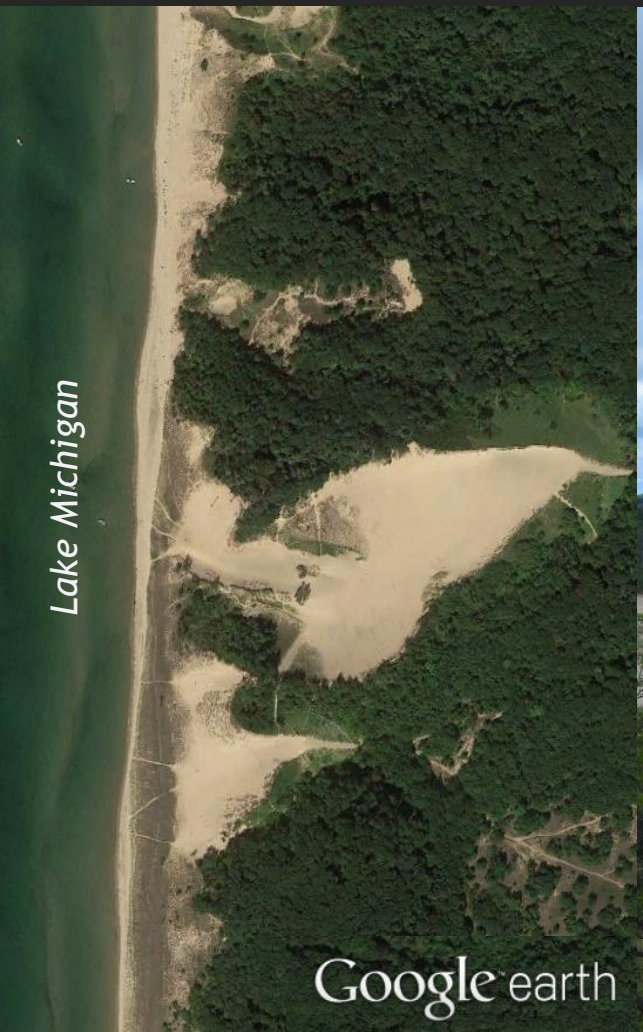
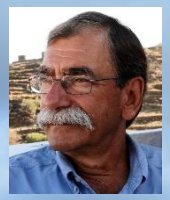
The Geomorphology and Evolution of Lake Michigan Coastal Dunes

Alan F. Arbogast, Ph.D.

MICHIGAN STATE UNIVERSITY
Department of Geography,
Environment, and Spatial Sciences

Michigan's Coastal Dunes – World Class!





Bill Lovis, MSU Anthropology

Bill Monaghan, Indiana Geological Survey

West Coast of England

Euro Dunes


NE Atlantic
Baltic Sea
North Sea
Celtic Seas
Key
Major dune coast
Discontinuous dune coast
Individual dune locations
Eastern Atlantic
English Channel
Bay of Biscay
Black Sea
Western Mediterranean
Eastern Mediterranean


Southwestern Coast of Australia


North Island of New Zealand


Oregon


Sleeping Bear


Camp Minniwanca


Ludington


Near Holland


Why??
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
1) westerly winds
2) long fetch across Lake Michigan
3) Lots of sand!

Dunes Are *Heavily* Utilized……

Recreation Search
Michigan Department of Natural Resources

Home | List | Map | Events

1

Warren Dunes State Park

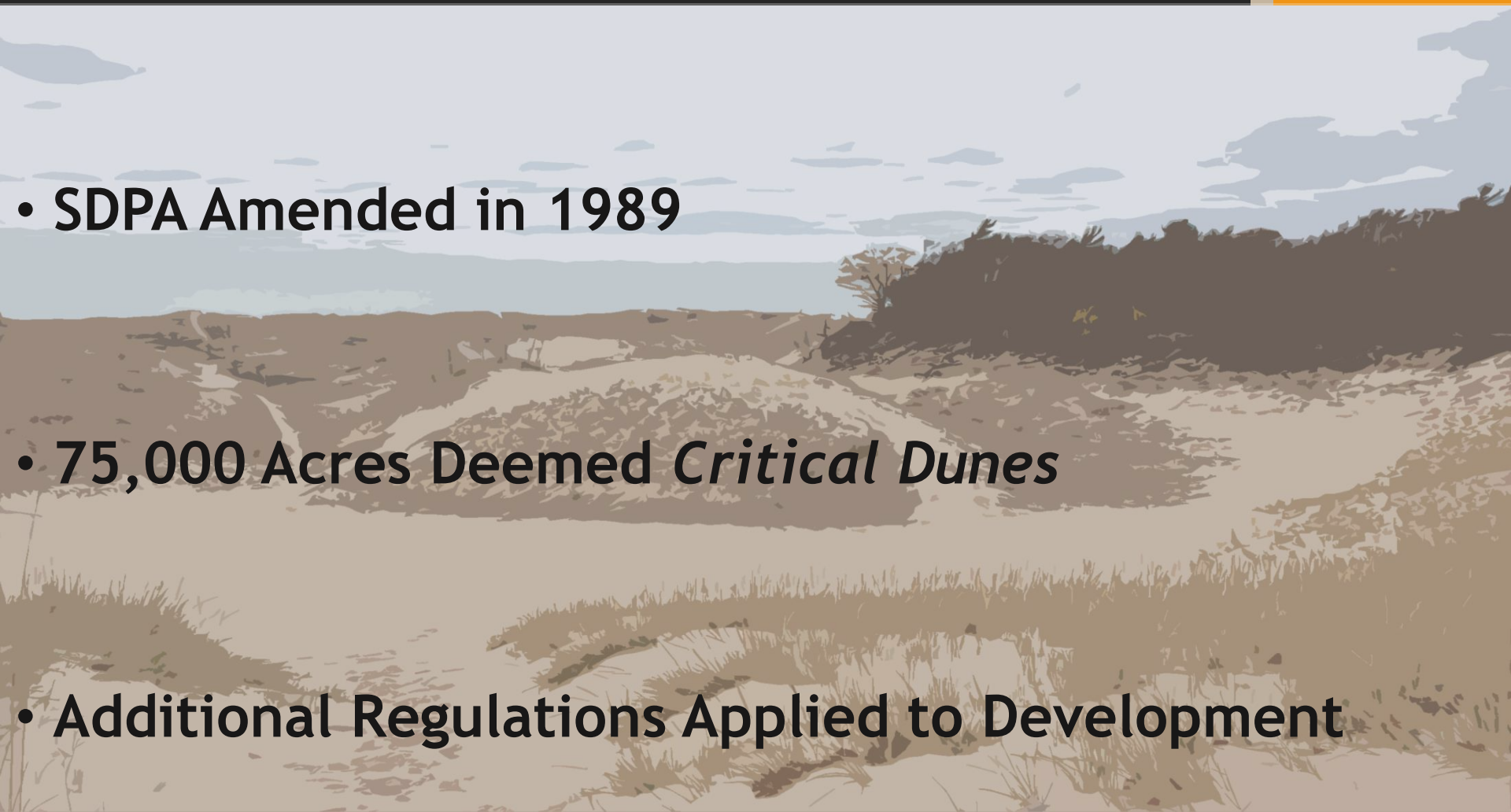
2

3

Sand Dune Protection

- **Sand Dune Protection & Management Act in 1976**
- **275,000 Acres Designated as “Sand Dune Areas”**
- **First Regulations on Sand Mining**

Sand Dune Protection



- SDPA Amended in 1989
- 75,000 Acres Deemed *Critical Dunes*
- Additional Regulations Applied to Development

This is Where I Walk In……

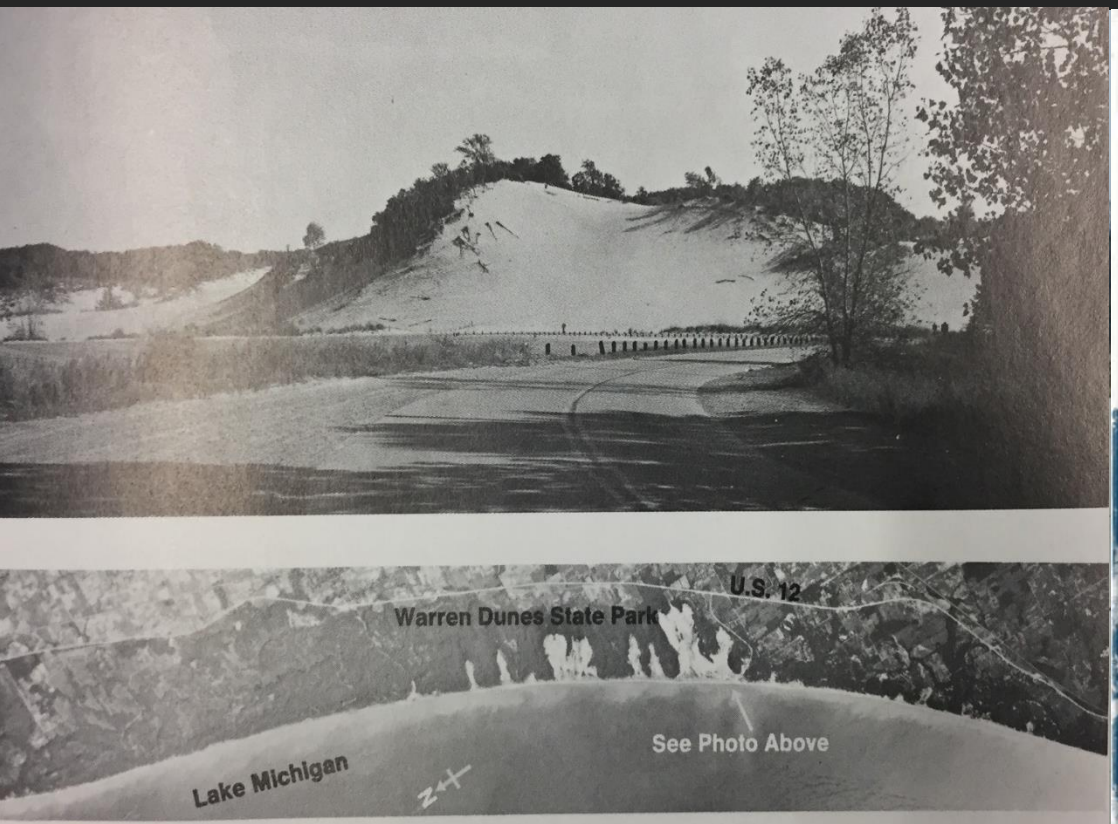
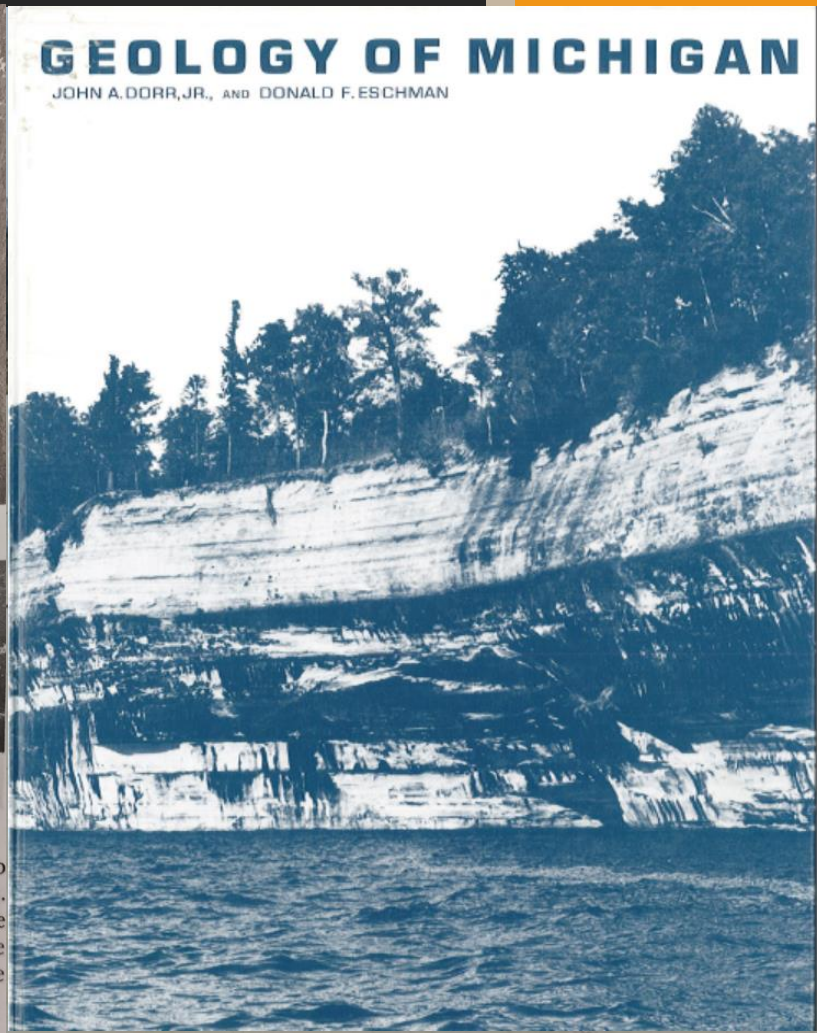
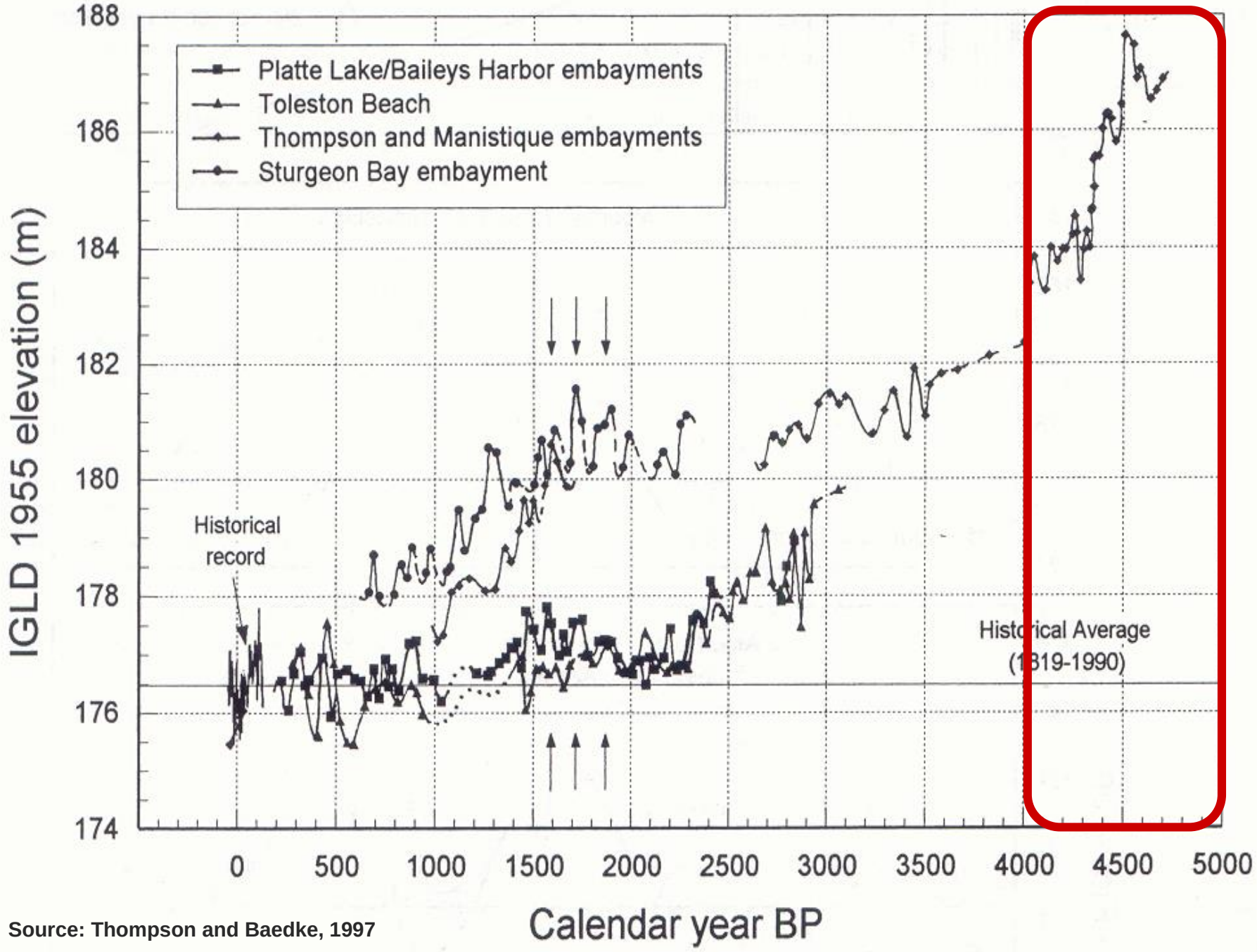


