

units can occur and more fracturing should enhance reservoir performance. (4) Younger sandstones in the Upper Cretaceous Lance and Paleocene Fort Union Formations are also overpressured in the deepest basin areas because of gas generation from associated coals. These formations should contain significant gas accumulations.

MEISSNER, FRED F., Webb Resources, Inc., Denver, CO

Examples of Abnormal Fluid Pressure Produced by Hydrocarbon Generation

Abnormally high pore fluid pressures may be produced as a result of hydrocarbon generation from organic matter (kerogen) contained in "source rocks." Contributing processes include: (1) collapse of rock matrix as overburden-supporting solid kerogen is converted to non-expelled fluid hydrocarbons and (2) volume increases produced by the conversion of solid kerogen to hydrocarbons.

Hydrocarbon generation overpressures exist in the following basins: Williston, Powder River, Anadarko, Delaware, Uinta, and San Joaquin. The phenomenon probably also exists elsewhere. These regions of overpressure represent vertically and laterally restricted "cells" or "pods" in which hydrocarbons are the overpressuring fluid and the only initially producible fluid species present. The pressure cells center around actively generating source-rock units.

Actively generating source rocks within the pressure cells may be characterized by abnormally high electrical resistivities and abnormally low sound velocities. Resistivity increases may be caused by the replacement of conductive pore water with non-conductive hydrocarbons. Low sound velocities may be caused by: (1) the replacement of higher velocity pore water with lower velocity hydrocarbons and (2) the effects of abnormal pressure on porosity enhancement or preservation through dilation or under-compaction.

Hydrocarbon generation overpressures lead to the spontaneous hydraulic fracturing of the source rock and may create associated fracture-type reservoirs. They may also create fractures which propagate upward or downward from the source rocks and control vertical migration through large thicknesses of seemingly impermeable confining strata.

When a source rock ceases to generate, abnormal pressures may decay, resulting in normal or subnormal pressure conditions.

MENCH, PATRICIA A., Conoco Inc., Ponca City, OK, F. J. PEARSON, JR., Intera Environmental Consultants, Houston, TX, and RUTH G. DEIKE, U.S. Geol. Survey, Reston, VA

Stable Isotope Evidence for Modern Freshwater Diagenesis of Cretaceous Edwards Limestone, San Antonio Area, Texas

The Cretaceous Edwards Limestone in south-central Texas was deposited in alternating shallow-marine, intertidal, and supratidal environments and underwent

normal early diagenesis. First-stage calcites include calcitic shell material, unaltered marine micrite, submarine cement, and meteoric phreatic or shallow subsurface cements. The first-stage calcites yield isotopic values of $\delta^{13}\text{C}$ from -1.0 to $+3.5$ and $\delta^{18}\text{O}$ from -6.0 to $+3.0$.

Dolomite in the Edwards occurs in a variety of forms. These forms range from "dirty" rhombs (1 to 5 μm), petrographically very similar to but isotopically slightly lighter than modern tidal flat dolomites ($\delta^{18}\text{O}$ of 0.5 and $\delta^{13}\text{C}$ of 3.0 for the most hypersaline dolomites), to perfectly formed rhombs (30 to 40 μm) interpreted as freshwater dolomite ($\delta^{18}\text{O}$ of -5.7 and $\delta^{13}\text{C}$ of 1.7).

The Edwards was divided into two diagenetic zones by Miocene faulting along the Balcones fault zone. On the upthrown side of the fault, an oxidized freshwater aquifer developed. This water is now saturated with calcite, but undersaturated with dolomite and gypsum. Relatively stagnant brackish and reduced water on the downthrown side of the fault is saturated with calcite, dolomite, and gypsum. Differences in the chemistry of the interstitial fluids in these zones are related to different types of diagenesis.

Second-stage calcites, which can be separated regionally and petrographically from first-stage calcites, formed after faulting and result from reactions between first-stage calcites and dolomites and fresh water introduced after faulting. These reactions can be written generally as: Fresh Water + Dolomite + Gypsum \rightarrow Brackish Water + Calcite. Second-stage calcites are as light as -7.5 ppm $\delta^{13}\text{C}$ and -10.0 ppm $\delta^{18}\text{O}$, and these values vary inversely while the ratios of first-stage calcite cements are heavier and vary together. The second-stage calcites are considerably lighter because they have grown in equilibrium with meteoric water containing some organically derived carbon, and sometimes at considerable depth.

MERRILL, GLEN K., College of Charleston, Charleston, SC, DAVID T. LONG, Michigan State Univ., East Lansing, MI, and W. FRED FALLS, Univ. South Carolina, Columbia, SC

Organophosphorites in Carboniferous Rocks of Central United States

Although generally called "black shales," "sheety shales," or "paper shales," thinly bedded black rocks in upper Carboniferous successions in the Illinois basin and Mid-Continent are actually fissile coals. Thin section examination demonstrates that these rocks are as much as 90% carbon by volume. In addition to carbon, all these rocks contain large amounts of non-skeletal and much skeletal phosphate as fecal masses, gastric residues, teeth, bones, cartilage, brachiopod shells, and conodonts. We have elected the term "organophosphorite" for these rocks rather than "shale," because many of them contain less than 10% terrigenous clay.

Sources of the organic carbon, including kerogens, were varied and distributed among several plant and animal groups. Driftwood is common and testifies to input from terrestrial plants. Algal components probably dominated the plant fraction, but have left only vague traces. Animal phyla from Protozoa through Chordata are represented, but with heavy bias toward

those with siliceous (radiolarians, sponges), or phosphatic (brachiopods, conodonts, bony fish and sharks) skeletons. This indicates an abundance of mobile organisms in the depositional environment, mostly nekton with some plankton and pseudoplankton.

