# *Stratigraphy, sedimentology, and geochemistry of the Upper Mississippian Pride Shale in the Appalachian Basin*

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## EXTENDED ABSTRACT

Tide-dominated or tide-influenced coastal marine deposits form some of the most complicated and largest hydrocarbon fields in the world (Wood, 2004 and references cited therein). Good outcrop analogs can provide significant insight to geologists for recognizing tidal influence in core and interpreting petrophysical log data, thus reducing uncertainty and risk when developing depositional models and planning for field development. Despite the observation that 8 of the 12 largest deltas in the modern world are either tide dominated or strongly tidally influenced (Middleton, 1991), many geologists fail to recognize tidal influence in the rock record, perhaps, in part, because of the influence of preexisting paradigms. This seems to be particularly so for many geologists prospecting for hydrocarbons within Pennsylvanian sediments in the Arkoma and Anadarko Basin of the southcentral United States.

Although good ancient analogs of tide-dominated deltas exist (see summary table in Feldman et al., 2014), many of these studies inferred tidal influence from the intercalation of sandstone and mudstone, an abundance of fluidized mud deposits, a dominance of structures formed from currents, and the shoreline-perpendicular orientation of elongate sandstone bodies. Few studies have identified sedimentary structures in delta-front and prodelta settings that can be directly related to semidiurnal, semimonthly, and longer-term tidal deposition. This may reflect background interference from storms or variable fluvial discharge that disrupted tidal deposition and thus obscures evidence of fortnightly or longer tidal signals, or it may reflect an absence of knowledge of what to look for when identifying such cycles.




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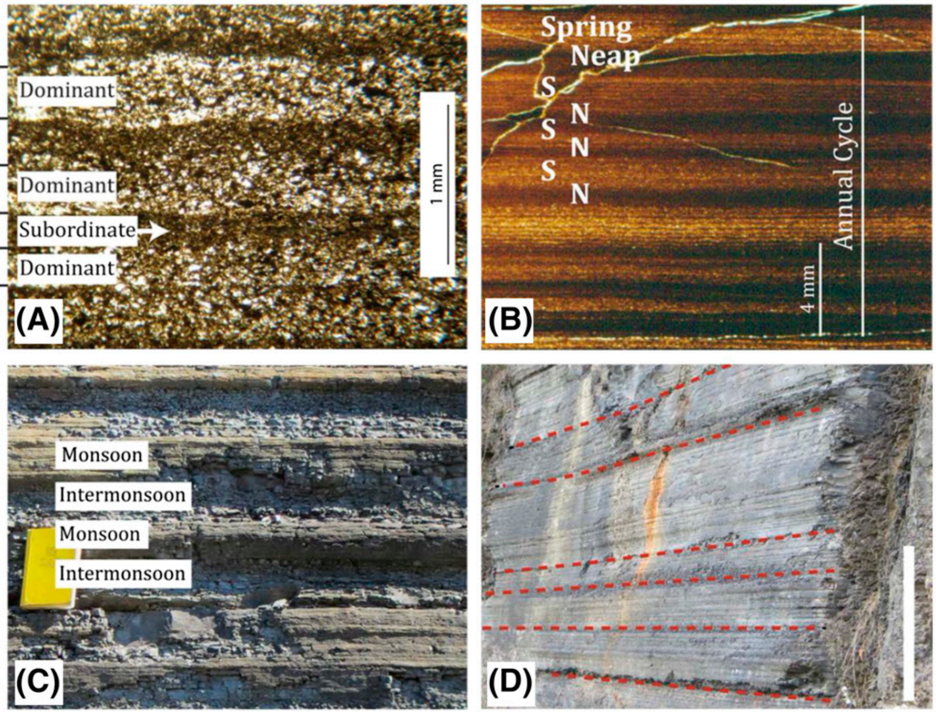