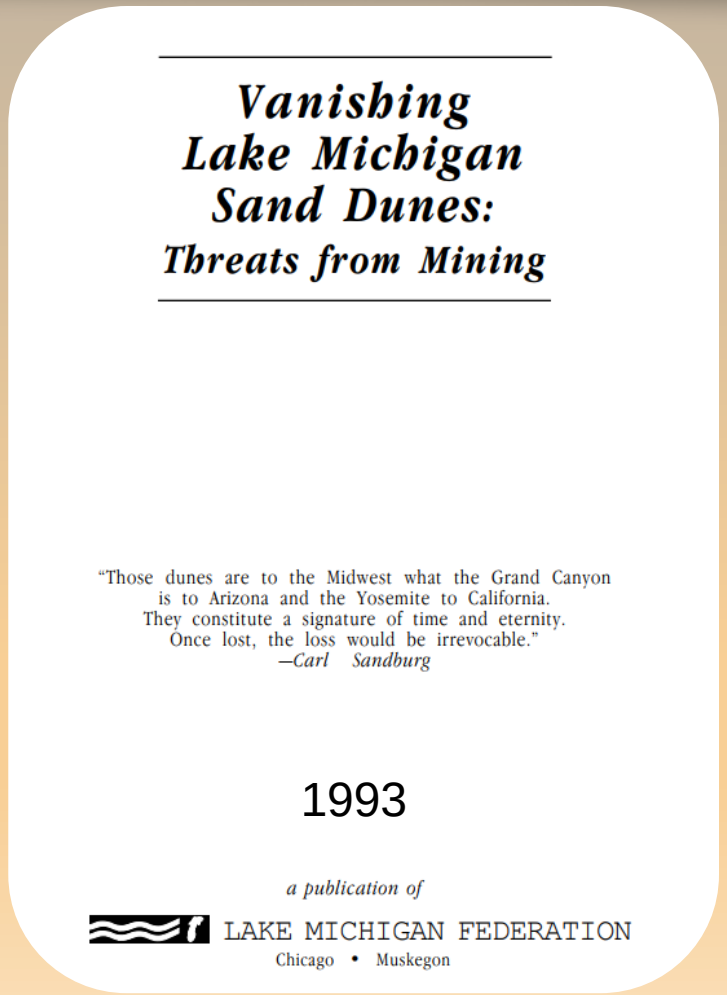
Figure IX–19. "Blowouts" due to wind action on shoreward side of old "high dunes" related to higher water level of Glacial Lake Nipissing at Warren Dunes State Park (also see Fig. IX–24). Arrow on lower aerial photograph indicates location and direction of upper photograph. The older, high dunes for the most part are stabilized by vegetation, but blowouts form locally where vegetative cover is destroyed by fire, disease, or drought, or where wave or stream erosion at base of dune causes sliding. (Aerial photo from U.S. Department of Agriculture.)





Source: Thompson and Baedke, 1997

Or.....



Vanishing Lake Michigan Sand Dunes:
Threats from Mining

"Those dunes are to the Midwest what the Grand Canyon is to Arizona and the Yosemite to California. They constitute a signature of time and eternity. Once lost, the loss would be irrevocable."
—*Carl Sandburg*

1993

a publication of

LAKE MICHIGAN FEDERATION
Chicago • Muskegon

The sand dunes were created in the last ice age, over thousands of years, and cannot be replaced once they are gone. Particularly along Lake Michigan's eastern shoreline, unusually fine sand builds up in small mountains up to 300 feet in height. In some places a person can walk for miles through dunes before reaching the lakeshore. The dunes support plant and animal life that can't be found elsewhere, and were the birthplace for the field of ecology.

Lake Michigan's rare, internationally unique dunes were created over 10,000 years ago as the glaciers receded and the winds blew sands along the shore. The dunes took years to form and the circumstances that formed them will likely not happen again.

What is Chronology?

Chronology is the arrangement of events or dates in the order of their occurrence

