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Soil-geomorphic relations of lamellae in eolian sand on the High Plains of Texas and New Mexico

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Abstract

Clay lamellae are ubiquitous features in sands in a wide variety of settings around the world. Most studies of lamellae focus on: 1) a few or individual locales or on 2) formation by experimental methods in the laboratory. This study reports on lamellae from eight localities in three late-Quaternary dune fields on the Southern High Plains of northwest Texas and eastern New Mexico. Most lamellae observed are illuvial and they increase in number and thickness through time. A few (1–3) thin (1–2 mm) lamellae formed in Historic sediments. Lamellae are more numerous (3–12) and thicker (3–5 mm) in older late Holocene (< 1000 ^{14}C years BP) and middle Holocene (< 7600 ^{14}C years BP) sands. Soils that formed through the late Pleistocene and into the early Holocene (14,300–7600 ^{14}C years BP) or soils that formed throughout the Holocene can exhibit as many as 30 lamellae or lamellae of 10–12 mm thickness. The micromorphology of the lamellae shows that argillans on sand grains are thicker, more laminated, more continuous, and cap and link more grains through time. Other variables affect lamella morphology. Within individual dunes, the lamellae are best expressed where the sand is thickest; they decrease in number and thickness as sand thins. The lamellae also form only in clean, well-drained sand. Poor drainage and/or bioturbation result in formation of a continuous argillic horizon encasing lamellae.

Keywords: Lamellae; Clay band; Southern High Plains; Eolian sand; Soil geomorphology

1. Introduction

Lamellae are common features in sandy soils in a variety of environments (e.g., Dijkerman et al., 1967; Gray et al., 1976; Ahlbrandt and Freyberger, 1980; Larsen and Schuldenrein, 1990; Prusinkiewicz et al., 1998; Rawling, 2000). The origins of these thin, relatively clay-rich zones within a sandy parent material have been debated for decades, based both

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on field and experimental observations (summarized by Rawling, 2000). They are thought to originate via primary deposition, via pedogenesis or via pedogenesis controlled by sedimentary characteristics (Rawling, 2000 and references therein). Specific pedogenic mechanisms involved in lamella formation include sieving at pore discontinuities, flocculation where the pH is increased by either calcium carbonate or iron, reduction in the carrying capacity of soil water as the wetting front dries or clay precipitation when a maximum carrying capacity of the soil water is exceeded (Rawling, 2000 and references therein).

Despite the apparent interest in lamella genesis, data on rates of lamella formation and on their spatial variability are lacking. Only a few papers report direct age control (radiocarbon or archaeological) (Gray et al., 1976; Ahlbrandt et al., 1983; Berg, 1984; Larsen and Schuldenrein, 1990; Prusinkiewicz et al., 1998; Rawling, 2000). Likewise, most studies deal with one or a few profiles or focus on a small area. Understanding the rates of lamella formation and looking at these soils from a variety of settings in a regional context may provide clues regarding their genesis and help in evaluating the utility of lamellae as correlation tools and as age indicators in soil-stratigraphic and soil-geomorphic research.

This paper presents the results of research into the evolution of lamellae in late-Quaternary eolian sand on the Southern High Plains (Fig. 1). This research builds on the work of Gile (1979, 1981, 1985), who first discussed lamellae in the region in his classic 1979 paper. His work in the Muleshoe Dunes suggested that: 1) the number and thickness of lamellae appear to increase with age; 2) continuous Bt horizons evolve from lamellae; and 3) lamella morphology could be a useful tool for stratigraphic correlation throughout the dune field. Gile's data was from a small study area within the Muleshoe Dunes, however, and he had only limited age control. The data presented here are from throughout the Muleshoe Dunes as well as several other dune fields and sand sheets on the Southern High Plains. Moreover, many of the soils with lamellae are now dated by radiocarbon assays, archaeological artifacts whose age range is well constrained, and stratigraphic correlation. In addition to firmer age control, this paper also presents the results of thin-section analysis of the lamellae. The thin sections were used to better characterize the lamellae and to help confirm their genesis.

2. Setting and factors of soil formation

The Southern High Plains or Llano Estacado ("stockaded plains") is a broad plateau covering approximately 130,000 km^2 in northwestern Texas and eastern New Mexico (Fig. 1). The climate of the region is continental and semi-arid, dry steppe (Carr, 1967; Bailey, 1995). Precipitation ranges from almost 500 mm/year in the north to 280 mm/year in the southwest, and mean annual air temperature ranges from approximately 14 °C to 18 °C (Bomar, 1983). As a result of high evapotranspiration rates and limited precipitation most soils on the High Plains have aridic or torric moisture regimes. Frequent strong winds (> 11 m/s) and dust are also important components of the climate (Orgill and Sehmel, 1976; Holliday, 1987a).

The natural vegetation of the Llano Estacado is a mixed-prairie grassland (Blair, 1950; Lotspeich and Everhart, 1962). The dominant native plant community is short-grass (e.g., grama *Bouteloua* sp., and buffalo grass *Buchloe dactyloides*). The sandy soils of the dunes and sand sheets, however, are characterized by grasses as well as "shinnery oak" (*Quercus harvardii*), which can grow in dense stands. Native plant communities of the region occur in very few areas today, however, because most of the Southern High Plains is under cultivation, including significant areas of the Muleshoe Dunes, which are being leveled for center-pivot irrigation. On a geologic time scale, the Llano Estacado probably was a semi-arid grassland throughout the Holocene (Johnson, 1986, 1987; Holliday, 1987b, 1989, 1997a, 2000a, 2001).

Extensive Cenozoic deposits comprise most of the exposed sections on the Southern High Plains. The principal surficial deposit is the Blackwater Draw Formation (Reeves, 1976). This unit consists of early to late Pleistocene eolian deposits and buried soils (Holliday 1989, 1990; Gustavson, 1996; Gustavson and Holliday, 1999). Paleustolls and Paleustalfs formed in the top of the Blackwater Draw Formation are the principal soils of the High Plains surface (Holliday, 1990).

Slight topographic relief on the surface of the Southern High Plains is provided by thousands of