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.

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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 $\delta^{13}C_{PDB}$ (+4.0 ppm). Phreatic cements become lighter in $\delta^{13}C$ 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 $\delta^{18}O$ with decreasing age suggests increasingly light waters isotopically. At 25°C, the waters responsible for zone 1 and 3 cements are estimated as $\delta^{18}O_{SMOW} = +1.5$ and -0.9 ppm, respectively. The $\delta^{13}C$ 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 $\delta^{18}O$ 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 $\delta^{18}O$). Zone 1 magnesium and carbon were derived from dissolution of skeletal high-Mg calcites (high Mg and heavy $\delta^{13}C$). 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 $\delta^{13}C$) and had a more landward recharge area (lighter $\delta^{18}O$). Likewise, zone 3 is formed in a shallow-phreatic lens but with the most landward (freshest) recharge (lightest $\delta^{18}O$). The inferred importance of organic-derived carbon in zone 3 (light $\delta^{13}C$) suggests degassing of CO_2 as a driving force for precipitation. The light $\delta^{18}O$ of zone 5 reflects precipitation at elevated temperatures of deeper burial (750); its element composition (table) suggests a variety of intraformational and extraformational sources.

	$\delta^{13}C_{PDB}$ o/oo	$\delta^{18}O_{PDB}$ o/oo	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

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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.

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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 geologist to interpret lithologic correlations and stratigraphic relations, and to chronostratigraphically reconstruct the geologic history of a field or basin.

A brief explanation of the graphic method of time correlation and examples of local, regional, and interregional correlations using both surface and subsurface micropaleontologic and palynologic data generated by the authors is presented. Examples are taken from California, Wyoming, Gulf coastal plain, and Blake Plateau, offshore Florida.

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Depositional Environments and Biogenic Structures, Uppermost Crab Orchard Group (Pennsylvanian), North-Central Tennessee

The depositional environments represented by the uppermost part of the Crab Orchard Group and the facies relations of the enclosed ichnofauna have been based on study of the rock type and physical and biogenic sedimentary structures at five exposures in Fentress County, Tennessee. The sequence includes sandstone, shales, and coals deposited in deltaic and nearshore environments. Rocks of the (?)tidal facies consist of thin-bedded, fine-grained sandstones separated by very thin shale interbeds; individual beds are traceable over 100 m. Some sandstone beds are graded, and low amplitude interference ripples are present but not abundant. Trace fossils include *Astericites, Planolites, ?Biformites*, a small form of *Skolithos*, and abundant trails of the *Palaeobullia* type. Thinly bedded laminated and cross-laminated sandstones deposited under higher energy conditions lack shale interbeds and have abundant oscillation and interference ripples. They have more silica cement and less fine-grained matrix. The ichnofauna consists of *Skolithos, Palaeobullia, Gordia, ?Lennea* and *?Kouphichnium* as well as clearly defined horseshoe crab resting traces. Physical sedimentary structures originally present in lagoonal or interdistributary bay sands were destroyed by intense bioturbation; recognizable trace fossils are *Conostichus, Planolites, Olivellites*, and two types of *Asterosoma*.

The ichnofaunal distribution in these rocks is significant for two reasons. (1) It shows that the distribution of trace producers was controlled by factors readily interpretable from the rock record. (2) The occurrence of horseshoe crab impressions, *Astericites*, and other marine traces gives further evidence that this part of the Tennessee Pennsylvanian section was deposited under predominantly marine conditions.

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Origin of Biogenic Carbonate Sands of Southern Shelf of St. Thomas, U.S. Virgin Islands

Sediments on the southern shelf of the Virgin Islands were investigated as a model of carbonate deposition on an open shelf. To determine the origin of the carbonate sands and to relate origin to environmental processes, surface and core samples were studied. Analysis of surface samples for composition shows that the sand has been derived mainly from calcareous algaes and mollusks by in-situ biogenic production. Zonation of the dominant sand producers is related to the present environmental setting where water depth has the greatest influence.

Dating of cores as long as 5 m by the C-14 method indicates accumulation rates of slightly less than 1 mm/year for the last 5,000 years in the areas of the thickest sand. Faunal studies show that the climate during the last 5,000 years was similar to the present-day climate. The only changes in environmental conditions appear to have been an increase in water depth and a concurrent change in the patterns of water movement. Areas protected during lower sea level have experienced a disappearance of the subtidal barnacle, *Balanus venustus*, and a gradual increase in the amount of coralline algae in the sediment beginning approximately 1,500 years ago. The disappearance of barnacles probably was caused by the introduction of open marine conditions into a previously protected lagoonal area. However, the articulate coralline algae increased in the quiet waters on the lee side of the offshore islands because of a niche created by deepening waters.

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Geometry and Mechanisms of Transverse Faulting, Rocky Mountain Front Ranges, Canmore, Alberta

Although well documented from both the Appalachian and Rocky Mountains, an actual mechanism for formation of faults oriented at high angles to the predominant structural trend appears somewhat enigmatic. A system of transverse faults contained within the major Rundle and Sulphur Mountain thrust sheets has been mapped in detail at a scale of 1:12,000. Mesoscopic fractures, minor folds, and lineations have been analyzed in terms of their interrelation with the major structural features to more accurately delineate the relative timing and actual deformation mechanisms. Analysis of available field data indicates progressive eastward-advancing deformation characterized by large-scale folding followed by thrusting. Specifically, the transverse fault system consists of a major fault which offsets the Sulphur Mountain thrust and terminates within the Rundle thrust sheet and several minor transverse offsets which are restricted to the Sulphur Mountain thrust sheet. Actual translation along transverse faults is thought to coincide with motion along a major hanging wall of an imbricate slice in the Rundle thrust sheet, while post-dating both motion along the Sulphur Mountain sheet and folding of foreland sediments. Calculated values for net slips are approximately parallel to associated lineations and range from a few centimeters to slightly greater than 300 m oriented at high angles to bedding. Analysis of mesocopic fractures indicates a predominance of planes striking roughly normal to the "b" tectonic axis with dips ranging between 60 and 90° in either direction. The observed displacements are thought to have occurred predominantly