Size distribution and statistical analysis of the sediments indicate contrasting physical environments on either side of the Ras, even though geomorphologically they are similar. Sediments in the southern sector are generally better sorted (moderate to good), nearly symmetrically to slightly coarsely skewed, and unimodal, whereas the sediments in the northern sector are badly sorted, coarsely skewed, and bimodal in the shallower lagoonal area.

The distribution patterns reflect the physical oceanographic parameters within the reef, the areal coverage by vegetation, and the sediment source. Pure populations having the best sorting values are on the beach and within the southern lagoon. Sediments finer than 4ϕ are scarce within the reef.

PHILLIPS, B. G., Amoco International Oil Co., Houston, Tex.

Small Computer Well-Data System

It would be desirable for offices in remote locations to be able to sort and select certain items of well data, but they usually lack on-site computer power. One system, an IBM System 32, is a small commercial computer used on a trial basis in this situation. Two files were input: (1) a general scout type containing drilling and production statistics and (2) data resulting from lithologic study containing test results and sand thickness. Programs executed against these files to generate reports based on the geologist's selection criteria are written in RPG 11 language, common to the System 32.

PHILLIPS, R. LAWRENCE, U.S. Geol. Survey, Menlo Park, Calif.

Bed Forms and Processes on Estuarine Tidal-Current Ridge, Willapa Bay, Washington

Distinctive ebb and flood oriented bed-form fields are present on the opposite flanks of a tidal ridge within Willapa Bay, Washington. The ridge is approximately 3 km long, arcuate in shape, asymmetric in profile, and rises a maximum of 13 m above the channel floor. Repeated high-resolution profiling, diving observations, and oriented cores define the formational processes and the depositional features of this migrating ridge.

Large-scale bed forms migrate along and up both ebb and flood flanks of the ridge during each respective tidal flow. Sinuous- to straight-crested sand waves occur on the steeper flood-dominated side; dunes and sand waves occur on the ebb flank. As the bed forms migrate up the ebb flank of the tidal ridge, they become lower and exhibit the following sequence in response to decreasing flow velocity: lunate dunes \rightarrow catenary sand waves \rightarrow sinuous- to straight-crested sand waves. The largest bed forms, 3 m high, occur between depths of 9 to 12 m within the lunate dune field.

Bed forms along the ridge crest change orientation with each tidal cycle. Bed forms on the ridge flanks reverse completely during spring tides, but during neap tides only the crests reverse. Oriented cores show unidirectional medium-scale cross-strata with reactivation surfaces on the flood and the ebb flanks of the ridge. Cores taken in troughs of some ebb-oriented dunes, however, show a veneer of ebb cross-strata overlying flood-oriented structures. Cores on the ridge crest have bimodal small-scale cross-strata.

The dominant ebb current transports sediment over the ridge crest where it is incorporated into flood bed forms on the reversing tide. Erosion on the ebb flank and deposition on the flood flank has moved the ridge 15 to 30 m/year for the last 20 years.

PICOU, EDWARD B., JR., Shell Oil Co., New Orleans, La., and DORIS M. CURTIS, Shell Development Co., Houston, Tex.

Applied Biostratigraphy in Gulf Coast Tertiary

Concepts resulting from studies of microfaunal successions and paleoecology (biofacies) together with vertical and lateral sediment-distribution patterns (lithofacies) can be applied to exploration and development problems. Examples include correlation problems, predicting reservoir distribution, determining base of objective section, predicting geopressures, calibrating seismic events, and exploitation of salt-dome fields.

PINGITORE, NICHOLAS E., JR., and PHILIP C. GOODELL, Univ. Texas-El Paso, El Paso, Tex.

Trace-Element Geochemistry and Diagenesis in Capitan Reef (Permian), West Texas

The lattice substitution of doubly charged cations into calcite during aqueous precipitation depends on solution composition and the appropriate partition coefficients. Thus, the trace-element geochemistry of a limestone encodes the chemical composition of the solution in which mineralogic stabilization occurred. Because different environments are characterized by specific solution chemistries, we can use the trace-element composition of a limestone to infer the diagenetic environment in which it stabilized.

A suite of calcite samples was collected in the reef core (massive) and upper fore-reef facies of the Permian reef complex (Guadalupian), from the cliffs above the entrance to McKittrick Canyon. These rocks averaged 375 ppm Sr²⁺, 13,900 ppm Mg²⁺, 9.4 ppm Zn²⁺, and 40.1 ppm Mn²⁺ (AA analyses). Petrographic examination of these wackestones and packstones provided no conclusive evidence of the environment in which mineralogic stabilization occurred. However, the trace-element values, when compared to probable starting (sedimentary) compositions, indicate equilibration in an open chemical system with insignificant introduction of cations from an external source. Autodepletion of strontium and magnesium ($k^{Sr}_{cal} = 0.14$; $k^{Mg}_{cal} = 0.02$) accompanied autoenrichment of zinc and manganese $(k^{Zn}_{cal} = 5; k^{Mn}_{cal} = 15)$. The degree of autoenrichment and autodepletion of these chemical species is characteristic of an open chemical system, that is, one in which fresh waters flush rapidly through the diagenetic site. This combination of fresh water and open system is diagnostic of a freshwater phreatic zone. We infer, then, that this part of the reef stabilized in a

freshwater phreatic environment. This intepretation is consistent with the vadose origin ascribed to features observed within other parts of the complex.

