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Volcanic tsunamis and prehistoric cultural transitions in Cook Inlet, Alaska

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ABSTRACT

The 1883 eruption of Augustine Volcano produced a tsunami when a debris avalanche traveled into the waters of Cook Inlet. Older debris avalanches and coeval paleotsunami deposits from sites around Cook Inlet record several older volcanic tsunamis. A debris avalanche into the sea on the west side of Augustine Island ca. 450 years ago produced a wave that affected areas 17 m above high tide on Augustine Island. A large volcanic tsunami was generated by a debris avalanche on the east side of Augustine Island ca. 1600 yr BP, and affected areas more than 7 m above high tide at distances of 80 km from the volcano on the Kenai Peninsula. A tsunami deposit dated to ca. 3600 yr BP is tentatively correlated with a southward directed collapse of the summit of Redoubt Volcano, although little is known about the magnitude of the tsunami. The 1600 yr BP tsunami from Augustine Volcano occurred about the same time as the collapse of the well-developed Kachemak culture in the southern Cook Inlet area, suggesting a link between volcanic tsunamis and prehistoric cultural changes in this region of Alaska.

1. Introduction

Volcanic eruptions can cause natural disasters that have significant effects on human societies over large areas (Torrence and Grattan, 2002). Volcanic phenomena such as lava flows, volcanic mudflows, debris avalanches, and pyroclastic flows can bury and damage extensive areas around volcanoes (Sheets and Grayson, 1979; Blong, 1984). Volcanic tsunamis can cause extensive damage at greater distances from eruptions than other volcanic processes and cause casualties in coastal areas where people are completely unaware of what is happening at the volcano. The 1883 Krakatau eruption in Indonesia, for example, produced large tsunamis that caused almost complete destruction and more than 36,000 fatalities in coastal areas of Java and Sumatra up to 100 km from the volcano, with more scattered damage and fatalities as far away as Sri Lanka, more than 2500 km from the volcano (Latter, 1981).

Augustine Volcano in the southern Cook Inlet area of Alaska also erupted in 1883 and also produced a tsunami, but the wave and its effects were much smaller than those at Krakatau. Historical accounts and paleotsunami deposits show the 1883 wave was about 6–8 m high in areas 80 km from the volcano and affected widely separated coastal sites over an area of 10,000 km^2 around southern Cook Inlet (Beget and Kowalik, 2006). By a stroke of luck no fatalities resulted from the Augustine volcanic tsunami because Cook Inlet has very large tides, ranging from 6–10 m, and the 1883 tsunami occurred near low tide (Kienle et al., 1987).

Paleotsunami deposits and erosional features can be used to reconstruct tsunami histories (Rhodes et al., 2006). The sedimentary deposits and erosional features produced by historic and prehistoric tsunamis can be used to reconstruct wave heights and the extent of inland inundation (Dawson and Shi, 2000; Carey et al., 2001). Most research on tsunami deposits has been done on sediments left by waves in tidal marshes and back beach areas, but tsunami waves may also carry marine and beach sediments into terrestrial lakes and peats (Bondevik et al., 1997, 1998, 2003). In both settings, tsunamis produce distinctive layers of sediment entrained from beaches and other coastal environments that record deposition from one or more waves that reach inland areas beyond the limits of normal wave activity (Tuttle et al., 2004).

Here we report on paleotsunami deposits and erosional features that suggest at least four volcanic tsunamis were produced from two different volcanoes in the Cook Inlet area of Alaska during the last 3600 years. Archeological studies indicate the native people living in the Cook Inlet area during this time interval inhabited coastal villages and depended on marine resources for survival (Klein, 1997). We show that one of the prehistoric volcanic tsunamis in southern Cook Inlet occurred at approximately the same time as a significant cultural break in the late Holocene archeological record of the Cook Inlet area, and we suggest the tsunami played a role in this cultural transition.

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2. The 1883 debris avalanche and tsunami from Augustine Volcano

The 1883 volcanic tsunami from Augustine Volcano provides a model for understanding the magnitude and possible effects of prehistoric tsunamis on the early inhabitants of Cook Inlet, Alaska. The tsunami was generated on October 6, 1883, when a portion of the summit of Augustine Volcano collapsed northward into the sea. Augustine Island is uninhabited, so the nearest observations of the eruption were made from English Bay (modern Nanwalek), located 80 km northeast of the volcano (Fig. 1). An eyewitness account of the volcanic tsunami produced by the eruption was recorded in the daily log of the Alaska Commercial Company trading post at English Bay (Alaska Commercial Company, 1883):

> "At this morning at 8:15 o'clock, 4 tidal waves flowed with a westerly current, one following the other at the rate of 30 miles p. hour into the shore, the sea rising 20 feet above the usual level. At the same time the air became black and foggy, and it began to thunder. With this at the same time it began to rain a finely Powdered Brimstone Ashes, which lasted for about 10 minutes, and which covered everything to a depth of over 1/4 inch… the rain of ashes commencing again at 11 o'clock and lasting all day."

