understanding of fossil reefs, ideas on genesis of the Cincinnati arch, and demonstration of the great stratigraphic-paleontologic principles. We have learned only recently, however, that the formations, thickening northward and all exposed, are, in ascending order, the Brassfield limestone, Osgood-Laurel section (so-called), Waldron shale, Louisville limestone, Missisinewa shale, Liston Creek limestone, unnamed rocks, and equivalents of lower Salina rocks of Michigan. Rocks below the Waldron (Llandovery in age) are coextensive with most of the undifferentiated Niagaran and lower rocks in southernmost Michigan and with the Cedarville dolomite and lower rocks in western Ohio. Waldron and higher Niagaran rocks (Wenlock and Ludlow) mostly terminate northward in a reef bank crossing the northern quarter of Indiana. The type Huntington dolomite is a reefy facies of Mississinewa and higher Niagaran rocks, although "Huntington" has been applied throughout the Niagaran. The Salina equivalents partly abut against the bank and partly overlie and extend in two tongues south of the bank, partly complement in thickness the reef-bearing formations, and lie from north to south on *lower* to upper Niagaran rocks.

We postulate southward Silurian expansion of the Michigan basin prototype and consider that lower and middle Silurian sediments were deposited in the subsiding basin in southernmost Michigan and northernmost Indiana and on a relatively stable shallow-water shelf at the south. During late Niagaran and then early Cayugan time, the basin margin became better defined by southward shelf-edge sharpening that resulted from continued relatively greater subsidence northward and extensive fringing bank growth. Bank growth resulted in near-restriction of sea-to-basin circulation to two inlets corresponding to present structural sags in Cass and Jasper Counties. Post-Silurian events helping to define the present basin and the flanking Cincinnati arch include interruption and renewal of basin subsidence; probable inlet closing and deposition of lower-middle Devonian evaporite-bearing sediments, whose southern boundary marks approximately the southern margin of the Michigan basin; and differential subsidence of the Illinois basin, which imparted the southwesterly dip to part of the Silurian shelf area.

We conclude, not entirely facetiously, with the question: Is part of the Cayugan in Michigan and Indiana Niagaran in age, or is part of the Niagaran Cayugan?

PITCHER, MAX, Continental Oil Company, Ponca City, Oklahoma

Evolution of Chazyan (Ordovician) Reefs of Eastern United States and Canada

Chazyan (lower middle Ordovician) reefs from the Virginias, Vermont and New York, and Quebec show changes in organic composition through time. In the evolution of reef communities, these Chazyan reefs represent assemblages or organisms which are transitional in taxonomic composition and ecologic setting between pre-Chazyan and Silurian reefs.

Early Chazyan trepostome (*Batostoma*) and cyclostome (*Cheiloporella*) bryozoans built linearly aligned reefs up to 10 feet high in shallow, agitated waters. The reef matrix of carbonate mud and skeletal debris differs markedly from the cross-bedded, mud-free skeletal carbonates adjacent to the reefs.

Middle Chazyan reefs shown an evolution of reef assemblages from a laminar stromatoporoid (*Cystostroma*)—algal (*Anthracoporella*) composition to an assemblage with a higher percentage of tabulate corals (*Billingsaria*), sponges (*Zittelella*), and a different stromatoporoid (*Pseudostylodictyon*). At the top of the Middle Chazyan, three separate assemblages (stromatolite-calcareous alga-nautiloid, trepostome and cyclostome bryozoans, and stromatoporoid-sponge-coral) are all in close lateral contact with each other and appear to have been contemporaneous. In the Upper Chazyan, the trepostome bryozoans replace the stromatoporoids of the early assemblages and combine with the alga (*Anthracoporella*) to form a different assemblage. This succession of assemblages takes place with no apparent change in habitat.

