ELSEVIER

Marine Geology 246 (2007) 24–41

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

Forcing of large-scale cycles of coastal change at the entrance to Willapa Bay, Washington

Robert A. Morton[a,*], H. Edward Clifton[b], Noreen A. Buster[c], Russell L. Peterson[a], Guy Gelfenbaum[b]

[a] *U.S. Geological Survey, 600 Fourth St. South, St. Petersburg, Fl. 33701, United States*
[b] *U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States*
[c] *ETI Professionals Inc., 600 Fourth St. South, St. Petersburg, Fl. 33701, United States*

Received 10 January 2007; received in revised form 17 July 2007; accepted 21 July 2007

Abstract

Anomalous morphological features within large estuaries may be: (1) recorders of external forces that periodically overwhelm the normal morphodynamic responses to estuarine energy fluxes, and (2) possible predictors of cycles of future coastal change. At the entrance to Willapa Bay, Washington, chronic beach erosion and frequent coastal flooding are related to the historical northward channel migration that destroyed the protective sand spits of Cape Shoalwater. Northward channel migration since the late 1800s conforms to the long-term net sediment transport direction. What requires explanation is periodic southward relocation of the trunk channel by as much as 5 km, and attendant construction of moderately large sand spits on the north side of the bay such as Kindred Island, Tokeland Peninsula, and Cape Shoalwater.

Both autocyclic and allocyclic processes may have been responsible for trunk channel realignment and associated spit deposition. Channel recycling may occur when the main channel becomes overextended to the north and the tidal flow is inefficient because of its decreased gradient and increased susceptibility to shoaling by the growth and migration of tidal sand ridges. Under those conditions trunk channel relocation would be facilitated by increased wave heights and water levels of El Niño winter storms. However, co-seismic subsidence is the most likely mechanism for abruptly increasing sand supply and longshore transport that would favor discrete periods of channel relocation and spit deposition. Unless external forcing changes sand supply and predominant sediment transport directions in the future, the relative rise in sea level, frequent winter storms, and local deficit in the sand budget assure that beach erosion will continue at the mouth of this large estuary.
Published by Elsevier B.V.

Keywords: tidal inlets; coastal change; sediment transport; Holocene geology; barrier islands; beach erosion; external forces

1. Introduction

Large estuaries are the convergent mixing zones of water and sediment delivered by fluvial and marine processes. They can also serve as important sediment traps (Meade, 1972) that record the geologic histories of respective regions and the interactions among complex geological processes, sediment supply, and changing forces at time scales of decades to millennia. Modern sediment distribution within an estuary is commonly related to the relative importance of and interplay among

* Corresponding author.
E-mail address: rmorton@usgs.gov (R.A. Morton).

0025-3227/$ - see front matter. Published by Elsevier B.V.
doi:10.1016/j.margeo.2007.07.008

the wave, tidal, and fluvial components (Nichols et al., 1991; Dalrymple et al., 1992), whereas the three-dimensional facies distribution within the estuarine fill considers the predominant sediment transport components in conjunction with fluctuations in sea level (Allen and Posamentier, 1994; Zaitlin et al., 1994). Prediction of estuary evolution typically relies on interpretation of its morphological and stratigraphic records in the context of the predominant long-term, time-averaged coastal processes operating at regional scales (Nichols et al., 1991; Allen and Posamentier, 1994). Less attention is paid to forces outside the estuarine system that produce erosional and depositional patterns within the estuary that are contradictory to those patterns expected on the basis of the long-term trends. According to Knight and FitzGerald (2005), the morphodynamic and evolutionary responses of estuaries to external forcing remains largely unknown.

