Coastal Hazards:
Geological Perspectives from the U.S. Atlantic Coast

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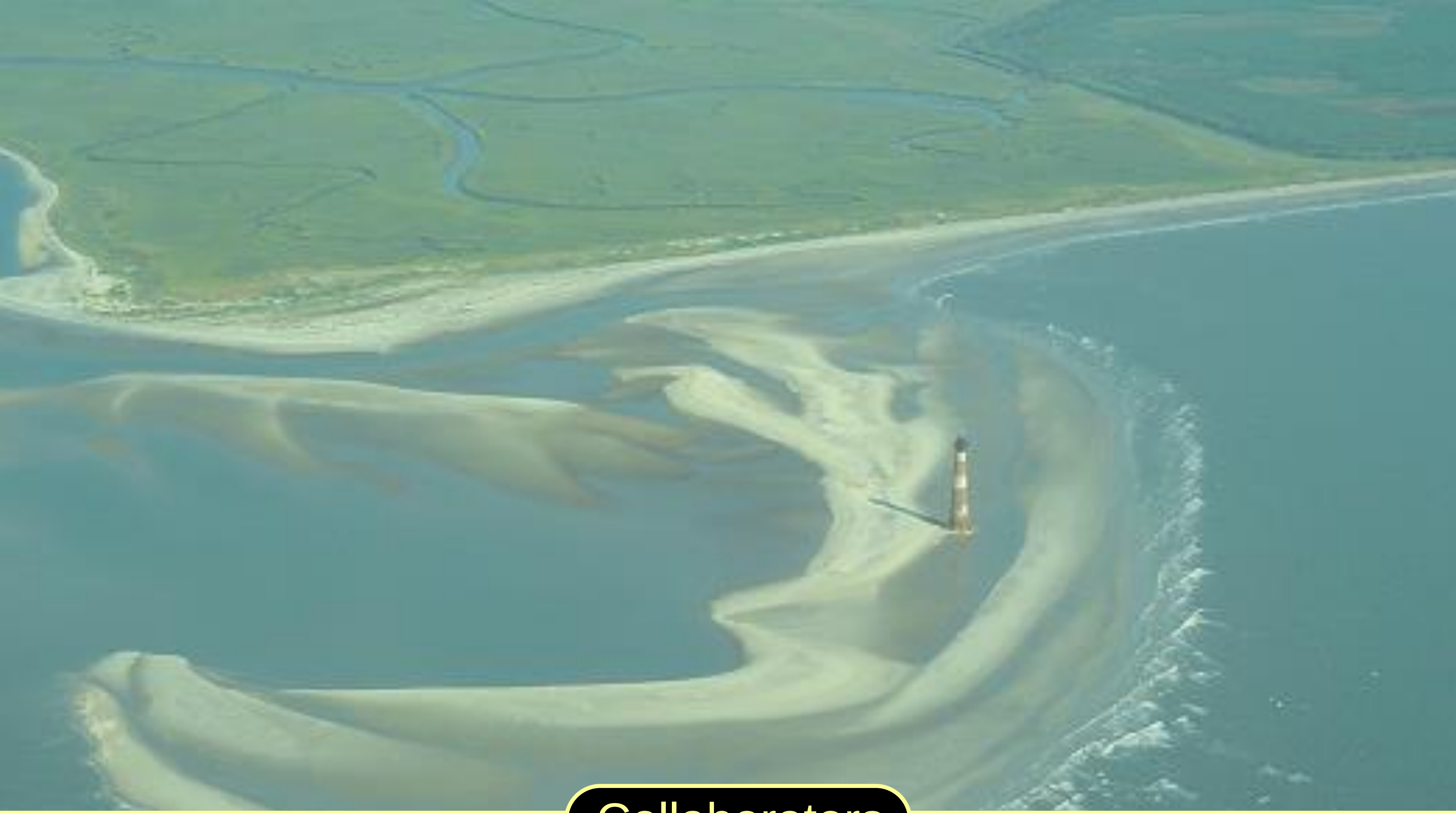

Collaborators

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M. Fenster — Randolph-Macon College

R. McBride — George Mason University

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Hurricane Katrina (2005)

- Erosion
- Flooding
- Submergence

Hurricane Sandy (2012)

Chandeleur Islands, LA

USGS Coastal and Marine Geology Program

USACOE

U.S. Atlantic
& Gulf Coasts
>$3 trillion

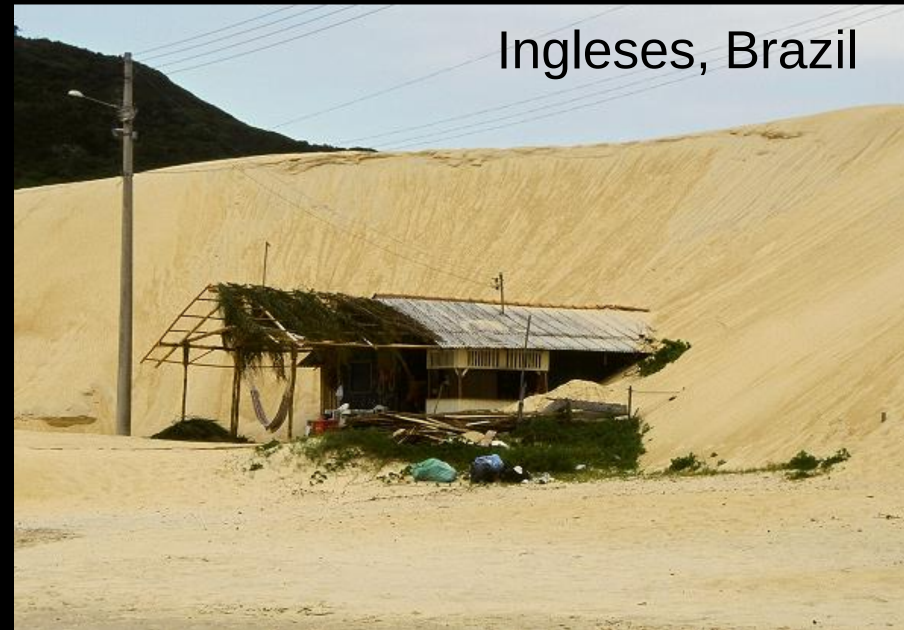
U.S. Army Corps of Engineers (USACOE)

USACOE

U.S. Atlantic
& Gulf Coasts
>$3 trillion

Deposition
(sand invasion)

Desert dunes, Mauritania



Ingleses, Brazil

Dune Village, Silver Lake, Michigan

Baltic Sea coast

Questions and Challenges

1. What are the stability thresholds for sandy coasts?

- signatures of erosion – timing and hindcasting
- quantitative analysis of wave climate and storm-surge parameters
- response to accelerated sea-level rise and increased storminess

2. How do old channels affect coastal behavior?

- subsurface anomalies within coastal sequences
- vulnerability of barrier segments to breaching
- tidal prism reconstruction and sea-level change

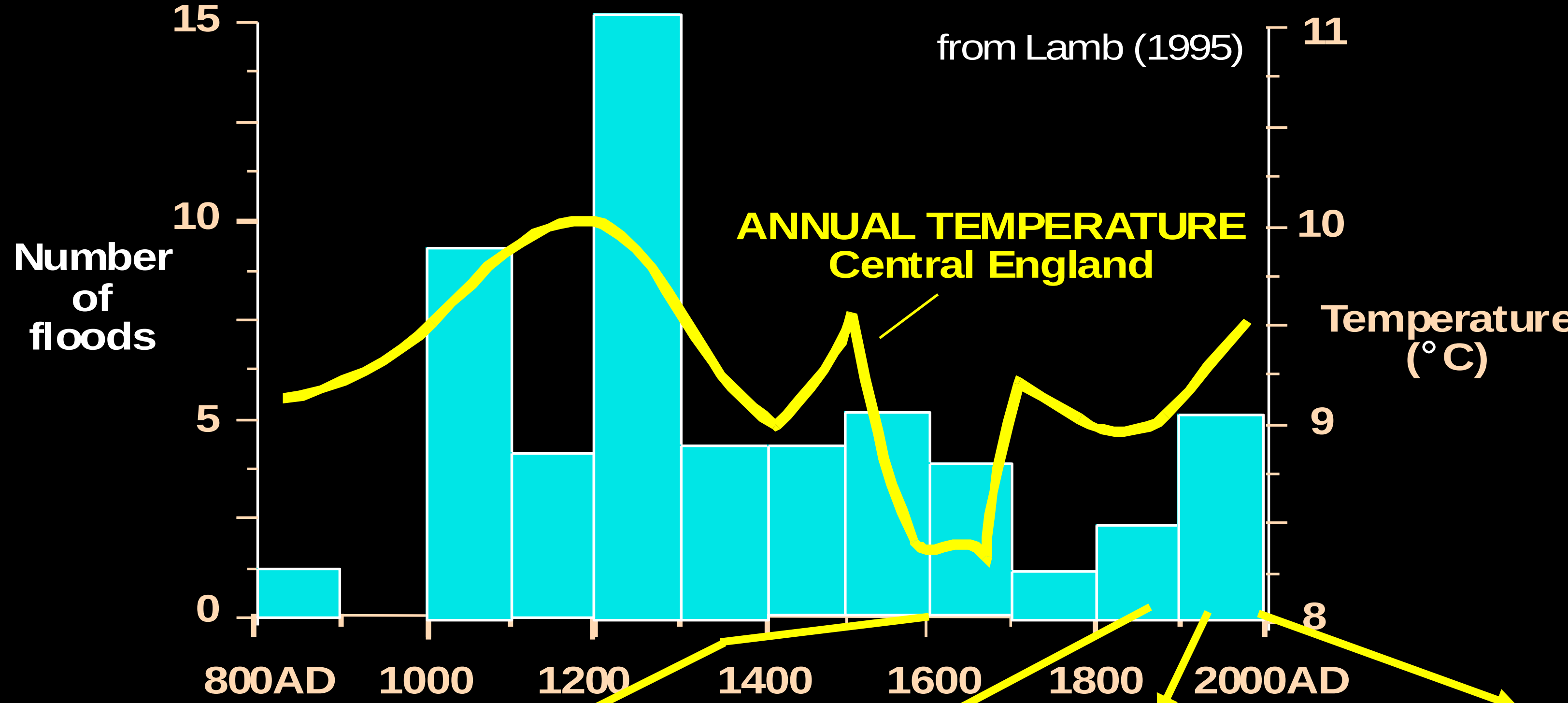
3. Dune reactivation phases: causes and timing

- climatic vs. internal triggering mechanisms
- paleo-wind reconstruction (10^2-10^3 yr)
- human-landscape interaction

