processed on other IBM or similar-type equipment to prepare compositional logs and maps which can be used for making correlations, defining lithologic features, determining environments, interpreting responses on geophysical-type logs, and predicting the location of reservoir rocks.

Very recent advances in technology have made it possible to build systems that will obtain and handle large masses of compositional information using simpler and faster analog systems as accessories to the X-ray diffractometer. Further refinements can be expected and well-site equipment capable of keeping pace with the drill is envisaged. The potentialities of automatic acquisition, processing, and interpretation of mineralogic as well as other geologic information have not yet been realized in exploration but trends are suggested.

EDIE, RALPH W., Andrichuk and Edie, consulting geologists, Calgary, Alberta, Canada

Paleoecology of Devonian Swan Hills Reef, Alberta, Canada

The Limestone reef reservoir at Swan Hills consists essentially of a "buildup" of successively smaller atoll-like layers. Precipitation of calcium carbonate within the lagoonal area of each layer essentially kept pace with growth of the outer organic lattice. Within the reef mass, six depositional environments characterized by specific suites of fossils (or fossil fragments) and associated limestone textures are recognized as follows.

1. Aerated moderately agitated water of normal marine salinity (widespread shelf or submerged reef-built platform). Thamnopora-type corals, *Amphipora*, "pancake" stromatoporoids, crinoids, articulate brachiopods, rare rugose cup corals, and ostracods occur in light gray-buff skeletal microgranular limestone of low permeability.
2. Semi-stagnant quiet water of normal marine salinity (leeward side of reef). Crinoids, articulate brachiopods, rare thamnopora-type corals, *Amphipora*, pancake and bulbous stromatoporoids, rugose cup corals, ostracods, and gastropods occur in impermeable dark brown argillaceous skeletal calcilutite with thin black bituminous shale beds and rare dark chert nodules.
3. Aerated highly agitated water of normal marine salinity (organic lattice). Light buff stromatoporoid bulbs and *Amphipora*, rare thamnopora-type corals, rugose cup corals, crinoids, and articulate brachiopods form permeable patch reefs and interbedded skeletal calcirudites.
4. Semi-stagnant quiet marine water of slightly increased salinity (partly restricted shelf). Dark gray biostromal "buildups" of stromatoporoid bulbs and minor *Amphipora* occur in impermeable black shaly matrix.
5. Aerated, quiet to highly agitated marine water of increased salinity (mud flats, tidal channels, and shoals within atoll-lagoon). *Amphipora*, rare ostracods and gastropods occur in light buff impermeable to highly permeable precipitated limestone (lithographic, microgranular, pseudo-oölitic, and intra-formational conglomerate).
6. Semi-stagnant quiet marine water of increased salinity (deeper protected pools in atoll-lagoon). *Amphipora*, rare stromatoporoid bulbs and ostracods occur in impermeable dark brown slightly argillaceous calcilutite of precipitated origin.

Mapping of these environments is of great value in outlining field extensions and evaluation of acreage during development drilling. Use of these techniques, in addition to contruction of isopach maps of critical intervals, should also be highly effective in exploration for undiscovered reef oil and gas fields.

EATON, J. P., PAKISER, L. C., JACKSON, W. H., STEWART, S. W., AND STUART, D. J., U. S. Geological Survey, Denver, Colo.

Exploring the Continental Crust of Western United States

Seismic-refraction measurements have been made by the U. S. Geological Survey along 10 profiles, each 300 km. long or more, in California and adjacent Nevada, and Colorado and adjacent New Mexico, as a part of the Vela Uniform program of the Advanced Research Projects Agency, Department of Defense. Initial interpretation of results along a line from Fallon to Eureka, Nevada, defines an intermediate crustal layer at a depth of about 22 km. with a velocity of 7.2 km. per sec., and the Mohorovicic discontinuity at a depth of about 40 km., below which the velocity is 8.0 km. per sec. Interpretation of the first profile completed in Colorado defines an intermediate crustal layer at a depth of about 31 km. with a velocity of 6.9 km. per sec., and the Mohorovicic discontinuity at a depth of about 48 km., below which the velocity is 8.0 km. per sec. The velocity in the upper crustal layer, below the near-surface rocks, is 6.1 km. per sec. along both profiles.

