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Stages of sedimentary prism development on a convergent margin — Eocene Tyee Forearc Basin, Coast Range, Oregon, USA

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ABSTRACT

Architecture of ancient forearc basin successions can be difficult to reconstruct because of the widespread syn-depositional and post-depositional deformations experienced by many forearc basin-fills. For this reason various techniques have been used for reconstructing forearc basin-infill geometry, including geochemical correlation. The Tyee Basin succession exposed in Coast Range of Western Oregon, USA, is an Eocene forearc-fill that includes genetically related non-marine, shallow marine and deepwater clastic deposits and is gently deformed. Reconstruction of the depositional geometry of the Tyee Basin succession from detailed outcrop and subsurface data reveals two distinct stages of development for this active basin-margin. These stages are characterized by two different basin-margin clinoform architectures and also by a pronounced change in the character of the associated deepwater deposits. During the initial stage, the basin-margin clinoforms are smaller (<250 m clinoform height) and strongly progradational, with clinoform topset dominated by fluvial deposits. At this stage thick sand-rich unconfined turbidite beds accumulated on the slope segment of the clinoforms and extended out onto the basin-floor. Large scale slope conduits such as slope channels or canyons, are notably absent in this stage. The second stage is characterized by larger clinoform height (>500 m), a greater degree of topset aggradation with repeated fluvio-deltaic cycles on the shelf, and well-organized, large turbidite channels on the slope. The turbidite channels supplied medium-grained sands to the extensive, stacked basin-floor fans. The first stage described above marks the early development of a shelf-slope prism on the Tyee continental margin, and has been interpreted by some earlier workers as an unique category of basin-margin architecture, termed as a 'submarine ramp'. However, this was only the initial stage of development of the Tyee margin and it was followed by a period of basin-filling when repeated fluvial and shallow marine shelf-transit cycles fed well-organized turbidite channels on the slope as well as Tyee Basin floor fans. The large volume of sediment deposited during the initial stage, resulted from of the unique geometry of the Tyee Basin, as influenced by the presence of pre-existing topography on the accreted oceanic basement underlying the Tyee succession.

1. Introduction

Because of the subsequent (post-depositional) tectonic deformation of forearc basin deposits, there are only a limited number of studies that describe large-scale depositional architecture of such basins in ancient successions (Tokuhashi, 1989; Takashima et al., 2004; Trop, 2008). In some cases, seismic data can provide a basis for basin-wide correlation (e.g., Marcaillou and Collot, 2008), but are of limited use in detailed identification of depositional environments. As a consequence, the well-known clinoformal geometry (Johannessen and Steel, 2005; Helland-Hansen et al., 2012) of the shelf-slope sedimentary prism (alternatively termed as the 'basin-margin sediment wedge' as described by Burgess and Steel, 2008) that include non-marine to shelfal topset and a deep-water slope foreset, cannot be easily demonstrated from many ancient forearc margins. The Tyee Forearc Basin in the Coast Range of Oregon (Fig. 1) was filled in Early to Middle Eocene and was gently deformed subsequently, so that a reconstruction of the clinoformal geometry of the shelf-slope sedimentary prism at the Tyee forearc margin can be attempted, using outcrop and subsurface data. The exposed deposits of the Tyee Forearc Basin include non-marine, shallow marine and deepwater deposits, which can be interpreted as various components of the proposed basin-margin clinothems, provided their chrostratigraphic equivalence is established by basin-scale correlation. This article puts forward a depositional model for the clastic succession of the Tyee Forearc Basin, primarily on the basis of outcrop observations, that allows reconstruction of the clinoform geometry, and demonstrates the stages of basin-margin sediment wedge development at this active forearc margin. The Tyee Basin is thought to have had topographic/bathymetric variations as a result of pre-existing basement structures (Snavely and Wagner, 1963). The proposed depositional model also demonstrates the effect of bathymetric variation on

