to the upper limit of *Prunopyle titan,* a cosmopolitan radiolarian that is an index to the later Miocene of California. It is further proposed that in the Antarctic the Pliocene-Pleistocene boundary is located approximately at the upper boundary of *Saturnulus planetes,* a level which is just below the extinction level of discoasters. Marked telescoping of faunal zones indicates significant gaps in the depositional record of some Antarctic deep-sea cores, probably caused by slumping or non-deposition of sediments at different times. A transition from red clay to diatomaceous sediments occurrred within the Pliocene Epoch.

BANDY, ORVILLE L., Department of Geology and and Allan Hancock Foundation, University of Southern California, Los Angeles, California

TIME-TRANSGRESSIVE PROBLEMS OF CALIFORNIA CENOZOIC

A significant change from dextral to sinistral populations of *Globigerina pachyderma* occurred at the Pliocene-Pleistocene boundary in southern California, as recorded in deep-water deposits. By using modern populations as a basis for comparison, it can be shown that this represents a major shift from dextral warm temperate to sinistral subarctic populations, and it defines a point in time which should coincide more dependably with the Pliocene-Pleistocene boundary than a boundary based upon benthic species. Use of this method shows that the upper limit of the Wheelerian Stage, which is based on the upper limits of the *Epistominella pacifica-Uvigerina peregrina* faunas, ranges from more than 200 meters below to more than 300 meters above the Pliocene-Pleistocene boundary.

A second problem is recorded in the Eocene of the Santa Barbara embayment. Planktonic Foraminifera suggest that the Eocene Narizian Stage, based primarily on benthic species, is as young as late Eocene in the Santa Rosa Hills and as old as middle Eocene elsewhere. Similarly, planktonic Foraminifera indicate that the Ulatisian Stage, also based upon benthic species, is early to middle Eocene in some places and is entirely middle Eocene in others.

BARNES, D. F., U. S. Geological Survey, Menlo Park, California, LUCAS, W. H., U. S. Coast and Geodetic Survey, Seattle, Washington, MACE, E. V., and MALLOY, R. J., U. S. Coast and Geodetic Survey, Washington, D.C.

RECONNAISSANCE GRAVITY AND OTHER GEOPHYSICAL DATA FROM CONTINENTAL END OF ALEUTIAN ARC

On the Alaskan continental shelf between the Shumagin Islands and Prince William Sound, ships of the U. S. Coast and Geodetic Survey have made about 12 traverses while recording gravity, sparker, magnetic, and bathymetry data, and about 12 other traverses while recording magnetic and bathymetry data alone. These marine measurements have been combined with gravity and geologic data obtained by the U. S. Geological Survey on adjacent shorelines to make a reconnaissance gravity map which provides new information on the structure of the continental end of the Aleutian arc.

The gravity anomalies associated with the oceanic part of the arc do not extend very far onto the continental shelf. A gravity high over the Aleutian Islands diminishes gradually near the continental margin, and negative Bouguer anomalies are present among the volcanoes of the eastern Aleutian Range and the southern Alaska Range; the gravity low associated with the inside edge of the oceanic trench is replaced by a gravity high that extends along the entire northern edge of the continental-margin trench. Between the eastern Aleutian gravity low and the continental-shelf gravity high is a series of elongate anomalies that parallel the tectonic trend and may be correlated with sedimentary and volcanic rock units.

Small gravity depressions in areas of positive gravity anomalies on the continental shelf indicate the presence of Cenozoic sedimentary deposits east of Kodiak and west of Middleton Island. Sparker data show that these deposits thicken northwest of a shelf-edge anticline where the free-air anomalies are greatest. However, a much larger decrease of 125–200 mgal. occurs at the southern edge of the Chugach Mountains geosyncline, which lies north of a coastal belt of lower Cenozoic submarine volcanic rocks (largely non-magnetic). These rocks cause local highs that are especially well developed in Prince William Sound and account for the steep gravity gradient between the continental shelf and Chugach Mountains. This 125–200-mgal. gravity change nearly coincides also with the line separating the emergence and subsidence areas of the 1964 Alaska earthquake. That earthquake increased the positive continental-shelf anomalies south of the gradient. At the northern edge of the Chugach Mountains geosyncline, another gravity high coincides with a belt of lower Mesozoic submarine volcanic rocks (largely magnetic); this high separates the Chugach Mountains low from a low caused by sedimentary rocks in Cook Inlet and Shelikof Straights. Although the gravity data indicate the presence of several thick sedimentary bodies, the large gradients associated with the volcanic and tectonic arcs make estimation of the thickness of the sedimentary column difficult.