ELIAS, GREGORY K., Durango, Colo.

Paleoecology, an Exploration Tool in Southern Paradox Basin, Four Corners Area

In the southern Paradox basin many of the oil and gas fields produce from bioherms. Extensive coring operations in the Ismay-Flodine Park field have permitted a detailed inspection of a typical bioherm in the lower Ismay zone of the Pennsylvanian Paradox Formation. The four basic depositional environments that have been differentiated are shoal, bioherm, basin, and channel environments. Variations of chemical composition, particle size, allochems, degree of winnowing, biological remains, color, and terrigenous clastics are used to differentiate the environments. Distribution of environments in relation to tectonic features leads to a reconstruction of the ecologic conditions that produced the bioherms. The bioherms are not considered to be reefs, but remains of algal forests.

Diagnostic parameters for identifying the major environments are: (1) shoal—light-colored calcareous muds and disturbed calcareous muds interbedded with poorly winnowed intraclasts, pellets, and Foraminifera (*Glomospira*); (2) bioherm—light-colored, slightly winnowed to well winnowed algal remains (*Ivanovia*); (3) basin—dark, argillaceous, calcareous muds near the biohermal front, with anhydrite followed by halite farther basinward; and (4) channel—light gray brown calcareous muds with siliceous sponge remains, in places overlain by relatively thick quartzose sands.

The depositional history begins with a transgressive sea, during which the green algae *Ivanovia* found favorable growth conditions on the slopes of calcareous shoals. The algae grew upward and shoreward as the sea rose. Near shore, the very gentle waves formed intraclasts and pellets from calcareous muds. These particles, together with fine fossil debris, then were loosely cemented in a matrix of contemporaneous calcareous mud. In the channels between the masses of algae, siliceous sponges were nourished by circulatory waters. During maximum transgression, calcareous muds covered the bioherms. Upon regression of the sea, the shoal environment moved basinward over the bioherms, terrigenous quartz sands were washed into the channels, and finally, evaporites were precipitated from the waters trapped in the basin.

By considering the Paradox basin as a vast lagoon, marginal to the open waters of the Cordilleran miogeosyncline, we may visualize the *Ivanovia* bioherms as algal masses or banks growing on lagoonal shoals comparable with the current habitat of the green algae *Halimeda*.

ELLISON, SAMUEL P., JR., University of Texas, Austin, Tex.

Conodonts from Trans-Pecos Paleozoic of Texas

This is a preliminary summary of the distribution of conodonts in Lower to Upper Ordovician, Middle and Upper Devonian, Mississippian, Pennsylvanian, and Permian strata in the Trans-Pecos area of West Texas. Conodonts are now known to occur in the following formations: El Paso (Lower Ordovician), Montoya (Upper Ordovician), Canutillo (Middle Devonian), Helms (Upper Mississippian), Rancheria (Lower Mississippian), Tesnus (in part Mississippian), Magdalena and Gaptank (both Pennsylvanian), and Wolfcamp (Lower Permian) Formations. In addition, previously described faunas from the Marathon (Lower Ordovician), Fort Pena and Woods Hollow (Middle Ordovician), Maravillas (Upper Ordovician), Caballos (Devonian) and Dimple (Lower Pennsylvanian) Formations have been re-studied. Comparisons of these conodont faunas have been made with similar conodont faunas in central and eastern United States, and in western Europe. Detailed biozones like those proposed by other workers for the Illinois basin and for western Europe have not yet been established in West Texas. Furthermore, the abundance of conodonts in the stratigraphic column in West Texas is considerably less than that of the central United States and Europe.

ENGEL, RENE L., U. S. Naval Ordnance Station, China Lake, Calif.