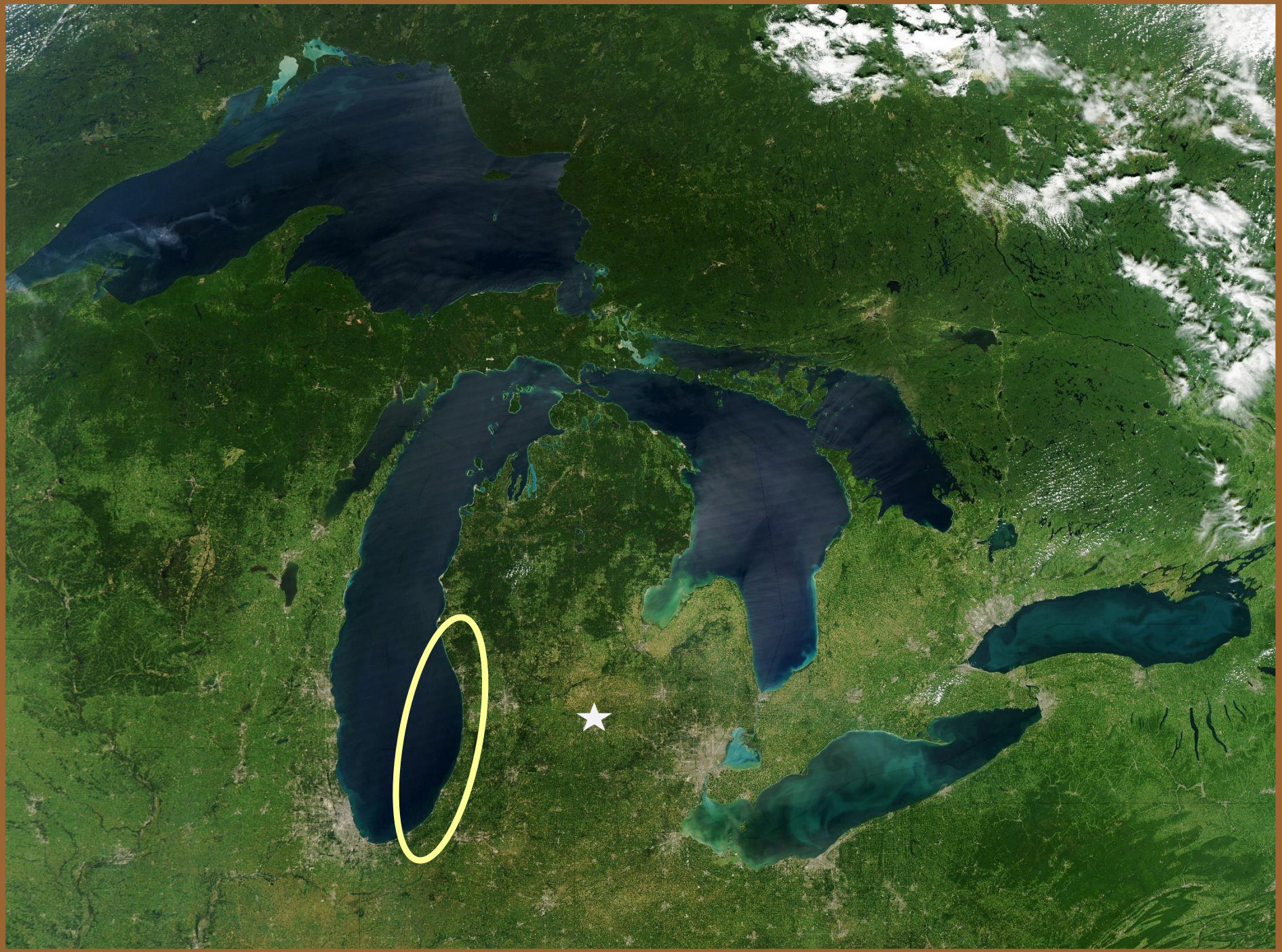
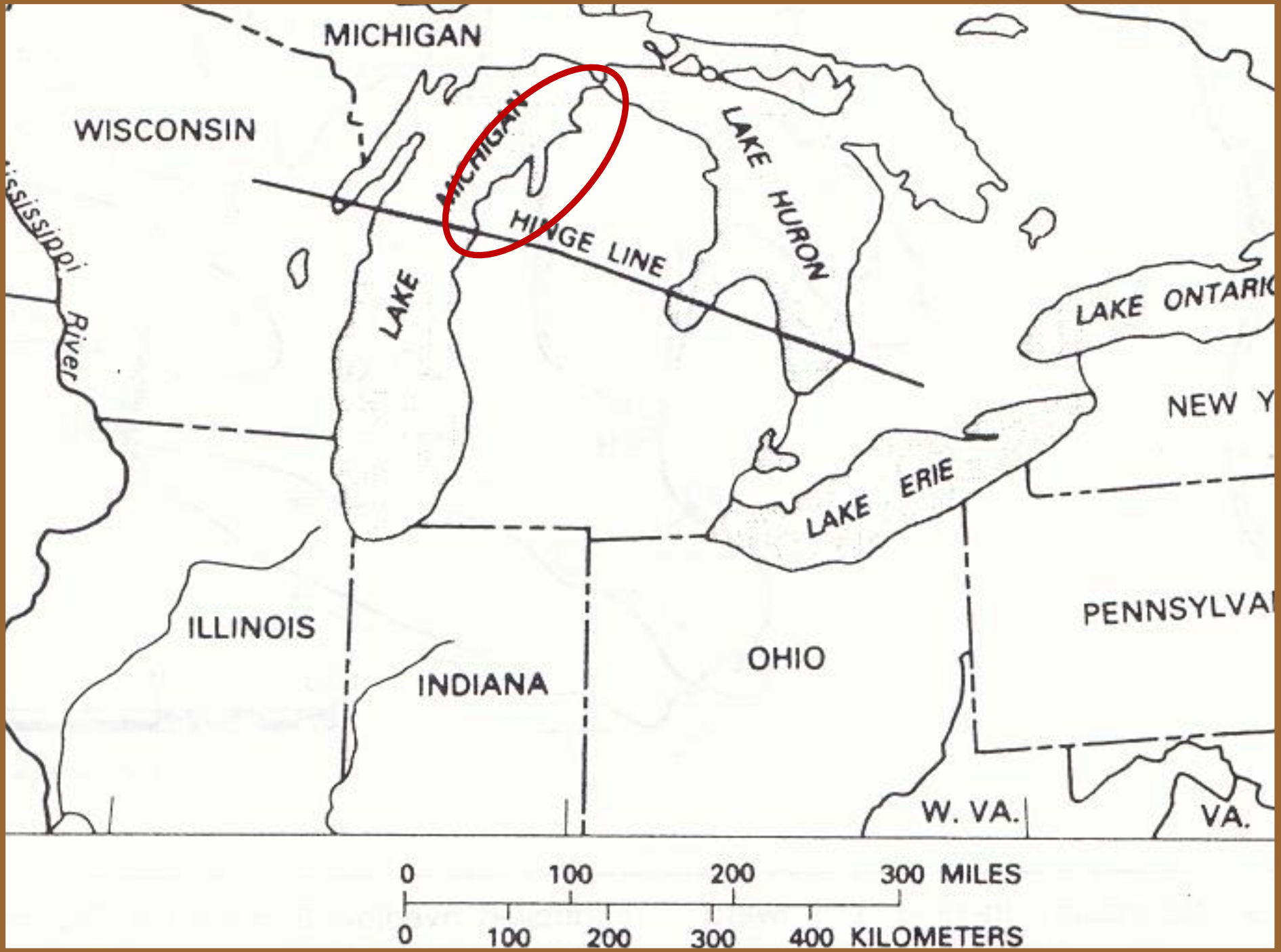
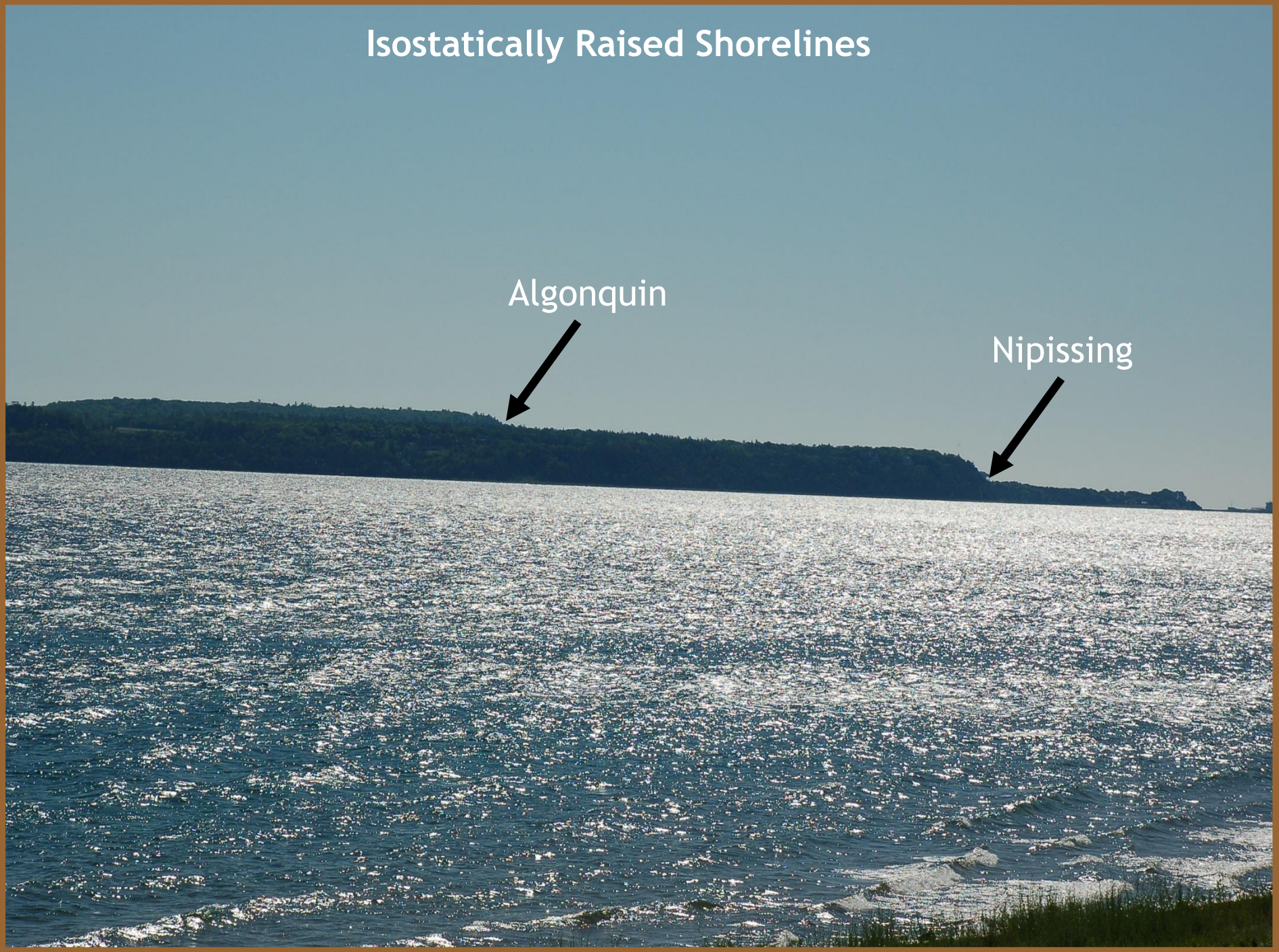


Photo: Ed Hanson

Van Buren State Park

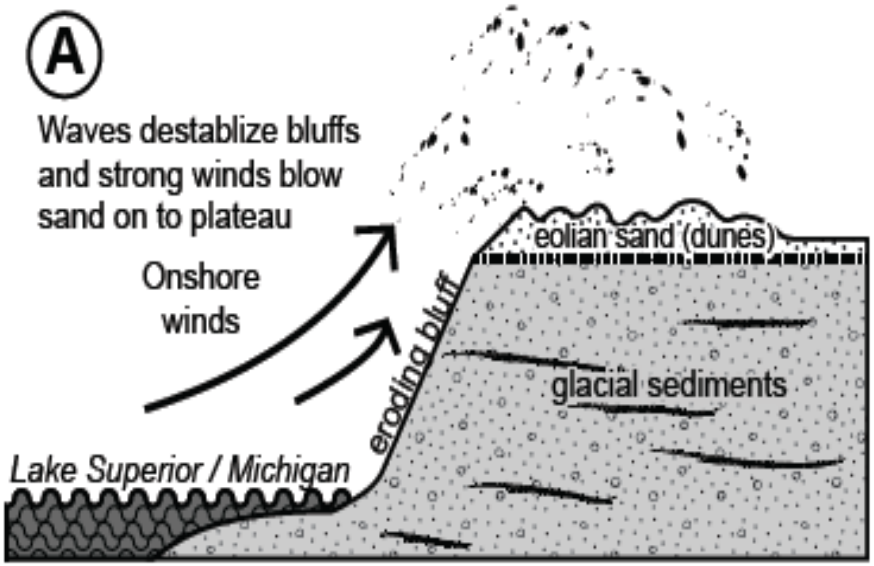

MICHIGAN
WISCONSIN
LAKE MICHIGAN
LAKE HURON
HINGE LINE
LAKE
LAKE ONTARIO
NEW Y
LAKE ERIE
PENNSYLVA
ILLINOIS
INDIANA
OHIO
W. VA.
VA.
0 100 200 300 MILES
0 100 200 300 400 KILOMETERS

Isostatically Raised Shorelines

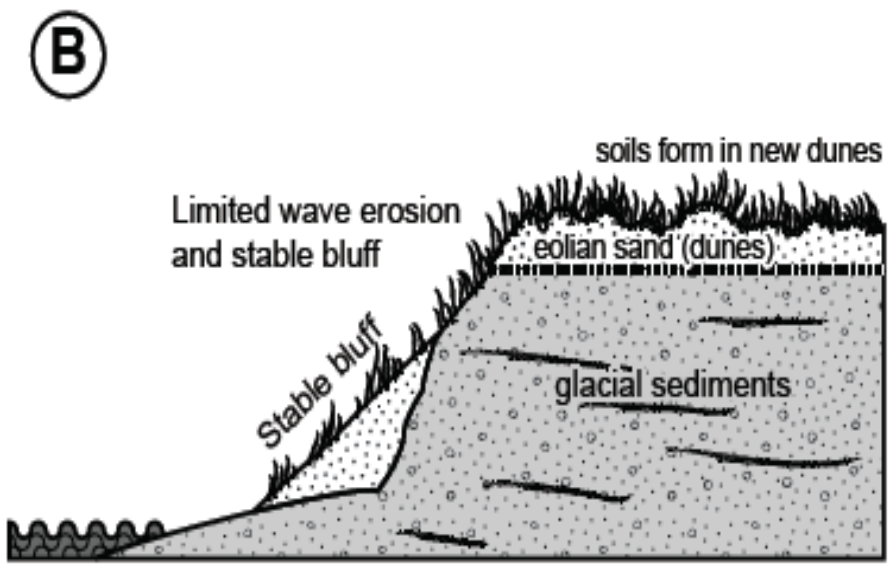


Perched Dunes

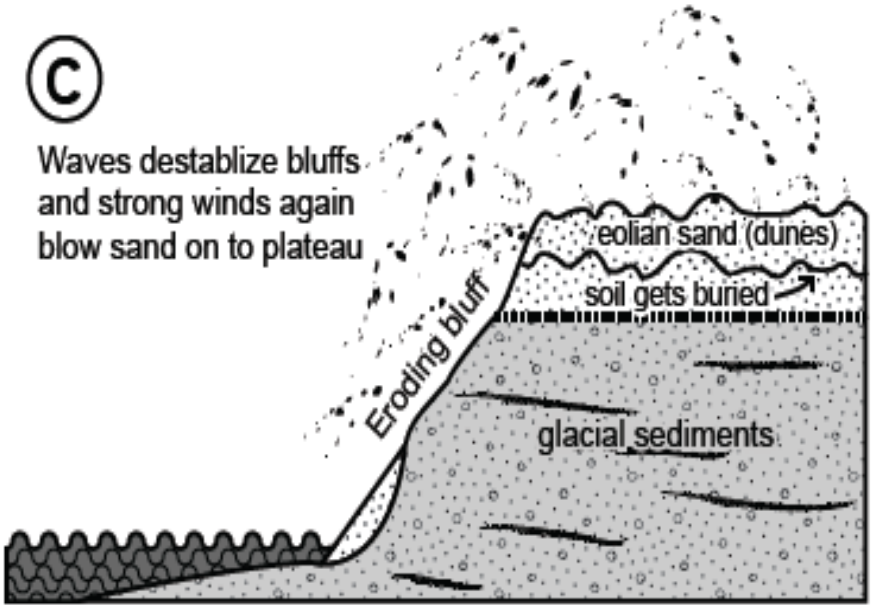
The Perched Dune Model



High lake phase

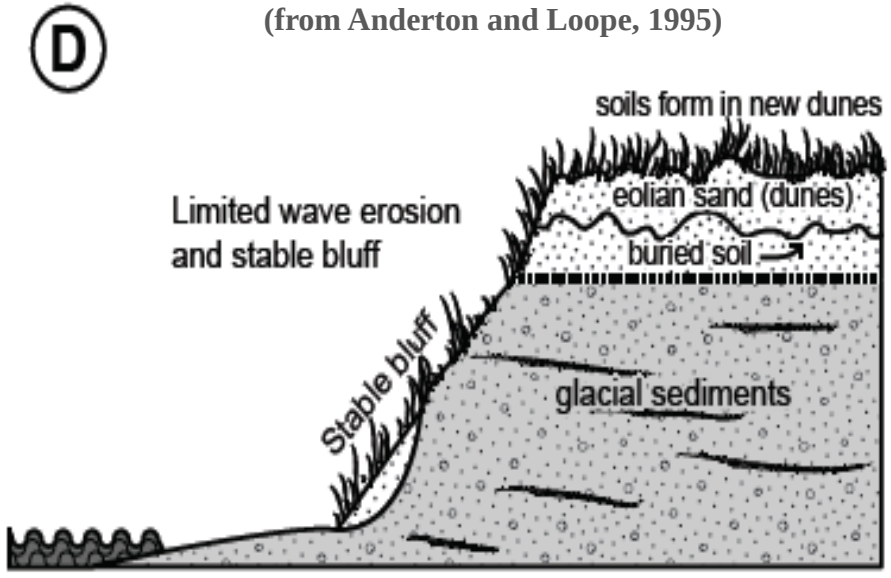


Low lake phase



High lake phase

(from Anderton and Loope, 1995)