The Lower Chazyan bryozoan reefs contain more detrital quartz and have more pronounced cross-bedding in adjacent sediments than the younger Chazyan reefs, indicating that the bryozoans existed in more agitated conditions closer to land than the later assemblages. However, close proximity of oölitic and oncolitic carbonates, dislodged and tumbled corals and stromatoporoids, erosional channels and margins cut into the reefs, and the presence of blue, green, and red algae suggest that the Middle and Upper Chazyan reefs also developed in shallow water.

A spectrum of textures in the non-reef sediments, mudstones through well washed grainstones, represents most stages from restricted to open circulation, high energy conditions in their environments of deposition.

The sequence of diagenetic events that affected the limestones is: formation of rim cement in grainstones before and concomitant with pore-filling drusy cementation, dolomitization, lithification of carbonate mud, and finally grain growth in the aragonite skeletons and carbonate mud.

POPENOE, W. P., University of California, Los Angeles, California; and KLEINPELL, R. M., 5959 Margarido Dr., Oakland, California

Age and Stratigraphic Significance for Lyellian Correlation of the Vigo Formation and Fauna, Luzon, Philippines

The late R. E. Dickerson, in 1921, put forward the theory that tropical Tertiary molluscan faunas evolve much more slowly than do faunas from temperate regions; hence, that the percentage of Recent species in later Tertiary tropical faunas is considerably higher than in contemporaneous faunas from temperate regions. This theory, derived from analysis of a tropical fauna of inferred Miocene age from the Philippine Islands, has been frequently cited but has never been critically evaluated.

Studies of Philippine and Indonesian later Tertiary molluscan and foraminiferal faunas collected since Dickerson's time, and accurately placed stratigraphically, indicate that the Philippine molluscan faunas Dickerson believed to be of Miocene age are more probably later Pliocene in age, with a percentage of extinct species differing not very greatly from the percentages established by Lyell and Deshayes for contemporary faunas in Europe. The theory that tropical molluscan faunas evolve at a markedly different rate than those of temperate regions is therefore without basis and is probably erroneous.

PURDY, EDWARD G., Rice University, Houston, Texas

Diagenesis of Recent Marine Carbonate Sediments

The diagenesis of carbonate sediments can be ascribed conveniently and naturally to pene-depositional and post-depositional processes. Pene-depositional effects occur at or a short distance below the sediment-water interface; post-depositional effects result largely from solution alteration accompanying subaerial exposure and (or) increasing lithostatic pressure. The thinness of Recent carbonate accumulations precludes solution alteration due to lithostatic pressure; consequently the present discussion is confined to the remaining diagenetic processes.

Within the marine environment pene-depositional diagenesis affects both sedimentary structures and grain textures. The most obvious, and perhaps most important, structural change is the destruction of stratification in carbonate mud deposits by a vagile infauna. Indeed, this absence of stratification is so commonplace that the occasional occurrence of laminated carbonate mud deposits heralds unusual environmental conditions.

The most important change in grain texture results from the recrystallization of various grain types, both skeletal and non-skeletal, to cryptocrystalline carbonate. Recrystallization is effected by the replacement of aragonite by aragonite or by the replacement of high magnesium calcite by high magnesium calcite. The only obvious change accompanying this replacement is the obliteration of the pre-existing crystal fabric of the affected grain. In fact, there seems to be no decrease in solubility accompanying the replacement. These data coupled with the observed replacement of organic matter by cryptocrystalline carbonate suggest that decomposition of the contained organic matter in certain carbonate grain types may indirectly effect recrystallization to cryptocrystalline carbonate.

Subaerial exposure of unconsolidated carbonate deposits results in carbonate solution, replacement, and precipitation in that order. High magnesium calcite and aragonite are dissolved preferentially by meteoric water until the percolating solutions become saturated with respect to low magnesium calcite. At this point the more soluble high magnesium calcite and aragonite constituents are replaced by less soluble low magnesium calcite. Pore space precipitation of low magnesium calcite occurs when calcite saturated solutions lose water or carbon dioxide. Precipitation and (or) replacement transform the unconsolidated carbonate deposit into a limestone.