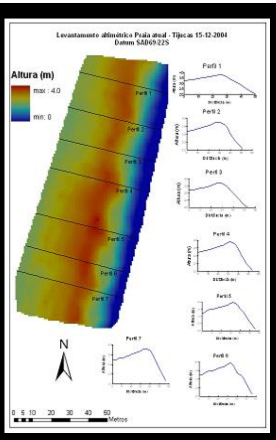
- NEW FRONTIERS

Recognition and Dating of Erosion in Sand-Dominated Systems

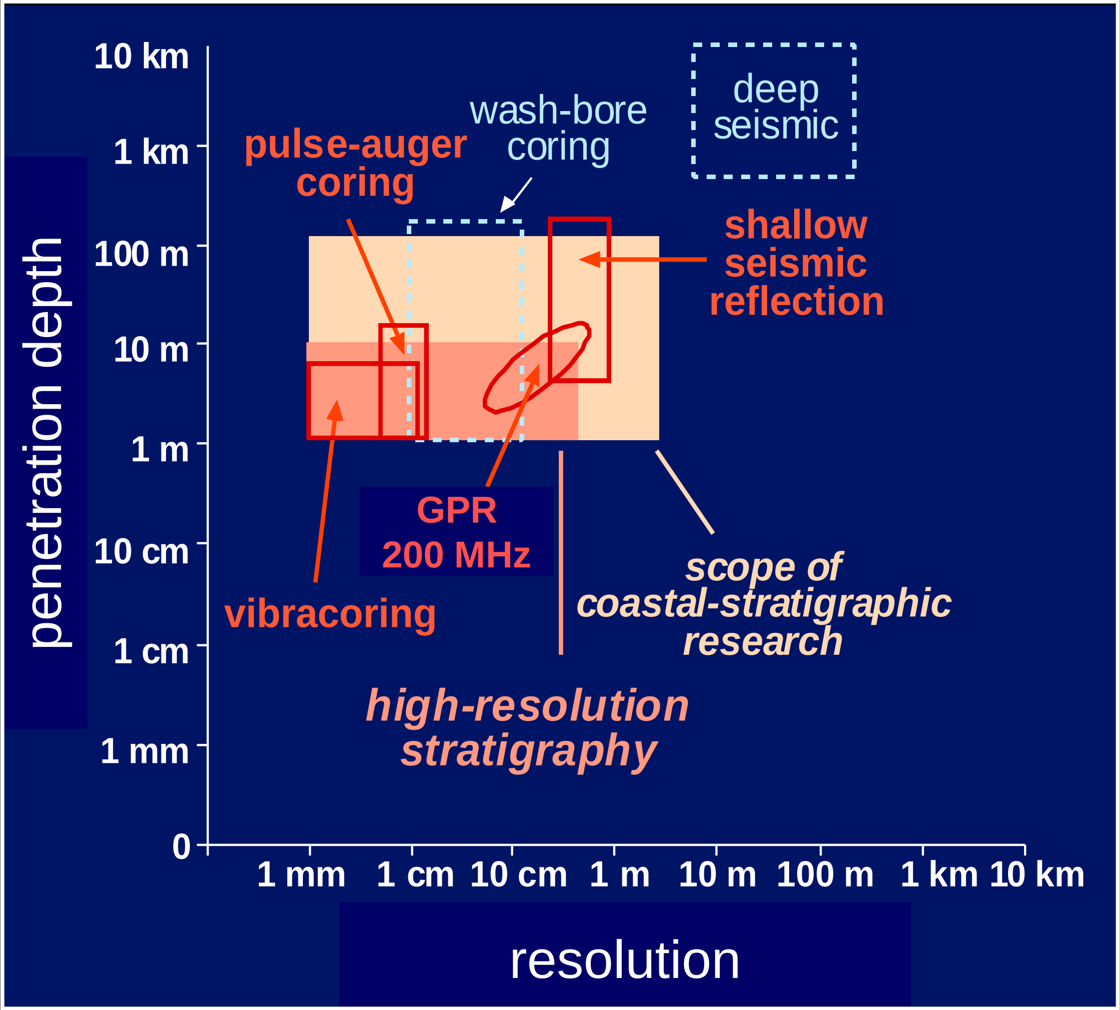
SEVERE SEA FLOODS
North Sea and English Channel



60-95%



Field Techniques



High-Resolution Geophysics

Groundtruth

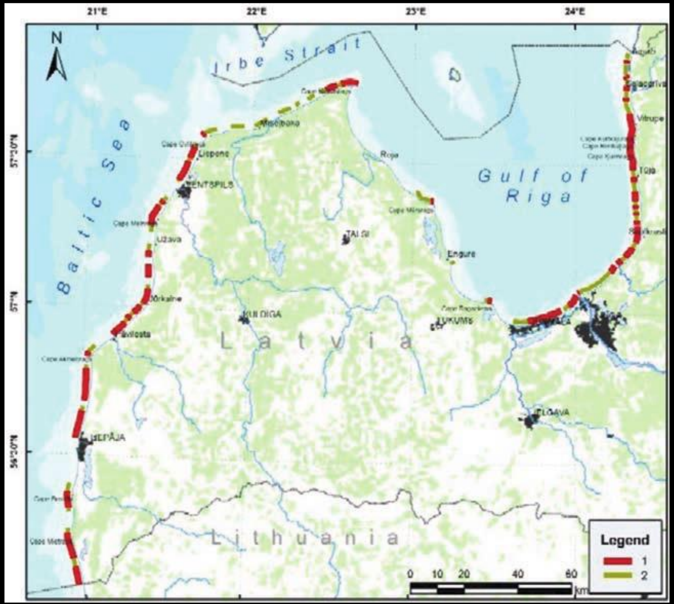
Research Sites

Part 1

Erosion: Signatures and Chronology

Progradation: Deposition - Erosion

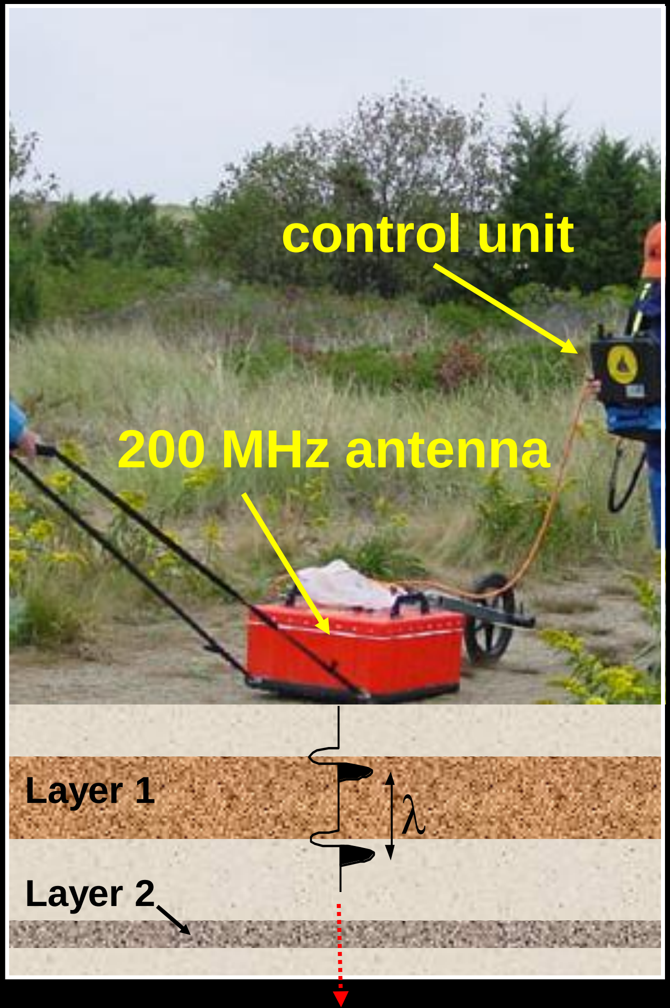
photo by P. Brown (Rocky Mountain Tree-Ring Research)



From Ebernards et al (2006)

Ground-Penetrating Radar (GPR)

Revolutionized coastal geological research: Continuous high-resolution imaging



electromagnetic waves

Causes of reflection:

- physical structures
- textural contrast
- composition
  (+ iron oxides,
  clays, organics)
- moisture content
- bulk density
- porosity

Signal loss:

- saltwater, thick clay, metal

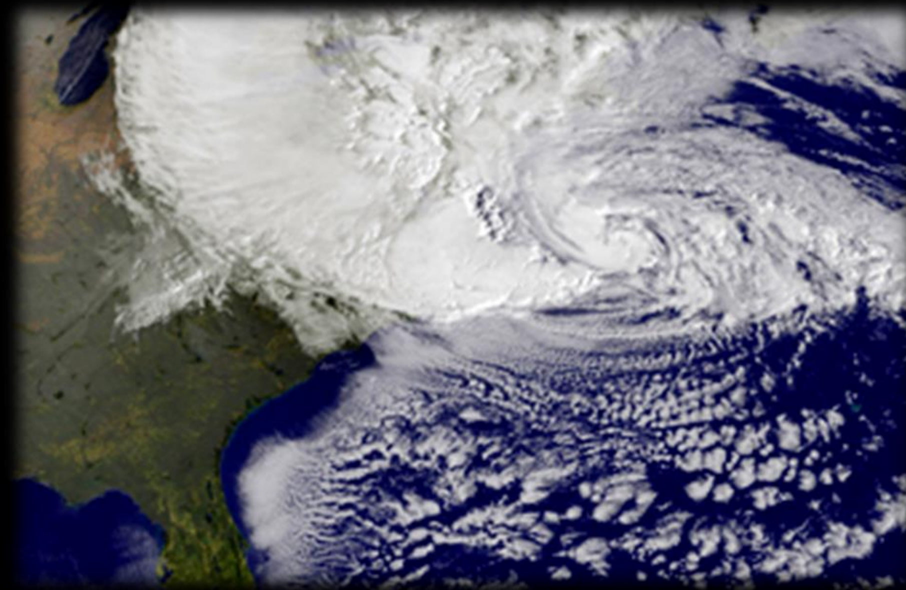
Heavy-Mineral Concentrations (HMCs)

proxies for high-energy events

South Waihi Beach, New Zealand

photos by T. Hume

Superstorm Sandy (2012)



HMC

Erosion: Events and Signatures

Hurricanes/Typhoons

Cyclones

Extra-tropical storms

Tsunamis

NASA/Digital Globe images

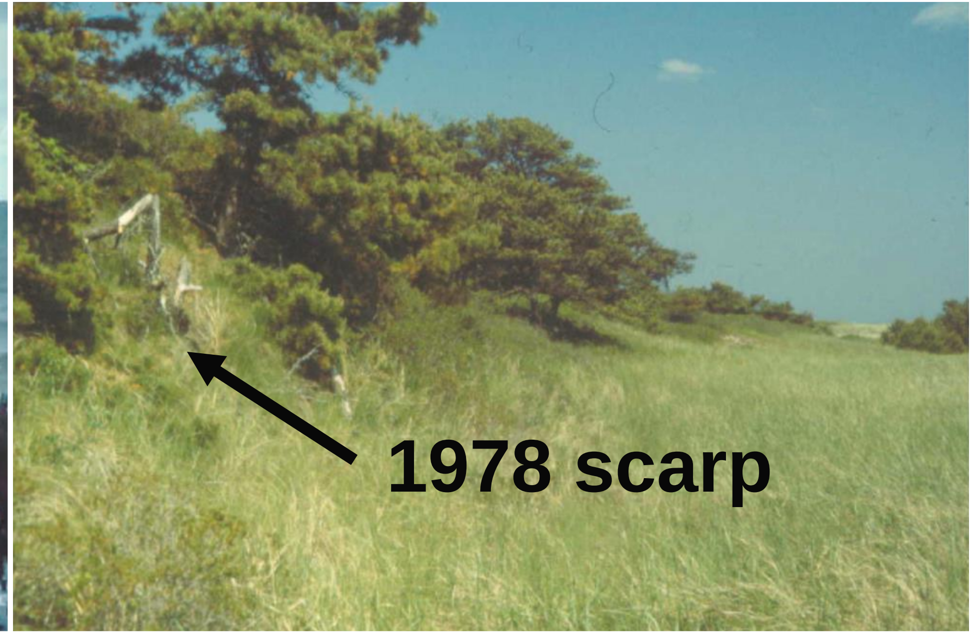
Beach/dune scarps

HMC

2004 tsunami (photo by Rob Evans)

