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Testing the use of bulk organic $\delta^{13}C$, $\delta^{15}N$, and C_{org}:N_{tot} ratios to estimate subsidence during the 1964 great Alaska earthquake

Adrian M. Bender [a,b,*], Robert C. Witter [a], Matthew Rogers [c]

[a] U.S. Geological Survey, Alaska Science Center, Anchorage, AK, USA
[b] Geological Science, Western Washington University, Bellingham, WA, USA
[c] ENRI Stable Isotope Laboratory, University of Alaska, Anchorage, Anchorage, AK, USA

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ABSTRACT

During the M_w 9.2 1964 great Alaska earthquake, Turnagain Arm near Girdwood, Alaska subsided 1.7 ± 0.1 m based on pre- and postearthquake leveling. The coseismic subsidence in 1964 caused equivalent sudden relative sea-level (RSL) rise that is stratigraphically preserved as mud-over-peat contacts where intertidal silt buried peaty marsh surfaces. Changes in intertidal microfossil assemblages across these contacts have been used to estimate subsidence in 1964 by applying quantitative microfossil transfer functions to reconstruct corresponding RSL rise. Here, we review the use of organic stable C and N isotope values and C_{org}:N_{tot} ratios as alternative proxies for reconstructing coseismic RSL changes, and report independent estimates of subsidence in 1964 by using $\delta^{13}C$ values from intertidal sediment to assess RSL change caused by the earthquake. We observe that surface sediment $\delta^{13}C$ values systematically decrease by ~4‰ over the ~2.5 m increase in elevation along three 60- to 100-m-long transects extending from intertidal mud flat to upland environments. We use a straightforward linear regression to quantify the relationship between modern sediment $\delta^{13}C$ values and elevation ($n = 84$, $R^2 = 0.56$). The linear regression provides a slope–intercept equation used to reconstruct the paleoelevation of the site before and after the earthquake based on $\delta^{13}C$ values in sandy silt above and herbaceous peat below the 1964 contact. The regression standard error (average = ±0.59‰) reflects the modern isotopic variability at sites of similar surface elevation, and is equivalent to an uncertainty of ±0.4 m elevation with respect to Mean Higher High Water. To reduce potential errors in paleoelevation and subsidence estimates, we analyzed multiple sediment $\delta^{13}C$ values in nine cores on a shore-perpendicular transect at Bird Point. Our method estimates 1.3 ± 0.4 m of coseismic RSL rise across the 1964 contact by taking the arithmetic mean of the differences ($n = 9$) between reconstructed elevations for sediment above and below the 1964 earthquake subsidence contact. This estimate compares well with independent subsidence estimates derived from post-earthquake leveling in Turnagain Arm, and from microfossil transfer functions at Girdwood (1.50 ± 0.32 m). While our results support the use of bulk organic $\delta^{13}C$ for reconstructing RSL change in southern Alaska, the variability of stable isotope values in modern and buried intertidal sediment required the analysis of multiple samples to reduce error.

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1. Introduction

Tectonic subsidence during the M_w 9.2 great Alaska earthquake in 1964 lowered Turnagain Arm near Girdwood, Alaska by 1.2–1.8 m (Fig. 1; Plafker, 1969). The subsidence resulted from regional vertical displacement of southern Alaska induced by coseismic slip on the Alaska-Aleutian megathrust (Plafker, 1965). Regional displacements in 1964 formed a broad trough of subsidence, extending from Kodiak Island to College Fjord in Prince William Sound (Fig. 1), which caused sudden relative sea-level (RSL) rise that submerged shorelines, drowned coastal spruce forests and shifted estuary mud flats inland over peat-forming marshes and swamps.

Sharp mud-over-peat stratigraphic contacts record these environmental shifts along Turnagain Arm, including sites at Girdwood and Bird Point (Fig. 2). Although the amount of coseismic

* Corresponding author. U.S. Geological Survey, Alaska Science Center, Anchorage, AK, USA. Tel.: +1 541 601 6185.
E-mail addresses: adrianmbender@gmail.com, bendera3@students.wwu.edu (A.M. Bender).

