Late Pleistocene Ice-Marginal Dune Fields on the Atlantic Coastal Plain, New Jersey Pine Barrens, USA

Mark Demitroff[1], Stephen A. Wolfe[2], Barbara Woronko[3], Dorota Chmielowska[4], Michael Cicali[5]

[1]Stockton University, Department of Geology, Galloway, NJ, USA
[2]Natural Resources Canada, Geological Survey of Canada, Ottawa, ON, CAN
[3]Warsaw University, Faculty of Geology, Warsaw, POL
[4]Pedagogical University of Cracow, Institute of Geography, Cracow, POL
[5]Stockton University, Environmental Studies, Galloway, NJ, USA

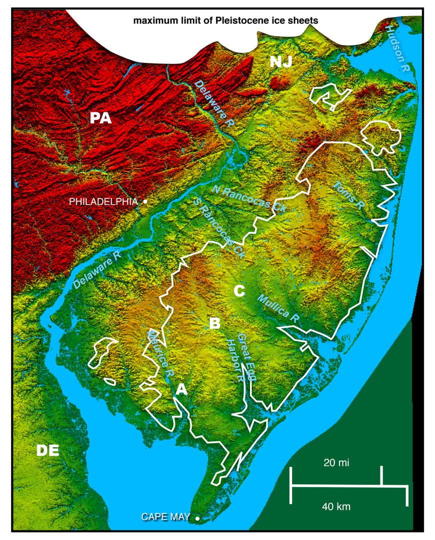
I. ABSTRACT

Source-bordering dunes evolved on the flat sandy terrain of the New Jersey Pine Barrens* during glacial episodes. Today the area is densely forested, obscuring the extent of dunes within a humid temperate region, its main portion residing 50–150 km south of the maximum glacial ice margin. Terrestrial relicts including thermal-contraction cracks, deflation basins, and ventifact lags attest to periglacial conditions in the area. However, the organization of windblown sand into dunes in the Pine Barrens has received scant attention.

Remote sensing was conducted using high resolution LiDAR to reveal the bare-earth ground surface. Six sample sites were examined from three watersheds (areas A, B, C to right) to assess the dune field dynamics. Soil observation pits were excavated, profiles stratigraphically documented, and sand samples collected for optical dating. The sand samples were examined for grain analysis by scanning electron microscope, granulometry, and for an improved Cailleux Method of surface-texture interpretation.

Dune fields reside on higher-lying river terraces and alluvial fans, and appear to be a climate-driven expression of changes from fluvial to fluvial-eolian to eolian units. South Jersey was probably a very windy and dusty place during episodes of the Wisconsinan glaciation. Grain-surface morphoscopy is further shown to be a useful tool in discerning dune-sand transport activity and the attendant post-depositional environment.

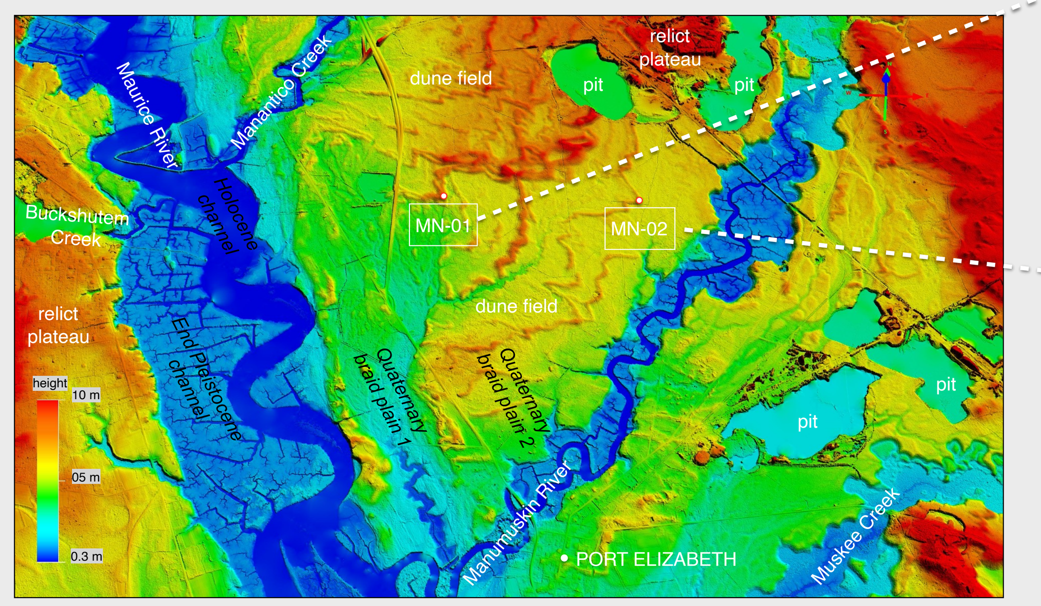
A) Manumuskin Dune Field
B) Weymouth Dune Field
C) West Mills Dune Field
* Pine Barrens outlined in white



