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Deposition and pedogenesis of periglacial sediments and buried soils at the Serpentine Hot Springs archaeological site, Seward Peninsula, AK

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ABSTRACT

Soil micromorphology is an excellent tool for relating quantitative laboratory data to soil development in complex pedogenic settings. This study utilizes micromorphology, scanning electron microscopy, bulk soil geochemistry, clay mineralogy, and particle-size analysis to reconstruct the depositional and pedogenic history of the Serpentine Hot Springs fluted point site on the Seward Peninsula, Alaska. Sediment deposition occurred via colluviation, which dominated during the late glacial period and early- to middle-Holocene, and aeolian processes, which dominated during the Younger Dryas (YD) and late Holocene. Two buried soils are present: one dating to the Holocene Thermal Maximum (HTM) and the other dating just before the Neoglacial period. Pedofeatures fall into four categories: 1) cryogenic features; 2) clay illuviation features; 3) podzolization/redox features; and 4) anthropogenic features. The spatial relationships among these features provides insight into the pedogenic history of the soil. The HTM soil is characterized by clay illuviation, suggesting warm, mildly acidic, well-drained soil conditions. The pre-Neoglacial soil is characterized by incipient placic horizon development and podzolization, indicative of moist, acidic, variably drained conditions. Cryogenic features associated with late Holocene Neoglaciation dominate the modern soil. Despite cryogenic activity and the presence of permafrost, the cultural stratigraphy of the site remains intact.

1. Introduction

Micromorphology, the microscopic examination of soils in their undisturbed states (Stoops, 2003), is concerned with the genesis, classification, and characterization of sediments, soils, and paleosols as well as the interaction of soils with the landscapes and climatic conditions which shape them (Kubiëna, 1938). It is a tool long used in paleopedology and, more recently, in geoarchaeology to better understand the processes by which soils form and change over time. Most commonly, micropedological techniques are applied to answer questions about deposition, site and soil formation, and paleoenvironment (Courty, 1991; Douglas et al., 1990; Ringrose-Voase et al., 1994; Rutherford, 1974).

Since the 1970s, micromorphology has been applied as a tool to better understand complex temporal and spatial relationships within soil profiles. It has been used in paleoenvironmental studies to help address interpretive difficulties resulting from the superposition of pedogenic features associated with one set of climatic or environmental conditions on top of features associated with a different set of conditions, often referred to as pedogenic overprinting (e.g. Bronger et al., 1993; Driese and Ashley, 2016; Kemp, 1999, 1998; McCarthy et al., 1998). From an archaeological perspective, micromorphological studies have been used to address concerns about the stratigraphic integrity of the archaeological record at sites in ‘active’ soils, such as Vertisols and Gelisols which can displace artifacts (e.g. Bertran, 1994; Bertran et al., 2010; Bertran and Texier, 1995; Driese et al., 2013; Gilbert, 2011; Todisco and Bhiry, 2008).

The periglacial soils and sediments at the Serpentine Hot Springs archaeological site on the Seward Peninsula offer an ideal opportunity to demonstrate the utility of micromorphology in geoarchaeological and paleoenvironmental contexts. The Serpentine Hot Springs site represents the first well-documented occurrence of fluted points in a buried, well-dated context in Alaska and, as such, plays an important role in understanding the migration of modern *Homo sapiens* into North America (Goebel et al., 2013; Smith et al., 2013). The place of Alaska's fluted point sites within the broader context of early human occupations of North America has long been debated (Goebel et al., 2013; Goebel and Potter, 2016; Smith et al., 2013; Solecki, 1950). Fluted points are diagnostic of Clovis technology, the first widespread and well-documented Paleoamerican archaeological complex in North

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America. Although the presence of modern humans in the Americas prior to the Clovis culture has gained increasing acceptance in recent years, a viable predecessor for Clovis technology has yet to be identified. When first discovered in the 1950s, Alaskan fluted points appeared to be a promising candidate for such an antecedent technology, but these first-discovered points were not recovered from contexts that could be dated reliably. Since that time, however, Alaskan fluted points have been recovered from buried contexts and a very different picture of their role in North American prehistory has emerged. Rather than representing a progenitor of Clovis technology, recent work suggests that Alaskan fluted points may instead represent a so-called 'reverse' migration of Clovis peoples from the northwestern United States and Canada back into Alaska (Smith and Goebel, 2018). Thus, understanding the integrity of the archaeological record at Serpentine, a key fluted point site in Alaska, is critical. However, the site is in a periglacial setting, where disruptive processes such as cryoturbation and solifluction are a major concern for the stratigraphic integrity of the archaeological record. Micromorphology allows for a more detailed assessment of the degree of site disturbance and can help identify problem areas for interpreting archaeological data.

