result of organo-mineral metamorphism. Consequently, they are useful thermal indices, especially for carbonate rocks and cherts in which other organic and mineral indices are virtually absent. Because of their mineral composition, conodonts can be concentrated from a variety of sedimentary rocks (particularly limestone, dolomite, shale, and chert) and persist into low-grade metamorphic rocks (marble and metacarbonate interbedded with chlorite-, biotite-, and garnet-bearing pelitic rocks).

Relatively new applications for conodonts include: (1) dating of siliceous facies; (2) dating of low to medium-grade metamorphic rocks; (3) timing of thermal events; (4) assessment of hydrocarbon and mineral-resource potential; and (5) tectonic interpretation. New techniques for thermal assessment and age determination, such as autofluorescence and stable-isotope analysis, are being actively investigated by several workers. Conodonts are versatile tools that provide chronologic and thermal clues for interpretation of the geologic history and evaluation of the resource potential of Paleozoic and Triassic sedimentary and metasedimentary terranes throughout the world.

HARRIS, ANITA G., U.S. Geol. Survey, Wshington, D.C., BRUCE R. WARDLAW, U.S. Geol. Survey, Denver, CO, CLAUDE C. RUST, Mobil-GC, Houston, TX, et al

Conodont-Based Assessment of Thermal Maturity in Paleozoic and Triassic Rocks, Central Great Basin

Conodonts (marine apatitic microfossils) are of organic origin and have biostratigraphic value. They are used as mineral thermal indices that undergo visible color changes between 50 and 500°C. Using these changes, color alteration index (CAI) maps were compiled for Ordovician through Triassic Systems in Nevada and adjacent parts of Idaho, Utah, and California using more than 5,000 samples. The maps show three thermal intervals which generally correspond to: (a) the thermal window for oil generation (CAI 1 to 2); (b) the upper thermal interval for gas generation (CAI 2 to 4.5); and (c) the thermal cutoff for most hydrocarbon generation (CAI >4.5).

The Great Basin is one of the most difficult areas in which to interpret thermal metamorphism in Paleozoic and Triassic rocks. Original burial metamorphic patterns are disrupted by thrust and normal faulting, masked by post-Triassic sedimentary and igneous rocks, and "overprinted" by post-Triassic thermal events. Nevertheless, maps show broad regional thermal patterns for Paleozoic and Triassic Systems which help delineate prospective areas for continued hydrocarbon and mineral exploration.

In general, Ordovician through Triassic rocks west of 117°30′W longitude and most Ordovician through Pennsylvanian rocks north of 41°30′N latitude and west of 113°W longitude and in the Oquirrh basin have CAI values >4.5 and appear to be unfavorable targets for hydrocarbon exploration.

Ordovician through Triassic rocks in central Nevada and Millard County, Utah, have regional moderate to low CAI values. This area, which includes the only two producing oil fields in Nevada, should provide a variety of hydrocarbon exploration targets. The Paleozoic and Triassic rocks of the Overthrust belt of southeast Idaho and Utah predictably have low to moderate CAI values.

HARRIS, P. M., S. H. FROST, C. KENDALL, et al, Gulf Science and Technology Co., Houston, TX

Cretaceous Sea Level and Stratigraphy, Eastern Arabian Peninsula

The stratigraphy of the eastern Arabian Peninsula should accurately record Cretaceous sea level changes owing to long-term regional tectonic quiescence and carbonate platform deposition. The setting is thus not dependent on coastal or shelf-edge processes. We have constructed from well studies and numerous published sources a regional sea level curve for the Cretaceous using paleobathymetric relations within precisely dated stratigraphic sequences adjusted for isostatic response to sea level motion. The isostatic response for any section encountered in a well can be calibrated by constructing a depth/burial curve which is corrected for compaction, sediment loading, thermal cooling, and tectonic subsidence.

The Cretaceous of the eastern Arabian Peninsula is comprised of three lithic sequences bounded by four regional unconformities. The lithic sequences are: the Lower Cretaceous Thammama Group, shallow-water carbonate rocks; the middle Cretaceous Wasia Group, shallow-water carbonate rocks; and the Upper Cretaceous Aruma Group, deep-water shales changing laterally into shallow-water limestones. The unconformities, agreeing closely with eustatic sea level lows, occur during: the latest Jurassic/earliest Cretaceous, the middle Aptian, the late Cenomanian-Turonian, and the latest Cretaceous/earliest Paleocene. The Turonian exposure was reinforced by regional tectonic upwarp. Low stands of less magnitude occur during the Barremian, late middle Albian, and middle Cenomanian. A Valanginian unconformity, recognized in the stratigraphic sequence of eastern Saudi Arabia, does not appear to be regional in extent. In the Upper Cretaceous (Coniacian-late Campanian), the effect of regional tectonic subsidence on the sedimentary facies overshadows the general eustatic high stand.

Our examination of carbonate provinces elsewhere indicate that the major unconformities are not localized and therefore probably represent global eustatic sea level lows.

HARRIS, PAUL M., Gulf Research & Development Co., Houston, TX

Freshwater Cementation of Holocene and Jurassic Grainstones

Freshwater cementation of Holocene sands in the Bahamas provides a modern analog to enhance our understanding of some cements in Jurassic grainstones of southern Arkansas. The Joulters Cays, three late Holocene islands on Great Bahama Bank, formed when ooid sands were subaerially exposed and lithified by freshwater cements. Cement fabric above the standing water table (vadose zone) and below (phreatic zone) is strikingly different. Vadose cements, characterized by patchily distributed spar most common at grain-contacts, change abruptly across the water table to phreatic cements, displaying a uniform rim of rhombohedrons surrounding each grain. Vadose cements preserve primary porosity and increase variation in permeability more than phreatic cements.