Low lake phase

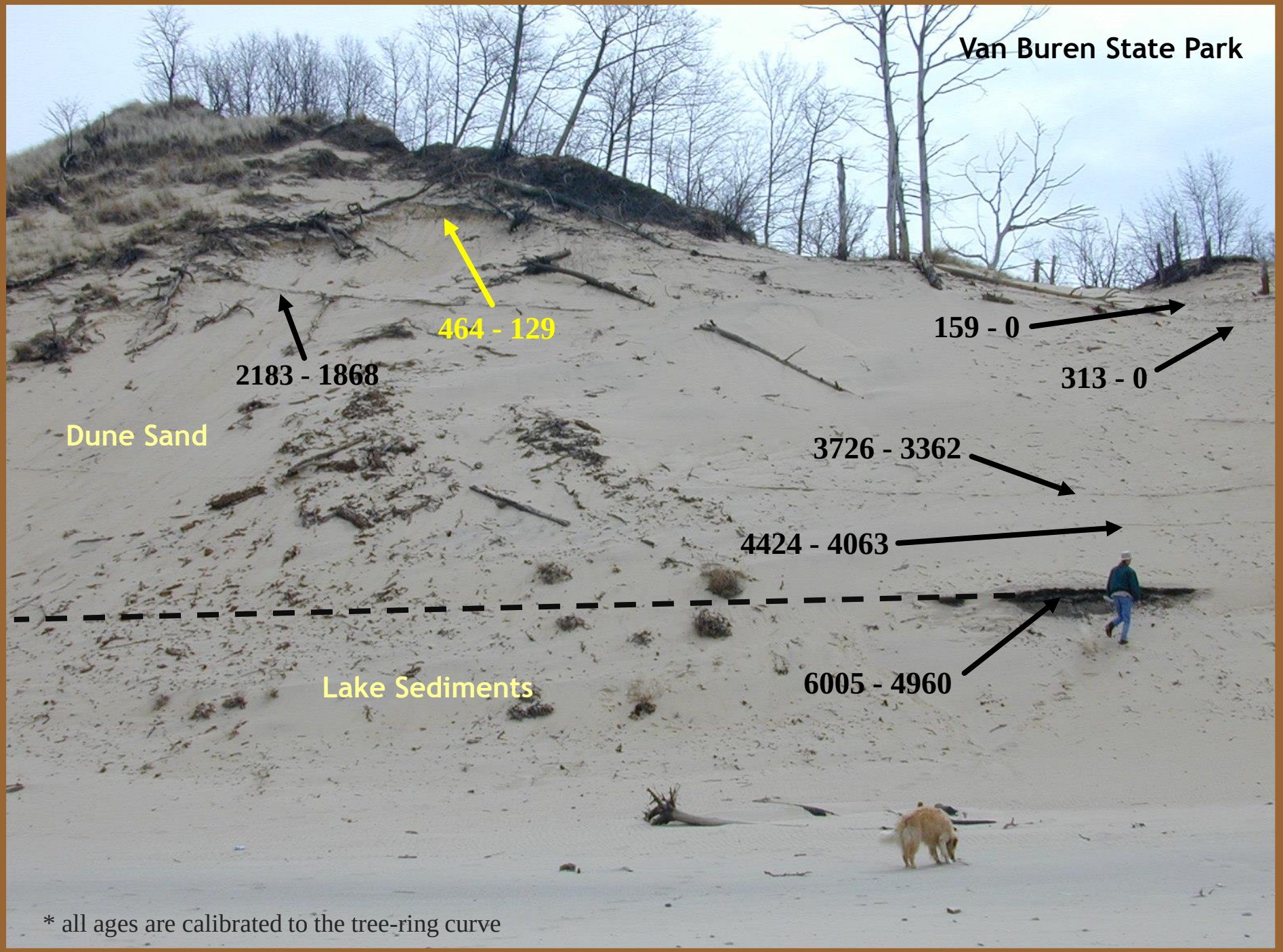

Little Traverse Bay
Wequetonsing
Beach Dr
Pennsylvania Ave
Fairview Ave
Bridge St
Beach Rd
Fischer Nature Preserve
Fern Ave
Beach Rd
Page Hill Rd
119
Harbor Springs Municipal Airport
Clayton Rd
W Conway Rd
W Conway Rd
Mink Rd
Watson Nature Preserve
Menonaqua Beach
Beach Rd
Powell Rd
Powell Rd
Round Lake Nature Preserve
Round Lake
Petoskey State Park
Hiawatha Trail
31
Konie Rd
Pickerel Lake Rd
Pickerel Lake
Kolinske Rd
Shire Ave
Bay View
Manvel Rd
Bay View Association
Terrace Ave
Knapp Ave
Petoskey - Bay View Country Club
Terrain
View topography and elevation


Photo: Maher Collection

Reconstructing Dune Chronologies

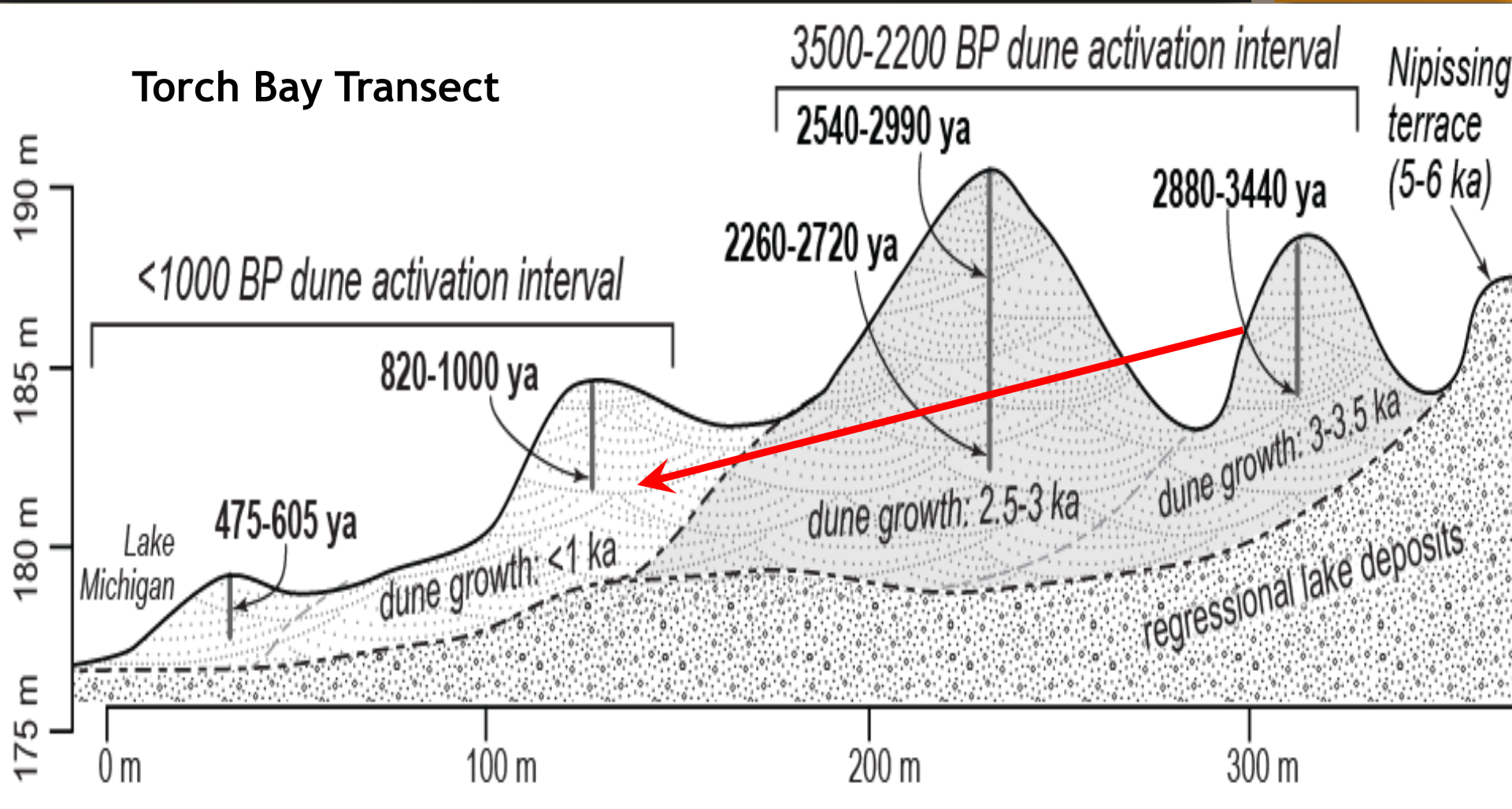
- **Optically Stimulated Luminescence** (OSL): burial age of eolian sand

