Upper Ordovician (Cincinnatian) strata in Ohio, Indiana, and Kentucky were deposited as cyclic sequences. Three types of cycles are represented: thin, graded storm cycles, moderately thick megacycles (carbonate to shale sequences), and thick shoaling-upward cycles (shale-rich, grainstone-poor facies that grade upward into shale-poor, grainstone-rich facies).

Cincinnatian strata were deposited on a gently sloping, shallow-marine carbonate ramp. Sedimentation was episodic; periods of in-situ carbonate accumulation were frequently interrupted by storm events. Tropical storms affected sedimentation and benthic ecology in seven ways by: (1) eroding sediments; (2) transporting allochthonous clays and silts onto a carbonate ramp; (3) winnowing, transporting, and redistributing carbonate sediments; (4) generating downslope gravity flows; (5) mixing benthic fauna from different communities; (6) periodically interrupting the process of community succession; and (7) creating favorable conditions for the evolution and success of opportunistic species.

Because of the excellent preservation of episodic storm events and their influence on sedimentation and paleoecology, the Cincinnatian Series is recognized as an example of an ancient storm-dominated, carbonate ramp. The following characteristics are diagnostic of storm domination in the rock record: (1) abundant storm sequences occur in all facies; (2) storm sequences are variable; (3) inner shelf facies have thin, discontinuous bedding; (4) rudites dominate in inner shelf facies; (5) fine grainstones are concentrated in outer-shelf facies; (6) textural inversions are common; (7) carbonate rock types are widely variable; (8) storm-generated structures occur in all facies; (9) in-situ faunal communities are rare; and (10) most beds contain a mixture of fossil-preservational states.

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Reservoir Development in Ellenburger Group of West Texas—a Diagenetic Jambalaya

Porosity and permeability in the Ellenburger Group of west Texas result from a complex interaction of early to late diagenetic processes. Porosity formation occurred in at least seven stages: (1) early marine phreatic calcite cementation, (2) fabric-selective (mixing-zone?) dolomitization, which created intercrystalline porosity, (3) episodic subaerial exposure and karstification, which created vuggy, cavern, solution-channel, moldic, fenestral, breccia, and fracture porosity, (4) mineralogy-selective meteoric phreatic or mixing-zone silicification, which preserved existing porosity by preventing further carbonate cementation, (5) deep-burial xenotopic dolomite recrystallization, which destroyed nearly all of the precursor intercrystalline porosity, (6) deep-burial dolomite, calcite, and anhydrite cementation of some vugs and fractures, and (7) late-stage tectonic fracturing, which created most of the reservoir permeability.

The Ellenburger Group consists of numerous vertically stacked subaerial exposure cycles 1-20 ft thick. Porosity within each cycle is laterally discontinuous and patchy. The complete cycle is composed of four zones (from top to bottom): (1) glauconitic shale, which is interpreted to be a paleosoil horizon, (2) brecciated dolomite, cherty dolomite, or chert, which formed from solution collapse, (3) nonbrecciated dolomite containing abundant dissolution-generated porosity, and (4) nonporous dolomite, which was largely unaffected by karstification. Zones 1 and 4 are nonporous with very low permeability; zones 2 and 3 have high porosity and permeability. The presence of subaerial exposure cycles throughout the Ellenburger Group has resulted in numerous vertical permeability barriers, which may be the cause of reservoir stratification in some fields.

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Diagenesis of Miocene Gas Sands in Pattani Basin, Gulf of Thailand

Diagenesis of early Miocene sandstones in the Pattani basin resulted in rapid cementation and degradation of reservoir quality with increasing depth of burial. These subquartzose sandstones provide an example of accelerated burial diagenesis in an area of unusually high geothermal gradient. Burial compaction, progressive cementation by quartz overgrowths, and development of authigenic kaolinite and illite have substantially reduced porosity and impaired permeability at depth. Abundance of quartz overgrowths increases with depth, indicating continuous or episodic silica cementation. Kaolinite occurs as a pore-filling cement between depths of 4,500 and 10,000 ft (1,375-3,050 m). Illite is common as pore-linings and also bridges pores in deeper zones (8,000-10,000 ft or 2,450-3,050 m). Minor cements include calcite, dolomite, siderite, pyrite, mixed-layer illite-smectite, and chlorite. Feldspars display textures that indicate progressive dissolution with increasing burial depth. Large intergranular pores are present in permeable sandstones between 3,000 and 7,500 ft (925-2,275 m). In low-permeability sandstones from deeper zones (7,500-10,000 ft or 2,275-3,050 m), porosity is largely restricted to voids within detrital feldspar grains. Many of these secondary pores are partly filled by authigenic kaolinite and illite, and their pore apertures are usually smaller (1-15 μm diameter) than intergranular pore apertures (10-75 μm diameter). Good reservoir properties in the Pattani basin are generally restricted to sandstones above 7,500 ft (2,275 m) that contain large intergranular pores. Abundant secondary porosity below 7,500 ft (2,275 m) is generally associated with poor reservoir properties; however, favorable reservoir properties may occur locally where large feldspars have been leached from coarse-grained sands.