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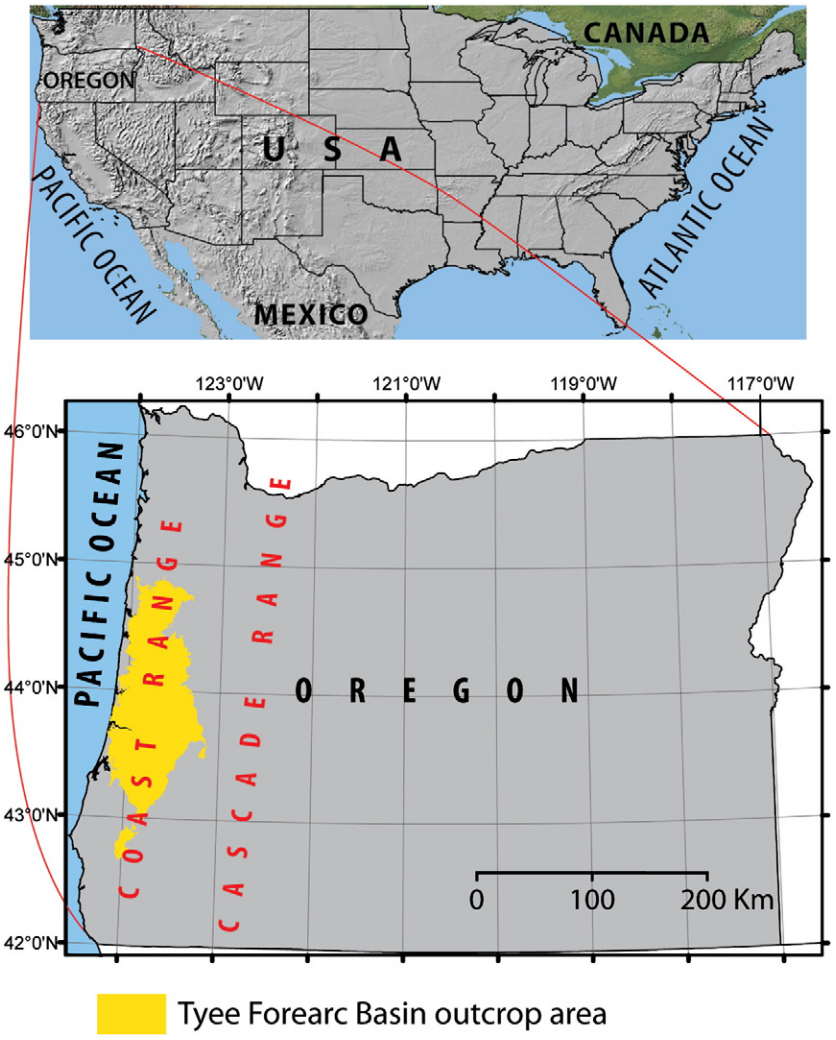

Fig. 1. Location of Tyee Forearc Basin outcrop area in Coast Range, western Oregon — the Cascade Range (volcanic arc) lies to the east of Coast Range.

basin-margin clinoform height, clinoform progradation direction and shelf-edge trajectory (a measure for relative importance of progradation of shelf-edge versus aggradation on the clinoform topset, e.g., Carvajal and Steel, 2006).

The fluvial to coastal, shallow marine and deepwater deposits of Tyee Forearc Basin were previously believed to be a near-continuous, axial fill succession, with the basin-axis running sub-parallel to the N–S tectonic grain of the convergent margin. In addition, the Tyee Forearc Basin was the type area for the development of "submarine ramp" model for such basin margins (Heller and Dickinson, 1985), built as an alternative to a previous fluvial-to-slope-to-fan model for the Tyee Forearc Basin (Chan and Dott, 1983) (Fig. 2). These two contrasting depositional models for the Tyee Forearc Basin infill, however, have some common features, including — (1) a narrow to missing shelf and a direct linkage of the fluvial deposits to slope and deepwater deposits; and (2) sediment input to the basin by multiple rivers, effectively behaving as a line source, and sand supply to the basin floor controlled by multiple sediment conduits on the slope.

A new depositional model for the Tyee Forearc Basin is advocated whereby most sediment was input in a transverse (SE to NW) manner before the deepwater turbiditic system swung longitudinally with the tectonic grain, and where there was clear clinoformal outbuilding of a shelf to deepwater slope system with numerous large-scale submarine channel systems for much of the time interval during which the basin was filled. Two main stages of development are documented for the Tyee Forearc Basin infilling — (1) a proto-shelf stage, steeper and narrower than normal, that developed along the early basin margin, characterized by the absence of large sediment bypass conduits on the slope (morphologically similar to the "deepwater ramp" margin model as described by Heller and Dickinson, 1985); and (2) a mature shelf stage, wide shelf to slope system that is common to most plate-margin basins worldwide (distinct alluvial to shelf segment, shelf-edge, well-developed deepwater slope segment with major turbidite channels supplying sediment to the basin floor).

The distribution of various lithofacies within the Tyee Forearc Basin and the paleo-current information indicate that pre-existing basin topography played a significant role in shaping the overall geometry of the basin-fill. Otherwise we suggest that the basin evolved in a fairly normal manner, with rivers and deltas repeatedly transiting a gradually widening shelf, with huge volumes of sand and mud being delivered periodically across the shelf edge, initially in sheets and later into spectacular turbidite channel systems that led out into large and thick basin-floor fan systems.

2. Geological background

The Paleogene sedimentary succession of the Coast Range of Oregon overlies an oceanic basement known as the Siletz River Volcanics. The Paleogene sedimentary succession includes Paleocene to Early Eocene Umpqua Group, Early Eocene Tyee Formation, and late Early Eocene to