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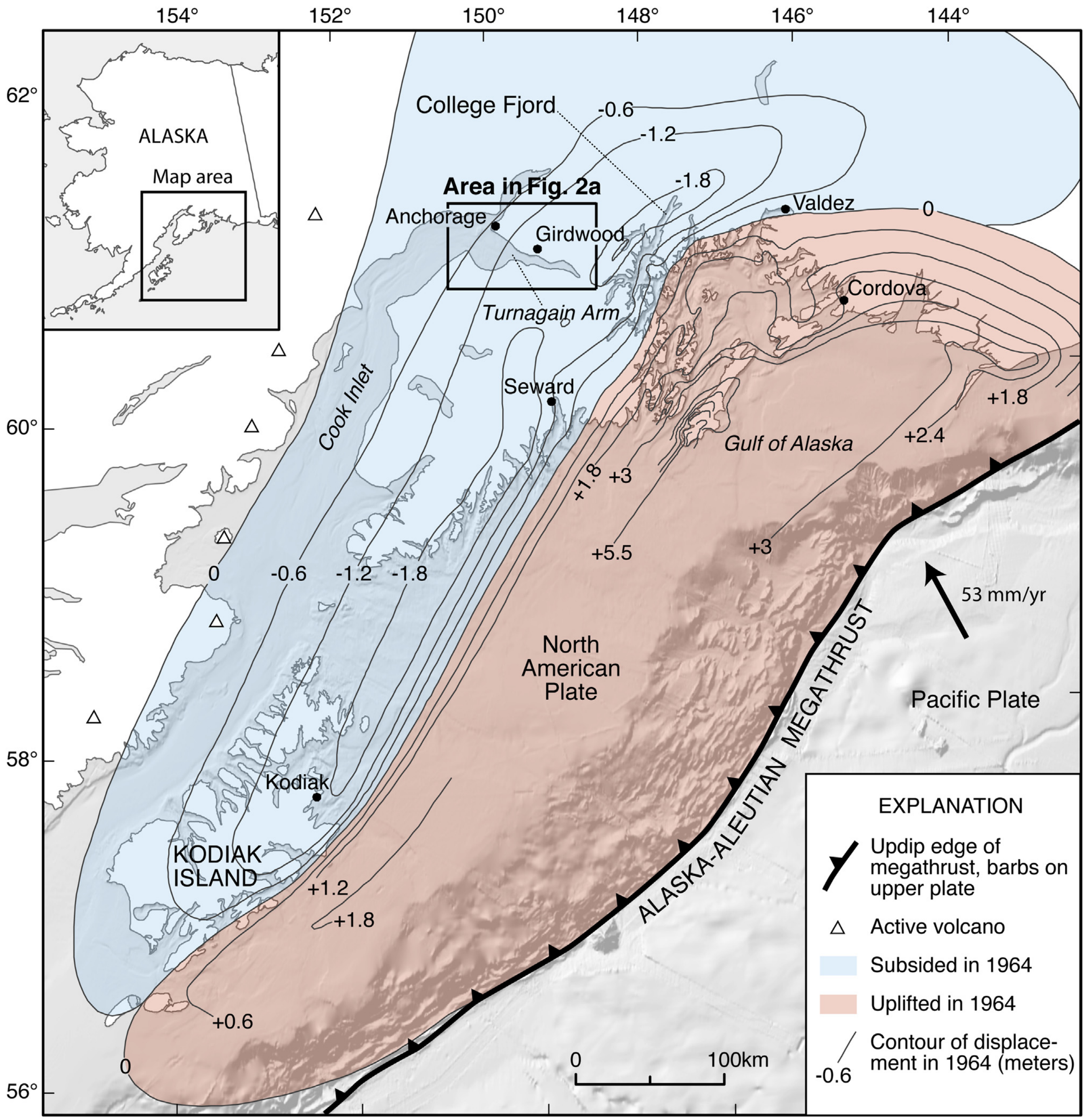

Fig. 1. Tectonic setting of southcentral Alaska above the eastern Alaska-Aleutian subduction zone. Shaded areas depict the distribution and magnitude of regional vertical coseismic displacements (blue, subsidence; red, uplift) that occurred during the 1964 M_w 9.2 great Alaska earthquake (after Plafker, 1969). Contour lines extrapolate between post-earthquake survey measurements, and approximate vertical deformation in meters.

subsidence in 1964 was measured by differencing pre- and post-earthquake leveling along Turnagain Arm (~1.7 m, Small, 1966; Wood, 1966), Hamilton and Shennan (2005) used microfossil transfer functions to estimate a 1.50 ± 0.32 m rise in RSL caused by earthquake subsidence at Girdwood in 1964. However, sparse abundance, poor preservation, or the absence of microfossils at some coastal sites in Alaska may hamper the use of this method to reconstruct RSL changes related to the earthquake deformation cycle (e.g., Wilson et al., 2005a). Reconstructing the vertical component of displacement over multiple earthquake deformation cycles provides critical data that aid assessments of regional seismic and pan-Pacific tsunami hazards.

Here, as an alternative to microfossil-based methods, we explore the potential of using stable carbon and nitrogen isotope ratios in coastal sediment as sea-level indicators. Several studies have shown that $\delta^{13}C$ values and ratios of organic carbon to total nitrogen (C_{org}:N_{tot}) in contemporary intertidal and sub-tidal surface sediment vary with respect to elevation and reflect the origin of organic matter in intertidal sediment (e.g., Chmura and Aharon, 1995; Wilson et al., 2005; Lamb et al., 2006). For example, recent studies have applied stable carbon isotopes in sediment to reconstruct RSL changes in the salt marshes of New Jersey (Kemp et al., 2011) and central Oregon (Engelhart et al., 2013). These studies compare RSL estimates derived from stable carbon isotope values in