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Full-glacial paleosols in perennially frozen loess sequences, Klondike goldfields, Yukon Territory, Canada

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Abstract

Perennially frozen loess deposits in the Klondike goldfields include paleosols formed in full-glacial environments, correlated by Alaskan distal tephra with Marine Isotope Stages (MIS) 2 and 4. Patterns of organic and inorganic carbon and clay distribution, microstructures, and profile morphologies indicate that soil formation occurred in a base-rich environment in which organic matter accreted predominantly as root detritus. At sites approximately 20 km apart, the expression of cryoturbation and ice wedge development decreases in strength upward in loess–paleosol sequences correlated with MIS 4, suggesting increasing aridity. Configurations of cryoturbation features and ice-wedge thaw unconformities, the presence of numerous ground squirrel burrows, and an absence of peat accumulation suggest that these substrates were predominantly well-drained, with active layers of equal or greater thickness than in modern soils on similar sites in the west-central Yukon. Some characteristics of these paleosols are similar to those of modern steppe and tundra soils, consistent with plant macrofossil evidence for local ecological diversity during full-glacial conditions in eastern Beringia.

Keywords: Beringia; Cryoturbation; Loess; Paleosols; Permafrost; Soil micromorphology; Steppe; Tephra; Tundra

Introduction

Paleoenvironmental reconstructions of Beringia during the last and earlier glaciations are based primarily on fossil biological evidence, including pollen, plant macro-remains, insects and megafauna, and have been used to support inferences about other ecosystem components such as soils (Cwynar and Ritchie, 1980; Ritchie and Cwynar, 1982; Guthrie, 1990; Zazula et al., 2005). The central importance of soils has been recognized in conceptual models of Beringian full-glacial ecosystems (Guthrie, 1990; Schweger, 1997), but there have been only limited direct paleopedological data to support these paleoenvironmental reconstructions. Full-glacial paleosols preserved under ca. 21,500 cal yr BP tephra on the northern Seward Peninsula in Alaska were interpreted as having formed in a climate that was cooler and drier than at present, with active loess deposition (Höfle and Ping, 1996; Höfle et al., 2000). Loess–paleosol sequences in central Alaska record several glacial–interglacial cycles, and research has emphasized loess provenance and accumulation rates, criteria for recognizing and classifying paleosols, and the interglacial record of paleosols, but it has not yet addressed the pedological characteristics of full-glacial environments (e.g., Muhs et al., 2000, 2003).

In the Klondike goldfields of west-central Yukon Territory, perennially frozen deposits contain a rich record of Pleistocene flora and fauna preserved in primary and redeposited loess, with chronological control provided by numerous distal tephra beds derived from vents in southern Alaska (Preece et al., 2000; Froese et al., 2001, 2002). The occurrence of full-glacial paleosols in these sediments has been reported (Fraser and

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Burn, 1997), but their characteristics, origins and paleoenvironmental significance have not been addressed previously. This paper presents data on the morphological, physical, and chemical properties of these full-glacial paleosols, interprets their genesis in relation to modern analogues, and demonstrates their regional nature.

Regional setting and study site locations

Perennially frozen organic matter-rich silty sediments, known as "muck" deposits, are preserved in valley bottoms and on north or north-east slope aspects in the Klondike goldfields of unglaciated west-central Yukon Territory (Fraser and Burn, 1997; Kotler and Burn, 2000) and central Alaska (Péwé, 1975). In central Yukon, radiocarbon ages indicate that muck aggradation was pronounced near the onset of the last glaciation, ca. 25,000 yr BP, associated with deteriorating climates that were conducive to loess entrainment and redistribution (Froese et al., 2002; Zazula et al., 2005). The occurrence of older tephra beds within muck deposits indicates several intervals of loess accumulation associated with previous glacial intervals (Westgate et al., 2001).

Paleosols and associated sediments were examined in muck deposits at two placer gold mines approximately 20 km apart: Tatlow Camp (63°49′19"N 139°1′41′′W) on Quartz Creek and the Christie Mine (63°39′59′′N 138°38′42′′W) on lower Dominion Creek (Fig. 1). On the basis of major element chemistry of glass shards, tephras at the Christie Mine and in deeper strata at Tatlow Camp are correlated with the Sheep Creek K (SCt-K) and Dominion Creek tephras (DCt) (Westgate and Preece, 2005). Dominion Creek tephra has a glass fission track age of 82,000 ± 9000 yr and occurs in close association with the SCt-K tephra, indicating that it is a much younger eruption than the better known Sheep Creek Fairbanks occurrence (Westgate et al., 2001; Westgate and Preece, 2005). Based on this chronology, paleosols associated with SCt-K and DCt are correlated to early marine isotope stage (MIS) 4, while the Dawson tephra, dated to 24,000 ^{14}C yr BP is associated with early MIS 2 (Froese et al., 2002).

