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Origin of Iowa's Sand Prairies

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Introduction

The sand prairies of Iowa are generally regarded as eolian sand blown from adjacent river valleys about 4000 years B.P. (Ruhe, 1969; Prior, 1991; Fleckenstein, 1992). The eolian origin is based primarily on the proximity of the sand prairies to river valleys and the timing is based solely on evidence for a Hypsithermal period ending about 4000 years B.P. (Prior, 1991). In fact, the sand prairies of Iowa have been little studied geologically aside from studies of wetlands occurring in the sand prairies (Knapp, 1983; Thompson et al., 1992). Our initial objective was to determine whether the sand prairies were actually eolian deposits. The leading alternative is that the sand prairies are remnants of sand bars that were abandoned by the widespread stream downcutting, which occurred during the Holocene (Prior, 1991).

A classic paper by Visher (1969) showed that conclusions can be drawn regarding the depositional environment of a sand deposit from the grain size distribution. Visher (1969) plotted the cumulative percentage of sand on a probability scale as a function of phi ø, where $ø = -\log_2$ (grain diameter in mm). The advantage of a probability scale is that normally distributed data fall on a straight line. Visher (1969) showed that log-probability plots of grain size distributions fit well to three connected straight lines. Visher (1969) interpreted the straight line for the coarse grains as the sand population transported by traction. The straight line for the fine grains corresponds to the sand population transported by suspension. The straight line for the intermediate grain sizes corresponds to the sand population transported by saltation. Visher (1969) examined thousands of sand samples from a wide variety of depositional environments and found that the depositional environment could be related to (1) the grain size that marks the transition between traction and saltation, (2) the grain size that marks the transition between saltation and suspension, (3) the fractions of the sand sample in the traction, saltation and suspension populations, and (4) the sorting in the traction, saltation and suspension populations. Since the publication of Visher's (1969) paper, further studies have applied his methodology to determine the depositional environments of unconsolidated sands and sandstones (e.g., Glaister and Nelson, 1974). Middleton (1976) and Sagoe and Visher (1977) have investigated the theoretical basis for the transition grain sizes.

Methods

This study focused on the five sand prairies that are held in Iowa state preserves, which are Behrens Ponds and Woodland (Linn County), Cedar Hills Sand Prairie (Black Hawk County), Kish-Ke-Kosh Prairie (Jasper County), Marietta Sand Prairie (Marshall County) and Rock Island (Linn County). Nine sand samples were collected from each of the five sand prairie state preserves. For each sample, about 2 kg of soil was collected between depths 10 – 20 cm. Care was taken to minimize the visual and environmental impact on state land by removing the intact vegetation with its upper roots, collecting the soil from beneath the root zone, and then replacing the vegetation. In order to de-flocculate the clay-sized particles, the samples were blended with Calgon (60 g/L) at a ratio of 1 mL Calgon to 4 g of field-moist soil. The clay and silt were then removed by washing the samples through

a 0.063 mm sieve. After drying the sand at 90 ˚C for four hours, the sand samples were passed through 18 sieve sizes using an electric sieve shaker.

Results and Discussion

Fig. 1 shows a typical grain size distribution for the sand prairie at Behrens Ponds and Woodland State Preserve. Table 1 summarizes preliminary results for the sand prairies in comparison to Visher's (1969) results for eolian and fluvial sands. The sand prairies clearly do not have a fluvial origin. On the other hand, with the exception of Kish-Ke-Kosh Prairie, the parameters do not fall within the ranges predicted by Visher (1969) for eolian sands. For the sand prairies, the grain sizes that mark the traction / saltation and saltation / suspension transitions are shifted toward coarser grains (smaller ø). In other words, a sand grain so coarse that it could only roll in the formation of a typical eolian deposit could bounce in the formation of the Iowa sand prairies. Moreover, a sand grain so coarse that it could only bounce in the formation of a typical eolian deposit could be carried in suspension in the formation of the Iowa sand prairies. In addition, the fraction of sand in the suspension population is considerably higher than is found in typical eolian sand deposits.