In addition to the production of diverse hydrocarbons, living organisms were responsible for the biogenic phosphate, some biogenic silica, and such heavy metals as zinc (<4,000 ppm) and uranium (<10 ppm).

Many lines of evidence, including stratigraphic distribution, paleoecology, and taphonomy, point convincingly to an origin in coastal marine environments analogous to modern salt marshes but with mostly floating vegetation.

MEYERS, WILLIAM J., and KYGER C. LOHMANN, State Univ. of New York, Stony Brook, NY

Geochemistry of Regionally Extensive Calcite Cement Zones in Mississippian Skeletal Limestones, New Mexico

Petrography and cement stratigraphy of four regionally extensive cement zones in Mississippian crinoidal limestones indicate that these cements precipitated in meteoric phreatic environments. Each major zone has a distinct isotopic and trace element composition.

Marine cements and lime muds in bioherms associated with the crinoidal sands have marine $\delta^{13}\text{C}_{\text{PDB}}$ (+4.0 ppm). Phreatic cements become lighter in $\delta^{13}\text{C}$ in progressively younger zones 1, 2, and 3, representing a trend toward more contribution of organically derived carbon to precipitating waters. Since zones 1, 2, and 3 were all precipitated at shallow burial depths, their trend toward lighter $\delta^{18}\text{O}$ with decreasing age suggests increasingly light waters isotopically. At 25°C, the waters responsible for zone 1 and 3 cements are estimated as $\delta^{18}\text{O}_{\text{SMOW}} = +1.5$ and -0.9 ppm, respectively. The $\delta^{13}\text{C}$ of zone 5 cement is interpreted as a combination of rock-derived and organic-derived carbon, some of which probably came from overlying Pennsylvanian strata. The distinctively light $\delta^{18}\text{O}$ of zone 5 is attributed to precipitation at somewhat elevated temperatures, averaging about 45°C, a value in agreement with estimated burial depths.

Zone 1 cements appear to have formed in seaward parts of a freshwater phreatic system at shallow burial depths (relatively heavy $\delta^{18}\text{O}$). Zone 1 magnesium and carbon were derived from dissolution of skeletal high-Mg calcites (high Mg and heavy $\delta^{13}\text{C}$). The driving force for zone 1 cementation was thus the solubility difference between high-Mg crinoidal calcite and low-Mg zone-1 calcite. Zone 2 also precipitated at shallow depths but in a more widespread groundwater system that contained some organic carbon (light $\delta^{13}\text{C}$) and had a more landward recharge area (lighter $\delta^{18}\text{O}$). Likewise, zone 3 is formed in a shallow-phreatic lens but with the most landward (freshest) recharge (lightest $\delta^{18}\text{O}$). The inferred importance of organic-derived carbon in zone 3 (light $\delta^{13}\text{C}$) suggests degassing of CO_2 as a driving force for precipitation. The light $\delta^{18}\text{O}$ of zone 5 reflects precipitation at elevated temperatures of deeper burial (750); its element composition (table) suggests a variety of intraformational and extraformational sources.

	$\delta^{13}\text{C}_{\text{PDB}} \text{ ‰}$	$\delta^{18}\text{O}_{\text{PDB}} \text{ ‰}$	Wt. % MgO	Wt. % MnO	Wt. % FeO
ZONE 1 (oldest)	+3.7	-1.4	0.28	0.012	0.015
ZONE 2	+2.4	-2.8	0.15	0.056	0.068
ZONE 3	-0.5	-3.6	0.10	0.015	0.016
ZONE 5 (youngest)	+2.2	-7.0	0.16	0.052	0.185

MIDDLETON, LARRY, and JAMES R. STEIDTMANN, Univ. Wyoming, Laramie, WY

Sedimentology and Paleogeography of Cambrian Transgression in Wyoming

Middle and Upper Cambrian deposits in Wyoming represent a classic transgression or onlapping sequence of clastic and non-clastic rocks. However, sedimentologic and paleontologic criteria indicate deposition in a variety of shallow-marine, nearshore environments rather than in a simple progressively deepening marine setting.

The basal, coarse-clastic Flathead Sandstone was deposited in fluvial and nearshore marine environments as evidenced by sedimentary and biogenic structures. Braided stream deposits are characterized by alternating sets of planar cross-stratified and horizontally-bedded conglomerate and sandstone. Intertidal deposits consist of ripple cross-stratified sandstone and silty mudstone. Herringbone cross-stratification and desiccation features are common. Subtidal deposits consist of tabular and lenticular sandstone with both large-scale compound cross-stratification and small-scale trough cross-bedding. Younger, fine clastic and carbonate sequences (Gros Ventre and Gallatin Formations) represent more offshore environments where ooids and stromatolites formed on carbonate shoals.

The shoreline was oriented north-south throughout the Cambrian and was characterized by numerous embayments and islands of Precambrian basement. A number of local, as well as regional, regressions are recorded within this easterly transgressive sequence.

MILLER, F. X., R. W. PIERCE, and F. R. SULLIVAN, Amoco Production Co., Tulsa, OK

New Precision in Biostratigraphy Through Graphic Correlations

Historically, many paleontologic techniques have been proposed which establish biostratigraphic correlations. None of these methods have entirely attained the biostratigraphic resolution now required by exploration geologists for their refined and often subtle stratigraphic plays.

The graphic correlation technique developed by A. B. Shaw offers new precision in biostratigraphy by simultaneously utilizing the "total stratigraphic range" of several fossil groups preserved in the geologic record. Precise correlations of time-equivalent intervals of rock can be made on a local, regional, or worldwide scale.

Time-stratigraphic correlations developed by the graphic technique can be used by the exploration geolo-