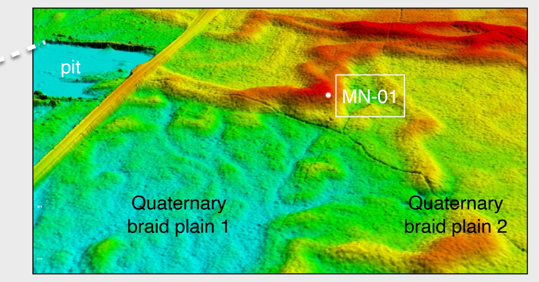
modified from Boyds Maps, 2019

II, a. METHODOLOGY – LiDAR IMAGERY, *MANUMUSKIN*

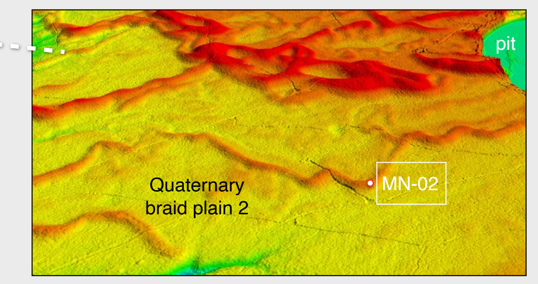
Maurice River Watershed
Manumuskin River Preserve / Long Ponds



Two parabolic dune sites; one proximal and one distal to river
—*Quick Terrain (QT) Modeler*—



MN-01 West Dune
Sampled at an ~3 m high crest of a transverse-to-parabolic dune migrating from WNW to ESE



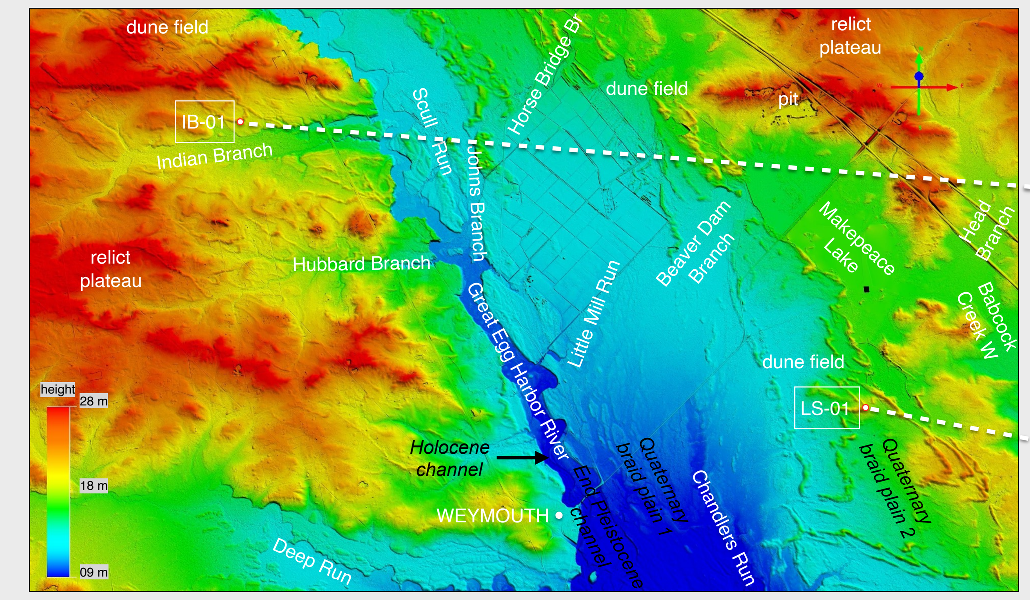
MN-02 East Dune
Sampled at an ~2 m high crest of a transverse-to-parabolic dune migrating from WNW to ESE