Surge channels

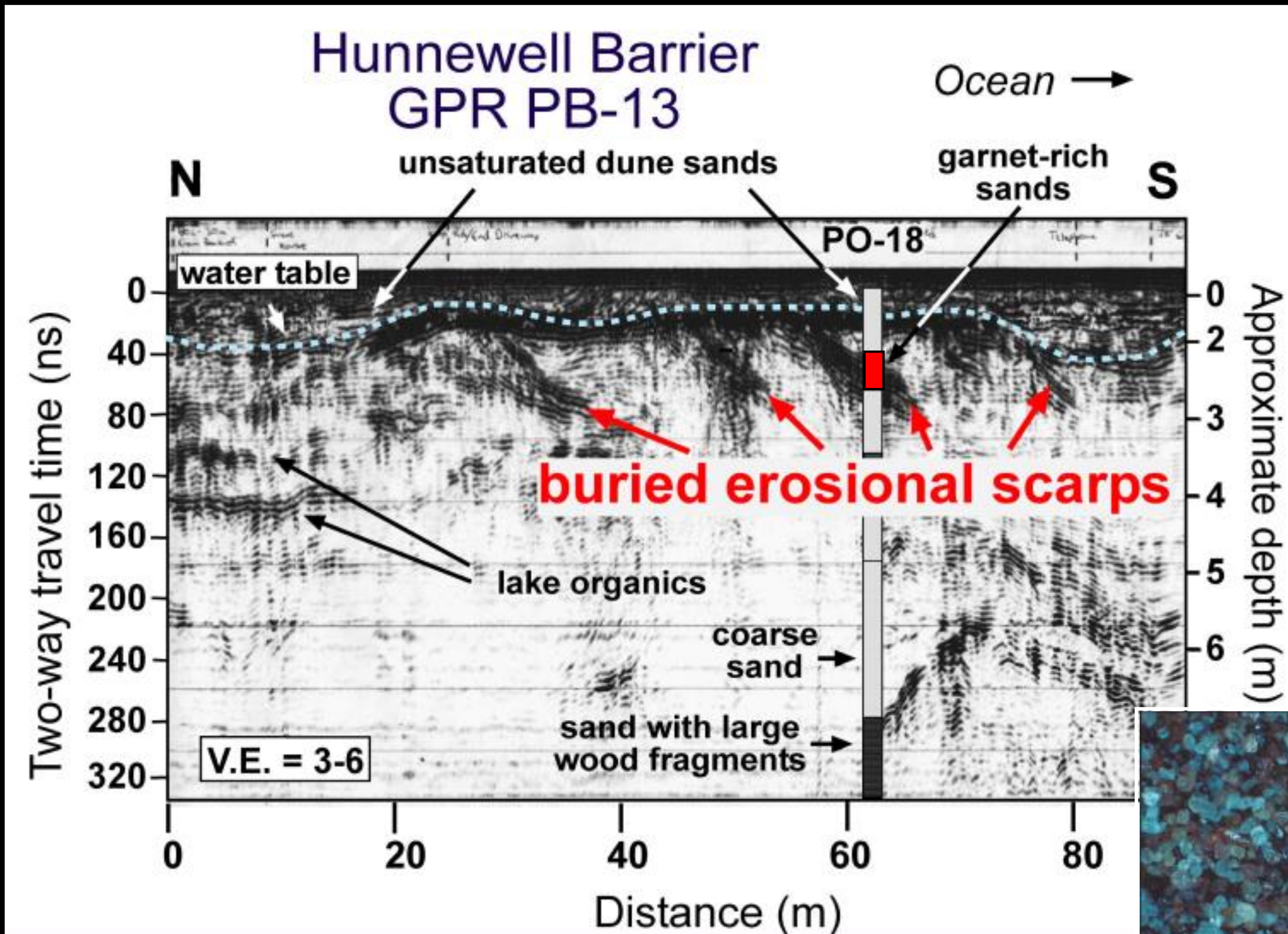

1983
photo by D.M. FitzGerald

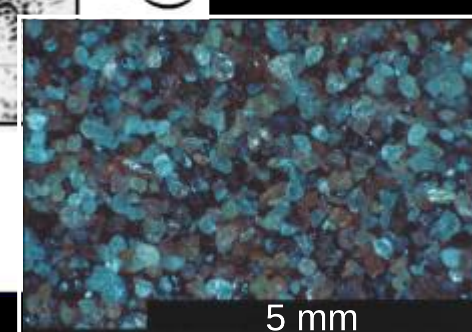

1978 scarp


1978 storm scarp
ocean

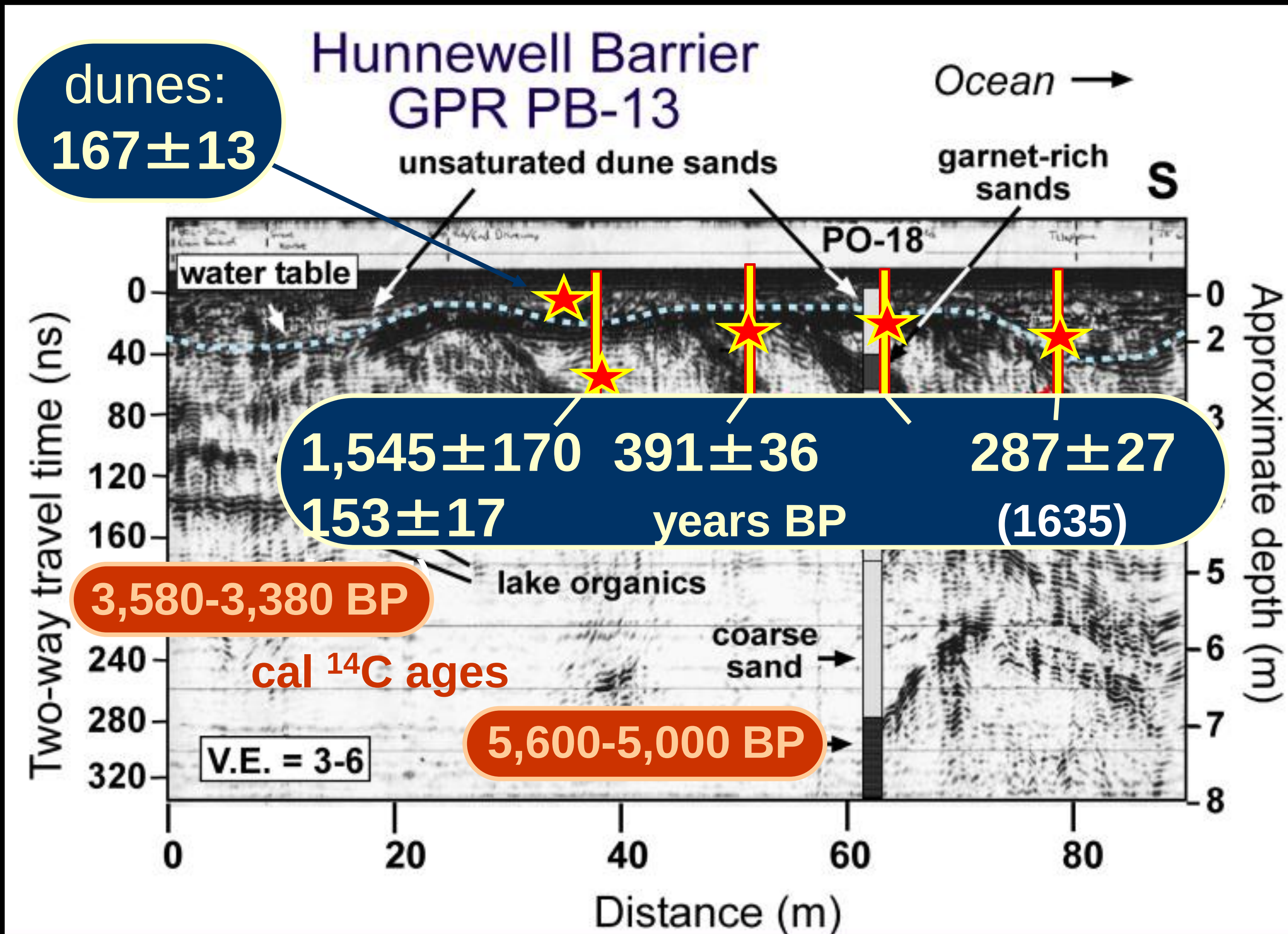
Relict erosional scarps

(no geomorphic evidence)





Optically-Stimulated Luminescence (OSL) Dating

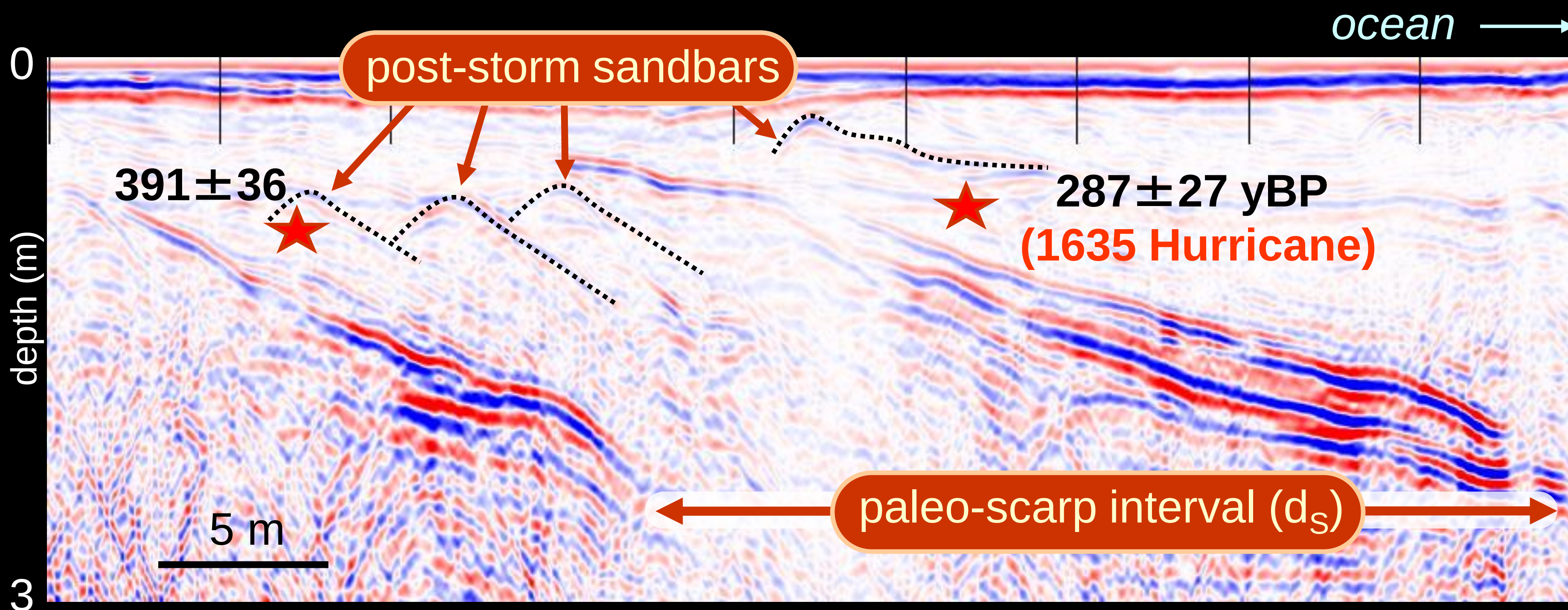


recent scarp

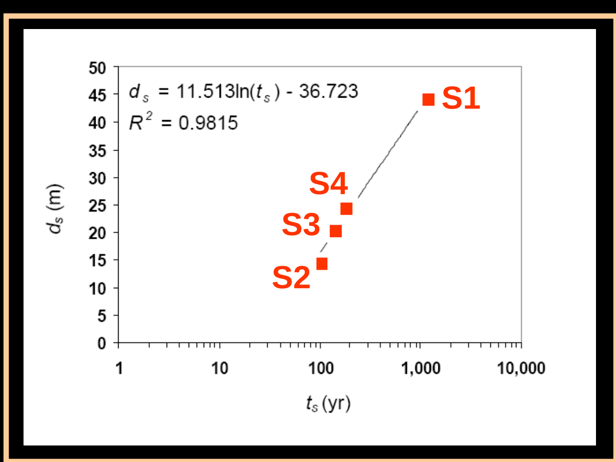
45±15

Buynevich et al. (2007)