- **Radiocarbon** (C-14): soil organics

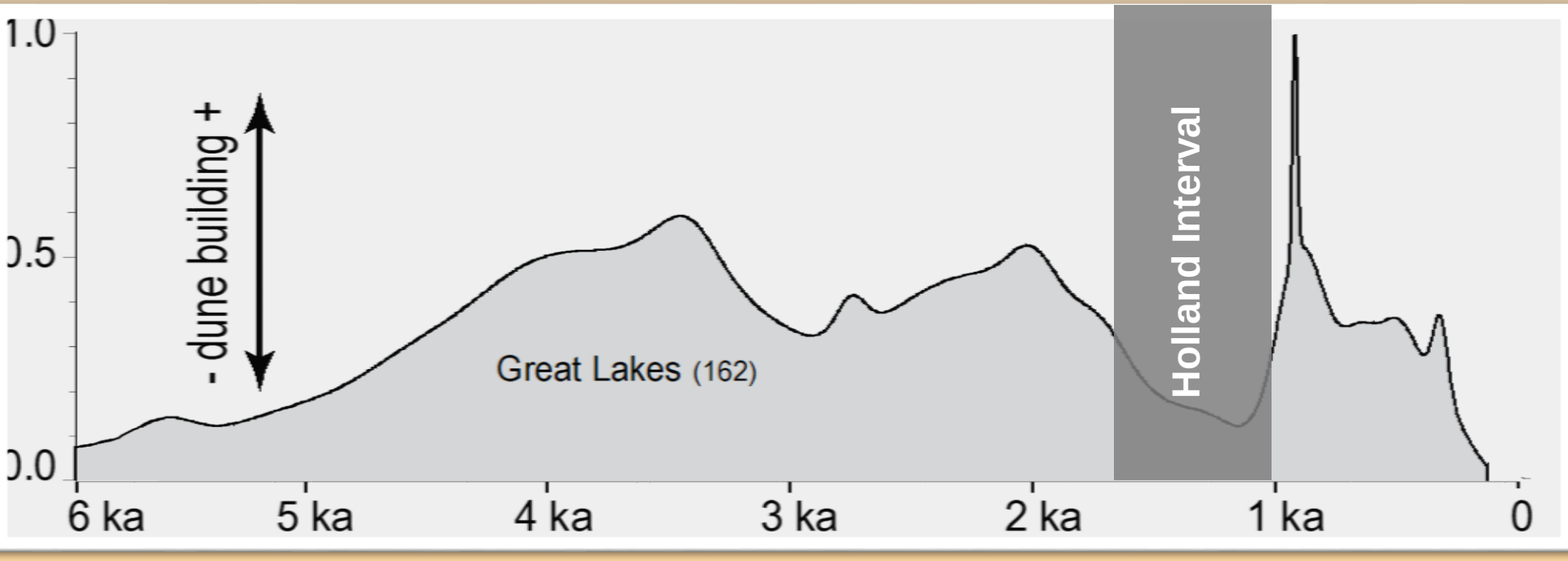


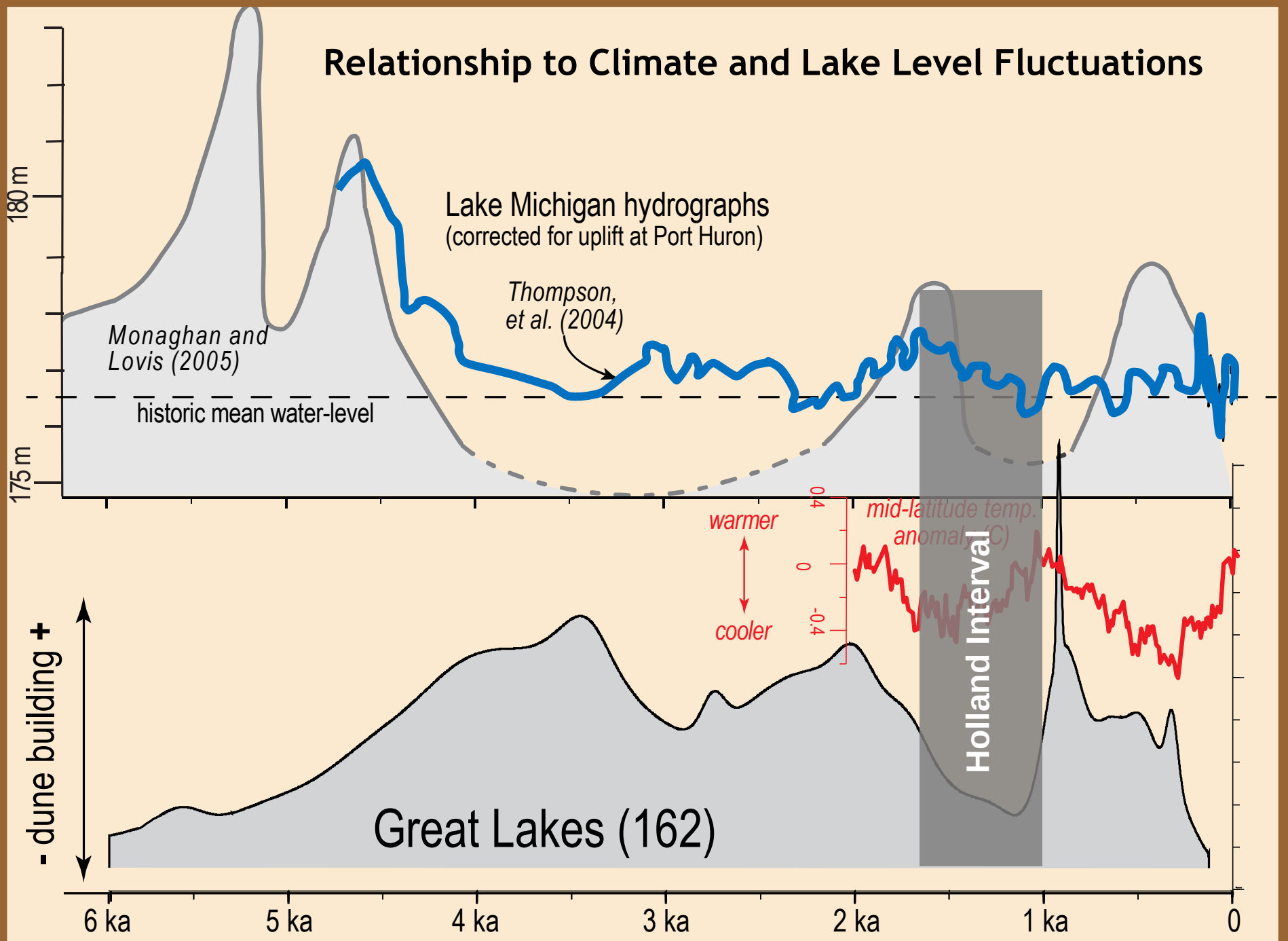
* all ages are calibrated to the tree-ring curve

Above the Hinge Line - Progradation

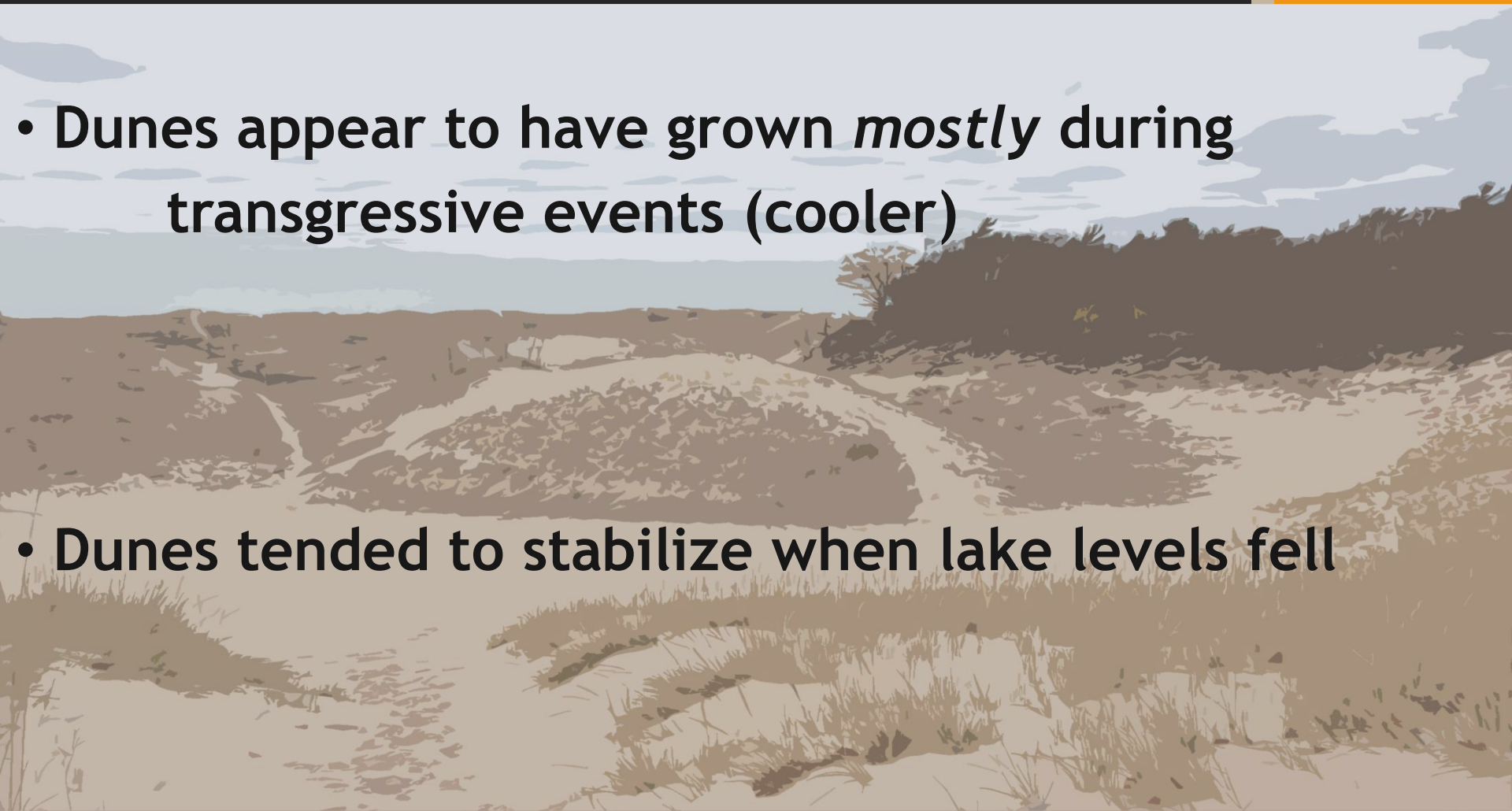


Statistical Analysis of OSL Ages (PDD)




Relationship to Climate and Lake Level Fluctuations
180 m
175 m
Lake Michigan hydrographs
(corrected for uplift at Port Huron)
Thompson,
et al. (2004)
Monaghan and
Lovis (2005)
historic mean water-level
warmer
cooler
0.4
0
-0.4
mid-latitude temp.
anomaly (°C)
Holland Interval
- dune building +
Great Lakes (162)
6 ka
5 ka
4 ka
3 ka
2 ka
1 ka
0

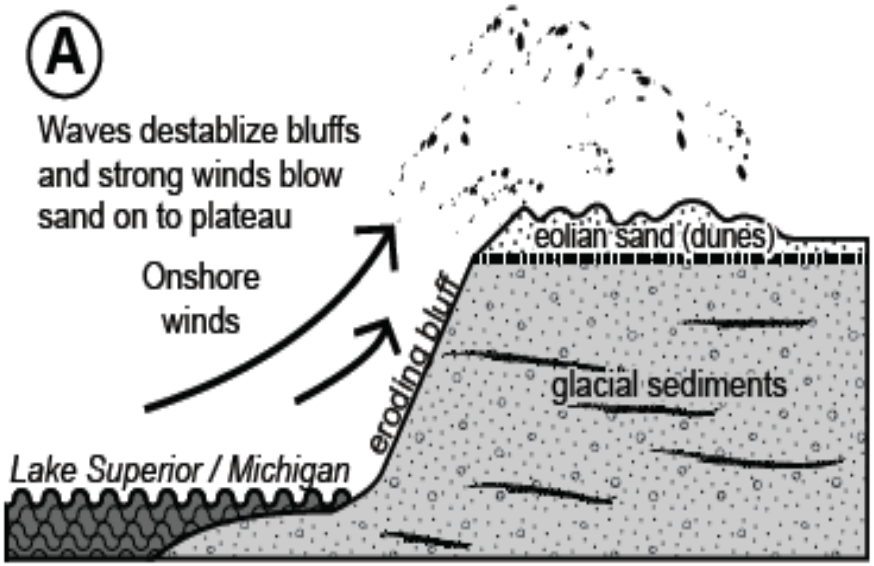
Chronological Relationships



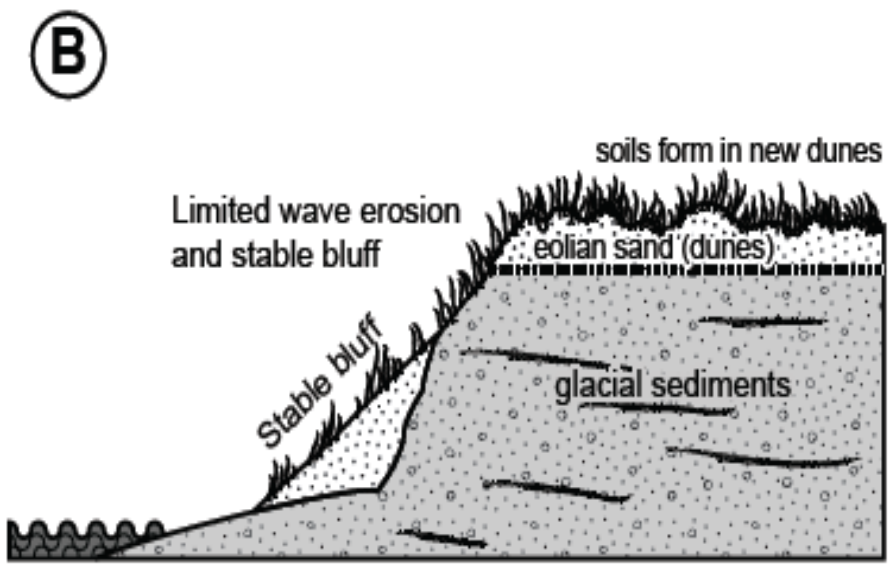
- **Dunes appear to have grown *mostly* during transgressive events (cooler)**

