each of which was emplaced over its foreland sequentially from west to east over a time spanning tens of millions of years. We attribute the mid-Cretaceous illite growth in the Absaroka sheet to burial conditions established when that part of the Nugget was thrust upon by the Crawford sheet. The burial was accomplished both tectonically and by synorogenically derived sediment. If true, our illite dates imply a somewhat older age for the Crawford sheet than previously interpreted. We attribute the post-illite hydrocarbon emplacement in the Absaroka Nugget as a result of thrusting of the Absaroka sheet on top of its foreland containing middle Cretaceous petroleum source-bed shales. These beds were thermally matured when buried by the emplacement of the Absaroka sheet and its derived sediment in the Late Cretaceous.

ARP, G. K., ARCO Oil and Gas Co., Dallas, TX

Yellow Cat Revisited: A Review of Helen Cannon's Selenium Indicator Plants

In the late 1940s, Helen Cannon of the USGS conducted her famous studies on the association of plants to selenium. She used this association for detection of sedimentary uranium deposits on the Colorado plateau. Cannon demonstrated that locoweeds (*Astragalus*) from the Yellow Cat area of the Thompson district in eastern Utah did reflect the presence of selenium-rich uranium deposits by their colonization of the soils over the deposits.

During the subsequent 30 years, Cannon's work has repeatedly been cited as a classic example of the use of indicator geobotany in mineral exploration. During the same 30-year period, geobotanical techniques have not found wide utilization as an exploration tool. Further, Cannon's work has not been demonstrated elsewhere to any extent.

In 1980, the author returned to Yellow Cat to see what changes, if any, may have transpired at the site. We also wanted to gather insight into why geobotanical methods have not gained wider acceptance and perhaps determine why subsequent work is so rare.

Results of this study support Cannon's basic work. The results also suggest that the methods are ecologically sound and have applicability to modern mineral exploration programs. Limitations to the method are also discussed, along with some speculation as to why geobotanical methods have not seen wider application.

ASQUITH, G. B., Pioneer Production Corp., Amarillo, TX, and M. D. ALLISON, Derrick Petroleum Co., Gainesville, TX

Depositional Environments of the Mississippian Chappel Bioherms, Hardeman County, Texas

Numerous crinoid-fenestrate bryozoan banks are developed within the Mississippian Chappel Formation, located in the Hardeman basin, Hardeman and Wilbarger Counties, Texas. The banks are oval in shape and range in size from 2 to 12 mi (3 to 19 km) in diameter. Stratigraphic, hydrocarbon entrapment in the banks has resulted in cumulative production exceeding 6 million bbl of oil plus 13 bcf of gas.

The Chappel Formation is a shallow-water limestone, over-