

Cored Successions from a Modern Estuarine Channel, Willapa Bay, Washington

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Introduction

Point bars – and their associated morphologic features – are common features found within estuarine environments. Estuarine point bars are deposited subtidally and build as a result of either lateral and / or vertical accretion, forming eta cross stratification. A characteristic feature of point-bar deposits is Inclined Heterolithic Stratification (IHS): alternating layers of sand and mud deposited due to changes in current direction and velocity (THOMAS ET AL., 1987). Variation in the sedimentological and ichnological character of estuarine IHS is intrinsically related to the nature of tidal and fluvial sediment sources. This interplay typically leads to distinct and predictable zones of sandy, muddy, and mixed sand and mud point-bar deposition.

Study Area

Willapa Bay is a large mesotidal estuary situated along the southern coastline of the state of Washington (**FIGURE 1A**). Two fluvial and five tidal channels flank the eastern portion of the bay. Sediments within the bay are siliciclastic. They are derived from two different sources. Sand enters the bay at the mouth, travelling via longshore currents from the Columbia River. Mud enters the bay from landward locales, primarily through drainage of the hinterlands and by the erosion of intertidal flats (CLIFTON AND PHILLIPS, 1980; CLIFTON, 1983; LUEPKE AND CLIFTON, 1983). As such, the composition of deposits is restricted by ability of tidal and fluvial processes to transport the sediments to different locations. This results in dominantly sandy lower estuary deposits, and dominantly muddy upper estuary deposits (GINGRAS ET AL., 1999). This zonation is most profound within IHS deposits of point bars. Sand-rich, mud-rich, and mixed sand and mud IHS are deposited at specific locations within rivers and tidal channels, depending on the dominant sediment type.

The Palix River is a large estuarine channel in the northern part of the bay (**FIGURE 1B**). The channel is predominantly tidally influenced, except for in the extreme upper portions, which is dominantly fluvial. Near the transition from the middle- to the inner-estuary, a large point bar has been deposited that consists of dominantly mixed sand and mud IHS (**FIGURE 2**).

Methods

Eight locations near the low-tide line were vibracored with 4 meter (8cm diameter) steel pipes (**FIGURE 3**). Recovery ranged from 2m to 3m. The pipes were cut in half – one half was sampled and x-rayed, while the other half was photographed and placed in a cooler for preservation. Sedimentological and ichnological characteristics were identified, and relative sand-mud ratio's were calculated (see **FIGURE 4** for example from station 6). The Bioturbation Index (BI) is assessed following Taylor and Goldring (1993). In this

approach, the degree of bioturbation within the facies is described using BI values from 0 to 6, in which BI 0 is unbioturbated and BI 6 indicates complete homogenization (Taylor and Goldring, 1993). The BI grades are: BI 0 (no bioturbation); BI 1 (1-4% 'sparse' bioturbation); BI 2 (5-30% 'low'); BI 3 (31-60% 'moderate'); BI 4 (61-90% 'high'); BI 5 (91-99% 'intense'); and BI 6 (100%).

Facies

Three facies are identified within the vibracores:

Facies 1 (F1): Mixed sand and mud IHS

Facies 1 comprises intercalated sand and mud beds in equal proportions. Both sand and mud beds range in thickness between 1cm and 3cm. Sand / mud couplet thickness is highly variable, and decreases in thickness upwards. Bioturbation is rare (B.I. 1 to 2), and is restricted to simple, diminutive traces. Bioturbation is most prevalent in the upper portions of the facies. The dominant tracemakers are polychaetes (*Nereis* sp., *Heteromastus* sp.), which render 2mm to 5mm diameter *Skolithos*-, *Monocraterion*-, *Gyrolithes*- and *Planolites*-like traces.