- **Dunes tended to stabilize when lake levels fell**

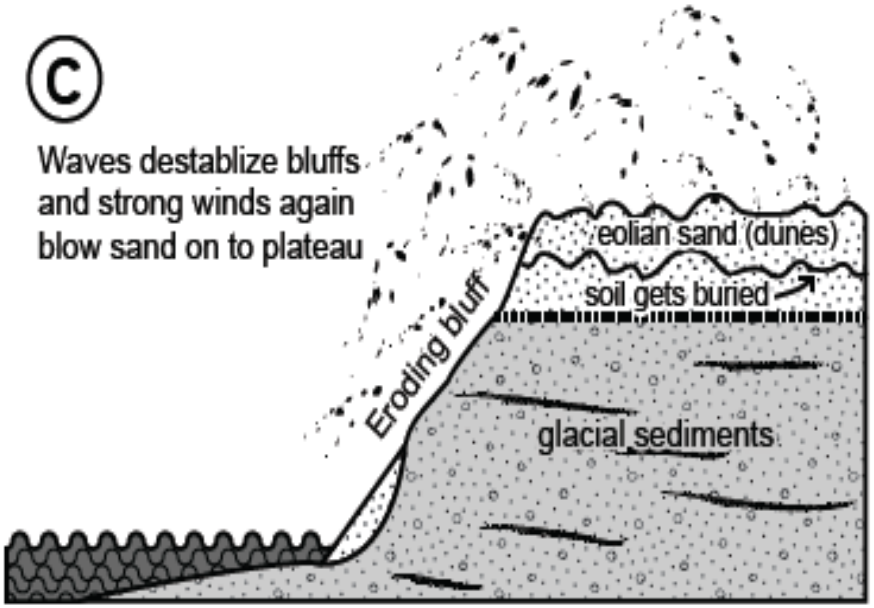
The Perched Dune Model



High lake phase

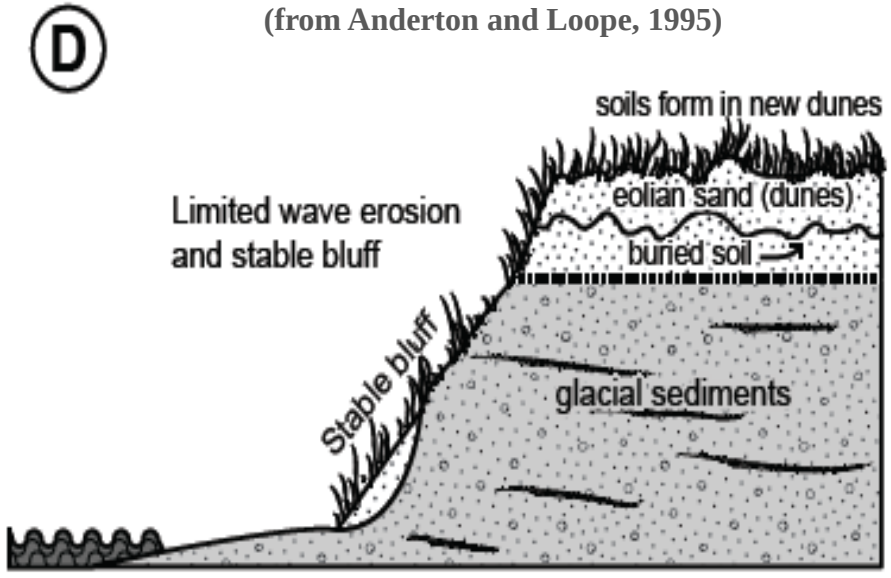


Low lake phase



High lake phase

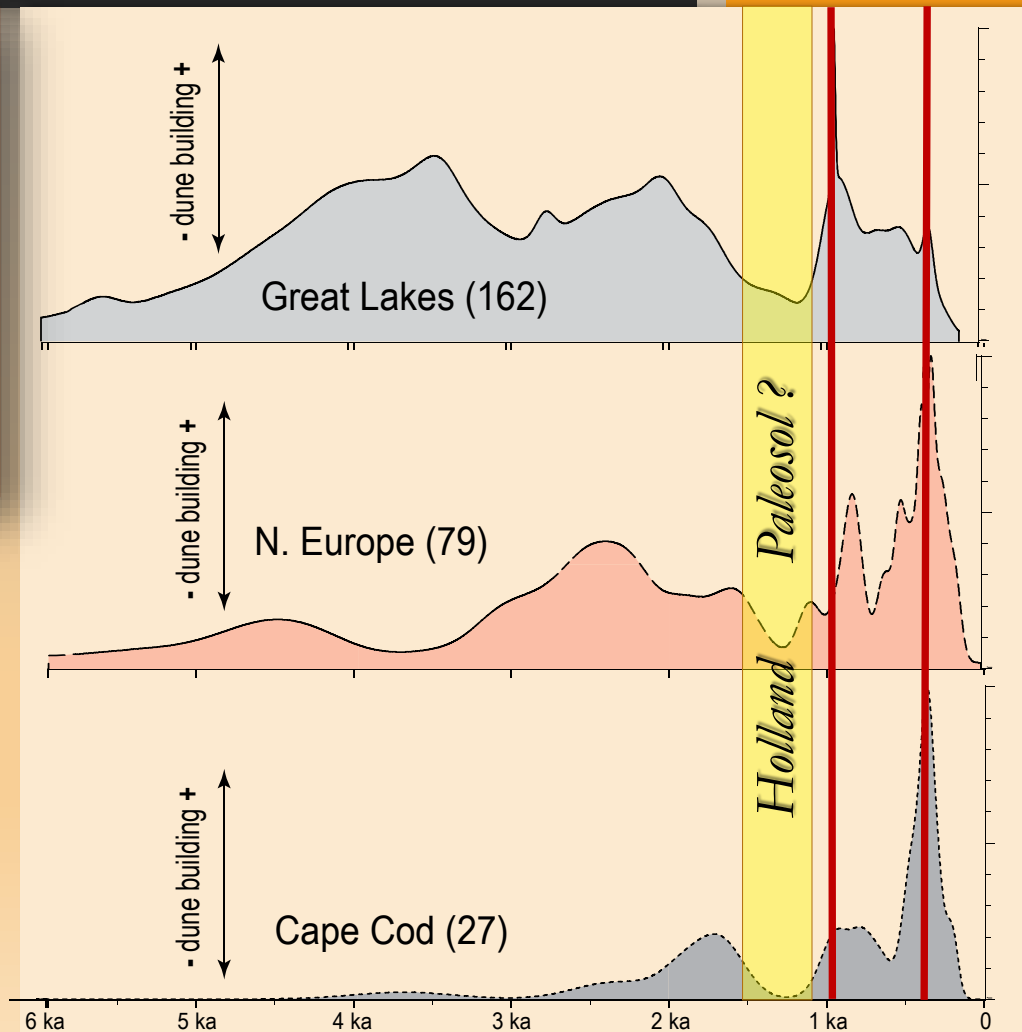
(from Anderton and Loope, 1995)

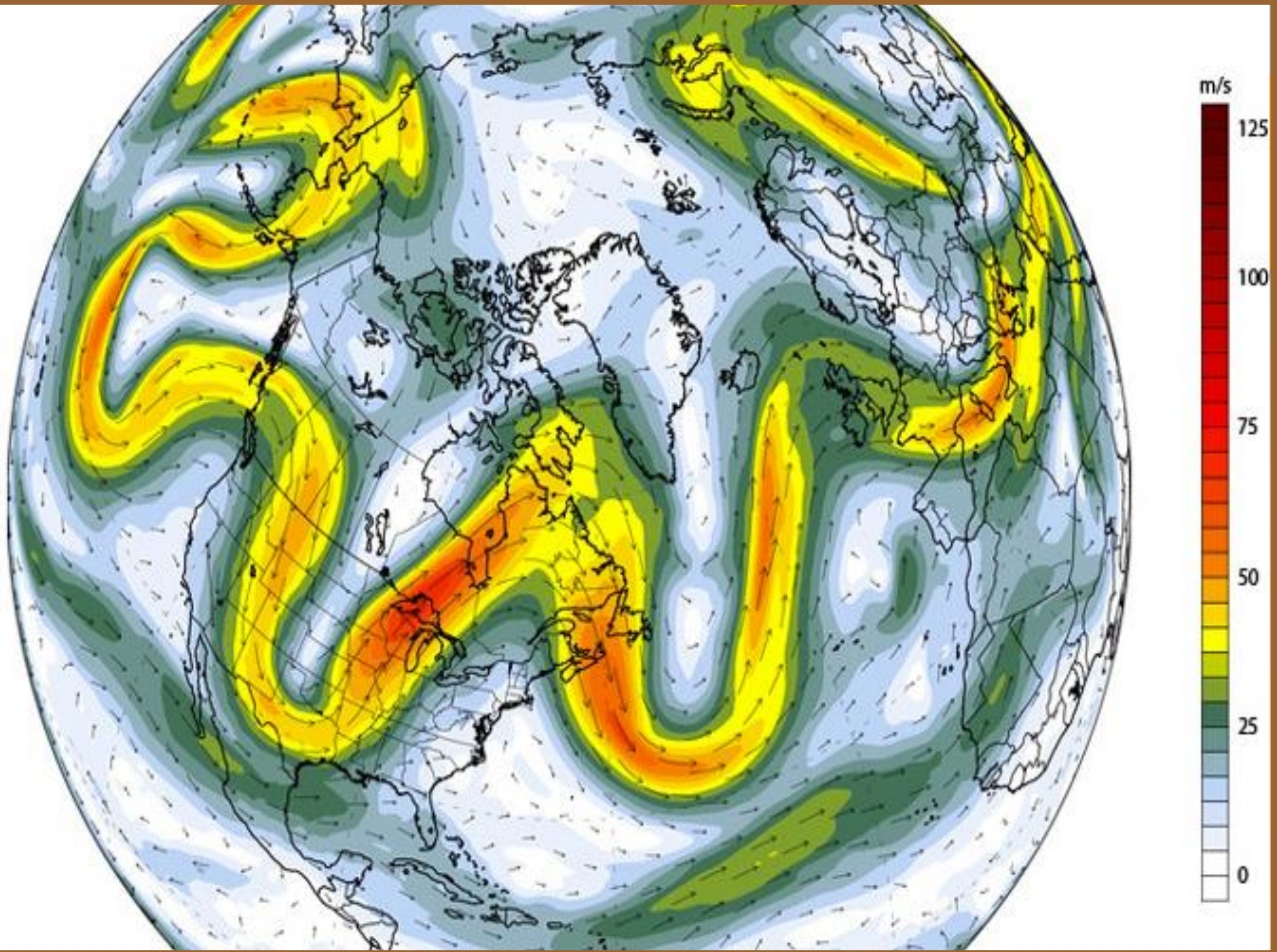


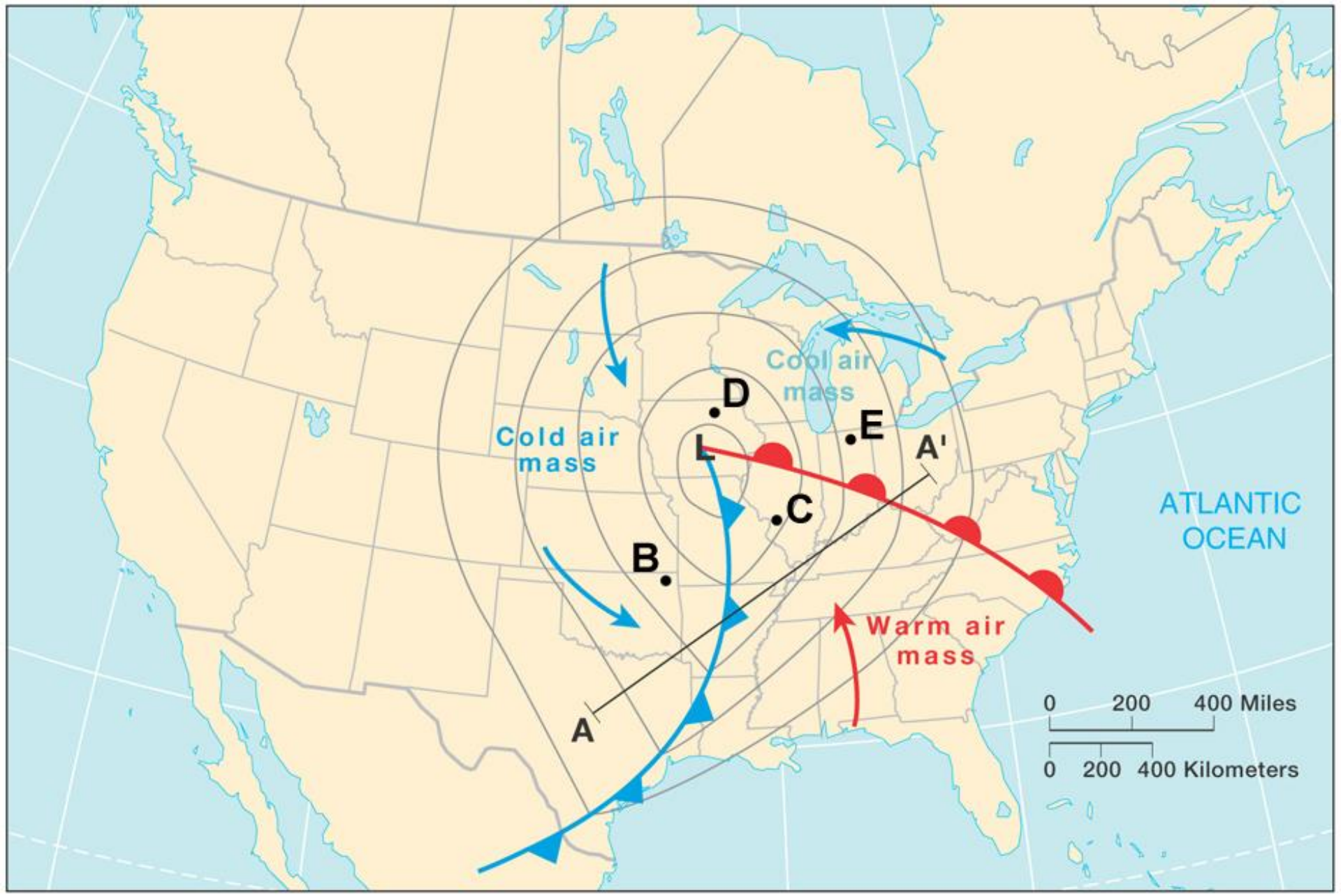
Low lake phase

Hemispheric Relationships??