One large estuary where morphological features and associated estuarine fill are not entirely consistent with the erosional and depositional patterns expected from long-term trends is Willapa Bay, Washington (Fig. 1). At the entrance to Willapa Bay, a series of erosional scars and three separate sand spits that grew to the south on the north side of the bay (Figs. 2 and 3) attest to cyclic changes that are inconsistent with the predominant long-

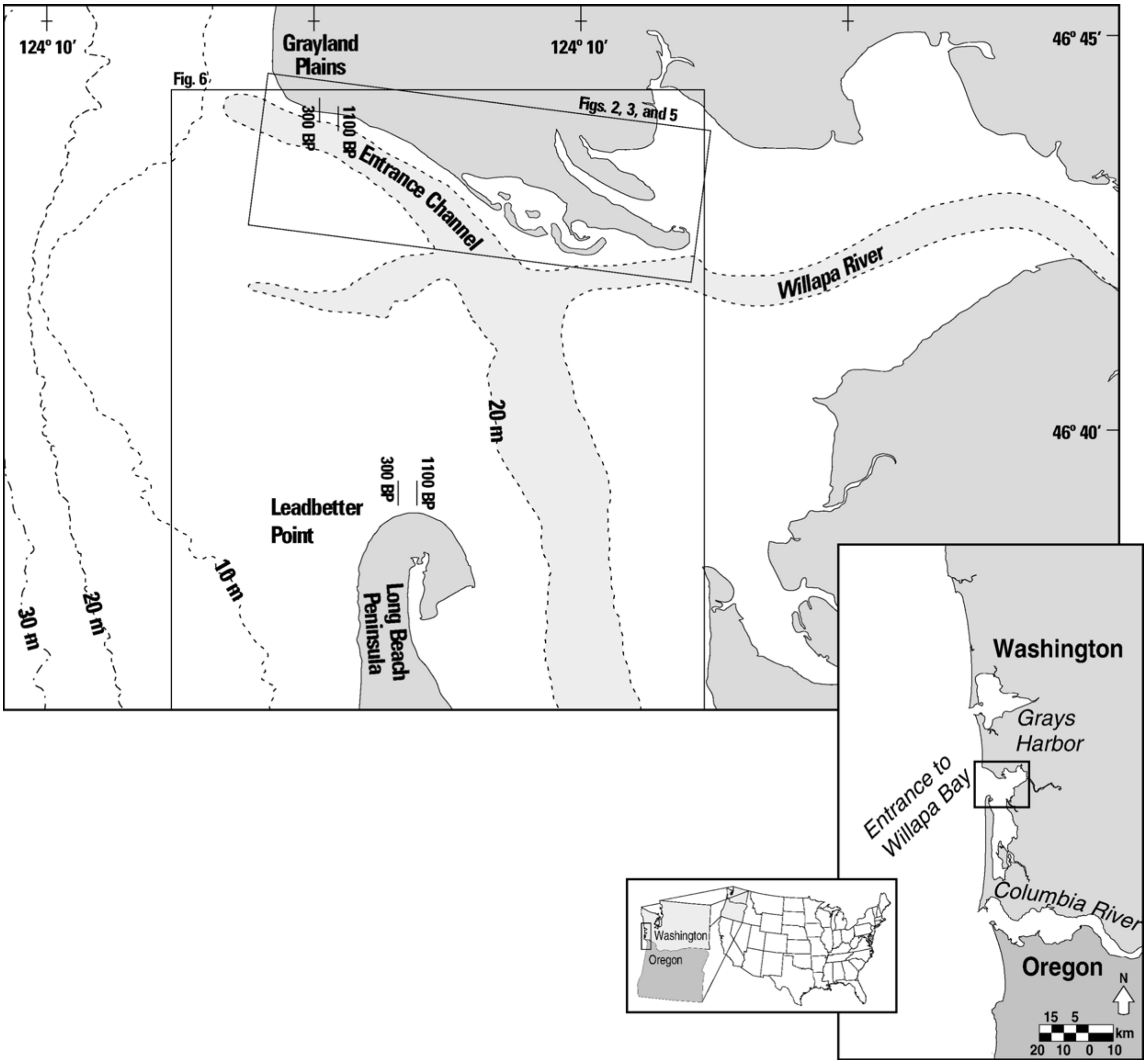

Fig. 1. Index map of Willapa Bay showing general setting, geographic features, and projected positions of beach-erosion scarps (300 BP and 1100 BP) imaged and dated by Peterson et al. (2002).