Geology and Tectonics of Trinidad Mountains, Las Villas Province, Cuba

The Trinidad Mountains in south-central Cuba include the San Juan, Trinidad, and Banao-Sancti Spiritus Mountains. The mountain system has steep south and west slopes and gentle north and east slopes. Karst topography characterizes the areas which are underlain by limestone.

The oldest rocks are Middle Jurassic (pre-Oxfordian) metasediments with micaschists at the base of the section and carbonate rocks above. Tentative correlation suggests the presence of a geosyncline during Middle Jurassic time. The metasediments are overlain unconformably by Middle to lower Upper Cretaceous sediments and pyroclastics (Albian to Santonian). Both are intruded by basic and acidic plutonics of middle Upper Cretaceous (pre-Maestrichtian) age. Sediments of younger Cretaceous and Tertiary age cover the margins of the mountain system.

At the close of the Lower Cretaceous, compressive forces oriented north-south, produced isoclinal folds and elevated the original Trinidad Mountains. Renewed orogenic activity during the middle Upper Cretaceous was accompanied by additional folding, cross-faulting, and jointing. Later intrusion of pyroxenites and periodotites was followed by acidic differentiates. At the end of the lower Eocene, tangential forces oriented southward produced a series of major overthrusts on the north coast of Las Villas Province and reverse structures in the Trinidad Mountains. Left-lateral strike-slip normal faults on the southwest margin of the mountains were developed during early Miocene time. They are part of a shear zone crossing Cuba in a northwest-southeast trend from the Bay of Cardenas to Cienfuegos.

EVITT, WILLIAM R., Jersey Production Research Company, Tulsa, Okla.

Dinoflagellates and Their Use in Petroleum Geology

Dinoflagellates are a group of chiefly planktonic one-celled organisms abundant in modern seas and lakes. Their fossil organic shells range from 15 to 150 microns or more and are commonly found in Jurassic and younger marine sediments by the same techniques as those currently more widely used for spores and pollen. Commonly they occur in the same samples. Being surface-dwellers, dinoflagellates are relatively independent of the type of bottom sediment, although most abundantly found in marine shales; fresh-water fossil types are very rare. Rapid evolutionary changes, combined with wide geographic distribution of many species, make them excellent fossils for zonation and correlation. This is exemplified by successions of distinctive assemblages in the late Mesozoic and Cenozoic of Australia, by two assemblages containing many identical species in the Upper Jurassic of Utah and France, and by the worldwide distribution of a particularly distinctive form in the Upper Cretaceous. The value of dinoflagellates for environmental interpretation is as yet largely unexplored.

Two major types of dinoflagellate fossils occur. One is the resistant shell, or theca, of the free-swimming organisms. This is commonly divided into polygonal plates and may contain a thick-walled and much ornamented protective structure, the cyst. The second type consists of isolated cysts, freed of their surrounding thecae. The latter type includes many of the minute spiny objects that have been called hystrichospheres. In fact, the majority of (but by no means all) post-Paleozoic hystrichospheres appear to be dinoflagellate cysts. Important criteria for distinguishing dinoflagellate genera and species include: the over-all shape, the number and arrangement of plates or of spine-like projections, the type of cyst, and the character of a special opening, the archeopyle, by which the protoplasm left the theca or cyst.

The literature on fossil dinoflagellates and the number of described genera and species are still small, but now explosively expanding as interest in the group increases. Although fossil dinoflagellates are already useful tools of the applied paleontologist, our understanding of them and the full development of their potentialities for applied paleontology are in early stages.

FORGOTSON, JAMES M., Jr., Pan American Petroleum Corporation, Tulsa, Okla.

Application of Digital Computers to Exploration Operations

The use of digital computers in exploration is oriented toward furnishing the geologist an additional tool. Two types of operations are performed by digital computer installations. Data processing involves filing, sorting, and comparing a large volume of data that require a small number of arithmetical calculations for each of many data entries. Computing involves the solution of mathematical formulas and includes problems requiring relatively few data but many arithmetical calculations.

Data processing is often merely a system for rapid recall of information and as such is being investigated