Storm Chronology and Climate Links



Paleo-scarp interval vs. time



Atlantic Hurricane Tracks (1980-2005)

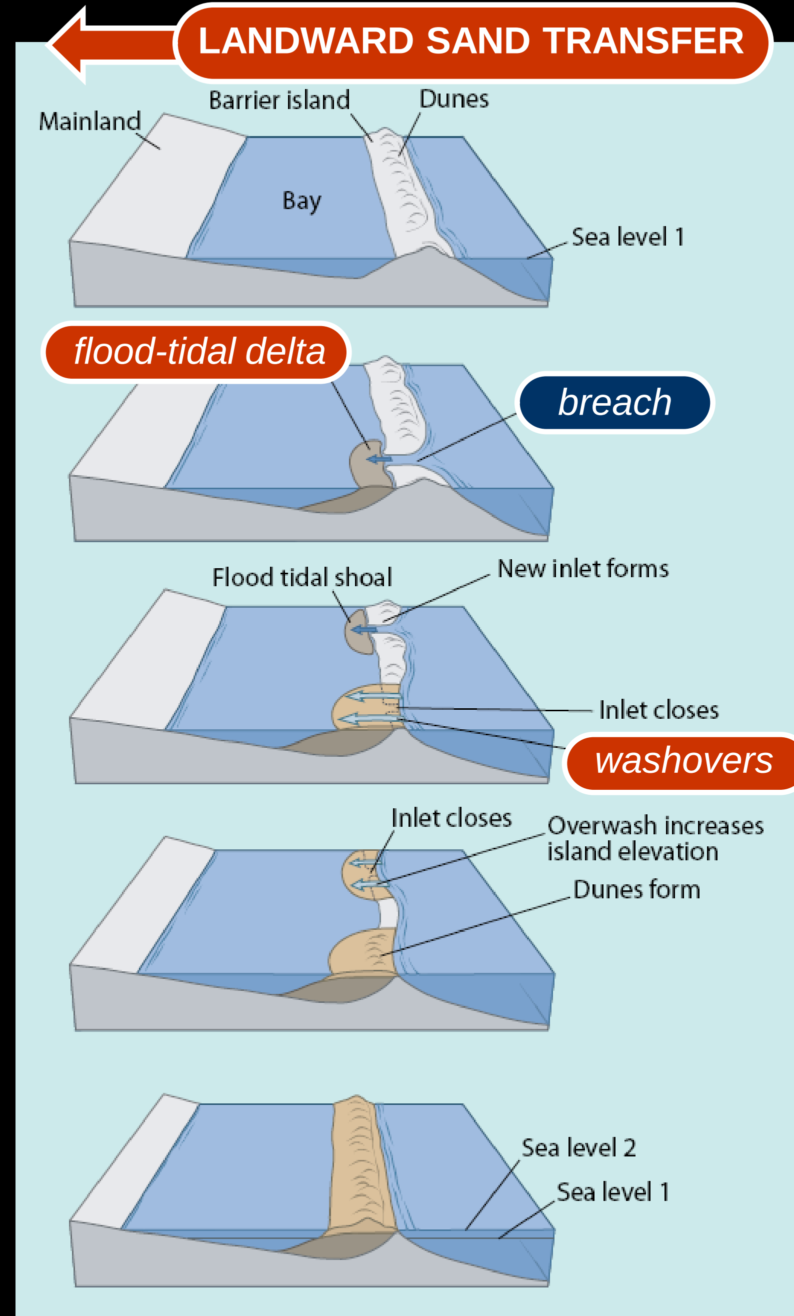
Part 2

Paleo-Channels: Geological Legacy

Transgressive Coastlines

Landward transfer of sand during storms:
integral to barrier migration
with sea-level rise

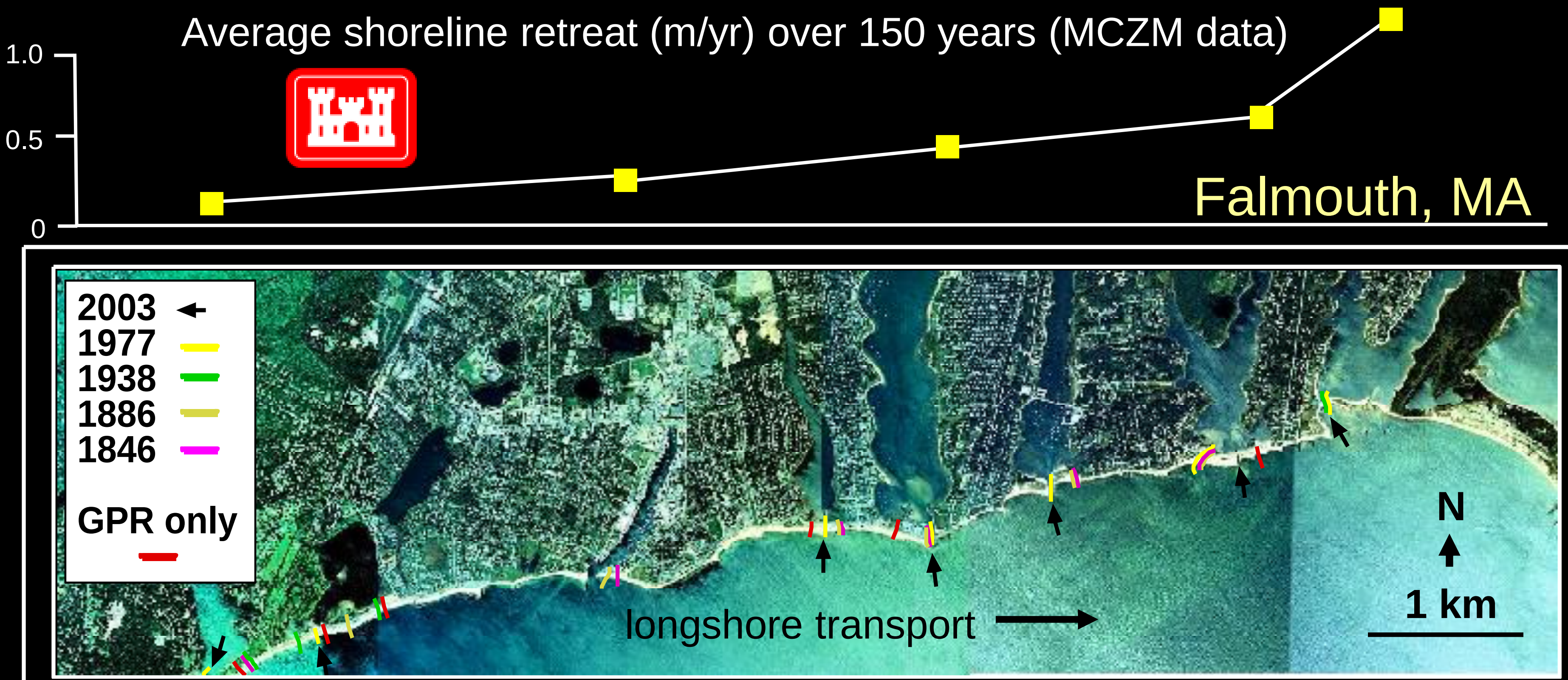
Long Island, NY (photo by Covello & Terchunian)



(modified after John Norton)

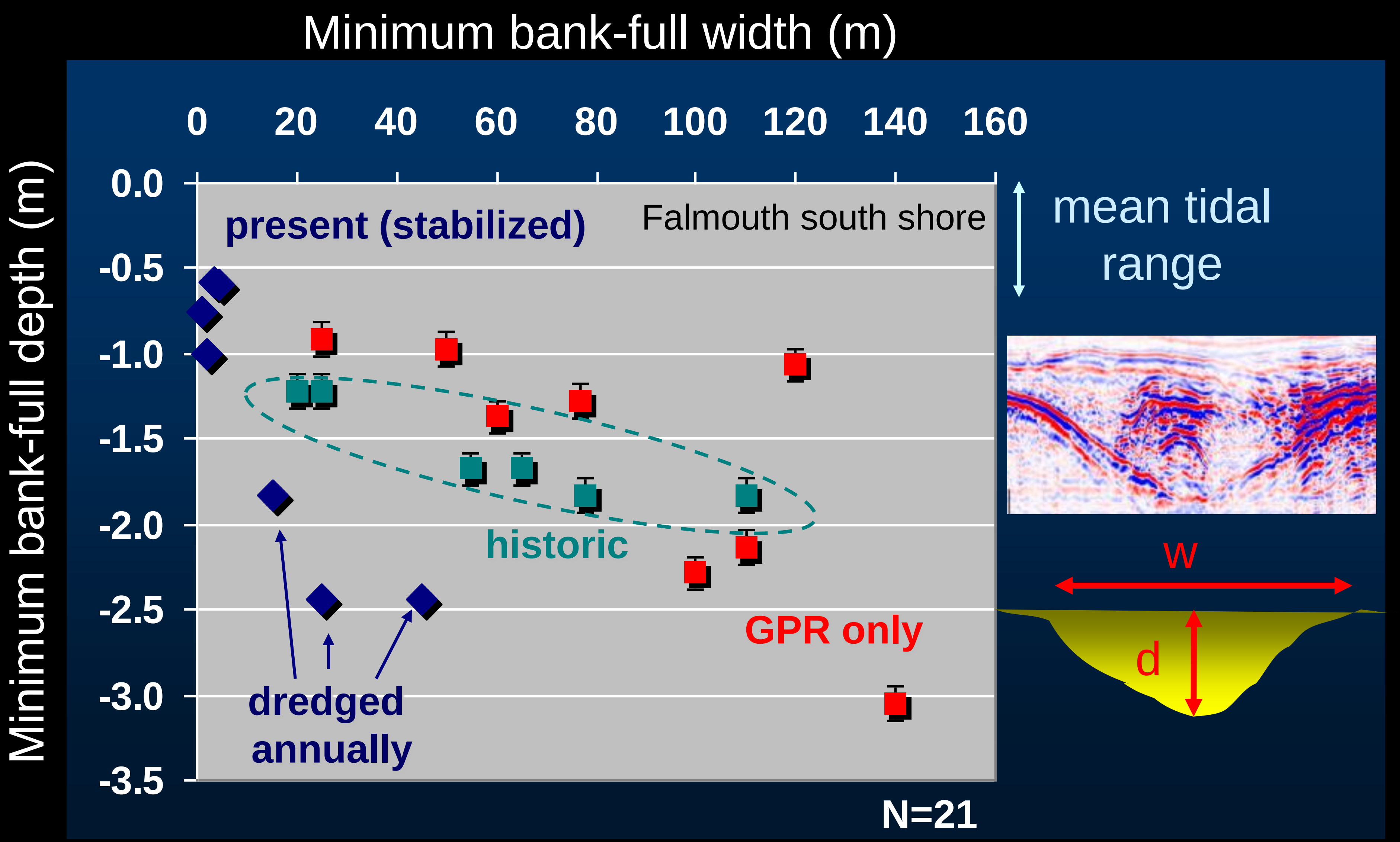
Superstorm Sandy (2012)