Accounts of the 1883 debris avalanche collected by archeologists and oral historians from the descendants of native Alaskans living in villages affected by the 1883 tsunami are consistent with the written account (Pratt Museum, 2004). There were no reported fatalities from the 1883 tsunami, but the tsunami flooded coastal dwellings and washed away small boats. Cook Inlet has some of the largest tides on earth, and the 1883 Augustine tsunami occurred during a falling tide, when water levels were several meters below high tide level (Fig. 2). The 20 ft (ca. 6 m) waves observed at English Bay mainly affected areas near the shore, and little damage occurred in the small coastal village that existed at that time. The distribution of 1883 paleotsunami deposits shows the tsunami washed over the southernmost part of the low-lying sand spit occupied by the village of English Bay (Beget and Kowalik, 2006).

Contemporary scientists reported the 1883 tsunami (Davidson, 1884), but didn't fully understand how the tsunami was generated at Augustine Volcano. Modern geologic studies on Augustine Island (Kienle et al., 1987; Siebert et al., 1989; Siebert et al., 1995; Waitt and Beget, 1996; Waitt and Beget, in press) have shown that edifice failure during the 1883 eruption generated a debris avalanche with a volume of ca. 0.5 km^3 that flowed down the north flank of the volcano towards the shoreline of Augustine Island and formed Burr Point (Fig. 2). Former seacliffs showing the position of the 1883 shoreline today lie 2 km inland from the coast. The former cliffs have been largely buried by hummocky 1883 avalanche debris deposits ca. 10–15 m thick and by more recent pyroclastic flows. The 1883 debris avalanche flowed an additional 4 to 5 km into the sea (Beget and Kienle, 1992; Beget and Kowalik, 2006).

The debris avalanche displaced enormous amounts of water from Cook Inlet as it flowed into the sea. Numerical modeling studies indicate that the tsunami was formed at and above the leading edge of the debris avalanche as it flowed beneath the sea, in a manner similar to the way local tsunami waves were observed forming above submarine landslides during the 1964 Good Friday earthquake near Valdez and Seward, Alaska. The numerical modeling shows that tsunamis generated at Augustine Island traveled at speeds of up to 100 km/h and took about 50 min to travel from Augustine Island to English Bay (Beget and Kowalik, 2006).

The eyewitness account from English Bay notes that a minor ash fall occurred at the same time as the tsunami arrived. This ash fall cannot have been a product of the same eruption that generated the tsunami, as ash would have traveled more slowly than the tsunami wave. Ash eruptions tracked during the 2006 eruption of Augustine

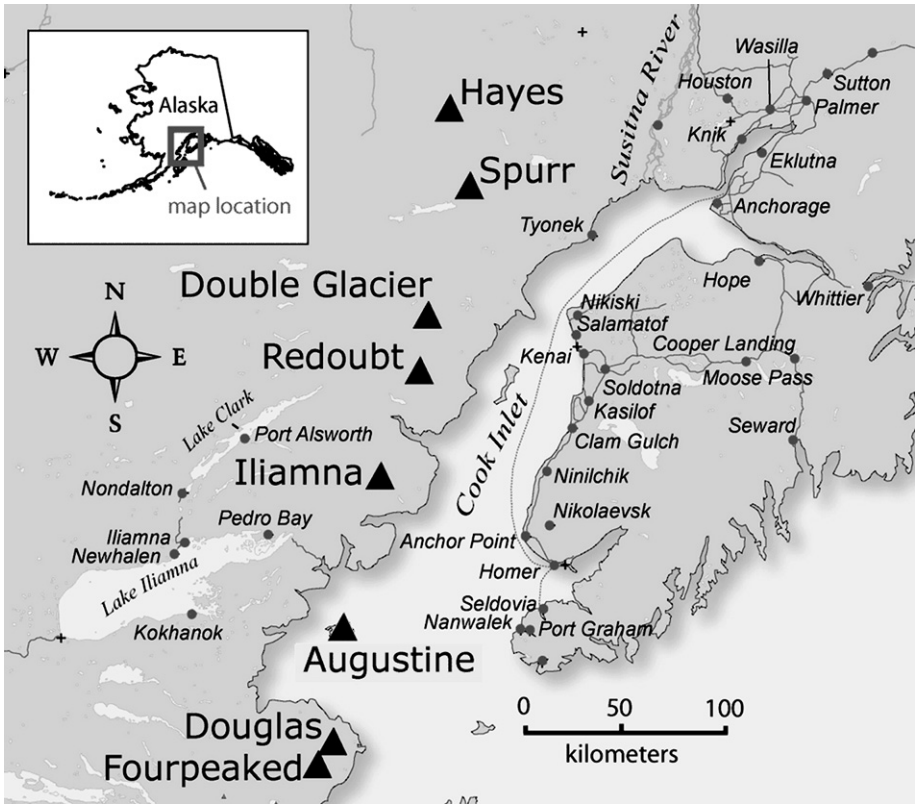

Fig. 1. Augustine and Redoubt Volcanoes have produced large debris avalanches and lahars that traveled into Cook Inlet and generated tsunamis. The western side of Cook Inlet is largely uninhabited, while on the eastern side a series small towns and villages occur along the coastline of the Kenai Peninsula. The road network (solid lines) and the state ferry system (dashed line) are restricted to the east side of the inlet, and remote sites beyond the road and ferry networks can only be accessed by small boat, air taxi, and helicopter.