Methods

Paleosol horizons and associated sediments were described and sampled in 2003 and 2004 at exposures created by recent placer mining. Morphological descriptions (Appendix A) used soil horizon designations and descriptive terminology according to the Canadian System of Soil Classification (Soil Classification Working Group, 1998) and the Expert Committee on Soil Survey (1983). Bulk soil samples for physical and chemical characterization were collected from freshly cleaned sections in a partially or completely thawed condition and dried at room temperature prior to analysis. Laboratory analyses consisted of particle-size analysis by the pipette method (Gee and Bauder, 1986) following removal of organic matter and carbonates, total carbon and nitrogen (Fisons NA1500 NC analyzer), and inorganic carbon (Bundy and Bremner, 1972). Organic C was

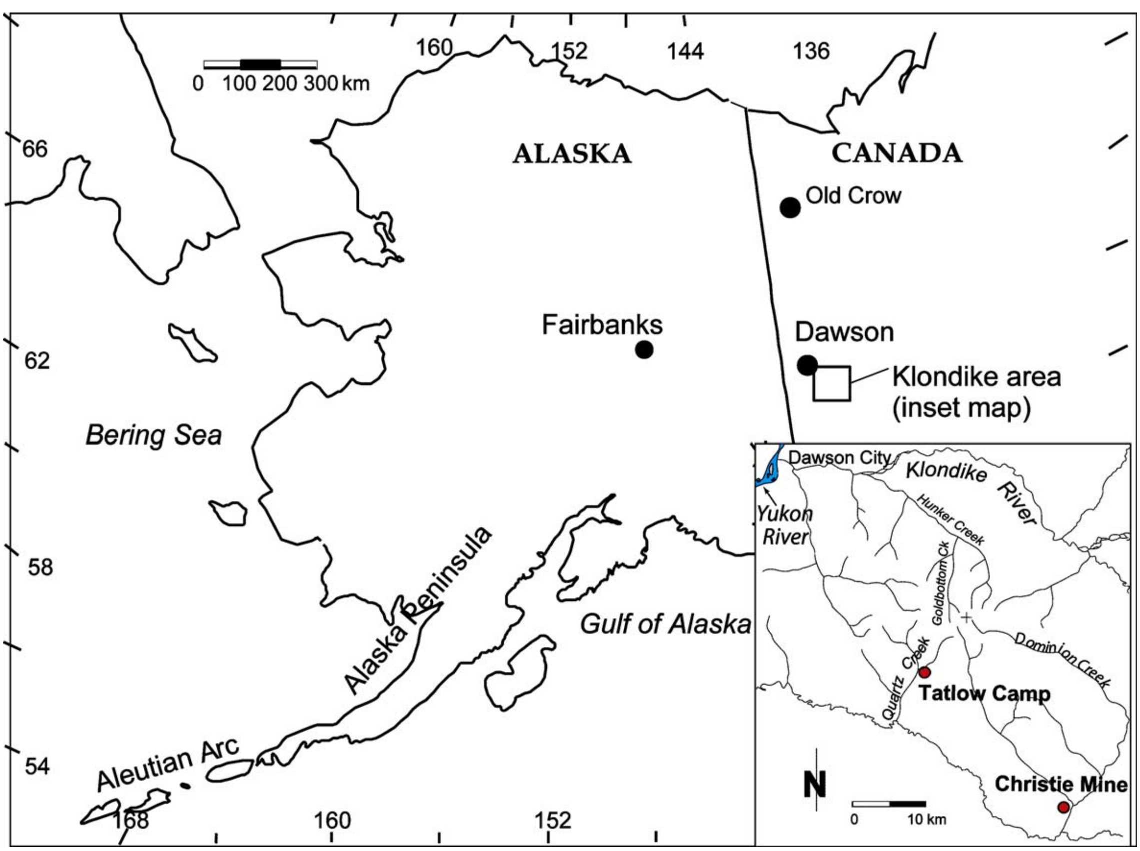

Figure 1. Study site locations.