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