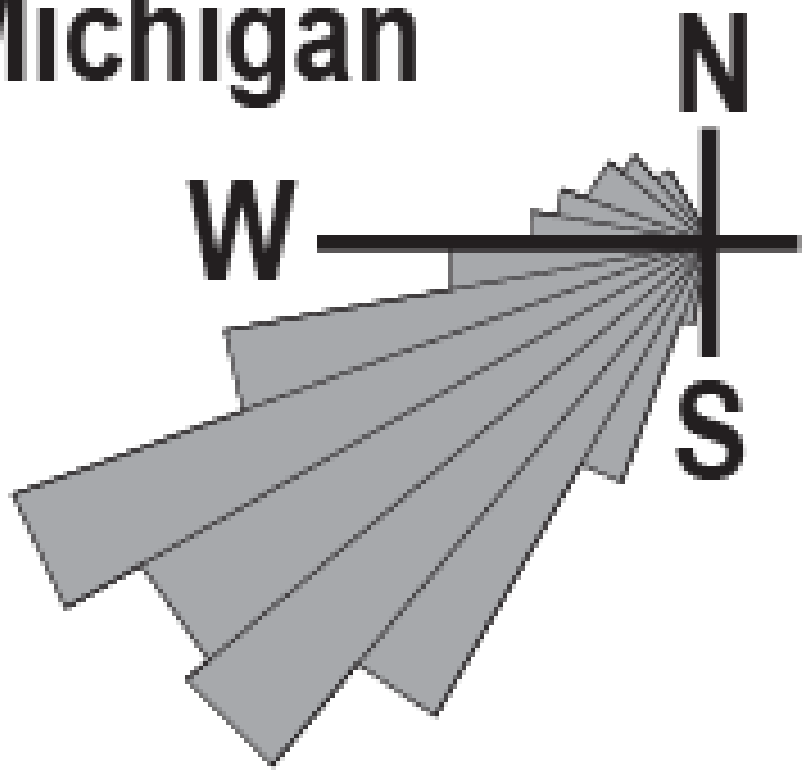
- **Can we integrate the large-scale cycles & hemispheric teleconnections by comparing dune cycles from the mid-continent/northeast North America with northern European coastal dunes.**

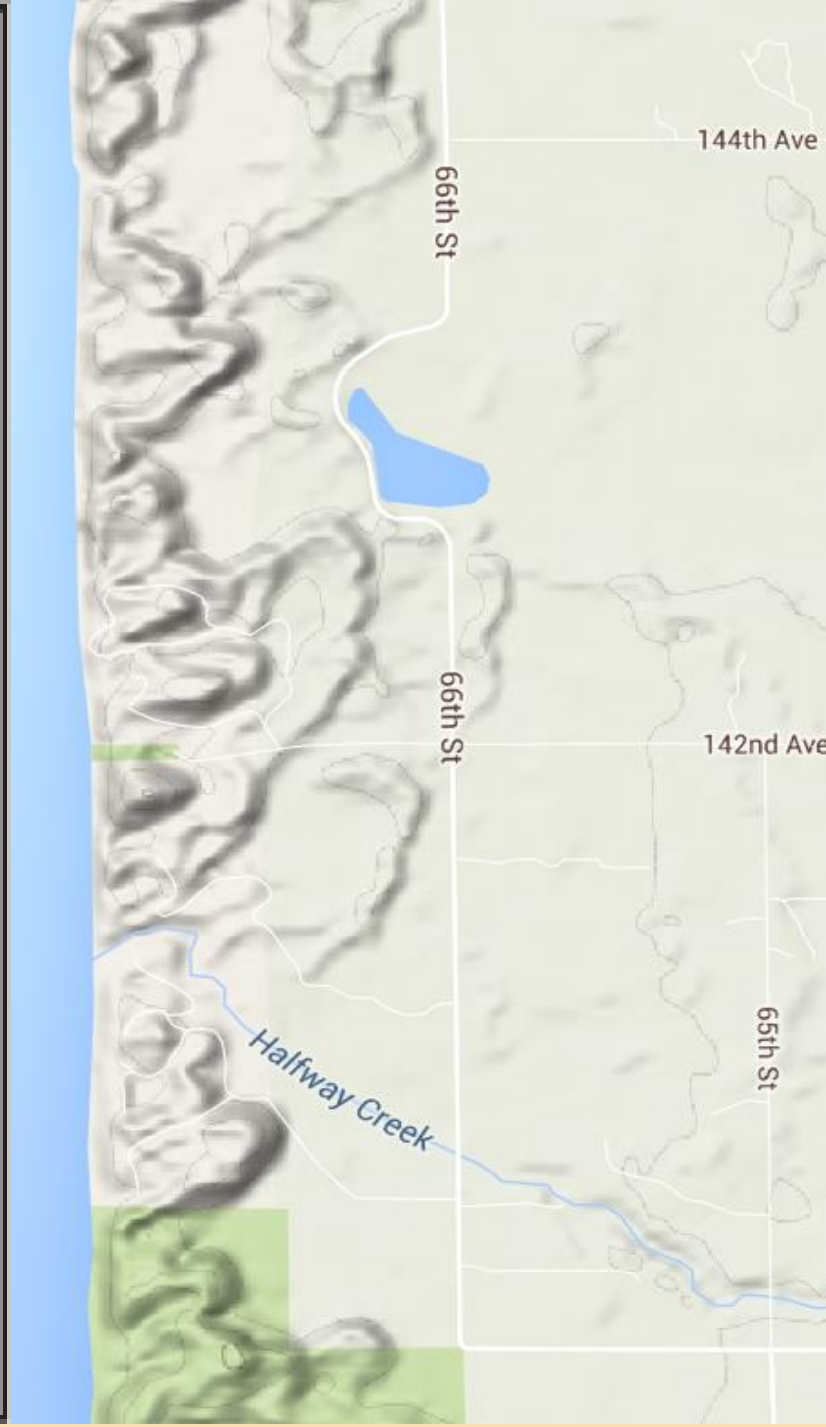



m/s
125
100
75
50
25
0


Cool air mass
Cold air mass
D
E
L
A'
C
B
A
ATLANTIC OCEAN
Warm air mass
0 200 400 Miles
0 200 400 Kilometers

wind direction for the formation of 1,213 parabolic coastal dunes, L. Michigan

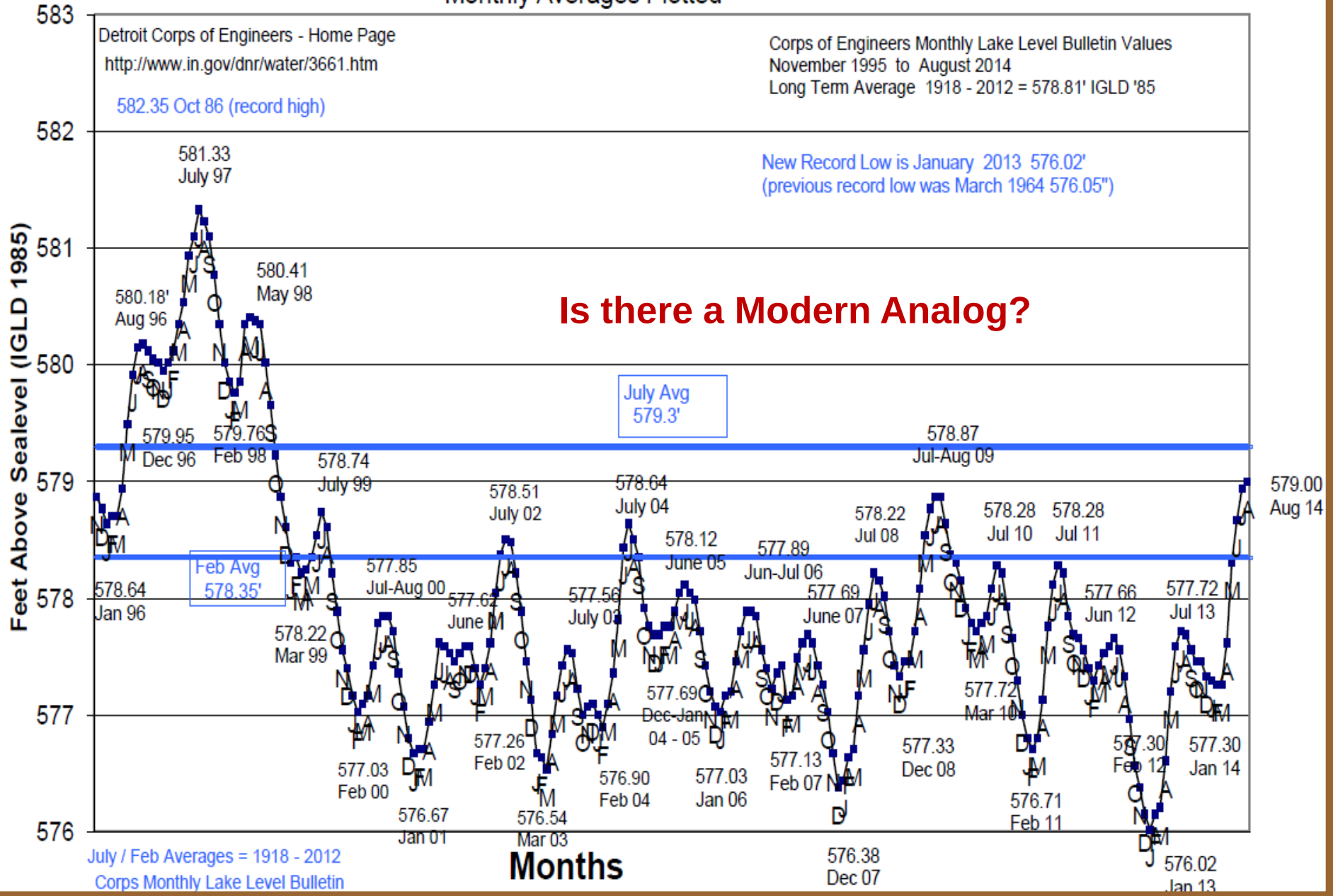




Note: All of these numbers are the average of 6 gages in Lake Michigan and Huron.

LAKE MICHIGAN LAKE LEVEL 1996 - 2014

Monthly Averages Plotted



Repeat Photography


Montague, 2001


Montague, 2008


Montague, 2014

Photo: Ed Hanson

Van Buren, 1999

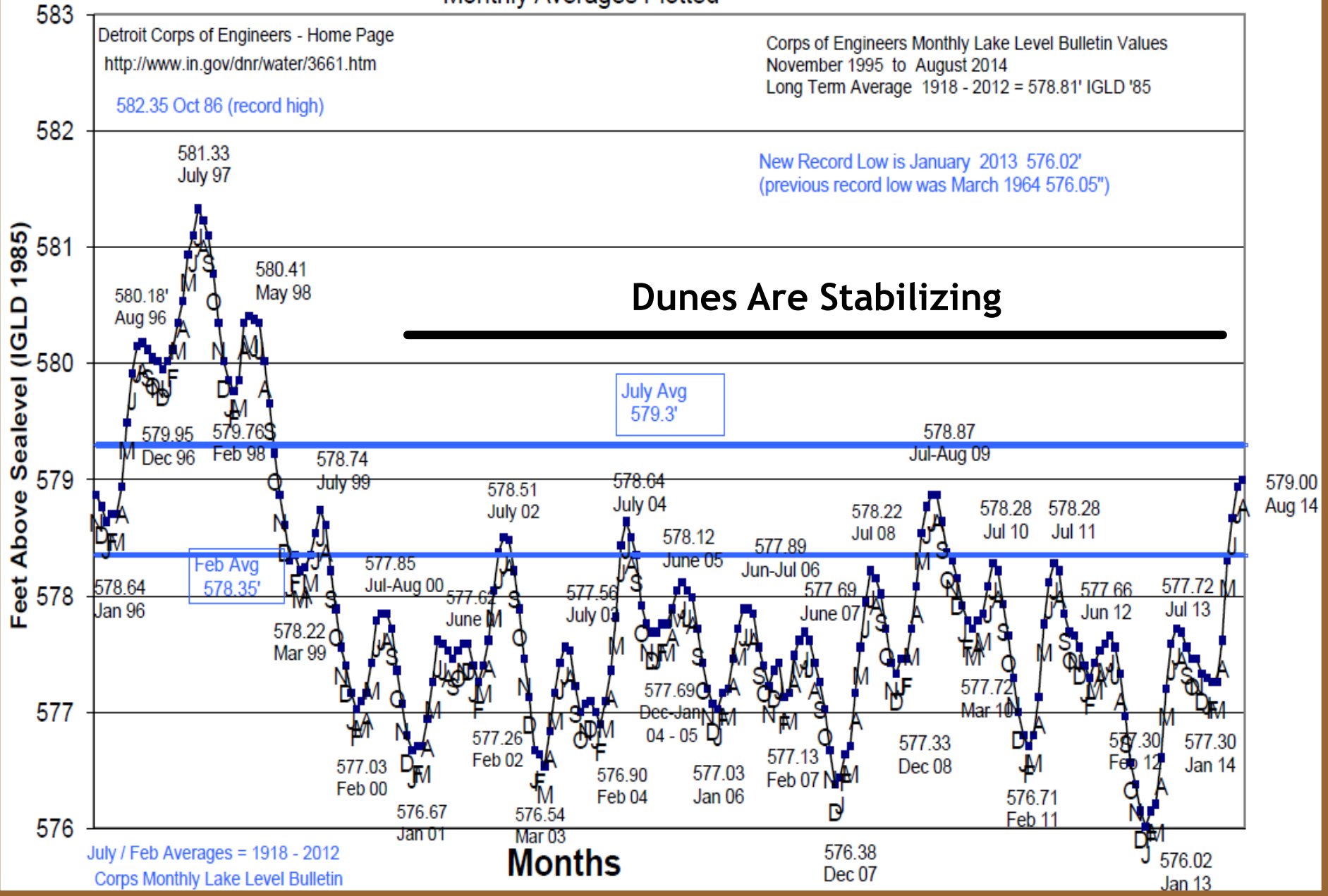

Van Buren, 2008


Van Buren, 2014

Note: All of these numbers are the average of 6 gages in Lake Michigan and Huron.