BERRY, F. A. F., Department of Geology and Geophysics, University of California, Berkeley, California

PROPOSED ORIGIN OF SUBSURFACE THERMAL BRINES, IMPERIAL VALLEY, CALIFORNIA

Saturated Na-Ca-KCl thermal brines (380°C @ depth) of unique chemistry (reported by D. E. White) are recovered by geothermal wells near the Salton Sea in the Imperial Valley—a tectonically active graben area of high heat flow at the north end of the Gulf of California. The reservoir chamber consists of alternating fractured greenschist and zeolitic facies metamorphic rocks at depths of 3,900–8,000 feet. The shallow waters adjacent to and overlying this and many other thermal anomalies are dilute $NaHCO_3$-Cl waters, high in B. NH_4, I, and F are present; the Na/K ratio is less than in the brines. CO_2 is abundant. The similarity of the deuterium content of these brines and various surficial waters of the Imperial Valley as determined by H. Craig and reported by White indicates that the waters of these brines are dominantly meteoric.

The most critical geochemical questions concern the mechanism by which the brines are concentrated to such a high degree, the origin of the Cl ion within the brine, and the surprisingly high Ca/Na, K/Na, and Cs/K ratios of the brine. The arkosic sedimentary fill of the graben contains ample material to provide by solution every chemical found within these thermal brines with the exception of the Cl ion. The high ^{18}O of the brines and its impoverishment in the reservoir rocks (Craig via White), the impoverishment of B in the reservoir rocks (White), and the similarity of the Rb/K ratios of the brines to those of arkosic materials indicate the high degree of interchange between the host rock and the thermal waters.

The Cl ion either must be introduced at depth as juvenile Cl transported solely by diffusion in the gaseous phase from a magmatic source or must result simply from the concentration of meteoric interstitial water of the sedimentary fill. Strong evidence suggests that no Cl-evaporites are present at depth in the graben. The similarity of the Br/Cl ratio of the thermal brines to all of the meteoric surface and ground waters of the Imperial Valley area (Chevron Research data) and its complete dissimilarity to ratios found within Cl-evaporites suggest that the brines are merely the meteoric water of the graben fill concentrated many-fold. No exotic source is needed.

Hyperfiltration of relatively dilute hydrothermal solutions through electrostatic semi-permeable membranes, composed of abundant montmorillonitic and illitic clays in the sedimentary fill, and probable zeolites overlying and laterally bounding the thermal anomaly, provides the best mechanism for concentrating the brines as well as determining their relative composition and that of the surface effluent waters overlying the thermal anomaly.

Such high concentrations could be achieved only by a very large volumetric transfer of dilute hydrothermal waters through the membrane material due to the progressive decrease of hyperfiltration efficiency of semi-permeable membranes with increasing concentrations. Relative hyperfiltration of Ca with respect to Na and the relative increase of B, NH_4, F, I, and HCO_3 in solutions effluent from membranes has been observed by White in subsurface waters at lower temperatures. The relative increase of K/Na and Cs/K by selective membrane transport in a hyperfiltrated solution is consistent with the known behavior of solutions through ion-exchange columns where the smaller hydrated ion is adsorbed preferentially in the double layer, thereby permitting preferential membrane transport for the larger and less hydrated ion.