Erosion is NOT uniform

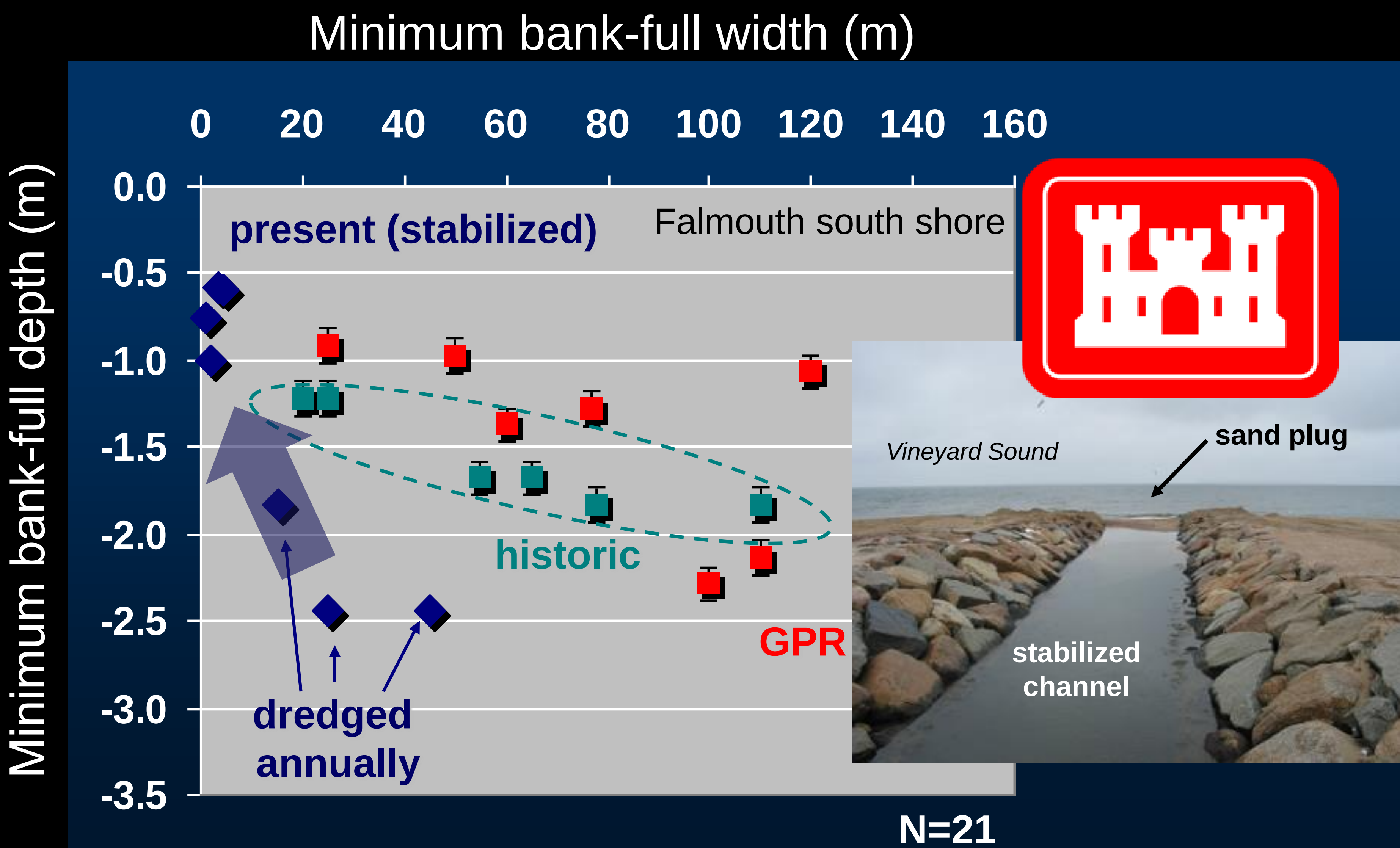


Cape Cod, Massachusetts

Channel Dimensions

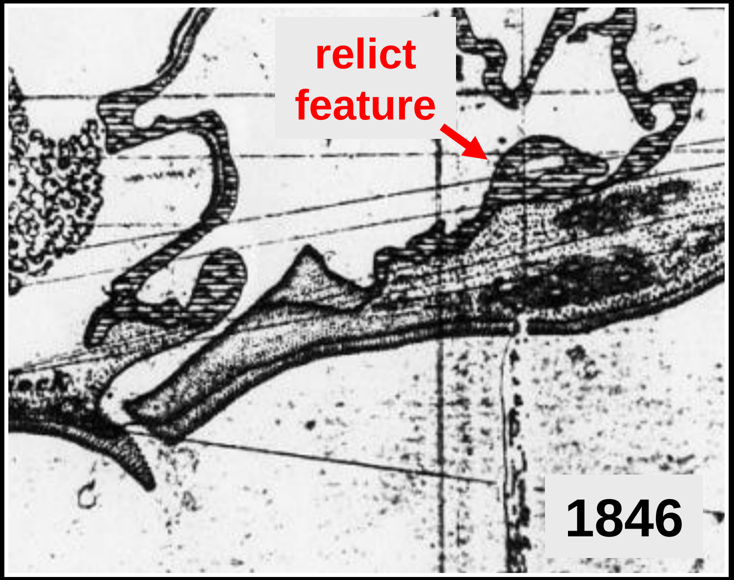


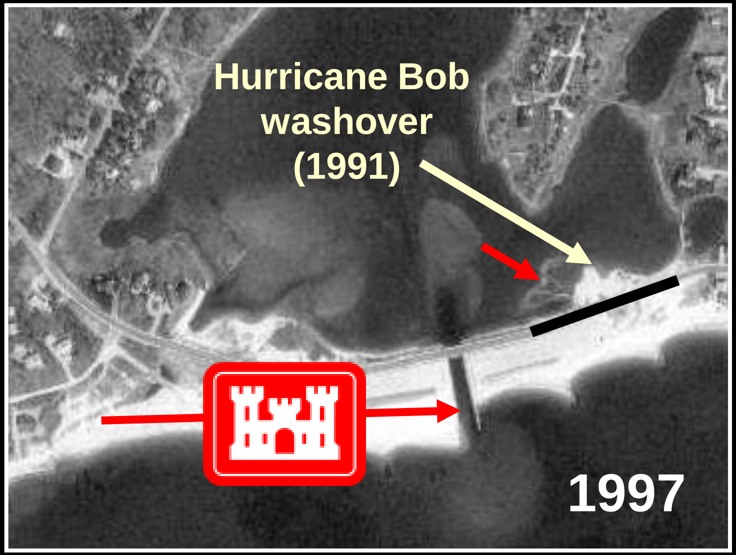
Channel Dimensions

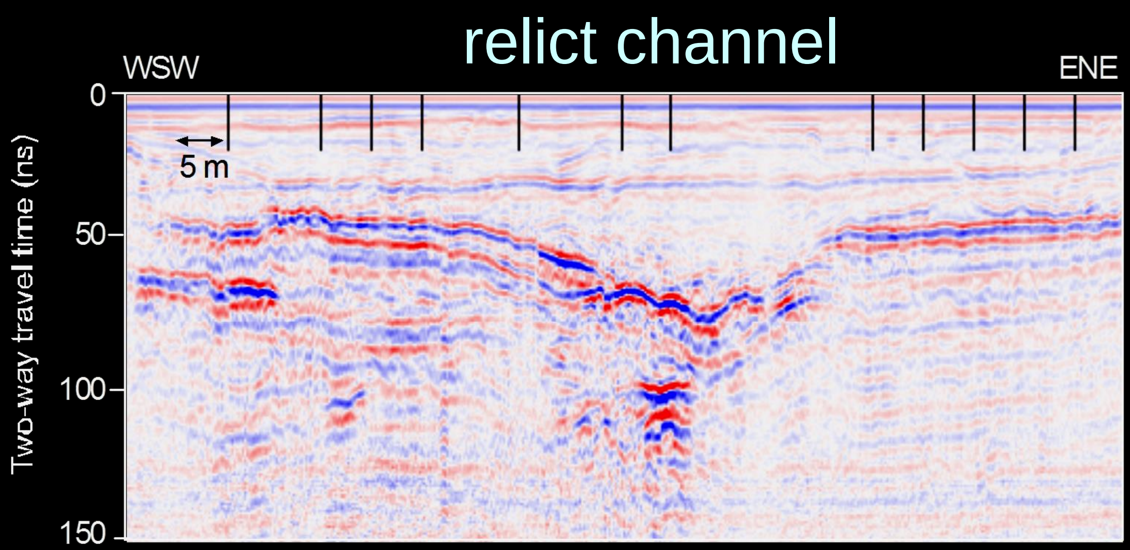


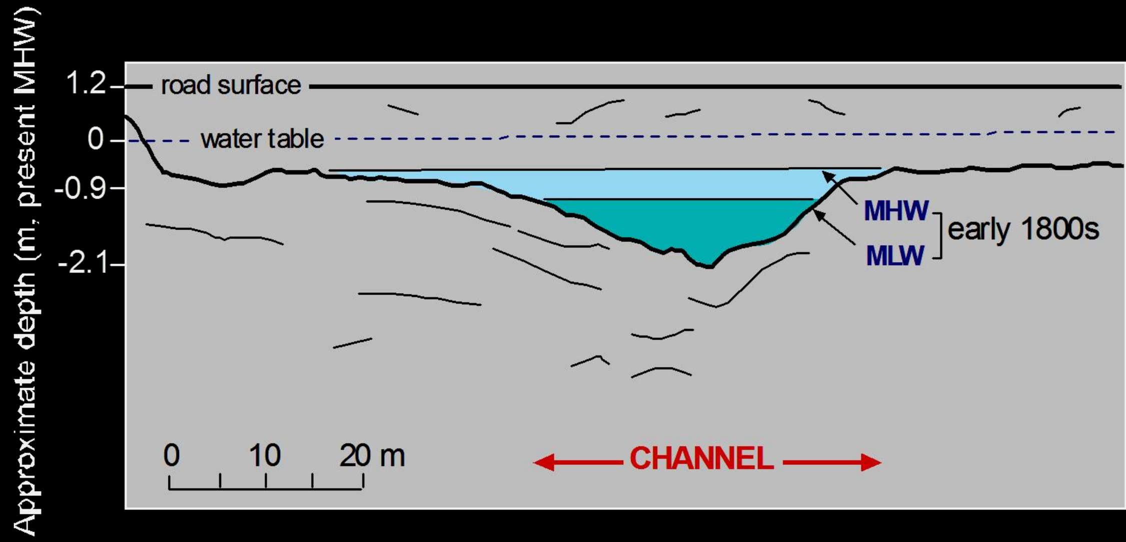
Paleo-channel Research

Menauhant Beach, Cape Cod, MA



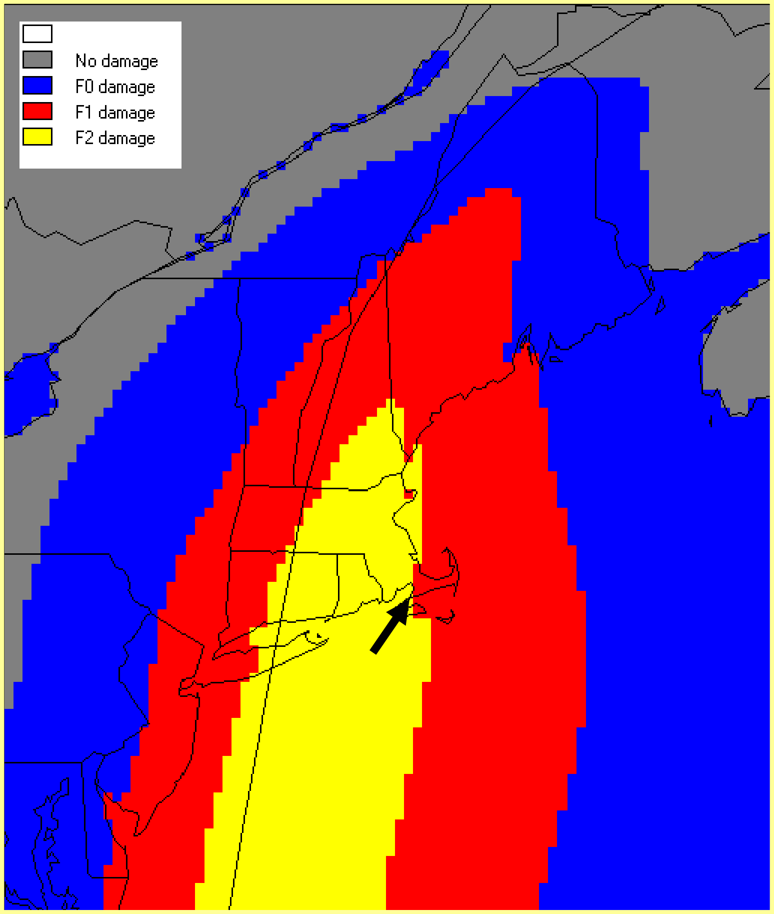






Buynevich (2003)

The Great September Gale of 1815



