Concentration levels of the elements in a suspended load, when compared to average reported values for shales, show iron and manganese to be low. The other elements are higher. Values for these elements in the dissolved part are variable, possibly reflecting lithologic differences. Correlation coefficients indicate little relation between trace element content and season in most Kansas streams. X-ray diffraction study of the mineralogic content of the suspended load indicated that montmorillonite was the clay mineral present in all cases. Other minerals present in almost all samples were calcite and quartz. Gypsum, dolomite, feldspar, illite, and kaolinite were present in lesser amounts in some samples. Some question of the source of specific trace elements in these stream waters exists. For nickel and lead, however, pollution is considered the most likely source. Some evidence is present to suggest that the major source of lead is fallout from the atmosphere. The data for partition coefficients suggest that nickel, lead, copper, and zinc are being strongly adsorbed onto the suspended load. The data are less certain for iron and manganese. The iron and manganese levels in the suspended loads of all streams are not unusual. Copper, nickel, lead, and zinc clearly are being concentrated by the suspended load. One source of copper and zinc may be from trace-element nutrient fertilizers.

ARMENTROUT, JOHN M., Dept. Geology, Univ. Oregon, Eugene, Ore.

OLIGOCENE BIOSTRATIGRAPHY OF LINCOLN CREEK FORMATION, SOUTHWESTERN WASHINGTON

Molluscan faunas of the Lincoln Creek Formation, southwestern Washington, represent 6 provincial invertebrate Opellian zones. Continuous late Eocene to early Miocene sequences have been studied in 6 sections where both mollusks and benthonic foraminifers are abundant. The stratigraphic control on both faunas in these and 7 other partial sections allows for detailed biostratigraphic analysis and the synthesis of superpositionally controlled megainvertebrate zones. These zones, moreover, are correlatable in the same sections with the standard Californian benthonic foraminiferal zones and stages.

The molluscan sequence includes faunas previously assigned by Weaver *et al.* to the Keasey, Lincoln, and Blakeley "Stages." These faunal assignments were made from geographically isolated sections. Durham defined 7 Oligocene megafaunal zones for northwestern Washington on the basis of 7 partial sections and other fossiliferous localities. The lack of superpositional control on boundaries for both these studies suggested the need for further biostratigraphic refinement of the Oligocene of western Washington.

The foraminiferal sequence includes faunas previously assigned by Rau to the Narizian Stage of Mallory, the Refugian Stage of Schenck and Kleinpell, and the Zemorrian and lower Saucesian Stages of Kleinpell.

ARMSTRONG, AUGUSTUS K., U.S. Geol. Survey, Menlo Park, Calif.

CARBONIFEROUS COLONIAL RUGOSE CORALS, BIOSTRATIGRAPHY, AND PALEOECOLOGY, LISBURNE GROUP, ARCTIC ALASKA

The Lisburne Group of arctic Alaska contains coral faunas of Osagian (Early Mississippian) to Atokan (Middle Pennsylvanian) age. Beds of Osagian age have a small fauna of solitary and tabulate corals. Beds of Meramecian and very earliest Chesterian ages contain a large fauna of *Ekvasophyllum* spp., *Faberophyllum* spp., *Diphyphyllum klawockensis* Armstrong, *D. nasorakensis* Armstrong, *Lithostrotion* (*Siphonodendron*) *dutroi* Armstrong, *L.* (*S.*) *sinuosum* (Kelly), *L.* (*S.*) *warreni* Nelson, *L.* (*S.*) *lisburnensis* Armstrong, *Lithostrotion reiseri* Armstrong, *Lithostrotionella niakensis* Armstrong, *L. banffensis* (Warren), *L. mclareni* (Sutherland), *L. birdi* Armstrong, *L. pennsylvanica* (Shimer), *Thysanophyllum astraeiforme* (Warren), *T. orientale* Thomson, *Sciophyllum lambarti* Harker and McLaren, and *S. alaskaensis* Armstrong. Corals are rare in beds of younger Chesterian age; they include *Lithostrotionella* aff. *L. mclareni* (Sutherland), *Lithostrotion* (*S.*) *ignekensis* Armstrong, *Syringopora* spp., and a few solitary corals. Pennsylvanian (Atokan) beds of the Lisburne Group contain *Lithostrotionella wahooensis* Armstrong, *Corwenia jagoensis* Armstrong, a thick-welled syringoporoid, and *Michelinia* sp.

The Lisburne Group limestones are cyclic and were deposited on a slowly subsiding carbonate platform. Colonial corals of Meramecian and Atokan ages are present in carbonate rocks associated with shallow-water shoaling facies. The scarcity of corals in carbonate rocks of Osagian, Chesterian, and Morrowan ages is attributed to regional temperature or salinity changes that inhibited their growth. Beds of Atokan age contain more calcareous algae and Foraminifera, indicating warmer waters. Paleoecologic analysis of the carbonate beds associated with the colonial corals of Atokan age indicates that the corals lived in clear, agitated water between oolitic tidal flats. Carboniferous corals are not known to have formed reef-like masses in arctic Alaska.