LAKE MICHIGAN LAKE LEVEL 1996 - 2014

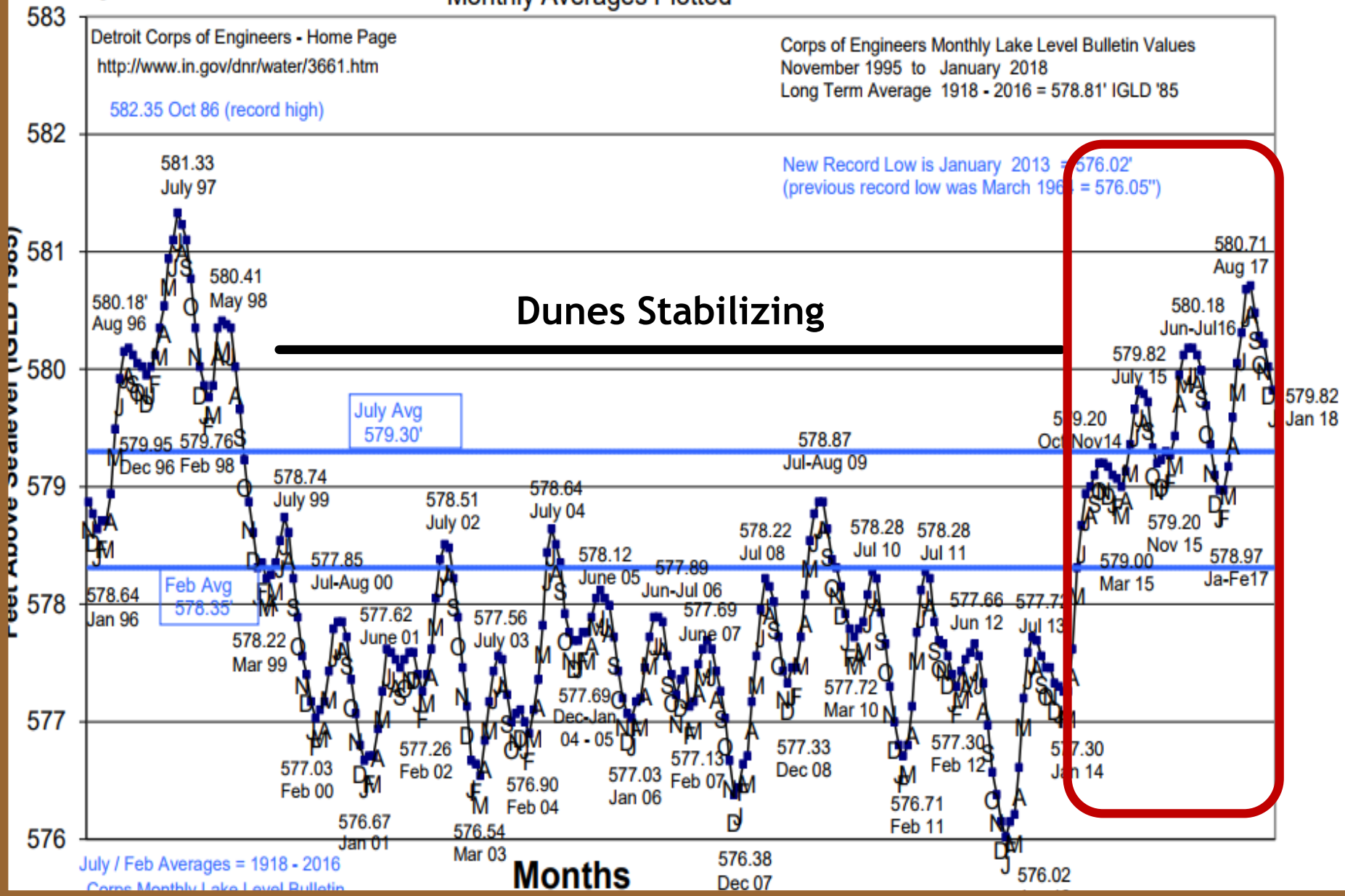
Monthly Averages Plotted



LAKE MICHIGAN LAKE LEVEL 1996 - 2018

Monthly Averages Plotted

lote: All of these numbers re the average of 6 gages Lake Michigan and Huron.




Van Buren, 2008


Van Buren, 2014


Van Buren State Park - in November

The Emerging Science of Coastal Sand Dune Age and Dynamics: Implications for Regulation and Risk Management in Michigan

Alan F. Arbogast
Department of Geography
Michigan State University

Brad Garmon
Director of Conservation and Emerging Issues
Michigan Environmental Council

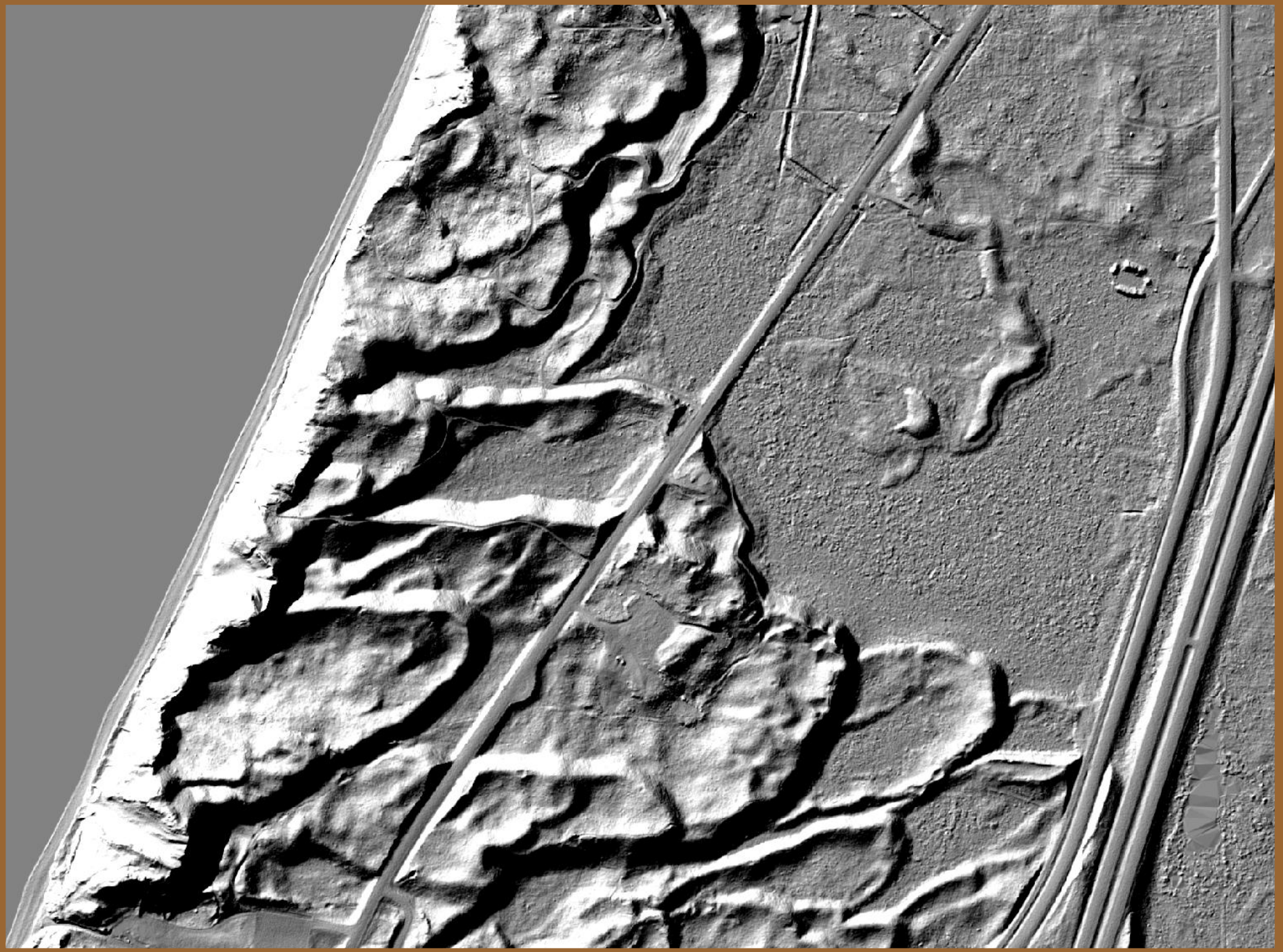
Coastal sand dunes are found in many places along the shores of the Great Lakes. They are particularly common along the western coast of Lower Michigan and the northern shore of Upper Michigan due to three reasons, including 1) the very high supply of fine sand (1-2mm in size) initially deposited during the ice age, 2) the orientation of the shore as it relates to prevailing westerly winds, and 3) the long fetch resulting in unencumbered air flow across Lake Michigan and Lake Superior. The interaction of these variables has resulted in spectacular dune fields that collectively embody the largest complex of freshwater dunes in the world. In fact, they rival any coastal dune systems in the world as far as their size and grandeur is concerned, including those in northern Europe, Australia, New Zealand, and South Africa, to name a few places where prominent coastal dunes occur.

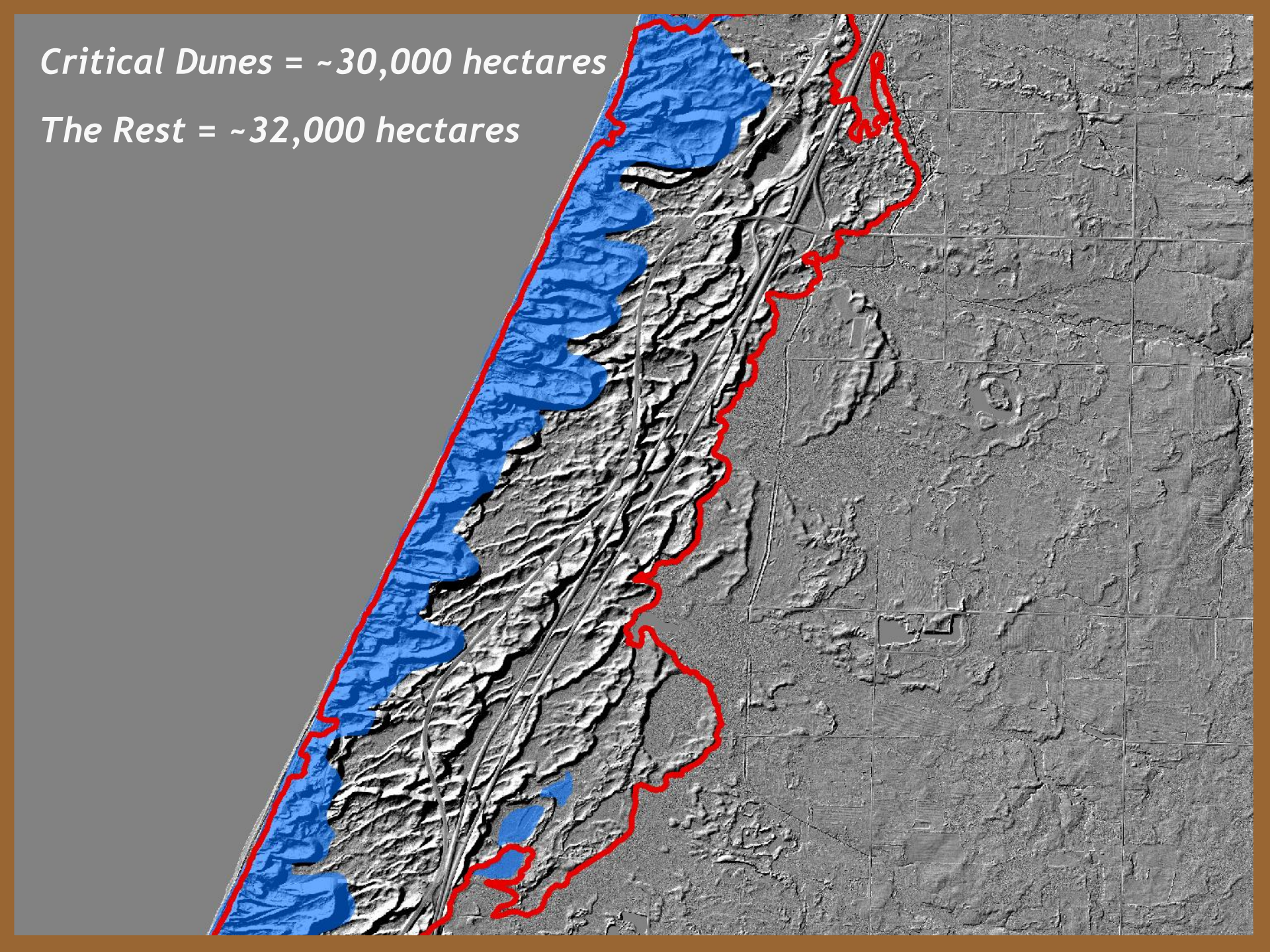
Recent Research Challenge Dune Age and Formation Assumptions

Given the high profile of the dunes, they have been a source of geological and geographical interest for over a century. Early studies (e.g., Cowles, 1899; Dow, 1937; Scott, 1942; Olson, 1958a, b) were largely descriptive in their character and focused on the general physical geography of the dune systems, including the relationship to hypothesized lake levels and the


Diverse, Dynamic, and Sensitive Landforms!

Remapping Coastal Dunes




Critical Dunes = ~30,000 hectares
The Rest = ~32,000 hectares

Thanks for Listening!