Understanding the paleoenvironmental history of the Serpentine soil is also important, because climate research has begun to predict the magnitude and effects of future climate change, and the models have suggested that the high-latitudes exhibit amplified responses to warming (Flato and Boer, 2001). Understanding amplified warming in the northern latitudes is especially important because it operates as a positive feedback mechanism-warming causes permafrost melting, which, in turn, leads to the oxidation of previously-sequestered organic matter and the release of CO_2 and CH_4. This process is a complex one (Davidson and Janssens, 2006) that highlights the need for real-world paleoclimate case studies to 'field check' the validity of model predictions. Paleoenvironmental studies of high-latitude soils are far fewer in number than studies of their temperate and tropical counterparts and micromorphological analysis of soils like those at Serpentine can provide an important, albeit qualitative, record of how these sensitive soils have responded to the dynamic climate shifts of the late Quaternary. This study integrates classical micromorphological analysis with scanning electron microscopy, detailed particle size analysis, and geochemical methods to determine the depositional and pedogenic history of the soils at the Serpentine site and the integrity of the important archaeological record it contains.

2. Background

2.1. Geographic setting

The Serpentine Hot Springs fluted point site, BEN-192, is located on the Seward Peninsula in northwest Alaska within the confines of Bering Land Bridge National Preserve (Fig. 1). Although the regional bedrock primarily consists of meta-sedimentary rocks and chlorite schists, the site itself sits at the edge of one of a series of tin ore-bearing, shallowly emplaced Late Cretaceous biotite granite stocks, locally known as the Oonatut Granite complex (Hudson, 1977). The landscape surrounding the site is characterized by granite tors, ridges, and rolling hills, separated by broad upland valleys. The bluff upon which the site is located overlooks the hot springs for which it is named to the southeast and a small, unnamed creek that flows into Hot Springs Creek to the south.

Non-acidic shrub tundra species, including dwarf birch, various blueberry species, lowbush cranberry, bear berry, crowberry, lichens, and mosses, dominate the modern upland vegetation. Stands of *Salix sp.* (willow) are commonly found along creek margins and floodplains in the valley.

Mean annual precipitation (MAP) at the site is ~400 mm/yr, about 60% of which falls during the summer months (Rupp et al., 2000). The area receives approximately 150 mm/yr snowfall during the winter. Winters are cold and long with temperatures reaching −30 °C on average, and temperatures are below freezing between October and May (Hopkins, 1959; Rupp et al., 2000). Summers (June–September) are generally cool, with an average temperature near 7 °C (Rupp et al., 2000), giving a mean annual temperature of −6 °C (Hopkins, 1959). Although it is located just south of the Arctic Circle, the site and surrounding area were not glaciated during the Last Glacial Maximum. Instead, glaciation was restricted to the Kigluaik, Darby, York, and Bendeleben Mountains (Calkin, 1988; Kaufman and Hopkins, 1986; Kaufman and Manley, 2004).

2.2. Site stratigraphy

Three major colluvial stratigraphic units were identified at Serpentine during excavation (Fig. 2). These units were differentiated primarily based on field textural analysis and were identified independently of soil horizons. Each of the three strata, designated as units 1, 2, and 3 from oldest to youngest, were interpreted as colluvial in origin, having washed down the gentle slope behind the site. The bedrock surface upon which the sediment package rests unconformably has irregular topography and is variably weathered across the landform. In most places, a thick layer of gruss or gravelly, saprolitized granite overlies fresh bedrock and forms the base of the profile (Unit 0). Colluviation of this grussy material from upslope was interpreted as the primary depositional mechanism for units 1, 2, and 3 (Goebel et al., 2013). A large blowout is located along the bluff edge directly adjacent to the site, and it is likely that this and other similar areas have contributed aeolian silt to the soil as well, although in lesser quantities than the colluvium.

Unit 1 is the basal sedimentary unit. It is a poorly-sorted, angular to subangular, brown, clayey to silty gravel with abundant silty and clayey matrix. Gravel clasts are primarily granite lithic fragments 3–5 mm in diameter. Coarse material (sand and gravel) is, in some instances, concentrated in lenses. Unit 2, a clayey silt, overlies Unit 1. The contact between the two depositional units is irregular to wavy. Unit 2 is more clay-rich and better sorted than Unit 1, although abundant sand and gravel are still present. Its color is much darker, and abundant charcoal is present. Overlying Unit 2 is Unit 3, another silty gravel that is texturally like Unit 1. The thickness of Unit 3 is variable, ranging from about 20–70 cm. All three units appear to have been affected by cryoturbation, because the boundaries between them are irregular and highly undulatory in places. It is important to note, however, that all three units are easily distinguishable from one another and readily identifiable across the site.

3. Materials and methods

3.1. Field description and sampling

Block excavation of 33 m^2 was conducted at Serpentine over the course of three summer field seasons between 2009 and 2011 (Fig. 2). During excavation, the three lithostratigraphic units described above were identified. Since the textural and morphological differences between the three units were easily recognized during excavation, these lithostratigraphic designations were used by most excavators when taking field notes and logging artifact provenance. Once excavation was finished and work on the soil profile itself began, the profile was described and mapped by Michael Waters and Kelly Graf (Texas A & M Univ.) in accordance with NRCS soil-description protocols. Samples were taken from the geologic trench excavated at the site. Bulk sediment samples were taken from each depositional unit: two samples from units 1 and 3, one sample from Unit 2, and one sample from the grussy saprolite (Fig. 2). Two oriented samples for micromorphological analysis were collected in plastic electrical conduit boxes from each unit.

During excavation, trend and plunge were measured for all large-sized artifacts (those whose size was great enough that the measuring