Reconstructed damage – Fujita Scale
(courtesy E. Boose – Harvard Forest)

Providence, RI – 23 September 1815

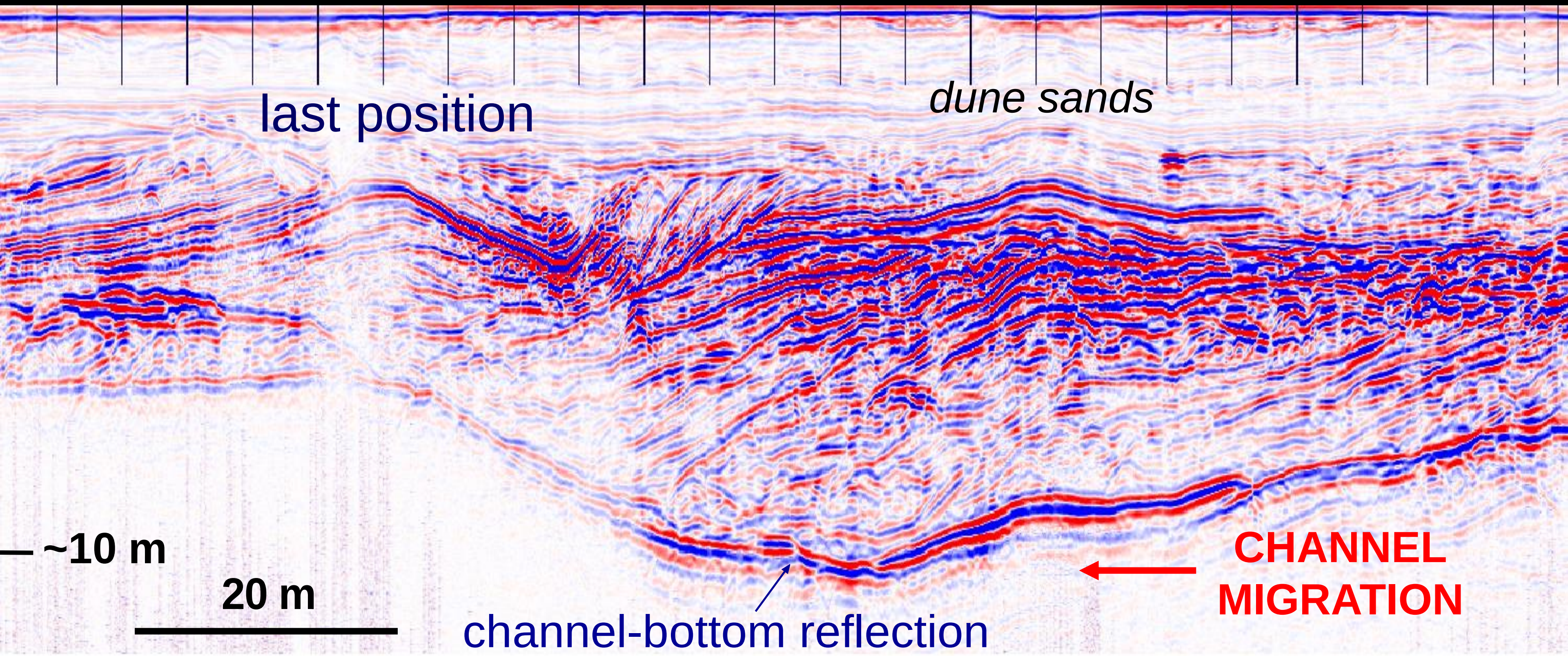
Old Currituck Inlet
(<1585 -1731)

New Currituck Inlet
(1713-1828)
storm breach

S

Old Currituck Inlet Paleo-channel

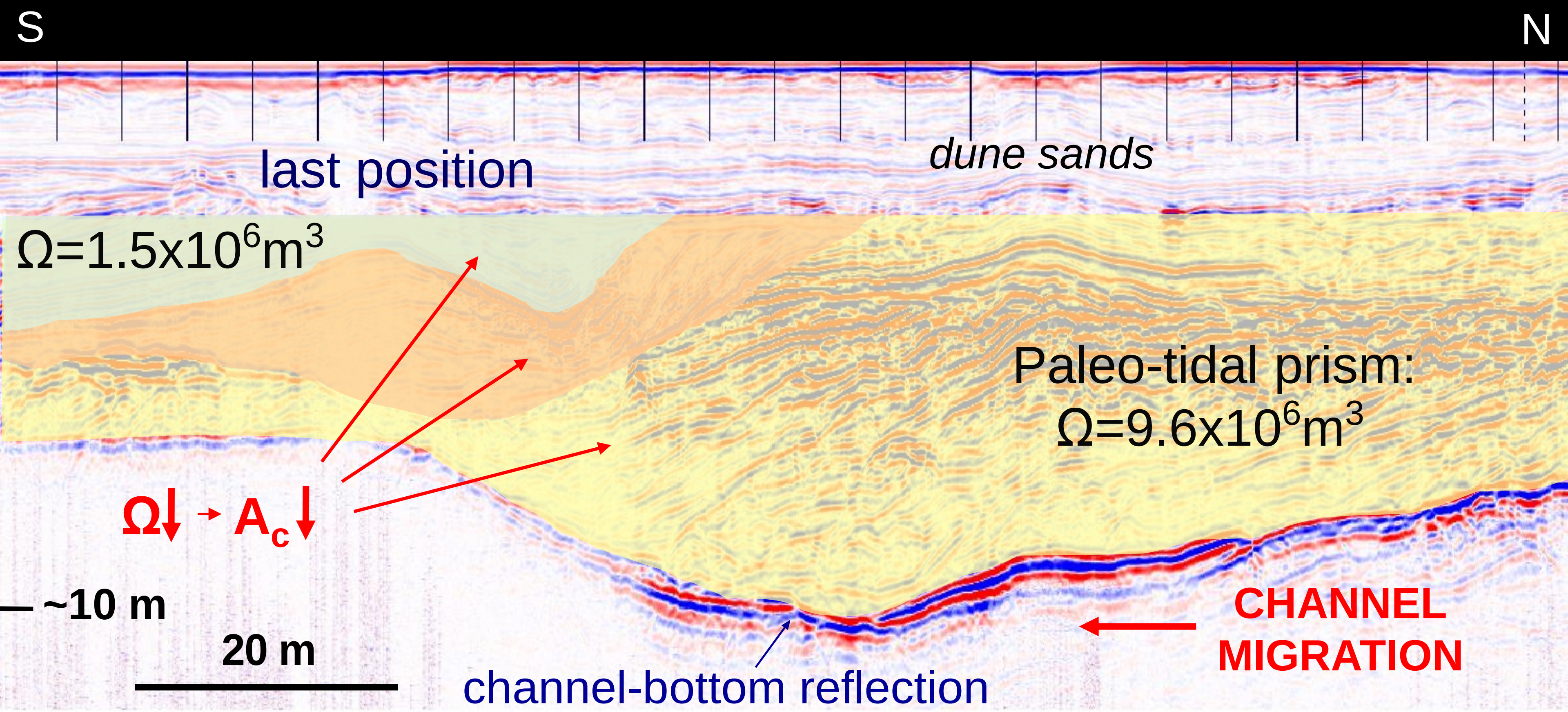
N



Tidal Prism Reconstruction

Oceanic Inlets (Jarrett, 1976)

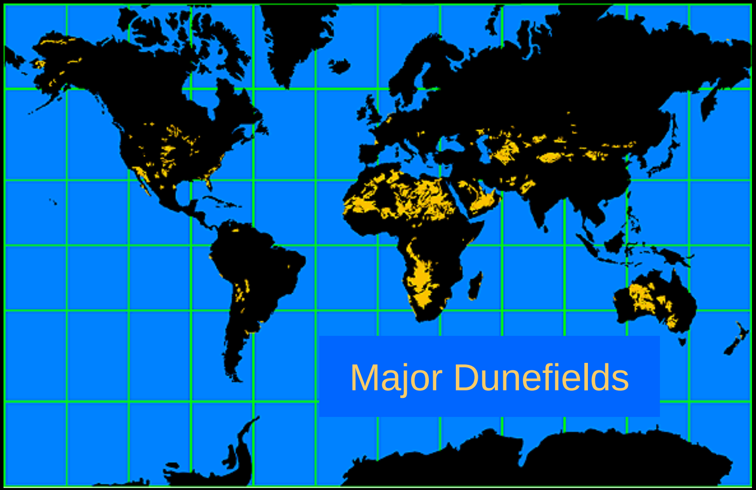
$$A_c = 6.954 \times 10^{-6} \Omega^{1.14}$$



