initial and final depth of burial. Because zones that have nonhydrostatic pressures must be effectively isolated from their surroundings (or the pressure should be equalized), a model would be a sand lens encased in shale. Consider, for example, where isolation occurs at 4,000 ft (1,200 m) where temperature is 123°F (51°C), and subsequent burial moves it to 8,000 ft (2,400 m) at 178°F (81°C). The pressure in the gas will start at 1,860 psi (12,815 kPa) hydrostatic at 4,000 ft (1,200 m), but the temperature rise will increase it to 2,035 psi (14,021 kPa), at 8,000 ft (2,400 m). However, the hydrostatic pressure at 8,000 ft (2,400 m) is 3,720 psi (25,630 kPa), so the gas reservoir will be 1,685 psi (11,610 kPa) underpressured. Real gas reservoirs contain both gas and water. Calculations show that for trapping at 4,000 ft (1,200 m) followed by burial to 8,000 ft (2,400 m) the reservoir will show various amounts of underpressuring if it contains more than 3 vol.% gas. With less than 3 vol.% gas it will overpressure. At greater trapping depths, high percentages of gas are needed to produce underpressuring, for example, 16 vol.% at 12,000 ft (3,600 m). Temperature decrease owing to uplift and removal of overburden produces the opposite effects, and reservoirs containing high percentages of gas develop abnormally high pressures.

This theoretical model provides an explanation for the common occurrence of underpressured gas, particularly in stratigraphic traps with low water contents. It also explains the underpressured gas in the bottom of basins (such as San Juan, Wattenberg, and western Canada "Deep Basin") and shows how abnormal and subnormal pressures can be developed in adjacent gas reservoirs in a restricted geographic area (such as the Appalachians). Regional tilting may bury a formation in one area but uplift it in another leading to regional trends from subnormal to abnormal pressures. An example of this is provided by the "gas sands" of the Morrow in western Oklahoma.

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Paleotidal-Range Indicators in Carboniferous Barrier Sequences of Eastern Kentucky

When compared with their modern counterparts, the internal morphologies and external geometries of flood-tidal-delta and tidal-channel deposits in Carboniferous rocks of eastern Kentucky suggest mean tidal ranges of 1 to 2 m.

Tidal-inlet, tidal-channel, and tidal-delta deposits of modern barriers each display characteristic vertical sequences; their relative proportions within barrier lithosomes vary consistently with tidal range. Increasing tidal range is accompanied by: (1) thicker inlet sequences; (2) changes in back-barrier deposits from thin, extensive flood-tidal-delta sheets intercalated with lagoonal muds to tidal-creek channel fills intercalated with marsh sediments; and (3) the increasing predominance of ebb-tidal deltas. Stratigraphic recognition of these environments provides an estimation of paleotidal range. Moreover, if basin geometry is known, tidal-wave-propagation theory allows evaluation of relative paleotidal range on a basin-wide scale, enabling prediction of sand-body-geometry patterns along depositional strike.

Several Carboniferous exposures in eastern Kentucky are composed of well-sorted fine to medium-grained orthoquartzites arranged in linear, lenticular bodies up to 14 m thick, 1 to 2 km wide, and 40 km long. They intertongue basinward with red and green shales and carbonate rocks containing marine faunas, and landward with dark shales and siltstones bearing brackish faunas. Two thin (<4 km) lithosomes display obvious flood-tidal-delta characteristics. These erosionally based sheets compose gently landward-dipping to subhorizontal accretion surfaces that bound cosets 1 to 2 m thick of decimeter-scale cross strata with bimodal/bipolar orientations. Washed-out ripples, ladder-backs, rill marks, and bubble sand textures attest to intertidal exposure; extensive root casts typify supratidal areas. Biogenic structures are similar to those on modern flood-tidal deltas. These lithologic and stratigraphic characteristics resemble those of back-barrier components transitional between microtidal and mesotidal environments.

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Modern and Ancient Examples of Annelid Burrows as Current-Direction Indicators

Estuarine burrow patterns of the modern polychaete *Diopatra cuprae* relate to tidal currents in arrangements closely resembling trace-fossil assemblages of a Cambrian tidal sand body.

Dwelling tubes of *Diopatra* on tidal creek point bars in South Carolina reflect local hydrodynamics in four preservable ways: (1) population density is markedly higher on intertidal bar flanks than in channels; (2) burrows are sparse on parts of the bar shielded from ebb currents; (3) in intertidal areas with high population densities, tubes comprise linear rows normal to flow; and (4) tubes in intertidal areas subject to supercritical flow are ringed by asymmetrically ellipsoidal, current-parallel scour pits preferentially oriented in the ebb direction.

Associations of sedimentary textures and structures in Cambrian orthoquartzites of eastern Pennsylvania are analogous to modern upward-fining tidal-channel and point-bar deposits. Channel deposits are characterized by nonburrowed, thick sets of planar-tangential cross-strata with erosional bases and abundant mudclast lags. Intertidal bars display higher population densities and are characterized by thin sets of planar-tabular cross-strata with bipolar orientations, herringbone cross-stratification, and reactivation surfaces. *Monocraterion* occurs as a *Skolithos* burrow top, and only in intertidal sequences; these structures are analogous to the scour pits around *Diopatra* burrows. In plan, the asymmetrical ellipses of *Monocraterion* burrows are parallel and arranged in rows. These features allow the measurement of paleocurrent directions from relatively small bedding-plane exposures.