tary sequences are typically free of hiatuses or contain very short hiatuses. Hence, hiatus distribution maps can outline regions of high paleo-productivity. Analyses of Miocene deep-sea cores reveal eight intervals of widespread hiatuses and four distinct sediment distribution changes in the world's oceans. These maps reveal major paleo-oceanographic changes affecting the biotic productivity in the Miocene ocean. Four main episodes in the evolution of oceanic circulation and paleo-productivity are apparent leading to the establishment of present-day high productivity regions.

(1) Circum-equatorial flow persisted to about 18 Ma with calcareous sedimentation in low and middle latitudes and predominantly siliceous sedimentation in the North Atlantic and Antarctic south of 60°S.

(2) Closing of the deep-water connection across Central America by 16 to 15 Ma initiated the "proto" Gulf Stream by diverting Atlantic deep and intermediate waters northward. Siliceous sedimentation increased in the Indian and Pacific Oceans at this time particularly in the eastern equatorial and marginal North Pacific. Coincident with the establishment of these high siliceous productivity regions is a decrease and eventual disappearance of biologic silica in the middle latitude North Atlantic presumably owing to the introduction of Norwegian Overflow Water.

(3) The main aspects of the present circulation and sediment distribution pattern were established by 12 Ma when major production of Norwegian Overflow Water displaced Antarctic deep water from the North and South Atlantic basins and enhanced siliceous sedimentation in the North Pacific.

(4) An essentially modern oceanic circulation system and high biotic productivity pattern were established by 6.5 Ma, possibly as a result of major production of Antarctic Bottom Water associated with the establishment of the West Antarctic ice sheet.

KENNETT, J. P., and M. S. SRINIVASAN, Univ. Rhode Island, Kingston, RI

Oligocene/Miocene Boundary: Correlation, Biostratigraphy, and Foraminiferal Evolution

Qualitative and quantitative planktonic foraminiferal trends have been examined across the Oligocene/Miocene transition in three DSDP sites in the South Pacific ranging from the equator to temperate regions. The evolutionary appearance of *Globoquadrina dehiscens* represents one of the most reliable datums for interregional correlation of the Oligocene/Miocene boundary. This datum occurs within the biostratigraphic range of *Globorotalia (Fohsella) kugleri* and marks the boundary between Zones N4A and N4B. *Globigerinoides* first evolved during the late Oligocene and is not coincident with the Oligocene/Miocene boundary.

Unlike the Eocene/Oligocene boundary, the Oligocene/Miocene boundary is not marked by a crisis in the Oligocene planktonic foraminiferal assemblages. Most Oligocene forms continue their range upward into the early Miocene where most are replaced by typical Neogene forms.

The evolution of *Globoquadrina dehiscens* effectively heralds the beginning of the major Neogene evolutionary radiations in planktonic foraminifera including: (1) the evolutionary radiation of *Globigerinoides* into a number of species; (2) the initial evolution of *Globorotalia (Globoconella) incognita,* which forms the earliest ancestral form of *Globoconella;* (3) the evolution of the *Globigerina (Zeaglobigerina) woodi* group; (4) the evolution of *Sphaeroidinellopsis disjuncta,* which is the ancestral stock of the *Sphaeroidinellopsis-Sphaeroidinella* lineage; and (5) the evolution of *Globorotalia (Fohsella) peripheroronda* from *Globorotalia (Fohsella) kugleri.* These evolutionary radiations are reflected by a general increase in simple species diversity through the early Miocene. In all sites, species diversity is lowest in the interval near the Oligocene/Miocene boundary. Amongst the sites examined, diversity is highest, not in the tropical site, but in warm-subtropical Site 208, because at this latitude the faunas include both tropical and temperate forms.

The earliest Miocene, immediately following the boundary, is marked by high frequencies of *Globorotalia (Fohsella) kugleri* in tropical areas and *Globoquadrina dehiscens* in warm subtropical to temperate areas.

KHARAKA, YOUSIF K., MICHAEL S. LICO, and LEROY M. LAW, U.S. Geol. Survey, Menlo Park, CA

Chemical Geothermometers Applied to Formation Waters, Gulf of Mexico and California Basins

Twelve chemical geothermometers based on the concentrations of silica and proportions of Na, K, Ca, and Mg in water from hot springs and geothermal wells are used successfully to estimate the subsurface temperatures of the reservoir rocks. These 12 geothermometers together with a new geothermometer based on the concentrations of Li and Na were used to estimate the subsurface temperatures of more than 200 formation-water samples from about 40 oil and gas fields in coastal Texas and Louisiana and the Central Valley, California. The samples were obtained from reservoir rocks ranging in depth from less than 1,000 m to about 5,600 m.

Quartz, Na-K-Ca-Mg, and Na-Li geothermometers give concordant subsurface temperatures that are within 10°C of the measured values for reservoir temperatures higher than about 75°C. Na-Li, chalcedony, and a modified Na-K geothermometers give the best results for reservoir temperatures from 40°C to 75°C. Subsurface temperatures higher than about 75°C calculated by chemical geothermometers are at least as reliable as those obtained by conventional methods. Chemical and conventional methods should be used where reliable temperature data are required.

KLAHN, LOUIS J,, JR., Compudyne Inc., Denver, CO, and JOHN H. DOVETON, Kansas Geol. Survey, Lawrence, KS

Utilization of Interactive Computer Graphics to Solve Complex Geological Problems—A Case Study

The exact role of the computer in the fields of geology and well log analysis has been the subject of some controversy and confusion. The computer, when properly implemented and programmed, can assume a different role—that of an analysis partner. In this approach, the user must be able to communicate both freely and naturally with the computer—and vice versa; i.e., the system must be truly interactive. Another key element is graphics, as the geologist's world is usually described using maps, graphs, diagrams, charts, logs, etc. An interactive graphics system has been used to analyze several formations in various parts of the world. The main portion of this paper uses some of these analyses in a "case study" approach to help describe the techniques.

Most of the analyses involve interactive log analysis. The logs were first subjected to a conventional analysis using the computer to help speed up the mathematical computations. The computer also generated all data listings, graphs, plotbacks, and crossplots during this phase.

The next phase was to perform an in-depth, detailed analysis to discover more about the key characteristics of the formation. Most of these algorithims are beyond the capability of a hand held calculator, but the interactive nature of the system makes them