Variable thickness of IHS sets is common in tidal environments, due to fluctuations in tidal currents. The lack of bioturbation coupled with thicker sand beds relative to mud beds in the lower portion of F1 indicates high energy and sedimentation rates. This is typical of subtidal deposition. The transition to bioturbated beds and increased mud thickness indicates lower energy and decreased sedimentation rates. This is likely the result of the upper portion of F1 becoming subaerially exposed, allowing for mud to more readily fall out of suspension and become deposited. Further, the shallowly and consistently dipping nature of the cosets indicates that the IHS beds were laterally accreted. The style of bioturbation – diminutive and morphologically simple traces – indicates a brackish-water environment, interpreted to be indicative of the *Teichichnus* Ichnofacies (GINGRAS AND MACEACHERN, 2002).

Facies 2 (F2): Highly bioturbated, lenticular bedded sand and mud

Facies 2 is composed of highly bioturbated interbedded sand and mud.. Bioturbation is high (B.I. 3 to 4), with a variety of tracemakers including polychaetes (*Nereis* sp., *Nephtys* sp., *Heteromastus* sp.), lugworms (*Arenicola* sp.), and bivalves (*Macoma baltica*). The traces produced resemble *Skolithos*, *Gyrolithes*, *Arenicolites*, *Planolites* and *Siphonichnus* traces. Rarely, 5mm to 10mm beds of disarticulated bivalve become intercalated with the sand and mud. Rootlets become incorporated in the upper portion facies.

Lenticular bedding is a common tidal depositional feature. Sedimentation rates are low, leading to high bioturbation rates. Polychaetes, lugworms and clams are able to thrive, as nutrients are constantly being replenished. Trace morphology is highly variable, as organisms are able to employ a variety of feeding strategies. As well, the presence of clams indicates an intertidal depositional locale, as clams are not able to withstand continuous submergence.

Facies 3 (F3): Rooted, organic-rich sand and mud

Facies 3 is comprised of an admixture of sand and mud with a high organic content. Marsh grass grows in the upper part, and their roots and stalks penetrate down through the facies, amalgamating the sand and mud.

The admixing and rooting of the sand and mud is indicative of a less tidally influenced environment. Submergence – if at all – only occurs during the highest part of the tidal cycle. Admixing is a result of sediment deposition by the baffling as opposed to settling out of suspension.

Facies Association

The facies association comprises mixed sand and mud IHS (F1) overlain by lenticular-bedded sand and mud (F2) and rooted, organic-rich mud (F3). Mixed IHS deposits of F1 vary in thickness from 20cm to upwards of 200cm. The basal contacts of F1, where observable, are erosional into a lower IHS package (i.e. F1). The IHS grade upwards into the lenticular-bedded deposits of F2. Facies 2 ranges in thickness from 10cm to

30cm. As the sand and mud becomes admixed, F2 grades into F3. Facies 3 ranges in thickness from 50cm to 100cm.

F1 through F3 are interpreted as representing a progradational middle-estuarine point bar sequence. IHS sets of Facies 1 are interpreted as point bar deposits. Point bars laterally and vertically accrete. Stacked F1 units likely reflect changes in current direction related to the incision of the tidal channel, or the build up of a new point bar atop an older one. Facies 2 is interpreted as representing intertidal flat deposits. Higher amounts of bioturbation are related to lower sedimentation rates. The rooted and muddy F3 is interpreted as salt marsh deposits.

Relation to Pleistocene-aged terrace sets

Morphological aspects present within the vibracores are also visible within Pleistocene-aged terrace sets rimming the modern bay, specifically along Highway 101 just north of the Bone River. This demonstrates that the eta cross-stratified tidal point-bar facies association reported herein is temporally recurring. As such, the model may have applicability in other ancient locales, such as the Cretaceous of the Western Canadian Sedimentary Basin.

