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Subglacial deformation of trees within overridden foreland strata, Bering Glacier, Alaska

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Abstract

The foreland stratigraphy overridden during recent Bering Glacier surges bears evidence of subglacial deformation. The pre-existing, fine textured substrate (till and diamicton) experienced diminished strength because of saturation, thus resulting in shallow mobilization and the formation of a new till of limited thickness. Glacial coupling with well drained sediment resulted in ploughing that generated a diamicton that retains vestiges of outwash sorting and stratification.

The outwash sequence extending decimeters beneath the surface till contains four prominent sub-meter sand beds. Each sand bed holds multiple small, fossil trees still rooted in underlying layers of gravel. Virtually all trees in the upper two sand beds are deformed. Several are offset by centimeter to decimeter horizontal shears confined to thin, silt, and clay-rich zones at the base of each sand bed. Trees that escaped shearing are warped and kinked. Deformed trees are present at depths that range from 15.76 to 5.31 m. beneath potential ice/substrate interface surfaces.

The most likely source of deforming stress in this foreland setting is related to glacial advance. The style and orientation of tree deformation are consistent with the direction of ice movement. Therefore, the occurrence of deformed trees is attributed to stress applied by overriding ice.

Keywords: Substrate deformation; Overriding glacial ice

1. Introduction

Bering Glacier, Alaska is known to have surged repeatedly in historic time (Post, 1972; Muller and Fleisher, 1995; Fleisher et al., 1995; Molnia and Post, 1995). Each of the past two surges (1965–67 and 1993–95) were punctuated by jokulhlaups along the eastern sector ice front. Observations during the 1993–95 surge, coupled with stratigraphy exposed because of flood erosion of bluffs indicate that pre-existing sediment was deformed when overridden by ice. Although recognition of substrate deformation is not new (Alley, 1989; Alley, 1993; Benn, 1995; Boulton, 1979; Boulton and Hindmarsh, 1987; Clarke, 1987; Clarke et al., 1984, Hart et al., 1990), seldom can the cause and effect be so clearly and directly linked.

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The deformed stratigraphic units are members of the Weeping Peat Formation that have type sections in the island bluffs along the eastern sector of the piedmont lobe of the Bering Glacier (Fleisher et al., 1998) (Fig. 1). Till and diamicton at the top of the section served as source material for a new till formed during 1993–95 surge. Young spruce trees and alder, killed by burial within lake sand and outwash gravel while still in the living position, were subsequently deformed at depth when the entire stratigraphic section was overridden by ice.

2. Methods

An archive of photographs taken at two- to five-month intervals from four survey stations on foreland islands documents changes in the ice front position, ice thickness, and conditions of ground saturation and deformation at the base of the advancing glacier during the initial six months of the 1993–95 surge, (Fleisher et al., 1995). Rates of advance were measured at six ground survey stations during summer months in 1994 and 1995, until surging advance finally ceased on the eastern sector in September 1995.

The stratigraphy exposed during post-surge retreat was examined in several measured sections on Weeping Peat Island. Buried sub-fossil trees partially exposed by bluff erosion were completely exhumed to expose trunks and root systems, and to establish autochthonous occurrence. Global Positioning System coordinates were recorded, trees and host sediment were photographed and sketched, and wood samples were obtained for the analysis of growth rings and future radiocarbon dating.

3. Shallow deformation of overridden substrate, Weeping Peat Island

During the initial six months of the 1993–95 surge, ice mounted island bluffs, advanced across the foreland and ploughed into ice-contact, proglacial lakes at measured rates of 3 to 7 m/day (Fleisher et al., 1995). The ground within a few meters of the ice front, consisting of till, diamicton, and outwash, was sufficiently saturated to completely lack shear strength and exhibit physical properties similar to that of freshly poured concrete. A few meters from the ice front, beyond this peripheral zone of saturation, the same sediment

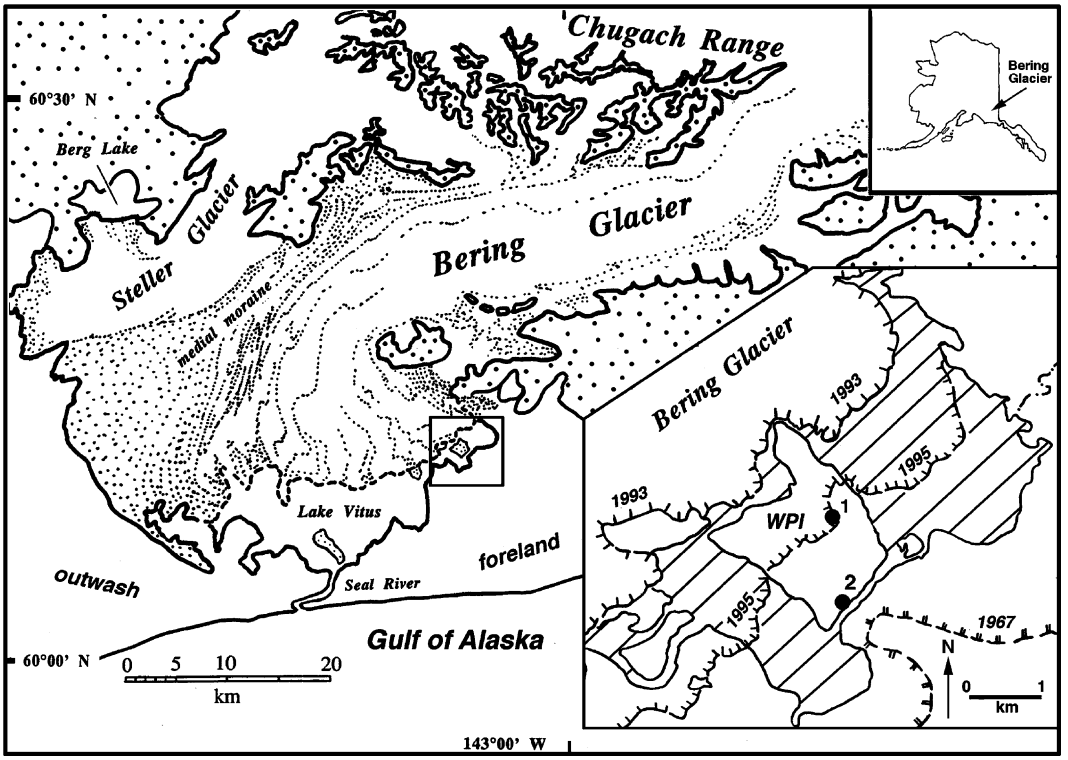

Fig. 1. Regional and eastern sector index map. Inset map illustrates the locations of study sites 1 (flutes and push moraine) and 2 (Waterworks) on Weeping Peat Island (WPI). Shown are ice front positions for the 1965–67 surge limit, retreat position in 1993, and maximum extent of 1993–95 surge.