by the Muncie Creek Shale and Raytown Limestone.

In a NE-SW outcrop trend across Allen County, Kansas, the Paola Limestone forms the initial substrate on which a phylloid algal buildup developed within the Raytown Limestone. The Paola consists of three distinctive carbonate microfacies (described below). Microfacies 2 overlies microfacies 1; this microfacies association occurs only beneath the phylloid algal buildup. Both exhibit petrographic features indicative of submarine lithification. Northeastward, away from the phylloid algal buildup, microfacies 1 and 2 change abruptly into microfacies 3.

Microfacies 1 is a moderately bioturbated pyritized calcilutite with *Archaeolithophyllum* crusts, *Hikorocodium, Tetrataxis, Tuberitina*, and low-spired gastropods. This microfacies has a highly irregular (scoured) upper surface that is encrusted by *Nubecularia, Archaeolithophyllum lamellosum*, and bryozoans and locally penetrated by borings.

Microfacies 2 consists of profusely bioturbated, matrix-supported, crinoidal-fusulinid biocalcarenite. Large, bean-shaped, algaloid concretions of *Nubecularia* and *Archaeolithophyllum lamellosum* are common accessory components. The large, ramose burrow networks are infilled with microcrystalline dolomite and scattered phosphate nodules; small rugose corals also occur in the burrow fills.

Microfacies 3 is a crinoidal-pelletoidal biocalcarenite containing *Archaeolithophyllum* crusts. *Composita*, oncolites, productid brachiopods, small gastropods, fenestrate bryozoans, brachiopod and echinoid spines, *Nubecularia*-encrusted bioclasts, ostracods, and neomorphosed pelecypods shells are accessory components. Baroque dolomite occurs as a filling within phylloid algal blades. Bioturbation textures are present, but sparse, relative to microfacies 1 and 2.

Prior to lithification, the hardground (microfacies 1) was bioturbated; following lithification it was scoured, encrusted, and bored. The lithification of microfacies 1 is inferred to have occurred in a submarine environment because: (1) it contains a fauna of encrusting marine organisms and (2) petrographic features indicative of subaerial exposure are lacking. Microfacies 2 is interpreted as a firm ground. Microfacies 3 represents a normal, shallow marine subtidal environment.

The recognition of ancient hardgrounds allows a more thorough understanding of the sedimentologic, paleoecologic, and diagenetic histories of carbonate sequences. Submarine diastems also have potential as chronostratigraphic markers.

Because petroleum accumulations are commonly associated with diastems, an awareness of these features could provide insights for the location of some obscure hydrocarbon traps. Additionally, hardgrounds can create intraformational permeability barriers; the recognition of such reservoir heterogeneities is essential for optimum hydrocarbon recovery. Detailed petrographic analysis is a prerequisite to the location and understanding of ancient hardground sequences.

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Regional Fracture Analysis in Western Valley and Ridge and Adjoining Plateau, West Virginia and Maryland

Approximately 2,500 stations were occupied for joint analysis in the western Valley and Ridge and eastern Allegheny Plateau of West Virginia and Maryland. Structural positions range from the Georges Creek-Stony River syncline atop the Allegheny Plateau to the Nittany anticlinorium and western Broad Top synclinorium in the Valley and Ridge. Rocks exposed range in age from Middle Ordovician carbonate within the core of the Wills Mountain anticline to Pennsylvanian coal measures on the Allegheny Plateau. The highest percentage of joint readings was obtained from Middle to Upper Devonian sandstone, siltstones, and shales because of the widespread areal distribution of these rocks within the Bedford and Clearville synclines. Here, fracture trends are similar to those observed in Devonian shale cores taken farther west.

As many as eight different joint sets are present within the study area although only four to five major systematic sets are pervasive throughout the entire region. Most commonly only two, or at the most three, joint sets are present at the scale of the individual outcrop. Consideration of joint crosscutting and offset relationships, tendential and transient features, fibrous mineralization, stylolites, and slickenlines has permitted the establishment of a consistent chronology of joint development throughout the region. Joint set I (N30° to 50°W) formed first as extension fractures early in the lithification history of all formations, followed by a less commonly developed orthogonal set trending N40° to 60°E. Both sets predated Alleghenian folding. Fracture plume data indicate upward propagation for joint development, perhaps associated with regional northeastward extension into the deepest part of the Paleozoic depositional basin. Joint set II (N55° to 70°W) formed second in response to early Alleghenian compressive stress, coupled with continuous subsidence, before folding. Locally, minor and nonregionally pervasive fractures showing shear joint geometry also developed at this time. Joint set III (N20° to 30°E) formed as extension fractures parallel to fold axes, with fracture inception early in fold development. Joint set IV (N75°E to N75°W) shows slickenlines more commonly than other sets and formed late in the folding history, possibly as shear joints where structures were effectively "locked." More likely this set formed as extension joints in response to post-folding stresses, perhaps consistent with the present-day regional stress field. A moderately to poorly developed joint set V (N10°E to N10°W) formed last in the region as an orthogonal set to IV.

The dominant joint set or sets at any location within the study area depend on the bedding thicknesses, lithology, structural position, and early fracture history. Prediction for joint trends, and possible hydrocarbon migration timing at depth in potential fractured reservoirs, must consider this aspect as well as chronological development, especially in view of the different stress fields within lower and upper thin-skinned plates.

The study did not reveal large-scale zones of high joint frequency except for the confirmation of increased fracturing in linear belts such as the Petersburg lineament and Parsons lineament previously reported by Sites, Dixon, Wheeler and Dixon, and Wilson.

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Sedimentology of a Shallowing-Upward Sequence in Middle Cambrian Carbonate-Siliciclastic Associations, Western Wyoming

The Middle-Upper Cambrian succession in western Wyoming comprises a series of interbedded siliciclastics and carbonates, some of which were deposited in a variety of shallowing-upward sequences. Although the overall succession of basal Flathead Sandstone-Gros Ventre Formation-Gallatin Limestone suggests a classic transgressive package, minor and major oscillations of the strandline resulted in several regressive phases. Carbonates of the upper Death Canyon Limestone member and siliciclastics and carbonates in the lower Park Shale member (middle and