CLUES IN SMALL LAKE SEDIMENTS TO HISTORIES OF COASTAL DUNES SOUTHWEST OF HOLLAND, MICHIGAN

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ABSTRACT

Six vibracores were studied from 3 small lakes in the coastal dunes between Holland and Saugatuck. Radiocarbon ages indicate that deposition began between 6,500 to 5,500 cal. YBP. Periods of enhanced sand deposition in the 2 northern lakes correlate with periods of dune mobility determined with paleosol radiocarbon and OSL ages. However, lake sediments give a more complete higher resolution chronology of aeolian activity. Peaks in sand concentrations in the southern lake indicates that dunes near the mouth of the Kalamazoo River were active while dunes further north were stable, probably reflecting the effect of sand supply. Pollen from these cores should reflect plant communities on the dunes, which should change with the degree of dune mobility. However, preliminary results show that shifts in the abundances of pollen types do not perfectly correlate with changes in dune mobility. Changes in diatom assemblages indicate changes in water depth, chemistry and clarity but it has not yet been possible to link these with environmental changes in the dunes.

INTRODUCTION

Figure 1. Traditional means of obtaining coastal dune histories. A: Relative geomorphic position. B: Radiocarbon ages from paleosols. C: Optically Stimulated Luminescence ages.

Chronologies of dune growth and migration in coastal dune complexes are typically worked out with some combination of relative geomorphic position, radiocarbon ages on paleosols and optically stimulated luminescence (OSL) analyses of sand. Geomorphic position can give only relative ages. The exposure of paleosols depends on the fortuitous distribution of eroding dune faces. The precision of OSL ages for Lake Michigan coastal dunes is relatively coarse: typically ~1000 years. On the other hand, sediments continuously accumulate on the bottom of small inland lakes within dune complexes. Thus, these lakes potentially contain a continuous high resolution record of changes in the surrounding dunes. Moreover changes in fossil assemblages within these lakes may give insights into environmental changes responsible for dune mobilization or stabilization.

GEOLOGIC SETTING AND SAMPLING

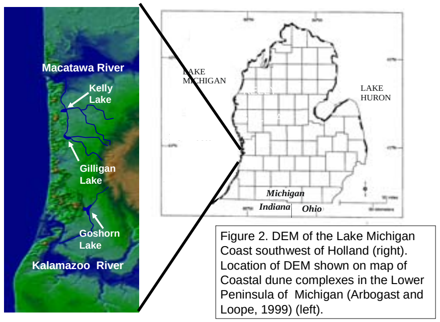

Figure 2. DEM of the Lake Michigan Coast southwest of Holland (right). Location of DEM shown on map of Coastal dune complexes in the Lower Peninsula of Michigan (Arbogast and Loope, 1999) (left).

Sediment cores were studied from three inland lakes between the Macatawa and Kalamazoo Rivers (Figure 2). One core was studied from Kelly Lake and three cores from Gilligan Lake. Both lie at the eastern edge of a low-perched dune complex for which a detailed geomorphic history has been worked out by Arbogast et al. (2002) and Hansen et al. (2004). Two cores were studied from Goshorn Lake at the eastern edge of the larger compound low-perched dune complex of Saugatuck Dunes State Park. Samples were collected with a piston-equipped vibracorer either from the frozen surface of the lake (Fisher, 2004) or from a University of Toledo pontoon boat.

Figure 3A. Collecting a sediment core with a vibracorer set on the frozen surface of Kelly Lake. Figure 3B. Collecting a sediment core from Goshorn Lake with a vibracorer set on a pontoon boat.

CHRONOLOGY

Twenty-three samples of seeds, leaves, wood, or charcoal, all of probable terrestrial origin, were removed from the cores and analyzed for C-14 by accelerated mass spectrometry (AMS). One sample was analyzed by Beta Analytic Inc. in Miami, Florida. The rest were analyzed at the Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory. All radiocarbon ages were calibrated using calib V5.0.1 (Stuvier and Reimer, 1993) using the calibration curve from Reimer et al. (2004). These ages are shown as a function of depths in the core in Figure 4. The ages of features at different depths in the core were calculated by a linear interpolation between the two closest measured ages.

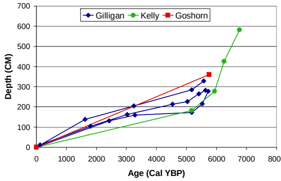

Figure 4. Calibrated AMS radiocarbon ages (in calendar years before present) plotted against depth in core for cores from the three lakes.

SEDIMENTOLOGY

After the examination of smear slides, the sediments in all of the cores were classified according to the scheme of Schnurrenberger et al. (2003). The bottom sediments from most of the cores were relatively rich in sand (Figure 5A). Higher in the cores the sediments tended to become both finer grained and richer in organic debris forming sapropels (Figure 5B) and sapropelic silts and clays (Figure 5C). Thin layers and lenses of sand were visible in the finer grained upper portions of all but one core (Figure 5D).

Figure 5. Photographs of segments of lake cores showing: 5A sandy sediment from near the bottom of a core. 5B sapropel from near the top of a core. 5C clay and silt from near the top of a core. 5D Thin sand layers and lenses within sapropel.