Part 3

Dunes as Archives of Climate Change and Human-Landscape Interaction

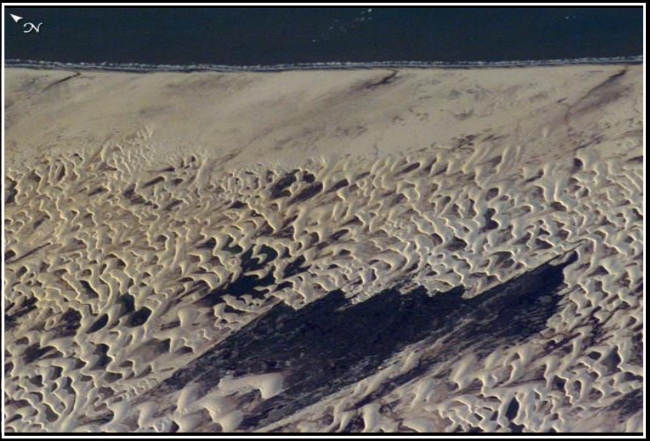
Coastal Dune Research



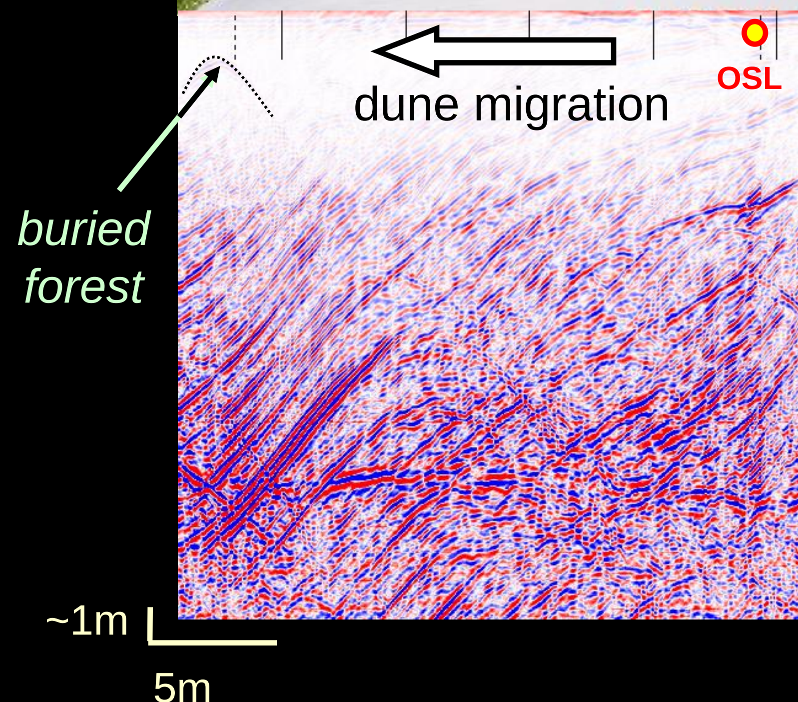
- Activity through Holocene
- Global distribution
- Sensitivity to environmental changes

<u>Record of:</u>

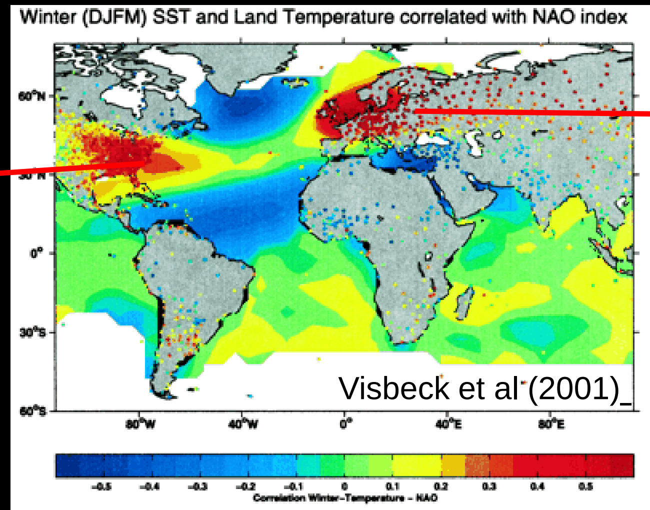
- wind patterns (GCM groundtruth)
- wind velocity
- sea-level change
- sediment supply
- precipitation/water table elevation
- vegetation dynamics
- recent human activities



Reactivated Dunes



Basin-Scale Links

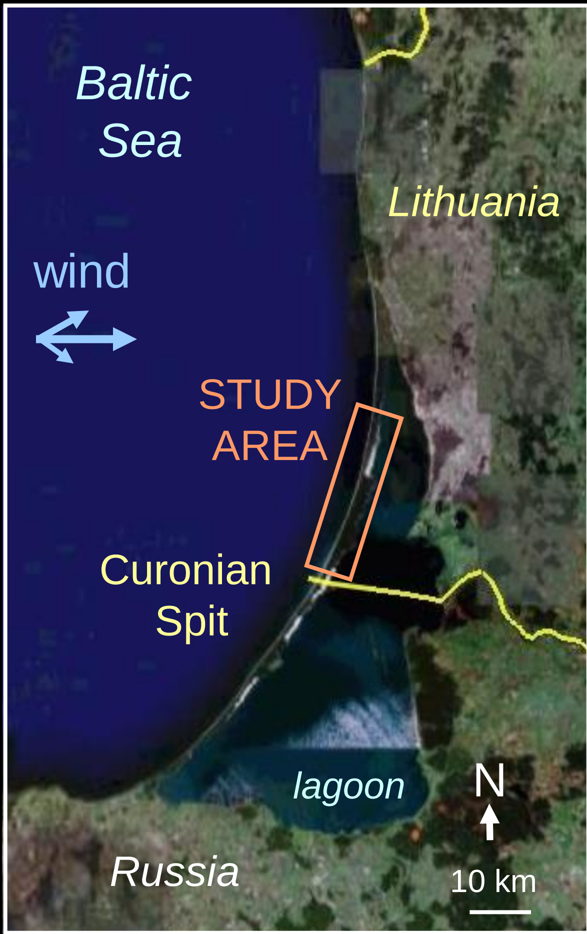


- NAO-sensitive regions
- similar SL history, climate, vegetation
- different history of human activities

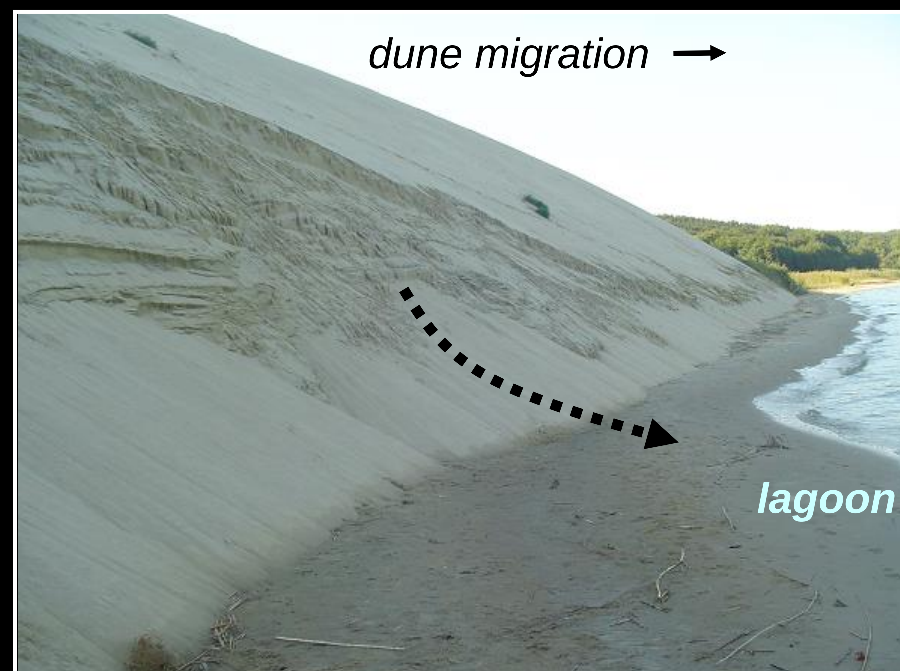
Ongoing research:

- Landscape change (6,000 – present)
- N. Atlantic climate: 10^2-10^3-yr shifts
- Synchroneity of aeolian phases?
- Storminess – trigger of dune activity?
- Natural vs. human-induced changes

Highest coastal dunes in Northern Europe



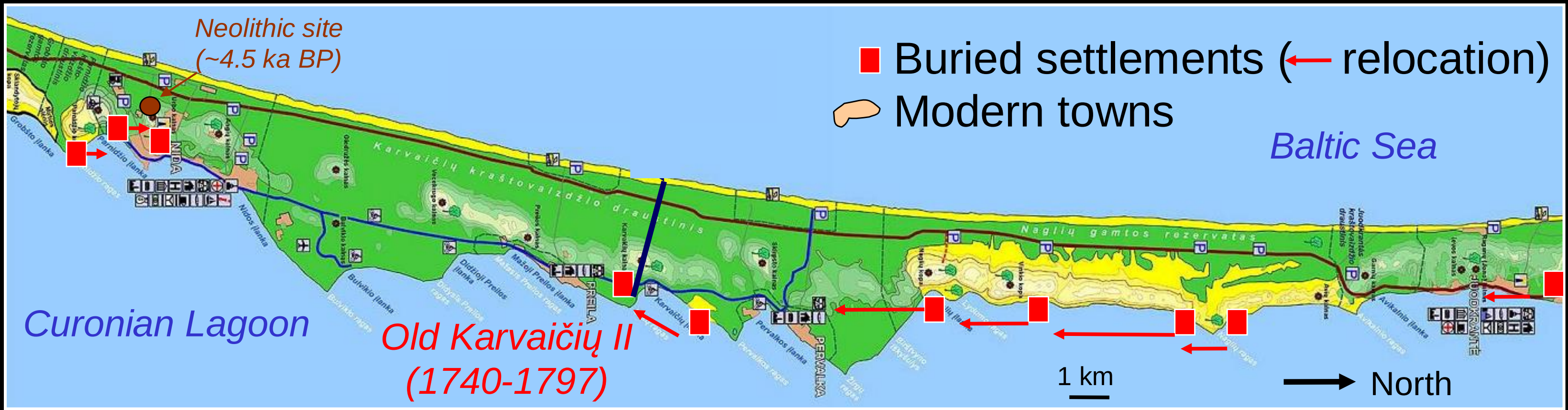
GoogleEarth Image



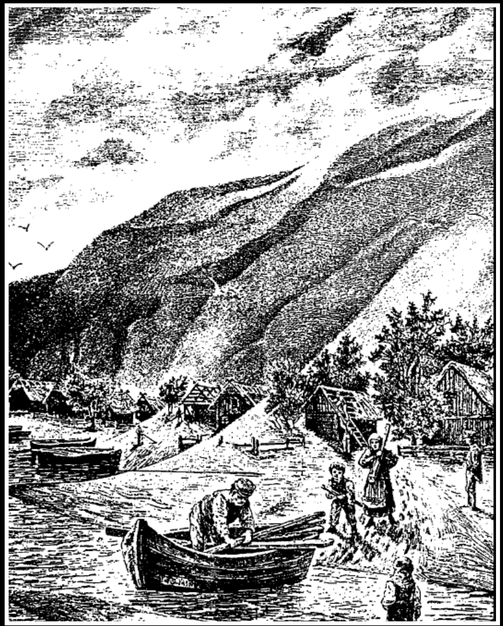
oversteepening
and collapse

Sand Invasion (14-19th centuries)

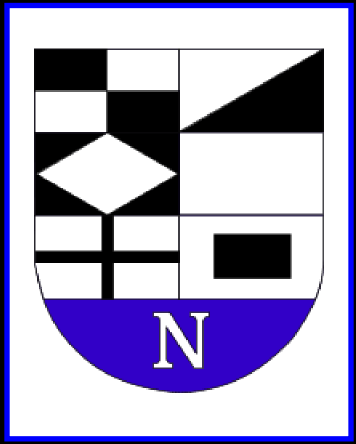
14 settlements buried by migrating dunes



