anhydrite is the mineral buried, when did it lose its large primary porosity, and has it recrystallized since initial formation? By (1) defining the first-formed mineral and its structures, textures, and chemical composition and (2) making analogous studies of ancient subsurface calcium sulfate minerals, we can, hopefully, answer some of these questions.

KONISHI, KENJI, Dept. Geological Sciences, Univ. California, Riverside, Calif.

FIBROUS ARAGONITE IN SEALED PLIOCENE *Glycymeris yessoensis*: POSTMORTEM

About 300 jointed bivalves of *Glycymeris yessoensis* were collected from a lenticle of an almost unispecific shell bed in the Onma Formation, central Japan. Most of the valves were partly open and completely infilled with the surrounding sandy silt; 5 were sealed and contained only a small amount of aragonite-cemented siltstone. The void in the chamber of the sealed valves is occupied with acicular needles of aragonite overgrown on the inner surface of the valves and on the surface of parasitic boreholes within the shells. The fibrous aragonite on the inner surface of the shells is in optical continuity with the aragonite crystals at both inner and outer structural layers. The fibrous aragonite indicates strong depletion of O^{18} and slight depletion of C^{13} compared with the shell. A cold to temperate open sea comparable with that off the western coast of Hokkaido at present is zoogeographically indicated for the Onma molluscan fauna. These isotopic depletions differ from that of aragonite cement generally found in grapestone clusters, reef rocks, and beachrocks, all of which are typically tropical. The textural evidence suggests that precipitation of the aragonite postdated the partial infilling by sediments, but took place when the sediments were plastic; hence a freshwater origin of the aragonite is excluded. A plausible interpretation is aragonitic growth from a solution trapped and warmed within the chamber during an early stage of fossilization. Aragonite cementation may occur in a localized space such as a shell chamber in nontropical seawater.

KRAFT, JOHN C., Dept. Geology, Univ. Delaware, Newark, Del.

MORPHOLOGY AND VERTICAL SEDIMENTARY SEQUENCES IN HOLOCENE TRANSGRESSIVE SAND BARRIERS

Studies of the barrier ridges and beaches along the presently transgressing mid-Atlantic coastal area have been used to formulate morphologic and vertical sequence models for transgressive beaches. Each type of barrier is a response to the topography being inundated in the ongoing transgression as well as to wave and current conditions. Four major types of sand-gravel barriers may be identified in coastal Delaware: (1) bay-mouth barriers, (2) beach against highlands, (3) estuarine barriers, and (4) spit complex.

The bay-mouth barriers, between enclosed lagoons and the open Atlantic Ocean, are characterized by a vertical transgressive sequence of sedimentary environments identical with the horizontal sequence in the direction of the transgression. In the beach against highland barrier, beach-bern system impinges on low-lying Pleistocene highlands (20–30 ft) which are being eroded and provide a partial source of sediment to the beach system. Estuarine barriers occur as long arcuate shorelines of large estuaries such as Delaware Bay. A barrier of sand and gravel is formed with small width (30 ft) and thickness (< 10 ft) but extreme length (50–75 mi). The internal structure of these thin but extremely long sand barriers is complex and mainly comprised of washover features. A modified version of the estuarine barriers is found in places near the leading edge of transgression on the landward shorelines of lagoons. The spit complex intrudes into the open marine and bay area. The spit-dune-barrier-marsh tract includes all of the expected coastal environment sediments of a normal barrier-lagoonal area in addition to typical spit-accretion sand and gravel. However, vertical sequences are disrupted and not in order.

KRAMER, J. R., Dept. Geology, McMaster Univ., Hamilton, Ont.