- PISCIOTTO, KENNETH A., Scripps Inst. Oceanog., La Jolla, Calif.
- Deduction of Past Geothermal Gradients in Neogene Siliceous Rocks in Circum-Pacific Region

Zones of diagenetic silica record past geothermal gradients in Neogene diatomaceous sediments and siliceous rocks in the Circum-Pacific region and are useful in evaluating the petroleum potential of these important source rocks. In many areas burial diagenesis has produced the well-known lithologic and mineralogic progression: diatomite (opal-A) \rightarrow chert and porcelanite $(opal-CT) \rightarrow chert and porcelanite (quartz). Tempera$ ture is an important control of these transformations. The range in temperature for the conversion of opal-A to opal-CT, calculated from measured values of heat flow and thermal conductivity, is 25 to 56°C. Opal-CT transforms to quartz in the range 43 to 81°C. Similar ranges of temperatures are calculated from oxygen isotopes of opal-CT and quartz from cherts and porcelanites using the experimental fractionation for quartz and water, assuming the transformations occurred in isotopic equilibrium with water whose oxygen isotopic composition differed only slightly from standard mean ocean water. Taking the top and base of the opal-CT zone as approximate isotherms, the past geothermal gradient for any area equals the difference between these isotherms divided by the thickness of the opal-CT zone. In addition, both the thickness and the depth (reconstructed maximum overburden) to the top of this zone decrease with increasing geothermal gradient. Because depth and thickness are related by a simple linear expression, either may be used to estimate past geothermal gradients in Neogene siliceous rocks.

- POAG, C. WYLIE, U.S. Geol. Survey, Woods Hole, Mass.
- Important Stratigraphic Breaks in COST GE-1 Well, Southeast Georgia Embayment

A foraminiferal analysis of the recently completed Continental Offshore Stratigraphic Test (COST) GE-1 well reveals that $\sim 1,000$ m of Cenozoic, ~ 700 m of Upper Cretaceous, and ~1,600 m of Lower Cretaceous sedimentary rocks lie above Devonian metamorphic basement in this part of the Southeast Georgia embayment. Seven regional hiatuses interrupt the depositional record and correspond to times of low global sea level. The hiatuses are between Albian and Turonian rocks; upper Maestrichtian and upper Paleocene; upper Paleocene and lower Eocene; upper Eocene and lower Oligocene; middle Oligocene and middle Miocene; middle Miocene and upper Pliocene; and upper Pliocene and lower Pleistocene. The depositional environments represented in the GE-1 well range from terrestrial nonfossiliferous biotopes to ocean depths equivalent to those of a modern continental slope. Most of the Cenozoic and Upper Cretaceous rocks accumulated in continentalshelf biotopes, but the Lower Cretaceous rocks are

largely nonmarine and marginal-marine deposits. The sequence of paleo-environments can be correlated with the supercycles of global sea-level change outlined by P. Vail et al. Sediment-accumulation rates were highest (5.0 to 6.4 cm/1,000 years) during the Albian through Santonian interval, the middle and late Eocene, and the middle Miocene. Lowest rates (1.3 to 2.5 cm/1,000 years) prevailed during the Campanian and Maestrichtian, the early and middle Oligocene, and the Pleistocene. Subsidence calculations reveal that Cretaceous subsidence was more rapid than that of the Cenozoic, that most of the major paleobathymetric changes were caused by eustatic sea-level fluctuations, and that subsidence rate of the embayment was sensitive to sediment loading and unloading.

POORE, RICHARD Z., U.S. Geol. Survey, Menlo Park, Calif.

Temporal and Spatial Distribution of Ice-Rafted Mineral Grains in Pliocene Sediments of North Atlantic

An important find of Deep Sea Drilling Project (DSDP) Leg 12 was ice-rafted mineral grains in Pliocene sediments of the Labrador Sea and the Hatton-Rockall Basin. The oldest (first) occurrence of ice-rafted mineral grains in these sediments is associated with the evolutionary first appearance of the planktonic foraminifer Globorotalia inflata (d'Orbigny) and the extinction of the coccolith Reticulofenestra pseudoumbilica Gartner. This association yields a paleontologic age estimate of 3.0 m.y.B.P. for the start of low-elevation Northern Hemisphere glaciation extensive enough to produce icebergs in the North Atlantic. Results from subsequent drilling in the North Atlantic (DSDP Legs 37, 48, and 49) confirm that the first occurrence of ice-rafted mineral grains in North Atlantic sediments is at about 3.0 m.y.B.P. and further show that, during the Pliocene, icebergs penetrated as far south as 45°N lat. (DSDP hole 410) but not as far south as 37°N lat. (DSDP holes 333 and 335).

The estimated age of 3.0 m.y.B.P. for the onset of Northern Hemisphere low-elevation glaciation derived from the North Atlantic is compatible with, although slightly younger than, the 3.2 m.y.B.P. estimate suggested by paleomagnetically controlled isotopic data from the Equatorial Pacific.

PORTER, KAREN W., and ROBERT J. WEIMER, Colorado School Mines, Golden, Colo.

Diagenesis in Hygiene and Terry Sandstones (Upper Cretaceous), Spindle Field, Colorado

Recent research in the field of sandstone diagenesis suggests a relation between depositional fabric and the observed pore-filling sequence. An ordered paragenetic sequence representing an ordered decrease in energy-of-formation (ΔG°_{f}) values is reported for fine-grained, poorly sorted sandstones. Coarser grained, better sorted sandstones from the same depositional environment show unordered diagenesis with respect to ΔG°_{f} , perhaps related to higher fluid flow and less influence of rock composition. A relation may also exist between diagenetic sequence and depositional environment;