Manumuskin Dune Field

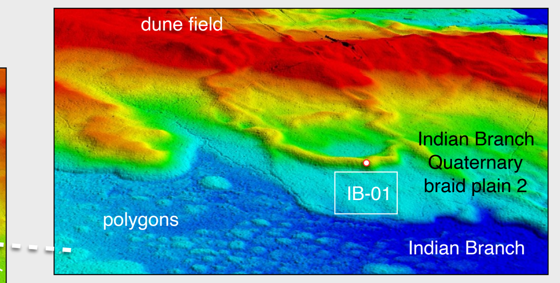
The dunes reside on an older fluvial braid-plain terrace that is eroded towards the west by a younger fluvial braid-plain terrace. The interdunal eolian sand sheet (coversand) is ~1 m thick, bounding over a sparse ventifact lag.

II, a. METHODOLOGY – LiDAR IMAGERY, *WEYMOUTH*

Great Egg Harbor River Watershed
Indian Branch (to west) & Lochs-of-the-Swamp (to east)



Two parabolic dune sites
—*Quick Terrain (QT) Modeler*—



IB-01 Dune
Sampled at an ~3 m high crest of a hairpin parabolic dune migrating from WNW to ESE

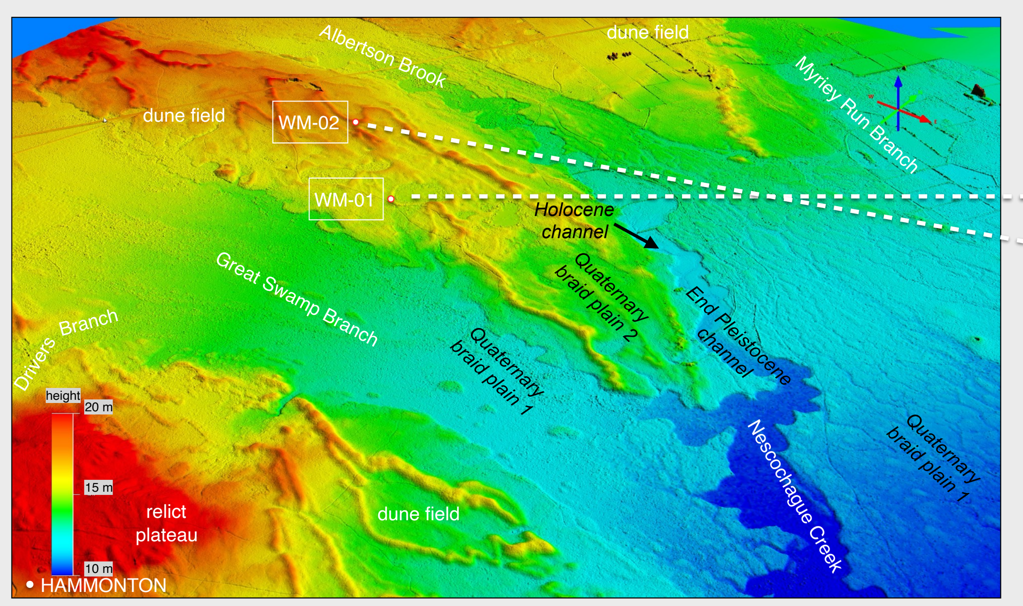
LS-01 Dune
Sampled at an ~6 m high crest of a parabolic dune migrating from WNW to ESE