GEOCHEMISTRY AND DEPOSITION OF LOWER SALINA GROUP, SOUTHWESTERN ONTARIO AND MICHIGAN

Calcite, dolomite, insoluble residue, and clay minerals of lower Salina (A_1 and A_2) and upper Niagaran rocks of southwestern Ontario and Michigan were analyzed. Analysis of variance, trend surface analysis, and factor analysis were carried out on the above constituents, as well as on color and oil and gas production. Dark units contain more carbonate and calcite than light units. Light units contain more dolomite than dark units. Dark units typically contain a 13.4 Å clay, whereas light units more typically contain a 10.8 and 9.4 Å clay. Light units are associated with proposed marine outlets from the Salina basin. Light/[dark + light] ratios show very good correlation with reported oil and/or gas production. Dark carbonate units (suggesting a restricted lagoon) lie behind (east of) the known reef arc. High-dolomite-content light units may be related in origin to a shallow-water, subaerial environment currently termed "supratidal."

KREBS, WOLFGANG, Geol. Palaeont. Inst., Braunschweig, Germany

DEVONIAN CARBONATE COMPLEXES OF CENTRAL EUROPE

The carbonate complexes in the Rhenish trough of the Variscan geosyncline (central Europe) range from late Givetian to early Frasnian and are restricted to the external and internal shelves and isolated submarine volcanic rises. On the western part of the external shelf (southeast margin of the Old Red continent), the carbonates form a widespread shelf-lagoon facies on deltalike clastic deposits (Belgium, Aachen, Eifel); in the eastern part they are isolated reef complexes and shelf-margin reefs on locally higher exposed platforms (Bergisches Land, Sauerland). On the internal shelf (northwest margin of the "Mitteldeutsche Schwell") the carbonates overlie crystalline rocks (borehole Sarr 1) or clastic Devonian strata (Giessen). The Middle to Upper Devonian carbonates generally are 350–400 m thick, and at Balve (Sauerland) they are more than 1,000 m. In the internal part of the trough the carbonates form isolated submarine volcanic rises on submarine ophiolites (Lahn-Dill syncline, Elbingerode in the Harz Mountains).

Carbonate sedimentation starts everywhere with a widespread carbonate bank (Schwelm facies). This bank is the foundation for the subsequent younger true reefs. The well-bedded bank carbonates are commonly dark and fine grained. The potential reef builders—stromatoporoids and tabulate and rugose corals—built flat, widespread biostromal structures in a muddy environment rather than wave-resistant structures. Within the bank, 8 subfacies can be distinguished.

Overlying the bank, isolated and locally restricted true reefs (Dorp facies) show mostly atoll-like features. At the western margin of the Old Red continent a now-eroded, oblong reef rim probably existed. Within the reefs, 7 forereef, 2 reef-core, and 12 backreef subtypes can be distinguished. Transgressions and regressions of the sea resulted in cyclic sedimentation on the flat, widespread shelf-lagoon. Locally the transgressive cycles start with black marls, whereas the regressive cycles terminate with laminites and erosion features. The topmost parts of the subsiding reefs are built of convex limestone caps (Iberg facies), tens of meters thick; there is no backreef lagoon facies. Two facies subtypes can be recognized within these very fossiliferous limestone caps—biodetrital limestones with a high original interframe porosity, and micritic limestones with "stromatactis" (so-called still-water bioherms).

The interreef basins between the isolated reef complexes are characterized by black bituminous shale (so-called "Flinz" facies). Also in the geosynclinal trough, dark, pelagic shales are present. Limestone turbidites are continuous from the outer forereef flanks into the adjacent deeper basins.

Dolomitization occurs mainly in the fine-grained bank types and the micritic backreef subtypes, whereas the reef-core and the sparry-cemented, forereef subtypes are less dolomitized. The dolomitization is preponderantly epigenetic (bound to joints, faults, bedding planes, or schistosity planes). No economic discoveries of oil or gas have been made in the Devonian carbonate complexes in central Europe. Origin and source of asphaltite in the isolated small Iberg-Winterberg reef, Harz Mountains, are still unresolved.

LENNON, R. B., Shell Oil Co., Bakersfield, Calif.

Width-Thickness Relations for Fluvial and Shoreline Sand Bodies

The relation between the width and thickness measurements of 2 different types of sand bodies were studied. The measurements were gathered from more than 100 literature sources.

