and the rate of decline in water levels has decreased significantly. The rate of subsidence has decreased since September 1976. As a result of increased use of surface water, groundwater production decreased about 303 million L/day and groundwater levels rose as much as 18 m in the central part of the region in 1977. Because of the pressure recovery, the rate of subsidence should decrease substantially in some critical areas.

The Harris-Galveston Coastal Subsidence District was created by the Texas Legislature in 1975 to cope with the problem of land-surface subsidence. The District plans to control subsidence by controlling and regulating groundwater pumping.

GAINES, ALAN M., Natl. Sci. Foundation, Washington, D.C.

Dolomitization—Recent Experimental Approaches

Experimental studies of the kinetics of reaction of calcium carbonate with magnesium-calcium chloride solutions indicate a solution-reprecipitation mechanism with a cation-ordered protodolomite as the initial reaction product. Nucleation of ordered dolomite is extremely difficult at low temperatures and is an important factor in the reaction. The kinetics of the reaction are strongly dependent on temperature and on the reactant (calcite or aragonite). Experimental dolomitization of aragonite at 100°C and atmospheric pressure has permitted study of the reaction under conditions approaching those of natural sedimentary environments. These studies indicate that other important kinetic factors include the ionic concentration (salinity), the Mg^{++}:Ca^{++} ratio in the dolomitizing fluids, and the presence of strongly hydrated ions. Certain amino acids and soluble proteins severely inhibit the reaction, but may be removed by oxidation. The results of these experiments may aid in the interpretation of the processes involved in sedimentary dolomitization.

GALLOWAY, WILLIAM E., Bur. Econ. Geol., Austin, Tex.

Oakville Formation of Texas Coastal Plain—Depositional Systems, Composition, Structure, Geohydrology, and Uranium Mineralization

The Oakville Formation consists of deposits of a bedload fluvial system composed of at least four major and several minor rivers that flowed across the Miocene Texas coastal plain. Rivers of the southwestern part of the system transported polymictic sand and gravel containing abundant volcanic clasts; stream deposits of the northeastern area are uniquely rich in reworked carbonate-rock fragments. Structures suggest highly variable to ephemeral flow and extensive development of crevasse splays. Bounding flood-plain muds consist of kaolinitic calcium to sodium montmorillonite. Illite is present locally.

Hydrogeology and uranium mineralization are strongly influenced by a broad belt of subjacent Wilcox (Eocene age) growth faults. Mineralization and alteration patterns reflect the complex flow of groundwater within a stratigraphically and structurally compartmentalized aquifer. With evolution of the Oakville aquifer system, faults have acted both as flow boundaries and as loci for intrusion of deep-seated highly reducing brines and shallow meteoric groundwater, further obscuring primary ore-forming processes. Volcanic glass within and possibly above the Oakville provides a probable source for the uranium.

GARDNER, J. V., Motorola Aerial Remote Sensing, Inc., Phoenix, Ariz., and L. F. DELLWIG, Univ. Kansas Remote Sensing Lab., Lawrence, Kans.

A New Look at Geology of Togo By SLAR

Imaging of Togo, West Africa, with Side-Looking Airborne Radar (SLAR) in 1977 provided the data required for the production of semicontrolled radar mosaics at a scale of 1:200,000. These mosaics revealed significant errors in the existing geologic and topographic maps of Togo. The mosaics also served as a base for the generation of a new geologic map of Togo. The use of two opposing radar "look" directions helped in making numerous revisions, such as identifying previously unknown structural features, age relationships, refinement of unit boundaries, and the repositioning of structural features and lithologic units. Positional errors in some cases involved relocation of points by as much as 12 km and reorientation of major faults by as much as 22°. Although the value of radar's synoptic view and low illumination angle for detecting geologic features has been clearly demonstrated, the utilization of a SLAR mosaic for rectifying the location and orientation of geologic features has not received sufficient attention.

Geologic mapping of Togo was initiated as early as 1905, and sporadic but continuing revisions occurred through 1973. The fact that numerous investigators with diverse interests have participated in subsequent mapping, without apparent rectification of major errors in position and orientation, suggests that errors on earlier maps were incorporated into more recent versions. That this is the case is emphasized by the lack of congruence of major, topographically expressed rock units and structures in recently published, small-scale maps with their well-defined counterparts on the radar mosaics. Furthermore, it suggests the seriousness of the error of geologic-map revision utilizing a previously published map as a base without verification of its geometric fidelity.

GARRETT, PETER, Univ. California, Santa Barbara, Calif., and ALBERT C. HINE, Univ. North Carolina Inst. Marine Sci., Morehead City, N.C.

Probing Bermuda's Lagoons and Reefs

Preliminary seismic reflection profiling of Bermuda's lagoons, using the Uniboom system, followed by reconnaissance drilling, has shown that the lowest horizon on the seismic profiles is a strongly reflecting layer, almost horizontal, and with surface roughness of 1 to 3 m. It lies at a depth of about 19 m below sea level near the center of the platform and slopes very gently to 32 m beneath the rim. It appears to be the foundation upon which the rim, reefs, and lagoons have developed, culminating in the present configuration.

Above this surface there are Pleistocene reefs, thick

sand bodies, and large expanses of lagoonal sediment. The reefs have only a few meters of relief and are commonly draped with lagoonal sediment of unknown age relative to the reefs. The sand bodies are especially common adjacent to the northwest rim and in the southwest lagoon. Drilling has revealed one marine sand body in the northwest, and another, possibly eolian, in the southwest. Lagoonal deposits cover large areas between reefs and sand bodies, and in the northeast, almost the entire area inside the rim.