Weymouth Dune Field

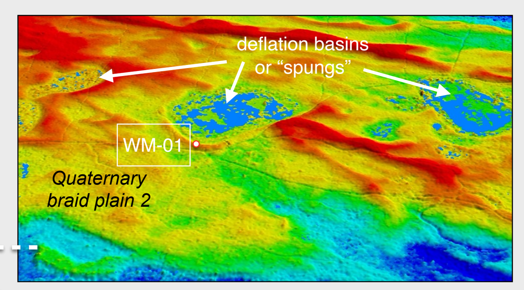
The dunes reside on older braid-plain terraces that are eroded by younger braid-plain terraces (*above*, one with polygons). The interdunal eolian sand sheets (coversands) are ~1 m thick, bounding over a ventifact lag.

II, a. METHODOLOGY – LiDAR IMAGERY, *WEST MILLS*

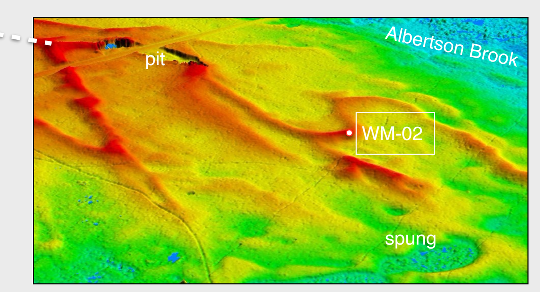
Mullica River Watershed
Gum Spung (to north) / West Mills (central) / Great Swamp (to south)



Closed basin ("spung") lunette & parabolic dune sites
—*Quick Terrain (QT) Modeler*—



WM-01 Lunette
Sampled at an ~1 m high dune-like structure rimming the closed basin's S & E outer edge.



WM-02 Dune
Sampled at a crest of an ~2.5 m high hairpin parabolic dune migrating from WNW to ESE.

West Mills Dune Field

The dunes reside on an older fluvial braid-plain terrace that is eroded by younger fluvial braid-plain terrace—all part of an alluvial fan system roughly 170 km^2 in area. The interdunal eolian sand sheet (coversand) is ~1 m thick, bounding over a ventifact lag.

II, b. METHODOLOGY – SEDIMENT ANALYSIS

- **Quartz-Grain Morphoscopy**: 18 samples were separated into 0.5–0.8 mm and 0.8–1.0 mm quartz-grain fractions, then analyzed according to methodology as proposed by Cailleux (1942) and modified by Mycielska-Dowgiałło & Woronko (1998). Dune sand grains were then classified according to 9 degrees of roundness along with the character of their surface, thus indicating the sediment's environmental residency and the nature of that environment.
- **Granulometry**: 18 samples were analyzed for grain size and shape characterization as determined by a Malvern® Instruments Morphologi® G3SE Particle Characterization System. Our morphoscopic image analysis is based on the automatic scanning of the surface of a three-dimensional (3D) particle and its conversion into a corresponding two-dimensional (2D) image. Quartz-grain shapes were determined by the following parameters: HS (High Sensitivity) Circularity and Convexity.
- **Grain Microtexture by Scanning Electron Microscope (SEM)**: whole-grain surfaces were scanned (JSM-6380 LA Joel, Japan), then analyzed for roundness and microtextures to help determine their sedimentary environment.
- **Optically Stimulated Luminescence (OSL) Dating**: Six tube samples of dune sediments were collected for OSL dating, five at 1.3 m depth, and one at 1.0 m depth—providing a date for each study site. They are currently under process at the University of the Fraser Valley Luminescence Dating Lab. A date of 28.16 ± 2.80 ka is noted from an earlier sample (USU-267), which was taken from Indian Branch paleochannel infill near IB-01. A sand sheet had dammed that stream below the thermal-contraction polygons seen in the IB-01 inset figure (*upper right*).