The reduced regression line through the width-thickness data for shoreline sand bodies is significantly different from a similar line determined for fluvial sand bodies. The lines are almost parallel with the shoreline sand line, a fact which shows that shoreline sands have a greater width than fluvial sands for any stated thickness. Both populations may be fit by bivariate log-normal distributions and both result in nearly linear relations between the mean, median, and modal widths and the thickness.

Equations are presented for determining the relative frequency function of the width for any thickness of sand found in a well. Therefore, the probability that the width is greater or less than a stated value, or the probability that the width lies within a particular range, can be determined if one knows only the maximum thickness of the cross section being studied and the type of sand body. The possible error resulting from using a thickness other than the maximum is small when the thickness used is 80 ft or more for a fluvial sand body and 50 ft or more for a shoreline sand body.

LINTZ, JOSEPH, JR., Univ. Nevada, Reno, Nev.

Remote Sensing for Petroleum

Remote sensing techniques in the exploration for petroleum have not moved from the small-scale, limited-study-area, experimental state to full-scale, large-area, operational status. Remote sensing techniques will have come to maturity when total basin surveys for known and potential hydrocarbon anomalies are commonplace. As with much of petroleum exploration, remote sensing is primarily an indirect technique limited to the development of drillable petroleum prospects. Remote sensing techniques include spectroscopic analysis, which offers the potential for airborne geochemical surveys. Research toward the latter objective is still in early phases.

The most commonly used wavelengths are the visible part of the spectrum (0.3–0.7μ), infrared film emulsions (0.3–1.1μ), and thermal infrared (8–14μ). Equipment and materials covering these spectral bands are the best developed and the most widely available.

Exploration in areas of consistently poor illumination because of meteorologic conditions will bring about increased use of the longer wavelength (microwave) equipment. Cloud penetration is a function of wavelength; passive microwave radiometers, side-looking radar, and scatterometers possess this capability. Currently, airborne microwave instrumentation is not widely available, but indications are that it will come into wider use.

Educational opportunities to orient exploration personnel to the uses and limitations of this new tool appear adequate. In addition to the proliferation of short courses on remote sensing at numerous universities, industry-sponsored seminars have been conducted.

Service companies prepared to perform multisensor data collecting on a global scale are now operational. They offer, on a contract basis, sophisticated equipment in advanced aircraft, with or without interpretation packages. In addition to petroleum companies, their clientele includes mining companies, widely diversified agricultural interests, and domestic and foreign government agencies.

LLOYD, R. MICHAEL, Shell Development Co. Exploration and Production Research Center, Houston, Tex.

Application of Stable Oxygen and Carbon Isotope Techniques to Studies of Diagenesis

Oxygen and carbon-isotope techniques are well established in classical paleotemperature work, in the fields of igneous and metamorphic petrology, and in certain phases of organic geochemistry. However, there is a wealth of fundamental data on the isotopic behavior of sedimentary rock-forming mineral systems (carbonates, silicates, sulfates, and their interaction with various fluids) that await systematic exploitation by geochemists interested in low-temperature diagenesis of sedimentary rocks. One example of specific isotopic studies involves early dolomitization.

LUMSDEN, D. M., Dept. Geology, Memphis State Univ., Memphis, Tenn.

Markov Chain Analysis of Carbonate Rocks: Applications, Limitations, and Implications as Exemplified by Pennsylvanian Carbonates in Southern Nevada

Markov chain analysis is a simple, powerful, mathematical tool for testing the presence, absence, and length of "memory" in a sequence of events. Use of this method on the Pennsylvanian carbonates of southern Nevada revealed the presence of a "memory" ($X^2 = 32.55$ with 15 df) in the thick basinal interval of the Bird Spring Group of the Arrow Canyon Mountains and a relative lack of memory ($X^2 = 20.5$ with 15 df) in the thinner, age-equivalent, shelf deposits of the Callville Limestone on Frenchman Mountain.

Covered intervals have little effect in situations