Analogy at the Facies Level: Architecture, Sedimentology and Ichnology of Modern and Pleistocene Deposits at Willapa Bay

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Summary

Willapa Bay is a mesotidal estuary situated near the southwest corner of Washington, USA. Outcropping Pleistocene terraces rim the bay on its east and north margins. The Pleistocene deposits represent ancient bay accumulations that reflect similar, but not identical, depositional conditions to the modern bay (*Figure 1*). It is the similarity of the ancient strata to the modern bay sediments that has inspired much of the previous geological investigation. At Willapa Bay the documentation of outcrop and modern occurrences of key sedimentary environments—i.e. tidal flat and point-bar deposits— aids in their characterization (Clifton, 1983; Luepke and Clifton, 1983; Gingras et al., 1999; Gingras et al., 2000). Datsets including ichnological content, sedimentary features and characteristic depositional dips aids in the identification of analogous deposits in other strata (*Figure 2*).

Intertidal Flat Deposits

Intertidal flat deposits at Willapa Bay are relatively common. Where present in complete vertical successions, intertidal sediments cap subtidal units, such as estuarine point bar or channel bar deposits. Pleistocene mud flats are reworked extensively and their bedding is massive to crudely defined by continuous horizons of silt- and sand-filled burrows. Meter-scale tidal-creek deposits cross-cut the bioturbated mud-flat sediments. Primary sedimentary structures are rarely preserved, but may include planar bedding, graded laminae, ripple and starved ripple lamination. Organic detritus is locally abundant, including wood fragments and transported rhizomes. Ichnofossils are display a broad range in size. The ichnology is limited to the ichnogenera *Skolithos, Arenicolites, Cylindrichnus, Planolites, and Palaeophycus. Thalassinoides* and *Psilonichnus* are locally common. Tubular tidalies (rythmically infilled burrows with sand and mud) are also common throughout intertidal deposits, typically in *Psilonichnus* burrows. Ancient sandflat deposits are also common in the Pleistocene strata, which display massive to crudely bedded sand intercalated with rare mm-scale mud beds. Of significant importance is that the sandflat deposits are intensely cross cut by decimeter-scale silt- and sand-filled run-off channels. Bioturbation within these run-off channels consists primarily of medium- to large sized bivalve traces (equilibrichnia and *Siphonichnus*), medium-sized *Thalassinoides*, passively-infilled crab domiciles, and diminutive *Planolites* and *Skolithos*. As a whole, smaller trace fossils are absent, probably due to extensive reworking of the deposit by larger burrowers and preservational bias in coarser-grained clastic deposits. Generally, the intertidal deposits tend to dip relatively shallow (<5°), if even at all, primarily due to the massive nature of the deposits. Intertidal deposits that display more sand may display greater dips (near 5°), while those deprived of sand tend to be shallowly dipping.

Point-bar Deposits

Point-bar deposits are common within the outcrop. Due to their association with fluvial tributaries, they exhibit notable ichnological, textural, and dip variability. As the major supply of coarser clastic detritus was delivered into the bay through its inlet, sandy deposits tend to be associated with outer estuary deposits. Inner estuary sediments are dominated by silt and mud. Physical sedimentary structures include planar lamination, graded bedding, and starved ripple lamination arranged in cm-scale Inclined Heterolithic Stratification (IHS). The deposits can be rich in organic detritus; wood clasts are abundant throughout the point-bar deposit. The lower contacts are erosional and sharp. Point bar deposits may be un-burrowed in the inner estuary. Middle estuary deposits contain a more diverse array of lebensspurren. These traces include *Skolithos*, ?*Cylindrichnus*, *Psilonichnus* and *Thalassinoides*. Passively-infilled, unlined burrows form tubular tidalites. Point-bar units intensely cross-cut each other. They range in thickness from 50cm to 8m (for individual channel units). The point bars are commonly capped by intertidal sediments and may grade into supratidal deposits (i.e. rooted and alluviated). Several examples show that vertical aggradation of the channel fill is as important as lateral accretion. This is an important difference from fluvial point-bar deposits. Point bar deposits display a wide variety of depositional dips, depending on location, and grain size present. Common to all deposits is the gradual decrease in dip angle as you move upwards within the IHS deposits. Landward IHS dip steeply (~20°), and bayward IHS dip more shallowly (5-8°).

