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Research paper

Variability of intertidal foraminiferal assemblages in a salt marsh, Oregon, USA

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ABSTRACT

We studied 18 sampling stations along a transect to investigate the similarity between live (rose Bengal stained) foraminiferal populations and dead assemblages, their small-scale spatial variations and the distribution of infaunal foraminifera in a salt marsh (Toms Creek marsh) at the upper end of the South Slough arm of the Coos Bay estuary, Oregon, USA. We aimed to test to what extent taphonomic processes, small-scale variability and infaunal distribution influence the accuracy of sea-level reconstructions based on intertidal foraminifera. Cluster analyses have shown that dead assemblages occur in distinct zones with respect to elevation, a prerequisite for using foraminifera as sea-level indicators. Our nonparametric multivariate analysis of variance showed that small-scale spatial variability has only a small influence on live (rose Bengal stained) populations and dead assemblages. The dissimilarity was higher, however, between live (rose Bengal stained) populations in the middle marsh. We observed early diagenetic dissolution of calcareous tests in the dead assemblages. If comparable post-depositional processes and similar minor spatial variability also characterize fossil assemblages, then dead assemblage are the best modern analogs for paleoenvironmental reconstructions. The Toms Creek tidal flat and low marsh vascular plant zones are dominated by *Miliammina fusca*, the middle marsh is dominated by *Balticammina pseudomacrescens* and *Trochammina inflata*, and the high marsh and upland–marsh transition zone are dominated by *Trochamminita irregularis*. Analysis of infaunal foraminifera showed that most living specimens are found in the surface sediments and the majority of live (rose Bengal stained) infaunal specimens are restricted to the upper 10 cm, but living individuals are found to depths of 50 cm. The dominant infaunal specimens are similar to those in the corresponding surface samples and no species have been found living solely infaunally. The total numbers of infaunal foraminifera are small compared to the total numbers of dead specimens in the surface samples. This suggests that surface samples adequately represent the modern intertidal environment in Toms Creek.

1. Introduction

Intertidal foraminifera have been widely used as indicators of former sea levels, because they are often well preserved, easily identified and occur in high numbers, thus, providing a statistical basis for paleoenvironmental interpretation (e.g., Thomas and Varekamp, 1991; Varekamp et al., 1992; Gehrels, 1994; Nydick et al., 1995; Hayward et al., 1999; Horton, 1999; Edwards and Horton, 2000; Haslett et al., 2001; Horton and Edwards, 2006; Leorri et al., 2010). The utility of foraminifera as sea level indicators results from the strong correlation that intertidal assemblages have with elevation within the tidal frame (e.g., Scott and Medioli, 1978; Horton and Edwards, 2006). Along tectonically active coastlines such as Oregon's, this correlation with elevation is used to reconstruct former sea levels, from which coastal land-level changes during prehistoric great earthquakes on the plate-boundary thrust fault of the Cascadia subduction zone can be inferred (Fig. 1; e.g., Guilbault et al., 1995, 1996; Nelson et al., 2008; Hawkes et al., 2010, 2011; Engelhart et al., 2013a). In this paper, we address three potential problems with using foraminiferal assemblages as sea-level indicators at Cascadia.

Firstly, the use of intertidal foraminifera to reconstruct former sea levels requires a comprehensive understanding of modern assemblage distributions and their relationship to tidal environments (e.g., Phleger and Walton, 1950; Scott and Medioli, 1978; Patterson, 1990; Hayward et al., 1999; Gehrels, 2000; Horton and Edwards, 2006;

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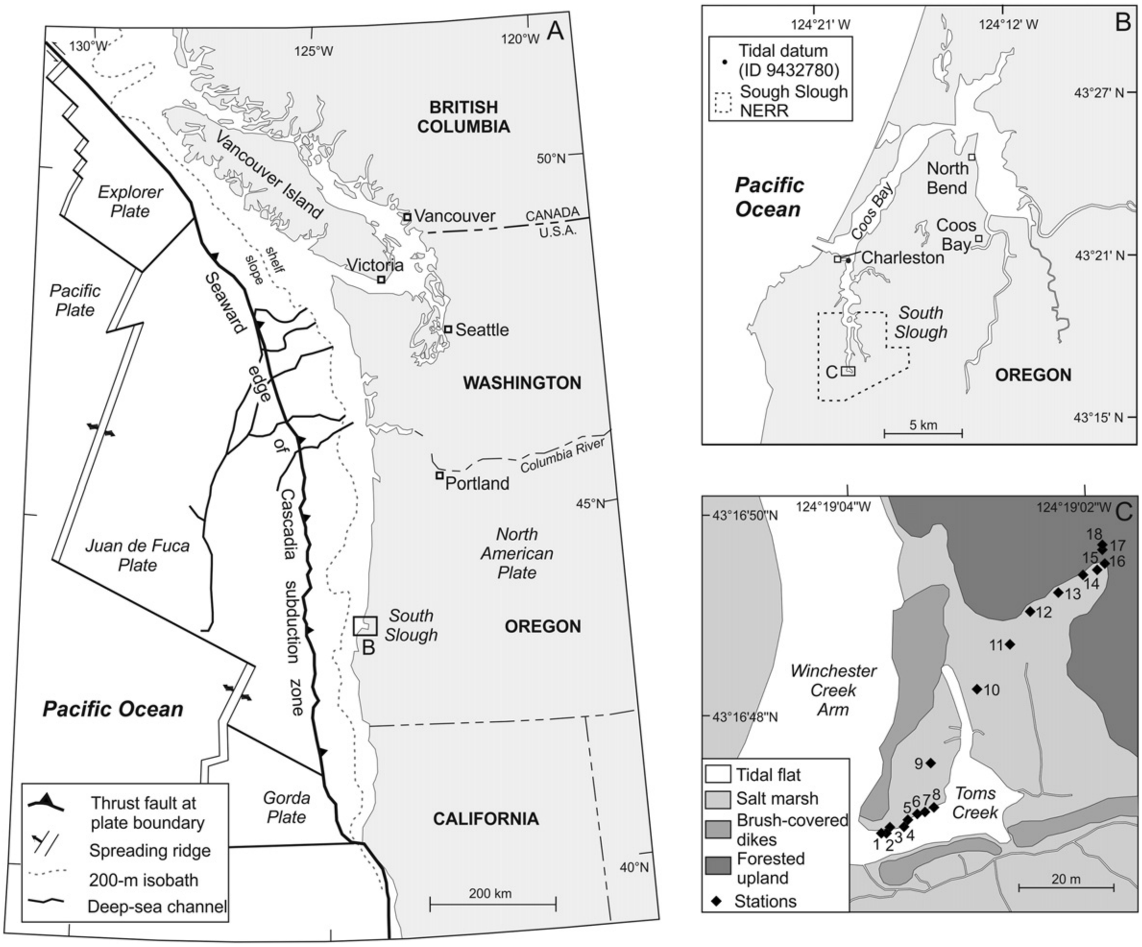