Soil Pit Sections

Six soil excavation pits were dug, five at the crest of parabolic dunes (130 cm deep), one at a lunette (100 cm deep). Soil weathering was most advanced at LOS-01, but was otherwise similar to the other study sites.

LS-01, Weymouth Dune Field at "Lochs-of-the-Swamp"

- **A** — dark gray-brown color, with organic matter & charcoal
- **E** — light-colored, albic horizon; the E/B boundary is wavy irregular with icicle-like glossic tongues; podzolization
- **Bs** — yellowish brown colored, spodic horizon
- **C** — unweathered yellow-brown eolian parent material, being Miocene-aged marginal marine and fluvial sands of the Cohansey (Tch) & Bridgeton (Tbr) Formations.

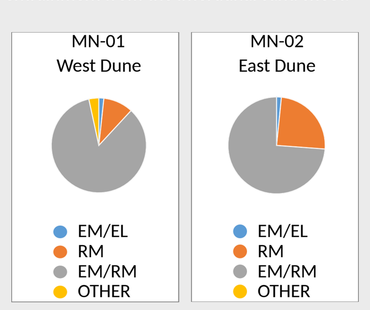
III, a. RESULTS – QUARTZ-GRAIN MORPHOSCOPY

Modified Cailleux Analysis for 0.8 to 1.0 mm grains at 30 cm depth (after Mycielska-Dowgiałło & Woronko, 1998)

GRAIN TYPE	KRUMBEIN ROUNDNESS	CHARACTERISTICS	ENVIRONMENTAL INTERPRETATION
RM	0.7–0.9	Well-rounded with matt surface	Long-term high energy collisions in an eolian environment
EM/RM	0.3–0.6	Matt surface on convexed grains	High-energy collisions in an eolian environment, shorter duration than RM
EM/EL	0.3–0.6	Moderately rounded, smooth-shiny surface	Transport in fluvial or beach environment
All Others (C, NU, O)	—	crushed, angular, or very intensively weathered	additional grain types not necessarily associated with eolian activity

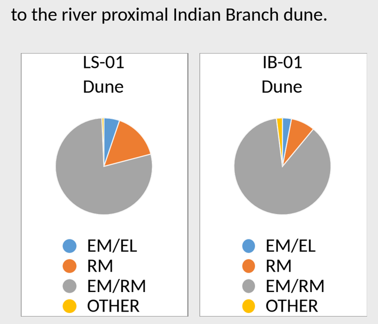
Manumuskin

Dunes are first fed by local fluvially sourced sand, then are increasingly enriched by sand entrainment from the interdunal sand sheet.



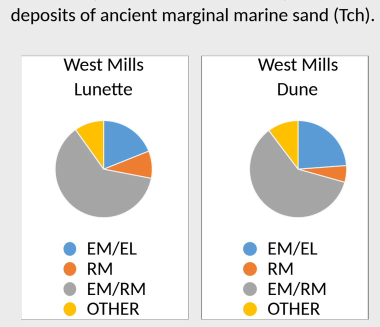
Weymouth

Lochs-of-the-Swamp dune is distal to the river, and is fed sand from the sand sheet in contrast to the river proximal Indian Branch dune.

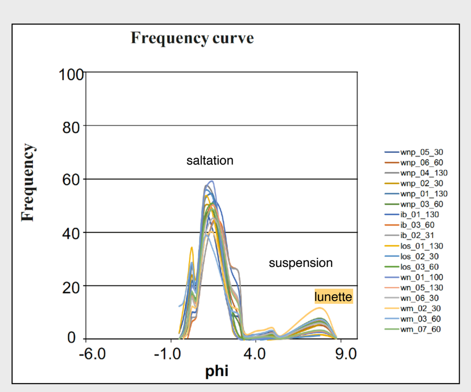


West Mills

Eolian bedforms here are more abundantly enriched by the excavation of locally sourced deposits of ancient marginal marine sand (Tch).