RAPSON, JUNE E., Calgary, Alberta, Canada

Diagenesis in Jurassic-Cretaceous Clastic Rocks in Southwestern Alberta and the Interpretation of Sedimentary Environments

Coarse-grained clastic rocks at the top of the Kootenay formation and the base of the Blairmore group are transitional between the Jurassic and Cretaceous systems in the westerly regions of the area.

The subsurface equivalents in the easterly regions of the area occur at the base of the Blairmore or Mannville groups and are known locally as the Basal quartz, Ellerslie, Sunburst, Cutbank and Dina sands, respectively; all are generally considered Cretaceous in age and overlay either the Paleozoic surface or members of the Jurassic Ellis group. Where the Cretaceous overlies the Paleozoic, a residual or detrital bed commonly occurs and is known as the Deville member of the Mannville group.

Petrographic examination of the transitional or basal Cretaceous clastic rocks indicates that there are three main authigenic mineral facies developed largely irrespective of rock type in "residual beds," shales, siltstones, sandstones, and (or) conglomerates.

The three diagnostic authigenic minerals are hematite, siderite, and pyrite; other significant authigenic minerals present are magnetite, iron-rich dolomite, calcite, kaolinite, silica chlorite, and glauconite.

The presence of these authigenic minerals, together with various physical features of the sedimentary rocks, assists in elucidating the intricate paleographic pattern of estuaries, rivers, lakes, and land surfaces.

RAPSON, JUNE E., University of Alberta, Calgary, Alberta, Canada

Intrusive Carbonate in the Ice River Complex, British Columbia

The Ice River valley is situated in Yoho National Park in the westerly ranges of the southern Rocky Mountains, British Columbia. The region is the site of a nepheline syenite-ijolite-jacupirangite complex which is intruded into Cambro-Ordovician sediments and is dated (potassium-argon method with biotite) as Devonian in age.

Associated with the ijolite-jacupirangite differentiates is a mass of brown-weathering carbonate (dominantly iron carbonate with calcite and iron oxide) at least 2 miles long and 900 feet across. This mass was originally described as a "stoped block or roof pendant" but recent field observation indicates that the carbonate is intrusive. Two traverses are described.

The carbonate is succeeded by an intensely fractured and brecciated ferruginous zone, which merges into carbonatized aegirine-feldspar gneisses which in turn merge into and alternate with ijolite or the aegirine-feldspar pegmatite dykes that cut the ijolite. Augen of unaltered to partly altered pegmatite occur commonly in the gneiss. Pods and lenses of carbonate (similar in composition to that of the main mass and as much as 500 feet from it) are associated with the gneiss.

A 10-foot zenolith of aegirine-feldspar pegmatite occurs in the main mass of carbonate. Toward the periphery of the zenolith the pegmatite merges into gneiss, then gneiss with carbonate and finally carbonate.

The carbonate mass may be termed carbonatite.

REXROAD, CARL B., Indiana Geological Survey, Bloomington, Indiana

Silurian Conodonts from Central Kentucky and Their Relation to European Zones*

The Brassfield limestone and the overlying Crab Orchard formation of Madison and Estill Counties, central Kentucky, represent a nearly continuous sequence of strata of Llandovery and early Wenlock age. The conodont sequence very closely parallels that of Europe, and zones I and II (Llandovery in age) and zone III (early Wenlock(?) in age), as recognized by Otto Walliser, are found here.

The Brassfield limestone and the Plum Creek clay, Oldham limestone, Lulbegrud clay, and Waco limestone members of the Crab Orchard contain conodonts of zone I for which *Icriodina* is the most important guide. Zone II conodonts are found in a thin zone transitional between the Waco and the Estill clay member, and the lower part of the Estill contains new genus A and *Bryantodus?* sp., which are characteristic of European zone III. Zone III conodonts have been considered to be early Wenlock in age, but exact correspondence with the graptolite zones is uncertain.

Northward in Ohio and west of the Cincinnati arch in Indiana and Kentucky, the Brassfield also contains a zone I fauna. As the Crab Orchard formation is traced

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