A steadily expanding dome-shaped zone of brittle, fractured rocks metamorphosed by the hydrothermal solutions ascending by convective transport from a high heat source at depth, presumably a silica melt, and surrounded by relatively unmetamorphosed membrane materials (zeolites and clays) is assumed as a model. Hyperfiltration would occur within the dome by passage of solutions through the bordering membrane materials. Brines whose composition would have increased steadily through time until reaching an equilibrium would be found in the dome within which a convection cell characterized by channel flow should exist. Relatively dilute effluent solutions of a particular chemistry would emerge continuously from the membrane material to form the dilute shallow waters of specific chemical composition that typically occur near the surface at the Salton Sea and other thermal anomalies. Occasional fractures would permit leakage of the concentrated brine outward from the dome where it would mix with effluent waters. Meteoric interstitial water of the sedimentary fill would mix with the membrane-effluent and leakage waters on the borders of this hydrochemical system.

BURK, C. A., Socony Mobil Oil Co., Inc., New York, New York

GEOLOGIC HISTORY OF ALASKA PENINSULA

The Alaska Peninsula area is of particular geologic interest because it is part both of the Aleutian volcanic arc and the continental margin of southwestern Alaska. Topographically, the peninsula is a ridge, rising above the general level of a broad marine platform consisting of the Bering Sea shelf and the Shumagin-Kodiak shelf. However, the structural and stratigraphic history of these shelves appears to be separate from that of the Alaska Peninsula. The islands of the Shumagin shelf consist largely of a thick flysch sequence of late Mesozoic turbidites and volcanic rocks containing ultramafic bodies and are intruded by earliest Tertiary quartz diorite plutons. Similar rocks comprise the Kenai and Chugach Mountains.

The oldest dated rocks of the Alaska Peninsula are Permo-Triassic carbonate and volcanic rocks and Lower Jurassic volcanic debris, both of which were intruded by an Early Jurassic granitic batholith. Uplift and erosion of these rocks caused the appearance of the Alaska Peninsula, and the accumulated arkosic debris now constitutes a thick Middle Jurassic to Lower Cretaceous sequence. Middle Cretaceous deformation was relatively small-scale, but rocks of this age are absent from the Alaska Peninsula. Uppermost Cretaceous strata constitute a thin, but widespread, transgressive sequence.

Marine and non-marine volcanic rocks and debris accumulated to great thicknesses throughout the early Tertiary, especially in the outer parts of the Alaska Peninsula; lesser amounts were deposited on the newly uplifted Shumagin shelf. These were deformed gently at the time of mid-Tertiary plutonic intrusions along the present Pacific shore. Miocene debris from older rocks, as well as new volcanic material, accumulated in great thickness, but Pliocene strata occur only as thin patches of volcanic rocks in the mountains and as isolated bodies of marine sediments near the present coast. Both the Pliocene volcanic and sedimentary rocks rest discordantly on older rocks. All of the prominent structural features of the Alaska Peninsula were formed by post-Miocene deformation.

The Alaska Peninsula thus may have existed as early as Middle Jurassic time. The Shumagin-Kodiak shelf was formed during the earliest Tertiary. The Aleutian volcanic arc and trench are no older than Tertiary, and the trench may be relatively young. The greatest thickness of Tertiary sediments accumulated in isolated depressions that were only partly controlled by earlier structure, *e.g.*, in the Gulf of Alaska, Cook Inlet, Bristol Bay, and at the outer parts of the Alaska Peninsula.

BYRNE, JOHN V., and KULM, L. D., Oregon State University, Corvallis, Oregon, and MALONEY, NEIL J., Instituto Oceanográfico, Universidad de Oriente, Cumaná, Venezuela

TEXTURAL TRENDS OF RECENT SEDIMENTS FROM RIVER TO ABYSSAL PLAIN OFF OREGON

Recent sediments from river to abyssal plain in the area of the central Oregon coast show distinct textural trends. Textural parameters were computed for more than 300 sediment samples from Yaquina River, Yaquina Bay, neighboring coastal beaches and dunes, and from the continental shelf, slope, and abyssal plain off Yaquina Bay.