The differences between the Iowa sand prairies and typical eolian deposits can be explained by assuming that the sand that blew from river valleys to form the sand prairies traveled through grass prior to deposition. Grass presents a very rough and heterogeneous surface to the wind and the effect is to increase the turbulence and gustiness of the wind (Thom, 1971; Jackson, 1981; Raupach, 1991; Livingstone and Warren, 1996). Therefore, the grain size for transition between saltation and suspension will be shifted toward coarser grains and the percentage of grains in the suspension population will increase. Moreover, traction will be impeded by the clumps of grass. Coarse grains will accumulate on the windward side of grass clumps until the impact of an unusually large number of descending saltating grains causes them to be forced over the grass clump. The effect will be to force grains that would normally roll due to their size into a manner of "psuedo-saltation," thus shifting the transition from traction to saltation toward coarser grains.

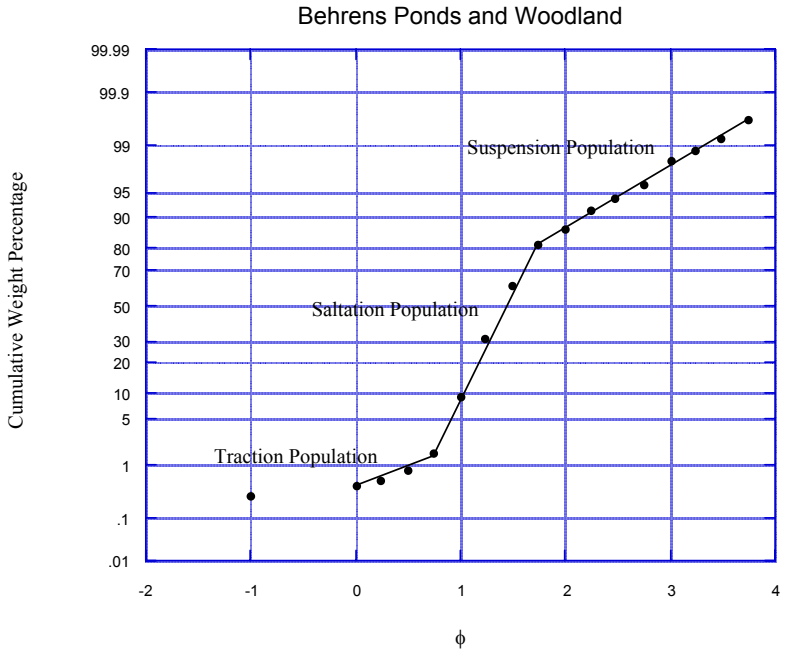

Figure 1. Typical sand size distribution for Behrens Ponds and Woodland. The transition from traction to saltation occurs at grain size ø = 0.74 (0.60 mm) . The transition from saltation to suspension occurs at grain size ø = 1.73 (0.30 mm) .

Table 1. Comparison of sand prairies of Iowa with Visher's (1969) results for eolian and fluvial sands.

	Transition Traction / Saltation (ø)	Transition Saltation / Suspension (ø)	Suspension Population (%)
Behrens Ponds and Woodland	0.69 ± 0.02	2.3 ± 0.2	9 ± 4
Cedar Hills Sand Prairie	1.0 ± 0.1	2.3 ± 0.1	24 ± 5
Kish-Ke-Kosh Prairie	1.3 ± 0.1	3.75 ± 0.00	0 ± 0
Marietta Sand Prairie	0.82 ± 0.04	2.71 ± 0.03	5.4 ± 0.4
Rock Island	0.58 ± 0.08	2.39 ± 0.07	10 ± 2
Eolian Sands (Visher, 1969)	1.0 – 2.0	3.0 – 4.0	1 – 3
Fluvial Sands (Visher, 1969)	-1.5 - -1.0	2.75 – 3.50	2 - 35

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