**Figure 1.** Plate of photomicrograph and outcrop photos tied to mosaics. (A) Photomicrograph of stacked, submillimeter, sandstone–siltstone/mudstone couplets from the Spanishburg outcrop with one example of a thinner couplet overlying a thicker couplet. Thicker couplets are interpreted as the deposits of semidiurnal, dominant, ebb currents that supplied sediment to the prograding delta, whereas the thinner couplets are interpreted as the deposits of semidiurnal, subordinate ebb currents. The dark, clotted textures within both the coarse- and fine-grained components of the couplets may represent clay floccules. (B) Photomicrograph of millimeter-thick cycles from the Spanishburg outcrop consisting of submillimeter, sandstone–mudstone couplets. Note that the couplets thicken and thin upward in cycles that consist of 15 or fewer distinct sandstone–mudstone couplets. Cycles are interpreted as neap-spring cycles. Each couplet represents a semidiurnal deposit of the dominant ebb tide of each day. Between 11 and 18 neap-spring-neap cycles display a systematic thickening and thinning upward within annual cycles. (C) Decimeter-scale annual cycles at Camp Creek, West Virginia. Each furrow–rib–furrow contains up to 18 neap-spring cycles. Annual cycles reflect climatic changes in which thicker, coarser laminae record seasonal monsoonal conditions when fluvial input was enhanced because of increase terrestrial runoff, and thinner, finer-grained laminae record intermonsoonal conditions when sediment flux was smaller (book is ~20 cm [8 in.] in length). (D) Decimeter-scale multiyear cycles from Spanishburg, West Virginia, interpreted to represent 18.6-yr nodal cycles (white vertical scale bar = 100 cm [3 ft]).

The Upper Mississippian Pride Shale in the Appalachians of West Virginia is an analog for tide-dominated deltaic sedimentation and, at the outcrops illustrated in the stops in this field guide, exhibits some of the most direct evidence of tidal influence within a deltaic succession found anywhere in the literature. The Pride Shale is an example of the pervasive influence of tides found throughout Upper Mississippian and Lower Pennsylvanian deposits in the Appalachian Basin and other basins in the southern and central United States. As such, its outcrops offer geologists an opportunity for viewing excellent exposures of prodelta through delta-plain facies associated with a tide-dominated delta.

The Pride Shale is an extensive, approximately 60-m (200-ft)-thick, prodeltaic deposit that coarsens upward into delta-front deposits of the Glady Fork Sandstone. The Pride Shale outcrops stand out above other outcrops that preserve tide-dominated facies because they provide unrivaled examples of tidal rhythmite successions that reflect a hierarchical bundling of tidal- and climate-forced processes that span semidiurnal through approximately 18.6-yr lunar nodal cycles (Miller and Eriksson, 1997). This will be particularly significant for those scientists interested in paleoastronomy.

Within the Pride Shale, sandstone/siltstone–shale couplets between 0.01 and 1 mm (0.0004 and 0.04 in.) thick are interpreted as suspension fallout deposits related to semidiurnal, ebb-tidal flows associated with the dominant tide of the day (Figure 1). Rare thick-thin couplets record semidiurnal dominant and subordinate tides. Up to 17 couplets display a progressive upward thickening and thinning in 0.1- to 3-cm (0.04- to 1.2-in.)-thick neap-spring (semimonthly) tidal cycles. Up to 18 neap-spring cycles are arranged in upward thickening and thinning bundles that range from 2 to 50 cm (0.8 to 20 in.) thick and reflect annual cycles. Annual cyclicity is interpreted to reflect climatic (seasonal) driven cycles related to monsoonal and intermonsoonal periods. Thicker, coarser-grained neap-spring cycles are interpreted to reflect the monsoonal season, and thinner, finer-grained cycles record the intermonsoonal period. Total organic carbon values range from 0.7% to 1.8% and are higher within intermonsoonal and lower within monsoonal components of annual cycles, reflecting, respectively, lesser and greater dilution by terrestrial flux. Weakly developed meter-scale cycles are interpreted to reflect the nodal (~18.6 yr) tidal periodicity that results from the slow rotation of the lunar orbital plane with respect to the ecliptic (solar plane).

Previously recognized and recently mapped, concave-up discontinuities in laterally extensive (hundreds of meters) outcrops along Interstate-77 at Camp Creek, West Virginia, are interpreted as slump-scar features related to oversteepening of the depositional interface. Thicknesses of annual cycles indicate that accumulation rates for the Pride Shale typically ranged between 3 to 20 cm/yr (0.8 to 8 in./yr) but reached over 60 cm/yr (24 in./yr) where sandy rhythmites developed as marginal infills of slump scars.

The purposes of this field trip are to (1) examine a complete lowstand-transgressive systems tract and highstand systems tract within a single fourth-order (~400 k.y.) sequence, with the objective of setting the Pride Shale within a sequence-stratigraphic context, and (2) evaluate stacking patterns of laminae within the Pride Shale that are inferred to record semidiurnal, diurnal, semimonthly, monthly, annual, and 18.6-yr tidal- and climate-forced periodicities.

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