

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.

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#### 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 *Coccolodiscus 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.

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#### 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.

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#### 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 heliring 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.

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#### 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 Pekelmeel 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