General Trends

At Willapa Bay, point bar and intertidal flat deposits are the exceedingly variable laterally, and are therefore useful paleogeographic indicators. Both of these depositional environments are characterized by striking changes (and fluctuations) in salinity and kinetic energy from the lower to the upper estuary. As such, textural changes can be linked to changes in the hydraulic energy and are generally evident in transects from the lower to upper estuary. Inner estuary pointbars and mudflats are mud-dominated, outer estuary accumulations are sandy. Trace assemblages present in the upper estuary are generally extremely stressed and are dominated by a low diversity suite of small (<2mm diameter) burrows attributable to worm-like animals. The middle to outer estuary is (additionally) characterized by large diameter ichnofossils attributed to crustaceans and bivalves. Dip angles increase from mudflats to intertidal flats to point bars, as well as from bayward deposits to landward deposits.

References

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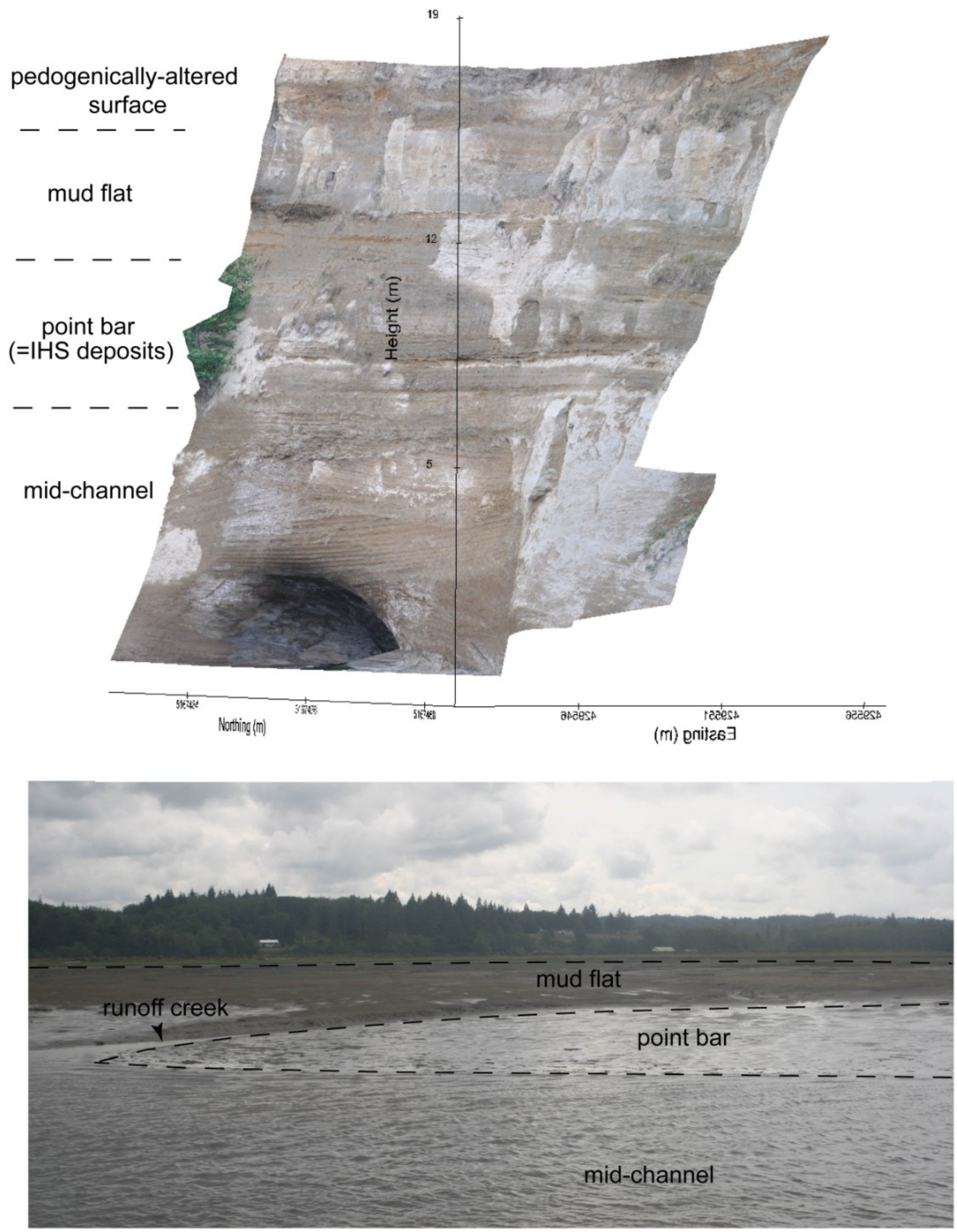