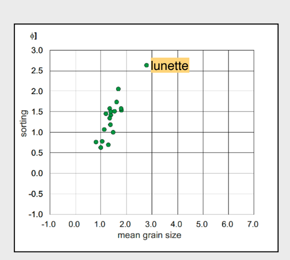


III, b. RESULTS – GRANULOMETRY



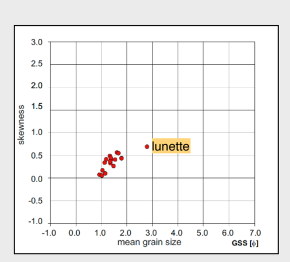
Frequency Curve

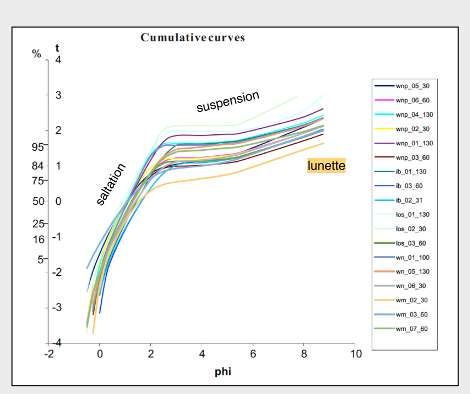
Grain size distribution shows that each of the tested samples has a bimodal distribution of grains. The first mode falls on 0.5 mm or 0.354 mm fraction grains, the second, finer on 0.0046 mm, i.e., on the border of dust and silt. Preliminarily, this suggests a high wind regime.



Sorting & Skewness

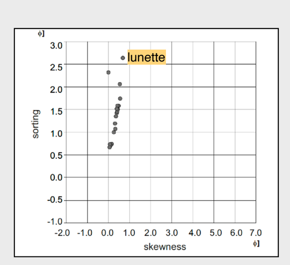
The mean grain size of dune samples is a medium grained sand, with the lunette sample residing within fine sand. The slight positive skewness of all samples is indicative of weighting towards finer sediments, which is primarily medium to fine-grained silt. Silt comprises between 2 and 15% of the dune sediment samples, whereas the lunette contains approximately 25% silt. Samples tend to be moderately sorted, with the lunette sample less sorted, owing again to the higher abundance of fine sediment.





Cumulative Curves

Two segments are marked on the cumulative curves, one responsible for transporting through saltation (steeply inclined), the other in suspension (with a small inclination angle). The steeper the slope section is, the better the sediments are sorting.



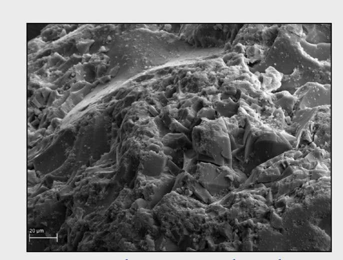
III, c. RESULTS – GRAIN MICROTEXTURE BY SEM

RM Type Grain

SEM of MN-01 130 cm: well rounded and matt surfaced; vey long duration of eolian abrasion.

EM/RM Type Grains

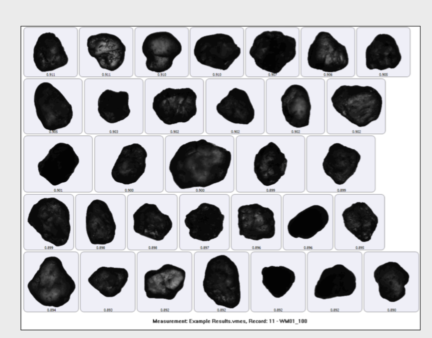
SEM of LS-01 30 cm: now coated (weathered), yet its earlier eolian microtexture is not eliminated.



Breakage Blocks

SEM of LS-01 30 cm: frost weathering on most convex portions of this eolian grain.

