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Wind deposition of mud aggregates and their role in development of lamellae in the Fair Oaks Dunes, Indiana

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Abstract

Three parabolic dunes from the Fair Oaks Dune field in northern Indiana were excavated, in order to study the properties and genesis of lamellae. Reddish lamellae with sharp upper boundaries and diffuse lower boundaries are intercalated with yellowish sand layers within the upper 3–5 m of each dune. The thicknesses of the lamellae decrease from >2 cm in the east (Winamac dune) to <0.3 cm in the west (Shelby dune). In deeper parts of the dunes lamellae were absent, but straight or slightly convex, clay rich depositional laminae were present. Thin sections of lamellae reveal that most of the clays are depositional with a lesser clay amount resulting from in situ weathering of feldspar grains. Clays were deposited as sand-size mud (silt/clay) aggregates that winds removed from glacio-fluvial valleys. Lithic fragments, primarily mud aggregates and carbonates, are much more abundant in unweathered depositional laminae than in weathered lamellae. Weathering and depletion of exchangeable Ca^{+} and Mg^{+} led to breakdown of mud aggregates and clay dispersion from clay rich sand laminae through clay-poor sand laminae. The reddish color of lamellae results from oxidation of mafic grains. Sand-size mud aggregates were lighter than quartz or feldspar grains and were carried further downwind and, as a result, the clay in the dunes, and the thickness of the lamellae, increases to the east. At 5.6 m depth in the Winamac dune we found the straight depositional laminae transitioning into wavy lamellae. This is the most direct evidence of depositional lamellae (petrogenic) formation in the literature to date.

Keywords: Lamellae; Laminae; Mud aggregates; Dunes

1. Introduction

A lamella is an illuvial soil horizon less than 7.5 cm thick that contains accumulation of oriented silicate clay on or bridging sand and silt grains (Soil Survey Staff, 1999). The genesis of lamellae is very controversial. Dijkerman et al. (1967) distinguished three kinds of lamellae: a) lamellae that originate by sedimentation during deposition of the parent material (laminae); b) lamellae that originate by clay illuviation, initiated and, to some degree, controlled by properties of the deposit acquired through sedimentation; and c) lamellae that originate by process of clay illuviation independent of inherited stratification. Recently, Rawling (2000) and Schaetzl (2001) summarized previous research on this topic and presented evidence of petrogenic, pedogenic, and polygenetic lamellae.

The following evidence has been used to document petrogenic lamellae: (1) depositional lamina changing into lamella (this paper, Fig. 5), (2) lamellae conform to bedding planes (Hannah and Zahner, 1970; Schaetzl, 2001; this paper), (3) lamellae are too thick to have been formed by pedogenesis (Robinson and Rich, 1960; Hannah and Zahner, 1970), (4) lamellae do not conform to the land surface (Schaetzl, 2001), (5) lamellae underlie a zone so devoid of clay as to preclude it as a clay source (Schaetzl, 2001), (6) lamellae occur at great depth (Robinson and Rich, 1960), and (7) lamellae form by mass wasting and reworking of dune sand during intense rain storms (Bigarella, 1975).

Pedogenic lamellae form by clay illuviation either from the entire solum (Torrent et al., 1980; Bond, 1986) or from the eluvial zone immediately overlying lamellae (McIntosh, 1988). The mechanisms invoked in pedogenic lamella formation include: a) wetting-front-drying (Gile, 1979; Torrent et al., 1980; Schaetzl, 1992); b) iron induced clay flocculation (Smith et al., 1950; Miles and Franzmeier, 1981); c) carbonate induced clay flocculation (Berg, 1984; Schaetzl, 1992). Evidence in support of the pedogenic lamellae development includes the following: (1) lamellae that cross bedding planes (Ehrman, 1987), (2) lamellae that cross-cut an archeological pit and undisturbed

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sediment (Leigh, 1998; Prusinkiewicz et al., 1998), (3) absence of lamellae deep within and below the C horizon and in the uppermost eluvial zone (Schaetzl, 1992), (4) increasing lamellae development in soils of increasing age (Gile, 1979; Miles and Franzmeier, 1981; Berg, 1984), and (5) the clear, sharp upper boundaries and lower, ragged boundaries of lamellae (Van Reeuwijk and de Villiers, 1985; Ehrman, 1987).

Polygenetic (Schaetzl, 2001) or pedo-petrogenic (Rawling, 2000) lamellae form by clay illuviation along sediment discontinuities. Bouabid et al. (1992) found lamellae developing in coarser sand with larger pores than the underlying interlamellae sand, while Rawling (2000) reports lamellae developing in finer sand with less pore space than the underlying interlamellae.

In this paper we demonstrate petrogenic (depositional) origin of lamellae in an inland Fair Oaks Dune (FOD) field of northwest Indiana, U.S.A.