GRAIN SIZE ANALYSIS: GILLIGAN LAKE

Grain sizes were analyzed in two cores using a technique developed by Kelly Weyer at the University of Toledo. Approximately 5 grams were extracted from each centimeter of core. The organic content was determined by loss on ignition at 500°C. After treatment with HCL to remove carbonates, the sample was placed in an ultrasonic cleaner in a hydrogen peroxide solution for 10 minutes in order to disperse peds. The samples were then wet sieved through a 0.062 mm mesh, weighed and the percentage of sand calculated (Figure 6). In Figure 7 ages of peaks in sand concentration (vertical lines) within finer grained sediments are plotted along with dune OSL and paleosol radiocarbon ages from the adjacent dune complex. The medium grained, well sorted, frosted sand is interpreted to have been transported from 30–40 m high parabolic dunes ~200 m to the lakes. Thus each peak in sand concentration corresponds to a peak in aeolian sand transport within the dunes. The radiocarbon dated sand signal corresponds in all but one case with radiocarbon dated paleosols and OSL dated dune surfaces, but also records past dune activity for which no paleosols have been dated. Thus the sand signal in the lake sediments appears to give a more complete, higher resolution signal than paleosol radiocarbon or OSL ages.

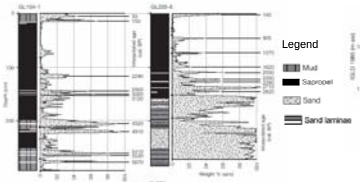

Figure 6: Weight % sand vs depth in two cores from Gilligan Lake. The age of sand peaks (>30% sand) in finer-grained sediment are also plotted.

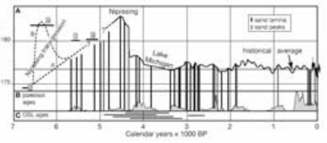

Figure 7. Composite plot of the sand data, dune palaeosols, and OSL ages compared with the Lake Michigan relative lake level curve from Baedke and Thompson (2000). Vertical lines are sand peak ages from the Gilligan and Kelly Lake cores.

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GRAIN SIZE ANALYSIS: GOSHORN LAKE

Grain size analysis was done on two cores from Goshorn Lake (Figure 8). The core collected from the edge of the lake directly abutting the dunes (Gosh 1) has abundant large peaks in sand concentration (Figure 9a). The core collected near the inlet for the stream that feeds Goshorn Lake (Gosh 2) has relatively little sand (Figure 9b). This provides supporting evidence for the hypothesis that sand in these lakes is aeolian rather than fluvial in origin. Throughout most of the southeastern Lake Michigan coast the period from 2000 to 1500 YBP was a time of relative dune stability. However, there is a high concentration of sand in the upper 150 centimeters of core GOSH 1 suggesting that the Saugatuck dunes have been very active in the last 2000 years. Both the exceptionally large size and the high rate of aeolian activity in the Saugatuck dunes may reflect the influence of sand transportation to the lakes shore by the Kalamazoo river

Figure 8. False color satellite image of Goshorn Lake with core locations.

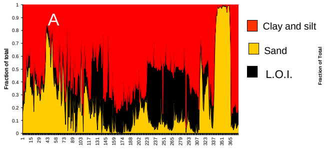

Figure 9A. Proportions of silt and clay, sand, and organic debris (LOI) vs. depth in Gosh 1.

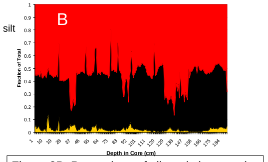

Figure 9B. Proportions of silt and clay, sand, and organic debris (LOI) vs. depth in Gosh 2.

Pollen

Pollen in these small lakes is derived largely from the surrounding dunes (Figure 10) . Our preliminary investigations have focused on relative proportions of earlier dune succession trees (pine family) and later dune succession trees (oak, maple and hemlock) in the expectation that these proportions would reflect the amount of dune mobility. Changes in these proportions do occur (Figure 11) but appear to be out of phase with changes in the amount of aeolian activity in the dunes.

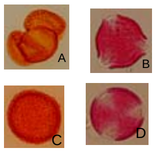

Figure 10: Pollen Grains A. Pine Family, B. Oak C. Hemlock, D. Maple

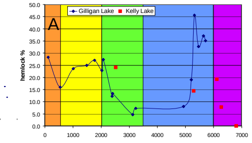

Figure 11A:. Hemlock abundance in Gilligan and Kelly Lakes against time.

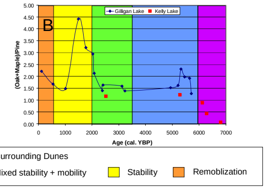

Figure 11 B.: Oak + maple to pine family ratios in Gilligan and Kelly Lakes against time.

Diatoms

Changes in the relative abundances of diatom taxa in lake sediments should reflect changes in the lacustrine environment which may reflect larger environmental changes affecting the dunes. Changes in the relative abundances of planktonic centric genera to the most common benthic or epiphytic genera (Navicula + Eunotia) probably reflect changes in water depth or water clarity (Figure 13A). Changes in abundances within these groups (Figures 13B and C) may reflect changes in water chemistry. Thus, for example Eunotia thrives in somewhat acidic water and changes in the relative abundances of Eunotia and Navicula (Figure 13B) may be due to changes in pH. Our studies of diatoms have just begun and it has not yet been possible to relate them to environmental factors controlling dune mobility and stability.

Figure 12: Typical Diatoms from Gilligan Lake

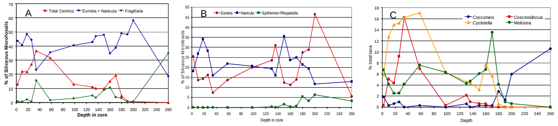

Figure 13: Plot of abundance versus depth in core GL 206 (Gilligan Lake) for selected diatom genera.

Conclusions

- Peaks in sand concentration in small inland lakes associated with the coastal dunes southwest of Holland, Michigan appear to be due to an influx of aeolian sand during periods of dune mobility.
- Peaks in sand concentrations in the lake cores give more continuous, higher resolution chronologies of aeolian activity than do either OSL ages on dune surfaces or radiocarbon ages from dune paleosols.
- Systematic changes in relative abundances of both pollen and diatom taxa occur with depth in the cores but it is still too early in these studies to determine how these changes relate to dune history.

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