BANDY, ORVILLE L., and LOUIE MARINCOVICH, JR., Dept. Geol. Sci., Univ. Southern California, Los Angeles, Calif.

BALDWIN HILLS, LOS ANGELES, CALIFORNIA—RATES OF LATE CENOZOIC UPLIFT

Planktonic foraminiferal biostratigraphy and paleomagnetic stratigraphy of late Cenozoic cores of the North Pacific suggest that the major polar planktonic foraminiferal invasions in southern California occurred in the last 800,000 years. In the Baldwin Hills of the Los Angeles basin, relations of the base of these polar planktonic assemblages and probable water depths at that time, on the basis of associated benthic assemblages, indicate an average rate of uplift of about 0.075 m/100 years.

On the basis of relation of radiocarbon dates with environments of deposition for the late Cenozoic, rates of uplift have increased to about 0.63 m/100 years for the past 36,000 years. Marine waters, approximately 100 m in depth 36,000 years ago, gave way gradually, through sedimentation and uplift, to nonmarine deposition in this area of the basin about 28,000 years ago. These early nonmarine deposits have been uplifted since then to elevations of 145 m atop the Baldwin Hills. Localized uplifts along the Newport-Inglewood fault trend may have formed recently, representing actively rising modern structural features along this trend in the Los Angeles basin.

BARNARD, WILLIAM D., Dept. Oceanography, Univ. Washington, Seattle, Wash.

LATE PLEISTOCENE DEFORMATION OF CASCADIA BASIN TURBIDITES ALONG WASHINGTON CONTINENTAL MARGIN

A minimum rate of underthrusting of the Juan de Fuca plate beneath North America for the late Pleistocene has been calculated to be approximately 0.7 ± 0.3 cm/yr. This estimate was determined in each of 18 CSP crossings of the continental slope off the coast of Washington by dividing the amount of shortening within the westernmost anticlinal ridge by an approximation of the time elapsed since the beginning of the ridge deformation. The latter estimate was obtained by tracing the late Pleistocene discontinuity as described by Leg 18 of the Deep Sea Drilling Project from site 174 on Astoria fan into the deformed Cascadia basin turbidites of the continental slope. Recent plate-tectonics theories predicting northwesterly movement of the Pacific plate parallel with the San Andreas fault at 6 cm/yr, and the spreading of the Juan de Fuca plate away from the Pacific plate at 6 cm/yr, require an underthrusting rate of 2 cm/yr measured perpendicular to the trend of the Washington continental margin. If the age of the late Pleistocene discontinuity is assumed to be a half-million years, the defor-

mation of the marginal ridge can account for nearly 40 percent of the theoretical crustal shortening between the Juan de Fuca and North American plates. Seismic profiles also indicate that accretion of Cascadia basin turbidites along the continental margin occurred during the Pliocene-Pleistocene and has continued to the present.

BARRON, JOHN A., Dept. Geology, Univ. California, Los Angeles, Calif.

PALEOCLIMATIC INTERPRETATIONS FOR LATE MIOCENE OF CALIFORNIA BASED ON MARINE DIATOMS

The diatom assemblages of a 1,600-ft section of diatomites in the Monterey and Sisquoc Formations near Lompoc, California, give evidence of a warming trend within the late Miocene. Frequency changes of individual warm and cold water species, ratios of different ecologic types, and variations in the overall assemblage indicate a general increase in temperature during the period of deposition. The lower third of the section (upper Mohnian Stage) contains a cool-temperate microflora, characterized by relatively high frequencies of *Denticula hustedtii* Simonsen and Kanaya. A mixed warm- and cold-temperate assemblage predominates through the overlying 1,000 ft of diatomites, and the highest 80 ft (Delmontian Stage?) contains a warm-temperate microflora, with *Coscinodiscus excentricus* Ehrenberg, *C. lineatus* Ehrenberg, *Thalassionema nitzschioides* Grunow, and *Thalassiosira* sp.

Diatom evidence for these temperature changes is further supported by that from the fossil fish and sparse Foraminifera of the Lompoc section. The changes may reflect a general climatic warming, but also may result from local variations in current distribution, such as the fluctuations in the cold-water California Current proposed for the late Miocene of southern California. Diatoms may provide valuable paleoecologic evidence for this extensive diatomite facies in California, which lacks the more commonly utilized foraminiferal and invertebrate paleoecologic indicators.

BARTOW, J. ALAN, ANDREI M. SARNA-WOJCICKI, WARREN O. ADDICOTT, and KENNETH R. LAJOIE, U.S. Geol. Survey, Menlo Park, Calif.