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Origin and Diagenesis of Beachrock, Discovery Bay, Jamaica

From in-situ pore water and rock analyses of a lithified Holocene beach deposit in Jamaica (1,240 ± 50 yr B. P. at 22 cm depth, 670 ± 50 yr B. P. at 14 cm depth, 0 yr B. P. at surface), we propose a geochemical model for intertidal carbonate cementation. The beachrock unit is laterally and vertically discontinuous with unconsolidated beach sands surrounding it. The unit dips seaward at an angle of 10° and contains localized open orthogonal fractures that are oriented parallel and normal to the shore line. Three distinct cement types are found in Jamaican beachrock: (1) equant and bladed high-Mg calcite (12-29 mole % $MgCO_3$), (2) low-strontium fibrous aragonite (1,700-3,100 ppm SrO), and (3) micritic high-Mg calcite envelopes. These cements vary both laterally and with depth in the unit, and accurately reflect the changes in time and space of the chemistry of the interstitial water; the cements are produced in stoichiometric equilibrium with the pore-water chemistry. The high-Mg calcite cements are precipitated when CO_2 degases ($P_{CO_2} = 10^{-5.1}$) through agitation in the surf and consequently raises the pH to a maximum of 8.4 during the higher tides. During these times, the pore waters are saturated with respect to the precipitating Mg calcite containing 15-29 mole % $MgCO_3$. During low tide, when the agitation of the surf is minimal, the CO_2 does not degas, increasing the P_{CO_2} to a maximum of $10^{-4.0}$. Continued precipitation aids in the increase in CO_2 levels, the decrease in pH to a minimum of 7.9 and the lowering of saturation states of Mg calcites. Phreatic fresh water flows seaward during low tide, preferentially through the open fractures, lowering strontium levels and saturation states in the pore waters. Thus, at low tide, lower Mg calcites of 12-15 mole % $MgCO_3$ are precipitated where fresh water has not invaded (maximum Cl = 22‰). Models of Sr partitioning show low-strontium aragonite is produced from the neomorphism of high-Mg calcites near the open fractures in mixed meteoric and marine interstitial waters (Cl = 11.05-13.48‰). Our data suggest that P_{CO_2} is the master variable and that beachrock cements are not static but ever-changing in mineralogy and chemistry.

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Fluid Inclusions and Porosity Development in Arun Gas Field, Indonesia

The Arun gas and condensate field in northern Sumatra is a large Miocene coral-algal reef complex. The Arun limestone is rich in lime mud throughout the section, and low to moderate-energy paleoenvironments are indicated. The reservoir facies are strongly affected by diagenesis and display several secondary porosity types, including moldic, vuggy, breccia, and fracture porosities. Without the diagenetic alteration of otherwise tight muddy limestones, reservoir facies would not have developed at Arun. To put constraints on the timing of porosity development in Arun field, fluid inclusions were examined in coarse calcite cements which partially or completely filled some of the secondary pores. The fluid within the inclusions is brackish with an equivalent of 2.5 wt. % NaCl.

Homogenization temperatures, after pressure correction, suggest that the cementation began close to the maximum burial depth and as recently as 5 Ma. Since the cement postdates the formation of secondary pores, it is conceivable that secondary porosity could have developed not only in the shallow subsurface (i. e., the vadose zone), but also in moderate to deep burial conditions. Shales surrounding the Arun reef are overpressured as a result of dewatering during smectite-illite conversion and have expelled water into the Arun limestone. This process may contribute to