References

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Figures

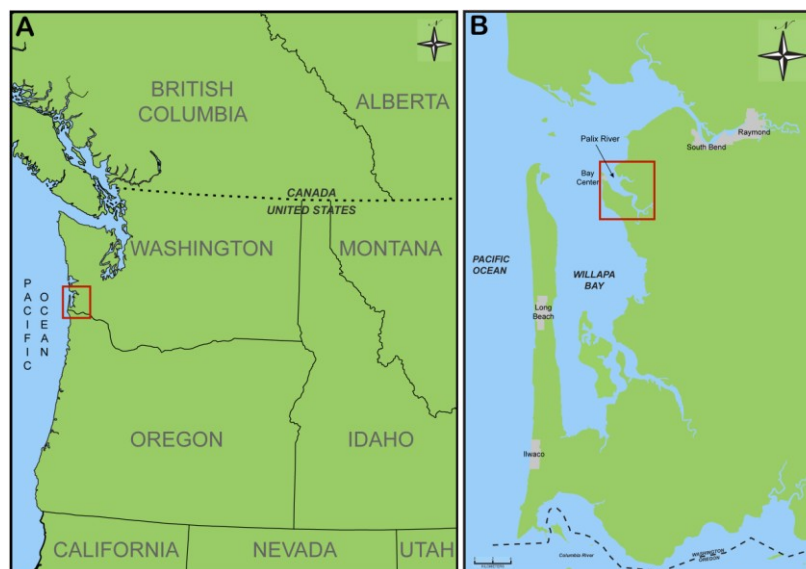


Figure 1: A. Location map of Willapa Bay in southwest Washington; B. Location of Palix River and study area within Willapa Bay.

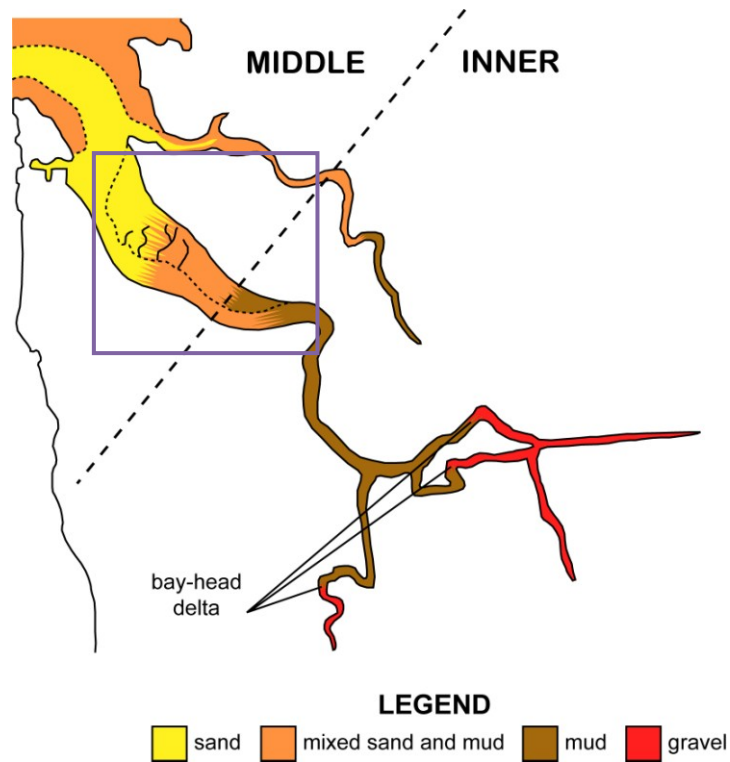


Figure 2: Sediment distribution within the Palix River (modified from Clifton and Phillips, 1980).