The updip Smackover grainstone reservoirs in southern Arkansas are characterized by (1) early cements that predate hydrocarbon emplacement and that resemble the Joulter Cays freshwater cements, (2) preserved primary intergranular porosity, and (3) leached moldic porosity. Vadose imprint is characterized by poorly developed cement rims around grains, a grain-contact meniscus fabric producing rounded pores, and a patchy distribution of block spar with crystals that increase in size away from the grains. The meniscus fabric is only partly preserved where grain interpenetration has occurred during burial. Phreatic cements occur as moderately to well-developed non-isopachous rims around most or all of the grain margins. They line pores forming jagged boundaries, and are patchy to extensively developed showing an increase in crystal size away from the grain. The cement rims are commonly broken and separated from the grains during compaction. Compaction features and late cements are not distributed uniformly in the grainstones, owing perhaps to heterogeneous porosity and permeability patterns established by early cements.

HARRISON, FRANK W., JR., Consulting Geologist, Lafayette, LA

False River Field

On August 14, 1975, Chevron Oil Co. spudded the No. 1 Alma Plantation in Sec. 87, T6S, R11E, Pointe Coupee Parish, Louisiana. The objective was in Cretaceous rocks at a projected total depth of 22,500 ft (6,858 m). This became the discovery well for False River field. To this date, nine wells have been completed in the field from the Tuscaloosa Formation of early Late Cretaceous age at a depth of 19,800 ft (6,035 m). In addition, seven wells are being drilled or tested, and two have been completed as dry holes. The No. 1 Alma Plantation flowed at the rate of 20 MMcf of gas per day with a flowing tubing pressure of 11,600 psig (79,878 kPa). The initial shut-in reservoir pressure was 16,806 psig (115,776 kPa). From subsurface and seismic data, a structure appears to be buried below the base of the Austin Chalk. This structure is 20-mi (32 km) long and 10-mi (16 km) wide at a depth of approximately 19,000 ft (5,791 m), and is situated adjacent to the south side of a Cretaceous hinge line. This hinge line extends from Lake Bornge northwesterly across south-central Louisiana into southern Vernon Parish. From subsurface and seismic data it appears that the structure is depositional in origin.

HATHON, CHRIS, Marathon Oil Co., Houston, TX, and DUNCAN F. SIBLEY, Michigan State Univ., East Lansing, MI

Authigenic Quartz in Devonian Black Shale

The Antrim Shale (Devonian, Michigan basin) contains a large volume of authigenic quartz. The shale contains appproximately 50% quartz by weight of which, in the >500 mesh-size fraction, 56% is polycrystalline. This is approximately twice the amount of quartz in most shales and 10 times the amount of polycrystalline quartz in the silt-size fraction of sandstones and shales. Scanning electron microscopy reveals an authigenic surface composed of hexagonal tabular plates which coalesce to form smooth grain surfaces. These plates have not been previously reported on quartz grains. Oxygen isotopes of quartz and carbonate phases are interpreted to indicate a gradual isotopic lightening of the pore fluids, from approximately -4 to -9 or -10 ppm. Most of the authigenic quartz has a $\delta^{18}O \approx 22$ ppm (SMOW).

HAUN, JOHN D., Colorado School Mines, Golden, CO

Petroleum Geology in 1980s

At no time in the history of petroleum geology has the need for marshaling our scientific knowledge and professional skill been more necessary than it is today. As a result of the mature stage of development in most United States petroleum-producing areas and recent concentration on close-in exploration targets, the barrels of oil equivalent (BOE) discovered per foot of new-field wildcat drilled has declined from 350+ in the late 1940s to 53 in the late 1970s.

If the decline in discovery per unit of drilling continues, and approximately the same rate of drilling is maintained, by 1990 the discoveries per foot in new-field wildcat wells are projected to be 24 BOE. If the rate of exploratory drilling is increased in the early 1980s, the discovery rate will decline more drastically.

Our knowledge of oil and gas source materials, source-bed maturation, mechanisms and time of primary migration has expanded greatly during past decades and new insights will be added in the 1980s. Stratigraphic and sedimentational concepts, methods of identifying depositional environments, tectonic and structural principles, and details of geologic history will continue to play prominent roles in our intensive probing of the frontiers of geologic knowledge. Pressure-temperature relations, origins of abnormally high or low pressures, and the delineation of hydrodynamic versus hydrostatic conditions have become increasingly important in understanding trap formation; more precise measurements and interpretation are essential in future exploration.

The role of the geologist in interpreting geophysical measurements, especially in seismic stratigraphy and mechanical logs, will grow in importance. Knowledge of the principles of petroleum geology will continue to be important in oil- and gas-field development, in enhanced recovery, and in uranium, coal, geothermal, and tar-sands exploration or exploitation.

With these increasing complexities and the resulting professional opportunities, it is unfortunate that so few universities have a meaningful program specifically designed for educating petroleum geologists. The developing surplus of bachelor-level geology graduates probably will be followed in the late 1980s by a shortage, i.e.,