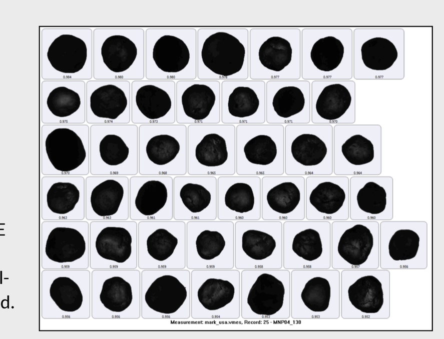
III, d. RESULTS – GRAIN MORPHOLOGY BY G3SE



HS Circularity

(*Left*) WM-01 Morphologi G3SE photos of lunette grains at 100 cm depth; lowest circularity, little travelled.

(*Right*) MN-02 130 cm: G3SE Morphologi photo of dune grains at 130 cm depth; well-rounded but not far travelled.



IV. CONCLUSIONS

1) **Quartz-Grain Morphoscopy**

- For all sites, we observe similarly developed sediments regardless of sampling depth. They are characterized by the dominance of grains that are the result of processing in the aeolian environment, grains with an intermediate degree of roundness and visible eolian treatment only on the edges and corners (type EM/RM).
- Generally the supply of material to the eolian system was limited—these are "skinny" sand-starved dune systems, although the West Mills dunes are better sand fed, apparently through the fluvial excavation of the underlying local Cohansey Formation (Tch) composed of Miocene-aged marginal-marine sands.
- The presence of breakage blocks microtextures at LS-01 (*left Fig.*) may indicate that the E horizon—near the glossic tongues—was subject to very intense *in situ* frost weathering under periglacial conditions.
- The fact that the 0.5–0.8 mm fraction grains are definitely less wind-processed (48–66% EM/RM) in relation to the 0.8–1.0 mm fraction grains (84–96% EM/RM) indicates that the wind speed may have been very high. This is confirmed by the results of the particle size analysis.

2) **Granulometry**

- High wind speed is also confirmed by particle-size analysis. A very high content of grains in fraction >0.5 mm and grain size <0.125 mm participated in suspension transport. The grain distribution has two distinct modes with virtually no deposits per fraction between modes. This suggests that the sediments were transported as a result of saltation and suspension, and that the NJ Pine Barrens may have been a particularly windy dusty place.

3) **Grain Microtexture by SEM**

- SEM interpretation supports Improved Cailleux Method findings; e.g., RM or EM/RM type grains, breakage blocks.

4) **Synthesis**

- Relict stabilized dune fields are abundant within the NJ Pine Barrens on the Atlantic Coastal Plain. They attest to intensive ice-marginal, cold-climate eolian conditions during the Late Pleistocene. Spatial associations between dune fields and Quaternary alluvial deposits—braid-plain and meander channel terraces—indicate a climate-change driven fluvial-to-eolian relationship of predominantly locally sourced sediments. Grain morphoscopy reveals an abundance of well-rounded grains and matted surfaces. Their extant, in association with ventifact lags and elongate (hairpin) parabolic dunes, supports the invocation of intensive eolian transport conditions. Soil structures and grain microtextures provide further evidence that intensive *in-situ* frost weathering had occurred under periglacial conditions.

V. BIBLIOGRAPHY

French HM, Demitroff M, Forman SL. 2003. Evidence for Late-Pleistocene permafrost in the New Jersey Pine Barrens (latitude 39°N), eastern USA. *Permafrost and Periglacial Processes*. **14**: 259–274.

Mycielska-Dowgiałło E, Woronko B. 1998. Analiza obtoczenia i zmatowienia powierzchni ziarn kwarcowych frakcji piaszczystej i jej wartość interpretacyjna (Rounding and frosting analysis of the sand quartz grains surface and its interpretative value). *Przegląd Geologiczny*. **46**: 1275–1281.

Woronko B, Zieliński P, Sokołowski RJ. Climate evolution during the Pleniglacial and Late Glacial as recorded in quartz grain morphoscopy of fluvial to aeolian successions of the European Sand Belt. *Geologos*. **21**: 89–103.

Newell WL, Newell WL, Powars DS, Owens JP, Stanford SD, Stone BD. 2000. Surficial geologic map of central and southern New Jersey. United States Geological Survey, Miscellaneous Investigations Series, Map 1–2540–D, Washington, DC.

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