Recent reefs are founded on a variety of substrates. Close to shore they locally fringe the Pleistocene ridges. Over Pleistocene sand bodies in the northwest and southwest, there are prominent reef and sediment shoals. On the rim, reefs encrust whatever Pleistocene rim lies below. However, many lagoon reefs are founded not on topographic highs but on nearly level lagoonal-sediment surfaces, some of which are the lagoonal drapes over Pleistocene reefs. In a few places, recent reefs occur over broad shallow depressions in Pleistocene surfaces. All recent reefs have far greater relief (5 to 20 m) than the buried Pleistocene reefs.

Few of the associations and features predicted by the karst origin of atolls hypothesis are present. For example: (1) the rim seems to have built up from the basal reflecting surface, rather than being a solutional modification of it; (2) stacked lagoonal sequences, where slow sedimentation perpetuates a steep-sided solutional depression, are uncommon, and most are present in the enclosed sounds and harbors; (3) many reefs are founded on flat surfaces, not on solutional pinnacles; and (4) deep sink holes are very rare. In general, Bermuda lacks clear signs of being a reef-encrusted paleokarst feature.

GARRISON, R. E., Univ. California, Santa Cruz, Calif., E. ESPIRITU, Bur. Mines, Manila, Philippines, and L. J. HORAN and L. E. MACK, Univ. California, Santa Cruz, Calif.

Petrology, Sedimentology, and Petroleum Potential of Early Cenozoic Back-Arc Limestone-Tuff Sequence, Central Luzon, Philippines

The Aksitero Formation of central Luzon is an upper Eocene to lower Oligocene sequence of evenly bedded hemipelagic limestones with a few thin interlayers of tuffaceous turbidites. The limestones consist chiefly of planktonic Foraminifera and calcareous nannofossils, but include up to 30% noncarbonate components which are mainly volcaniclastic debris. The tuff layers are graded beds comprising glass shards, pumice fragments, crystals, and fine-grained volcanic rock fragments. Hydrocarbons migrated into the pores of the tuffaceous layers at a relatively early stage during diagenesis. However, subsequent flushing has left only a bitumen residue, chiefly as thin coatings on grains and within pumice vesicles. During later stages of burial diagenesis, zeolites (mordenite and clinoptilolite), and secondary calcite preferentially replaced glass shards and pumice fragments. The zeolite assemblage suggests maximum burial temperatures of 55 to 90°C.

Deposition of the Aksitero Formation apparently occurred at water depths of at least 1,000 m in a subsiding back-arc basin lying west of an east-facing early Cenozoic island-arc system. Pelagic carbonate skeletal material was the main sediment source, but submarine ash eruptions of silicic composition generated volcaniclastic turbidity currents whose distal edges occasionally reached the basin floor. The thicker and coarser, more proximal facies of these volcaniclastic deposits may be prospective for hydrocarbons.

GAUDETTE, HENRI E., Univ. New Hampshire, Durham, N.H., PATRICK M. HURLEY, Massachusetts Inst. Technology, Cambridge, Mass., and T. LAJMI, Tunisian Geol. Service, Tunis, Tunisia

Provenance Studies in Tunisia by U-Pb Ages of Detrital Zircons

In recent years, with increasing availability of radiometric age determinations, age provinces in continental areas have become more clearly defined. Thus the possibility of establishing source areas for extensive sedimentary sequences by means of radiometric age determination of included detrital minerals is enhanced. With this objective, samples in northern and central Tunisia of detritus in river channels draining Oligocene–early Miocene sandstones, and rock samples of the Oligocene–early Miocene Numidian flysch, and Chercheri-Fortuna sandstones were obtained. Permian and Triassic sandstone outcrops and Ordovician sandstone cores from exploratory wells in southern Tunisia were also sampled. Zircons were separated from the detritus and the sandstones, and U-Pb isotopic compositions of the zircons were determined. Analytic results are interpreted on Concordia plots.

The results of zircon analyses of detrital sands in drainages from northern and central Tunisia indicate a primary intercept age of $1,750 \pm 100$ m.y. Analyses of the zircons from the Oligocene-Miocene sandstones cropping out in the drainage areas yield an age of $1,706 \pm 50$ m.y., strongly suggesting that the zircons in the drainage channel sands represent the population of zircons in the rocks themselves, and that the detrital zircon may provide a useful indicator of provenance. F. C. Wezel has shown a predominant transport direction of south to north for the Oligocene-Miocene sedimentary units of Tunisia. A southern source for the sedimentary sequences in northern Tunisia was sought in the Permian-Triassic and Ordovician sandstones of the Medenine area. Zircons from the Permian and Triassic sandstones give an intercept age of $1,650 \pm 60$ m.y. The U-Pb age of zircons from the Ordovician sandstone core samples is $1,871 \pm 26$ m.y. Thus, we find a coherence, within analytical error, of all the zircon separates from rocks of widely differing stratigraphic ages and geographic locations. This does not preclude the possibility of mixed populations; however, on the basis of our analytical methods, it is strongly suggested that the zircon populations appear homogeneous, and that their U-Pb isotopic ages do represent the primary age (i.e., the source age) of the zircons regardless of stratigraphic setting.

GAUTIER, DONALD L., U.S. Geol. Survey, Denver, Colo., and Univ. Colorado, Boulder, Colo.

Authigenic Tourmaline Crystals in Pore Spaces of Upper Cretaceous Gas-Productive Sandstone, North-Central Montana