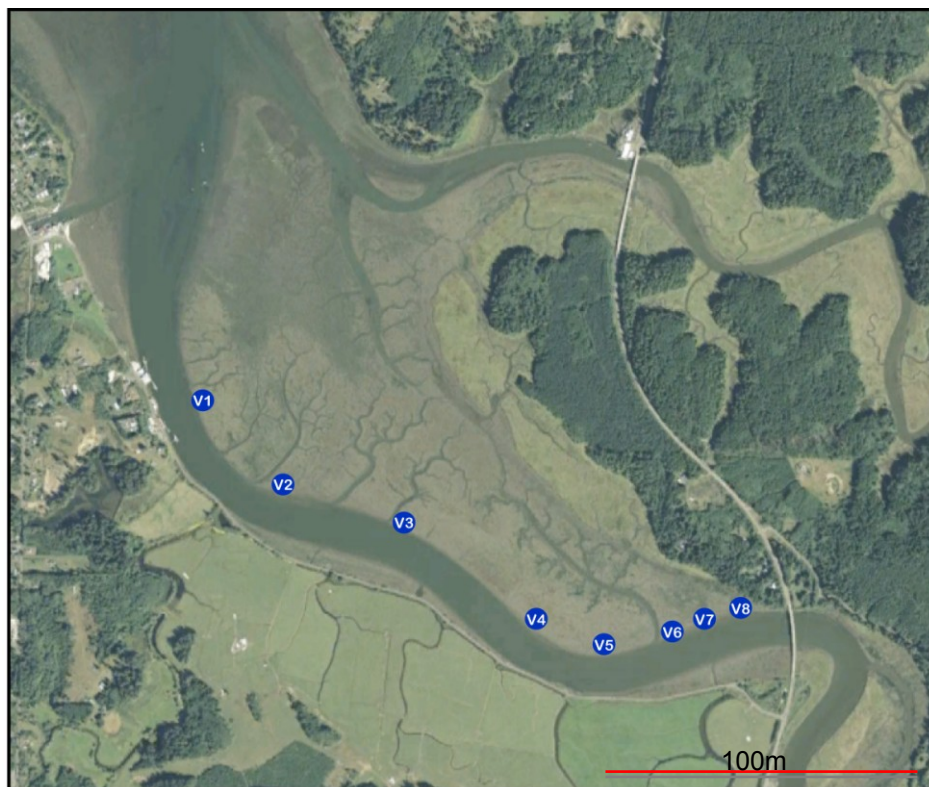


Figure 3: Location of eight vibracores.

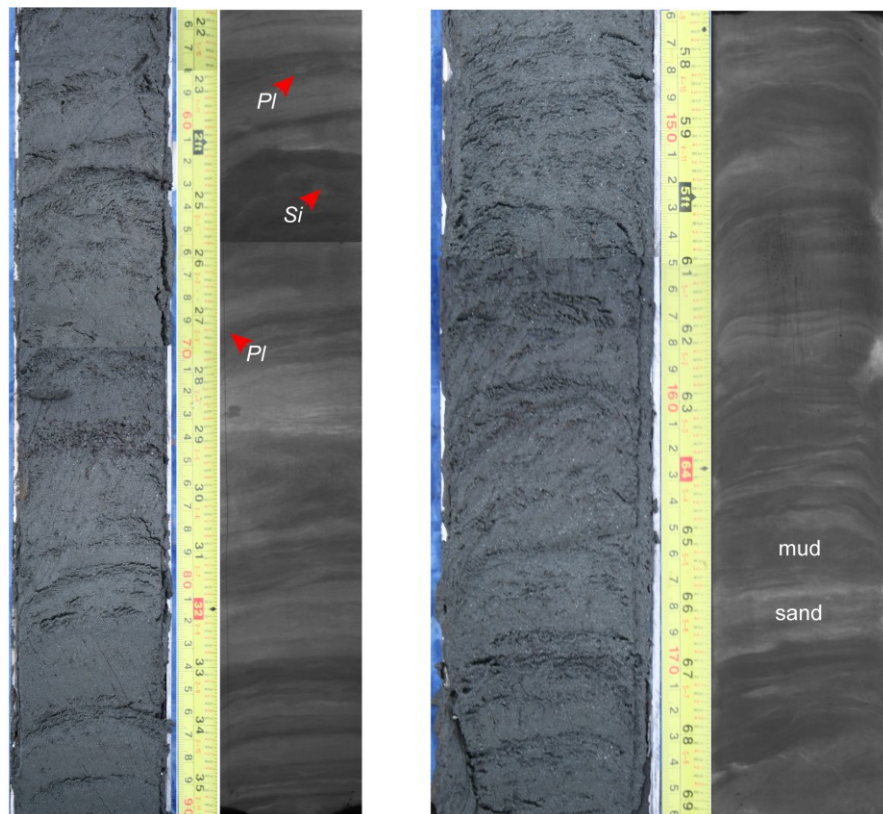


Figure 4: Examples of vibracores taken from Location 6. **A.** 56-90cm displaying Facies 2 with *Planolites* (Pl) and *Siphonichnus* (Si) traces. **B.** 148-178cm displaying Facies 1.