CORRELATION OF MARINE AND CONTINENTAL PLIOCENE DEPOSITS IN NORTHERN CALIFORNIA BY TEPHROCHRONOLOGY

Recent reconnaissance of the Tertiary rocks of the Coast Ranges north of San Francisco Bay, together with trace-element studies and K-Ar dating of the associated tuffs, has necessitated revision of the age assignments and correlations of some units. Previous workers generally have held that the Merced(?) Formation of Sonoma County interfingers laterally with the Sonoma Volcanics, which in turn unconformably overlie the Petaluma Formation. Age assignments have varied, but most recent workers assign the Merced(?) Formation and the Sonoma Volcanics to the late Pliocene and the Petaluma Formation to the middle Pliocene. We have determined that most of the molluscan collections from the Merced(?) Formation are late Pliocene, but at least 2 are older (early Pliocene in terms of a twofold provincial division of the epoch). Hemphillian and Blancan vertebrates reported from 7 localities in the Petaluma Formation, indicate an early or middle Pliocene and late Pliocene age, respectively, for this formation, in terms of the nonmarine chronology. A pumiceous, vitric-crystal tuff in the Merced(?) Formation occurs stratigraphically between the early and late Pliocene molluscan localities. This tuff has been dated by the K-Ar method at 5.9 m.y., and has been correlated by trace-element "fingerprinting" (using X-ray fluorescence on the glass) with a petrologically similar tuff in the Petaluma Formation. This dating confirms the correlation of early and late Pliocene mollusks with Hemphillian and Blancan mammals, and suggests a provincial early Pliocene-late Pliocene boundary of about 6 m.y.

BASS, J. HOWARD, Texaco Inc., Coral Gables, Fla.

SUBANDEAN BASIN OIL FIELDS, ECUADOR AND COLOMBIA

The Subandean basin of Colombia and Ecuador covers an area of approximately 50,000 sq mi, and is part of a foreland which extends from the Guyana shield to the Andes Mountains. The present structural basin is asymmetric and plunges toward the south. More than 30,000 ft of Paleozoic to Tertiary sedimentary rocks are present. During the Early Cretaceous, a marine transgression buried a basal sandstone member (Caballos in Colombia, Hollin in Ecuador). Later fluctuations in sea level resulted in deposition of marginal marine-fluvial sandstones of the Upper Cretaceous. Major petroleum reserves are trapped in large anticlines and faulted structures in these Cretaceous sandstones.

Texaco began exploration for petroleum reserves in the trackless jungles of the Upper Amazon region of South America in 1941. During the early 1940s, the Orito anticline was discovered and mapped in detail by geologic field parties. In 1963, the decision to drill Orito was made, and Texaco acquired an aggressive partner, Gulf Oil, which earned one-half interest in the Texaco holdings by drilling the Orito No. 1 discovery well.

Following the Orito field discovery, exploration was accelerated and geophysical exploration began in 1965 with air magnetics and analogic seismic work. The helicopter gave support to portable geophysical crews, and later the helirig opened the entire area for exploratory drilling. The helicopter also figured prominently in the subsequent construction of two pipelines across the Andes Mountains.

Production began in Ecuador in August 1972, climaxing the long, arduous exploration and development of the Texaco-Gulf holdings in the Oriente.

BEBOUT, D. G., ESSO Production Research Co., Houston, Tex., and W. R. MAIKLEM, Imperial Oil Ltd., Calgary, Alta.

ANCIENT ANHYDRITE FACIES AND ENVIRONMENTS—THEIR ROLE IN RECONSTRUCTING GEOLOGIC HISTORY OF MIDDLE DEVONIAN ELK POINT BASIN, ALBERTA

The association of evaporites with a large percentage of the world's oil and gas reservoirs makes these rocks economically significant. Good core control for study of environments of deposition and diagenesis of these rocks is available in the Middle Devonian Elk Point basin, Alberta.

We have recognized 4 major types of anhydrite formation—supratidal, shallow-water, deep-water, and replacement. Supratidal anhydrite includes gypsum pseudomorphs and most of the nodular, nodular-mosaic, and mosaic types. These are identified by comparison with the anhydrite in the sabkha sequence of the Trucial Coast. Bedded anhydrite is interpreted to have been deposited in shallow water under conditions comparable with those in the Pekelmee of Bonaire Island. Tiny nodules and thin laminae of anhydrite, which are usually within or interbedded with laminated limestone, are interpreted as deep-water in origin, from their stratigraphic position in the deeper parts of the Elk Point basin. No modern analogues of these types are known. Some massive, nodular, nodular-mosaic, and mosaic anhydrites, considered to be postlithification replacement types, are located on the edges of shoals, banks, and reefs, and are characterized by their relatively greater thickness and by the inclusion of carbonate fragments of the host rock within the anhydrite.

By detailed core studies of the anhydrite environments and their order of occurrence in the subbasins, we have recognized 11 major sedimentary events. By correlation of these events