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Beach ridges as paleoseismic indicators of abrupt coastal subsidence during subduction zone earthquakes, and implications for Alaska-Aleutian subduction zone paleoseismology, southeast coast of the Kenai Peninsula, Alaska

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ABSTRACT

The Kenai section of the eastern Alaska-Aleutian subduction zone straddles two areas of high slip in the 1964 great Alaska earthquake and is the least studied of the three megathrust segments (Kodiak, Kenai, Prince William Sound) that ruptured in 1964. Investigation of two coastal sites in the eastern part of the Kenai segment, on the southeast coast of the Kenai Peninsula, identified evidence for two subduction zone earthquakes that predate the 1964 earthquake. Both coastal sites provide paleoseismic data through inferred coseismic subsidence of wetlands and associated subsidence-induced erosion of beach ridges. At Verdant Cove, paleo-beach ridges record the paleoseismic history; whereas at Quicksand Cove, buried soils in drowned coastal wetlands are the primary indicators of paleoearthquake occurrence and age. The timing of submergence and death of trees mark the oldest earthquake at Verdant Cove that is consistent with the age of a well documented ~900-year-ago subduction zone earthquake that ruptured the Prince William Sound segment of the megathrust to the east and the Kodiak segment to the west. Soils buried within the last 400–450 years mark the penultimate earthquake on the southeast coast of the Kenai Peninsula. The penultimate earthquake probably occurred before AD 1840 from its absence in Russian historical accounts. The penultimate subduction zone earthquake on the Kenai segment did not rupture in conjunction with the Prince William Sound to the northeast. Therefore the Kenai segment, which is presently creeping, can rupture independently of the adjacent Prince William Sound segment that is presently locked.

1. Introduction

1.1. Tectonic context of the investigation

In March 1964, an 800-km-long rupture of the eastern Alaska-Aleutian megathrust (Plafker, 1969) (Fig. 1A) involved along-strike variations in coseismic slip that define separate segments of the megathrust (Christensen and Beck, 1994). Megathrust slip was highest (up to 20 m) on the Prince William Sound (PWS) and Kodiak segments, and less on the Kenai segment (Suito and Freymueller, 2009). These segments also show contemporary along-strike variability in interplate coupling derived from GPS velocities in the region of the 1964 rupture (Freymueller et al., 2008). GPS observations indicate that presently the PWS and Kodiak segments of the megathrust are locked and the Kenai segment is creeping (Fig. 1A).

The Kenai segment, between the Kodiak and PWS segments of the Alaskan megathrust (Fig. 1A), has an unknown earthquake history prior to 1964. Plafker (1969) identified coastal forests drowned after the 1964 earthquake and measured vertical shifts of

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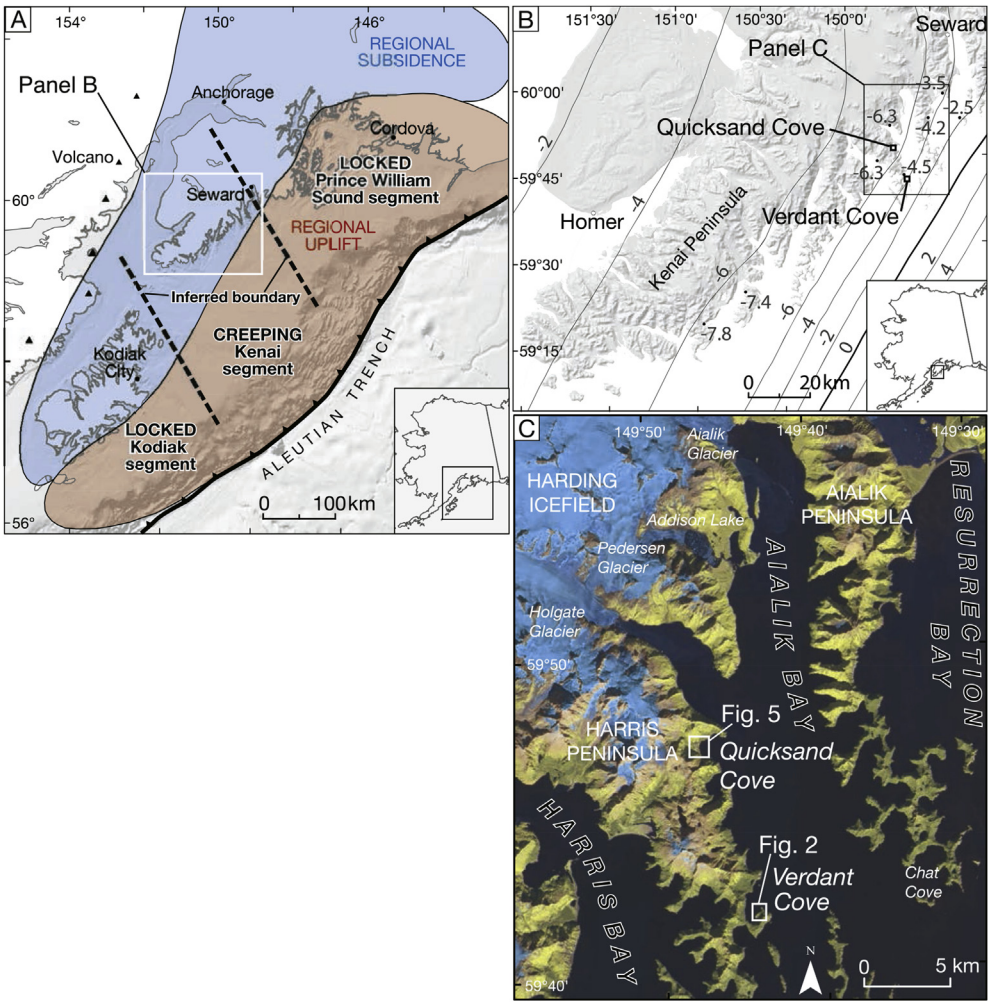