Figure 2: Example of similarities between the facies and facies associations found in Pleistocene deposits (top) and modern environments (bottom). The top, Pleistocene example is from the Bone River outcrop, and shows a transition from mid-channel tidal deposits (at the base) through point-bar (=IHS) deposits and into mud/tidal flats at the top. The bottom photo is from the Willapa River, and shows similar environments. Small drainage or runoff creeks are common features on the modern mudflats. Deposits interpreted to be from small tidal runoff creeks are visible at many locations in the Pleistocene outcrop,

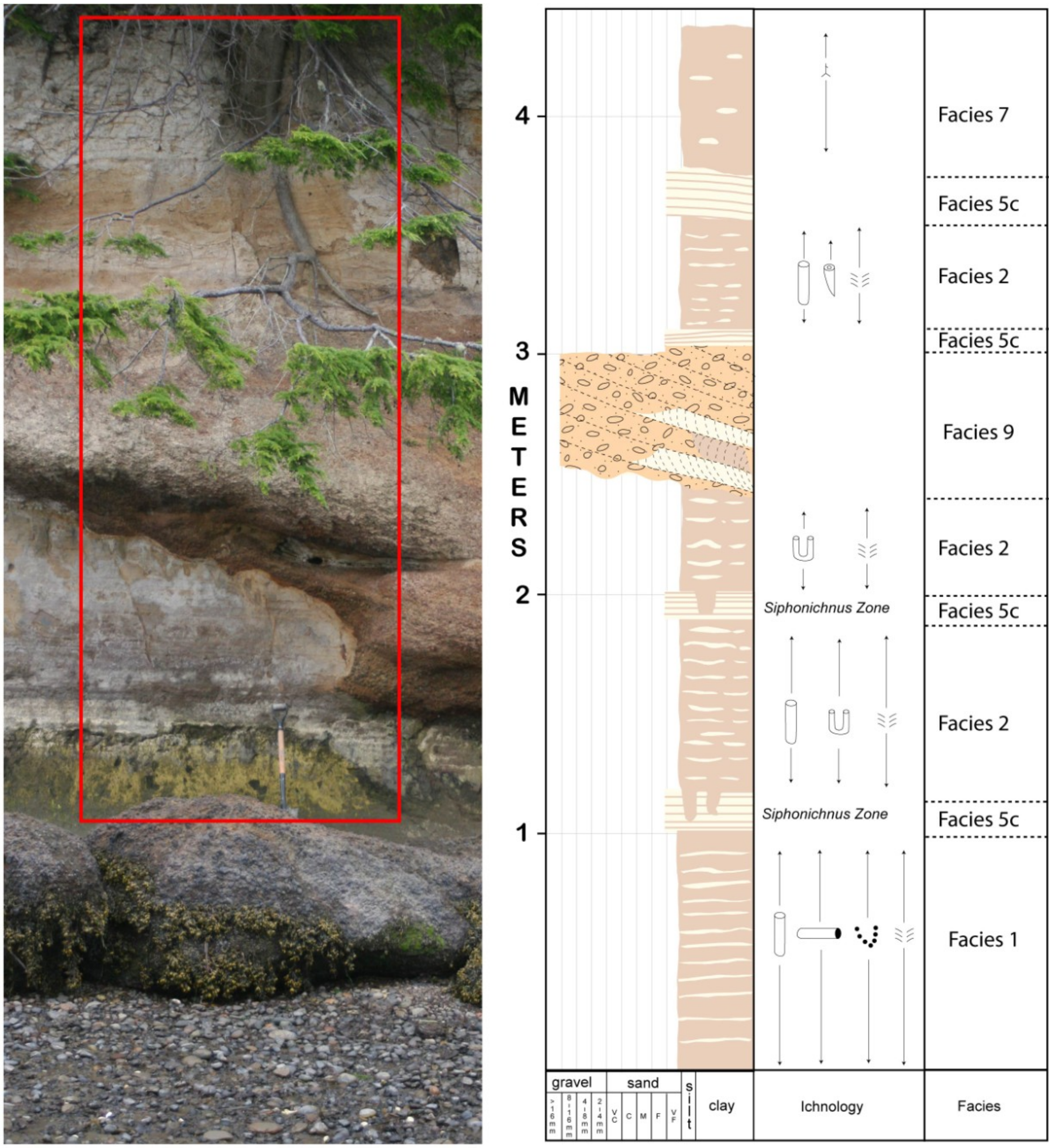

Figure 2: Example strip-log from Pleistocene outcrop. Red box (left photo) shows approximate location of strip log on outcrop. Strip log (right photo) shows the sedimentology (brown: mud; yellow: sand; orange: conglomerate), ichnological content and range, as well as where the individual units fit in the facies classification.