2. Location of the study area

The Fair Oaks Dunes (FOD) are located in northwestern Indiana and cover about 2800 km^2, thus being, after Nebraska Sand Hills, one of the larger inland dune fields in North America (Muhs et al., 1999; Bettis et al., 2003). Dunes extend in a SW–NE direction for about 110 km, while the maximum N–S extent is over 80 km in the eastern part of the dune field (Fig. 1). The Kankakee River outwash plain forms the northern boundary of the FOD. The eastern boundary of the dune field is marked by the complex Maxincuckee morainal system, an area full of collapsed ice features, kettles and kames. To the west the dune field extends into Kankakee County of northeastern Illinois, where it is known as Parkland sand (Masters, 1983). The southern boundary of the dune field is marked by the Iroquois moraine, until the dune field wraps around the eastern side of the Iroquois moraine and extends south to Monticello, Indiana.

Dunes and interdune sand sheets (Fraser and Bleuer, 1991) rise from about 204 m above sea level in the western part of the study area to about 247 m in the east. In the same W–E direction, relative dune height rises from 7 m to over 15 m, with the maximum dune height of 25 m just east of Toto, Indiana. The Fair Oaks Dunes are fixed and stable dunes overgrown by oak and ash forest that contrasts with agricultural fields in flat

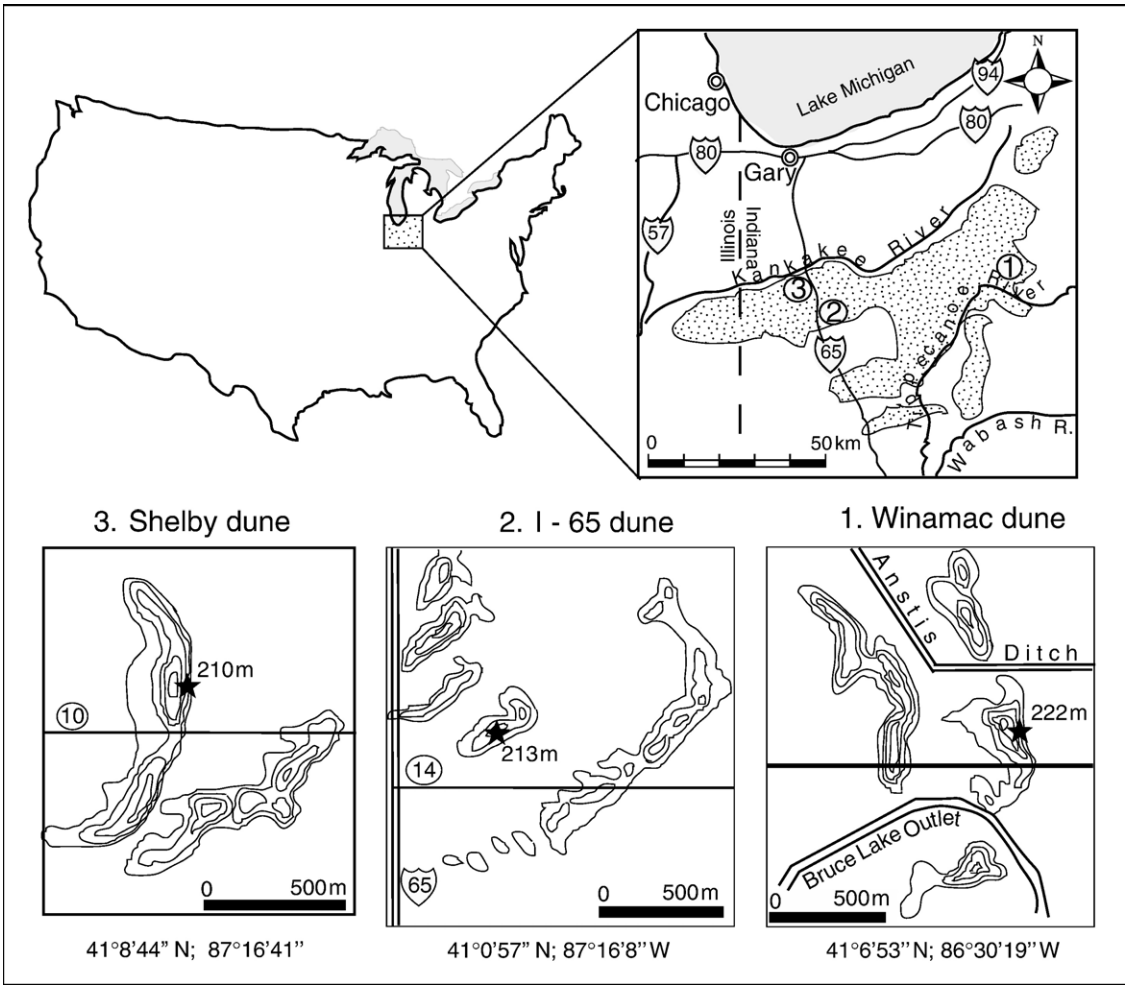

Fig. 1. Location of the Fair Oaks Dunes in northwestern Indiana and three study sites including dunes at Winamac (1), I-65 (2) and Shelby (3). Drawing after Rarick and Thornbury (1971–1972), Muhs et al. (1999), Bettis et al. (2003), and USGS 7.5 min maps of Shelby, Fair Oaks, and Winamac quadrangles in NW Indiana. Contour interval = 1.5 m.