Fig. 1. A. Tectonic setting of the eastern Alaska-Aleutian subduction zone megathrust. Bold line delineates the surface trace of the megathrust, barbs on upper (North American) plate. Vertical deformation during the 1964 great Alaska earthquake depicted by two adjoining margin-parallel belts: a region of landward subsidence (blue) and a region of seaward uplift (red) (Plafker, 1969). Areas of highest slip occurred below the Prince William Sound and Kodiak segments, which are currently locked currently; while the intervening Kenai segment is creeping presently (Freymueller et al., 2008).B. Map of the Kenai Peninsula that shows contours of vertical deformation, in feet, caused by the 1964 Alaska earthquake (Plafker, 1969). Black circles mark sites where subsidence in 1964 was reported by Plafker (1969). Black open squares, two field sites; note that Quicksand Cove site is in the axis of maximum subsidence as a result of the 1964 subduction zone earthquake. C. Landsat image from 4 May 2014 showing the two paleoseismic sites within Kenai Fjords National Park. The white dashed line to the west and northwest of Quicksand Cove is the outline of the basin that drains into the Quicksand Cove coastal wetland.

the shoreline indicative of tectonic subsidence along the southeastern Kenai Peninsula (Fig. 1A and B), but reported no evidence of older Holocene earthquakes. Mann and Crowell (1996) reported ghost forests killed by the 1964 earthquake at several sites on the southeast Kenai coast and evidence for an earlier earthquake about 900 years ago at Verdant Cove. Carver and Plafker (2008) summarize evidence for nine prehistoric earthquakes in the Prince William Sound region inferred from geological evidence for sudden land-level change and, in some cases, tsunami deposits. Radiocarbon-based earthquake chronologies suggest the most recent predecessor to the 1964 earthquake in the Prince William Sound area occurred about 900 years ago and time intervals between earthquakes ranged from around 390 to 900 years (Carver and Plafker, 2008; Shennan et al., 2014a, 2014b). By contrast, paleoseismic evidence to the west of the Kenai Peninsula, at Sitkinak and Kodiak Islands, imply a different earthquake history. Sites on both islands suggest that in addition to a great earthquake about 900 years ago, a historic earthquake ruptured near Sitkinak and Kodiak in AD 1788 (Briggs et al., 2014; Shennan et al., 2014c) and another large or great earthquake occurred between AD 1430 to AD 1650 (Briggs et al., 2014; Shennan et al., 2014a, 2014c).

1.2. Statement of the problem

Our investigations sought evidence for Aleutian megathrust earthquakes and tsunamis, including the 1964 earthquake, in the boundary region between the Kenai and PWS segments (Fig. 1). The problem we address is that, although in 1964 the Aleutian megathrust ruptured from Prince William Sound to the southwest end of Kodiak segment (Plafker, 1969), rupturing through what is now the central creeping Kenai segment, the history of earlier subduction zone earthquakes in the Kenai segment is unknown. To address the problem, we reconstructed a record of prehistoric earthquakes and tsunamis along the Kenai segment to compare with paleoseismic records from the PWS and Kodiak segments.

To investigate tectonic history of the Kenai segment of the subduction zone, we focus field work on the southeast Kenai coast where there was >1 m of coseismic subsidence during the 1964 earthquake (Fig. 1B); and where the coastal setting has a high potential for preservation of a record of earlier instances of subsidence. The southeast Kenai coast is a high-wave-energy coast that receives sediment from basins that were extensively glaciated at the Last Glacial Maximum and glaciated to a lesser extent during