Fig. 1. Map of the North American Pacific coast showing major features of the Cascadia subduction zone (A), the Coos Bay estuary with the study site in the South Slough National Estuarine Research Reserve (NERR), the tide gauge in Charleston (NOAA ID 9432780; B), and station locations (surface samples and Russian cores; see Table 1) in Toms Creek marsh along the Winchester Creek Arm of South Slough (C).

Kemp et al., 2009). Much previous debate has focused on which type of assemblage—the live population, the dead assemblage or the total (live plus dead) assemblage—should be used to characterize modern environments and reconstruct prior sea levels. Many researchers state that total assemblages most accurately represent intertidal environments because they reflect temporal fluctuations (e.g., Scott and Medioli, 1980; de Rijk, 1995; Jennings et al., 1995). However, Murray (2000) notes that the use of total assemblages disregards taphonomic changes that affect live populations after their death. Many intertidal foraminiferal studies concentrate on agglutinated foraminifera, because calcareous taxa are commonly not preserved (or not present) in low pH salt-marsh environments. To investigate the extent of this effect, Culver and Horton (2005) and Horton and Murray (2006, 2007) analyzed seasonal and post-depositional changes of agglutinated and calcareous foraminiferal species from salt-marsh environments as well as from tidal flat and sand flat environments along the U.S. Atlantic and U.K. coasts, respectively. They concluded that if studies encompass the whole intertidal zone, the modern dead assemblages are the most accurate analogs for fossil assemblages, because of the early diagenetic dissolution of calcareous species.

Secondly, most sea-level reconstruction studies investigate modern surface foraminiferal distributions along elevational transects across one or more intertidal zones (e.g., Horton and Edwards, 2006). Transects are usually positioned perpendicular to the shore and extend from tidal flats to freshwater-upland environments, but sampling along transects does not address small-scale variability in foraminiferal distribution (Kemp et al., 2011). Such small-scale spatial variability of foraminiferal distributions in intertidal environments has been reported both for living populations (e.g., Buzas, 1968, 1970; Schafer, 1971; Swallow, 2000; Buzas et al., 2002) and dead assemblages (Kemp et al., 2011) from different coastal regions. If foraminifera have a patchy distribution in intertidal environments, then assemblages in samples along single transects may be too variable to accurately describe the species–environment relationship and so compromise the reliability of sea-level reconstructions.

Thirdly, most studies of the modern distribution of intertidal foraminifera have sampled surface sediment (upper 1 to 2 cm) with the assumption that intertidal foraminifera are primarily epifaunal (e.g., Scott and Medioli, 1980; Gehrels, 1994; de Rijk, 1995; Horton, 1999; Alve and Murray, 2001; Horton and Edwards, 2006; Kemp et al., 2009). Infaunal living foraminifera, however, have been widely reported in North American and European salt marshes (e.g., Matera and Lee, 1972; Buzas, 1977; Steineck and Bergstein, 1979; Goldstein et al., 1995; Goldstein and Watkins, 1998, 1999; Duchemin et al., 2005; Tobin et al., 2005; Berkeley et al., 2007; Leorri and Martin, 2009). Preferentially infaunal species could change the composition of dead assemblages in subsurface sediments (Goldstein and Harben, 1993; Saffert and Thomas, 1998; Patterson et al., 1999; Hippensteel et al., 2000; Culver and Horton, 2005). For example, the benthic foraminifer *Arenoparrella mexicana* is more abundant in subsurface than in surface samples in a Georgia salt marsh (Goldstein and Harben, 1993). Duchemin et al. (2005) also suggested that infaunal taxa need to be considered when analyzing the distribution of modern salt-marsh foraminifera. To include the effects of infaunal species,