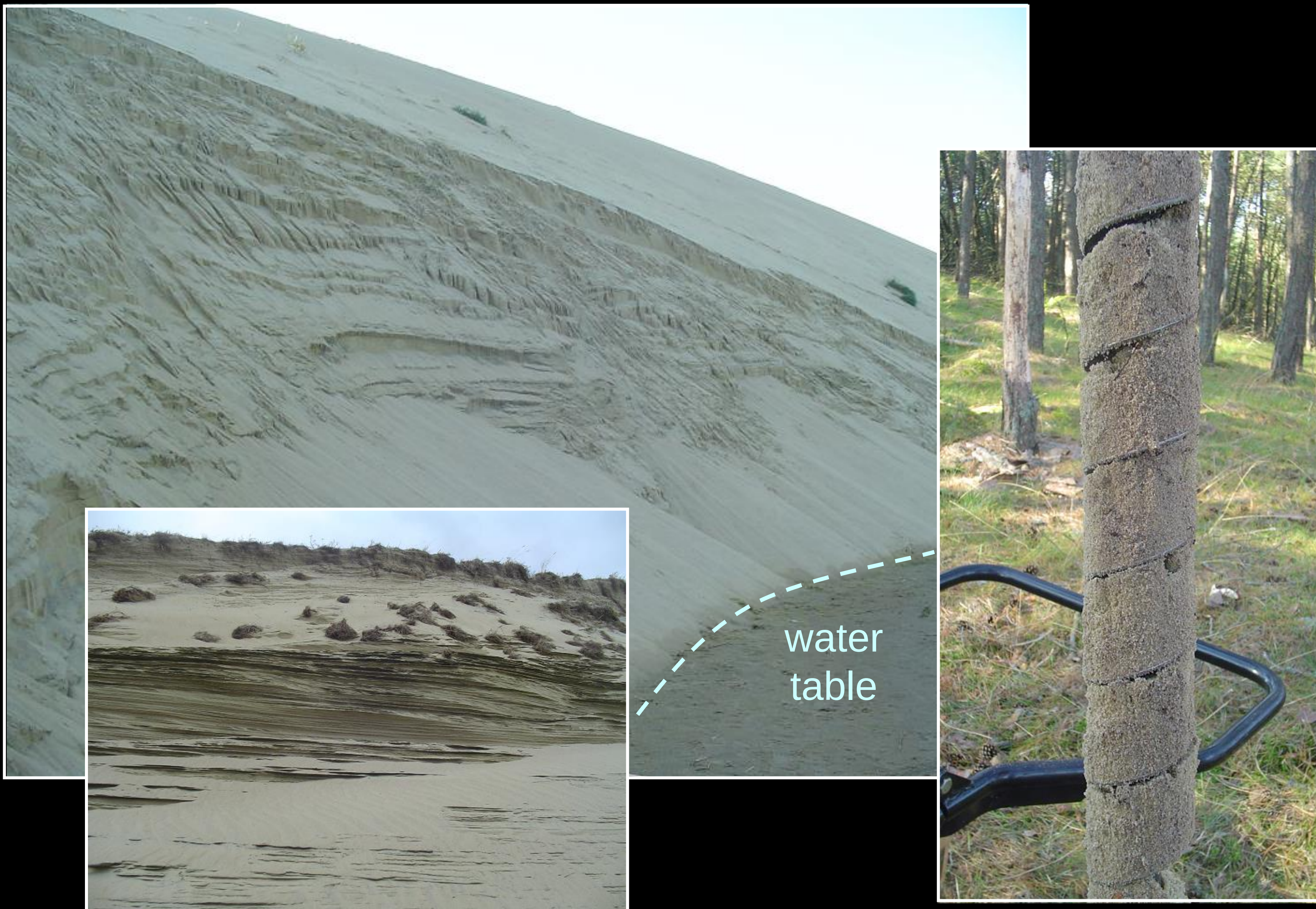
Advancing dunes(16-18th century)



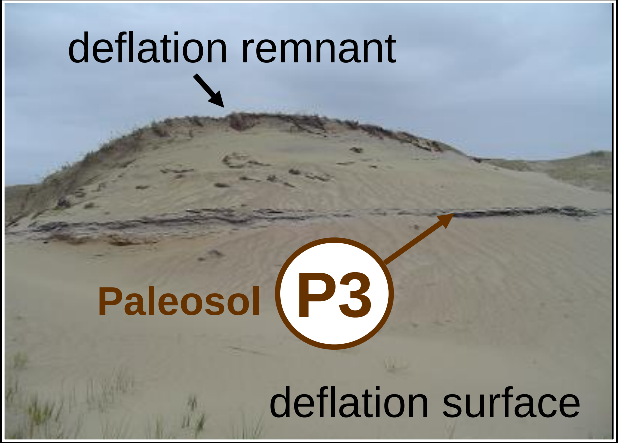
Neringa

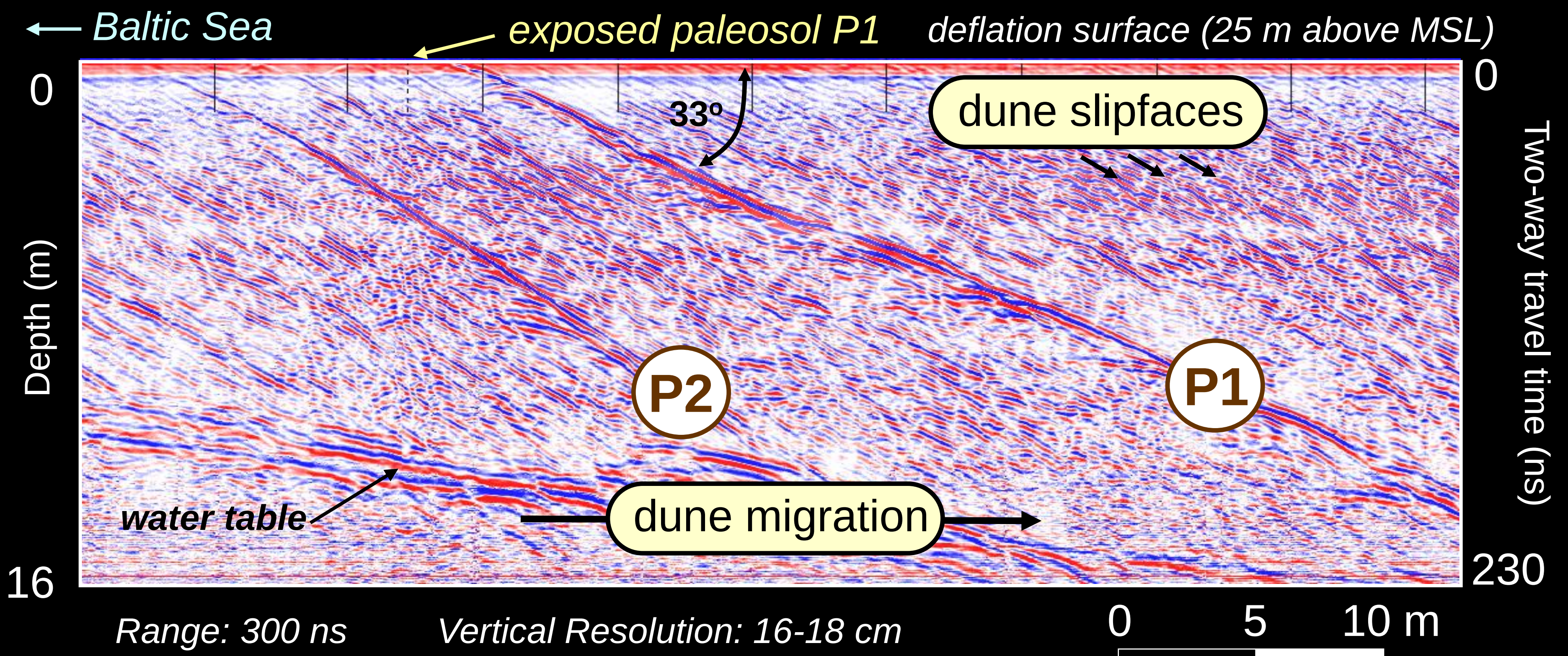


Outcrop/core studies – limited information

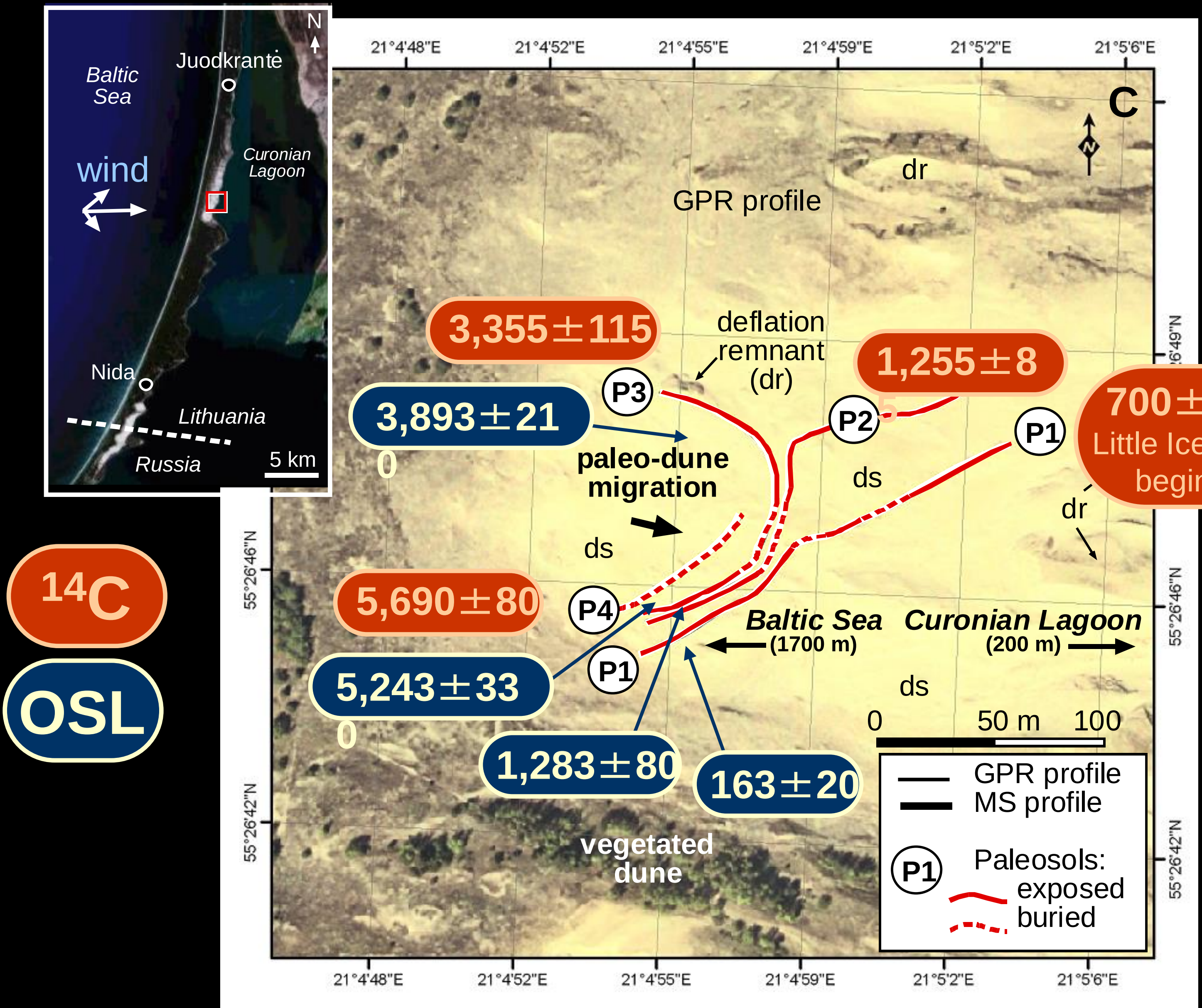


Paleosols – Chronology & Landscape Stability





Radiocarbon and OSL Chronology (cal yBP)

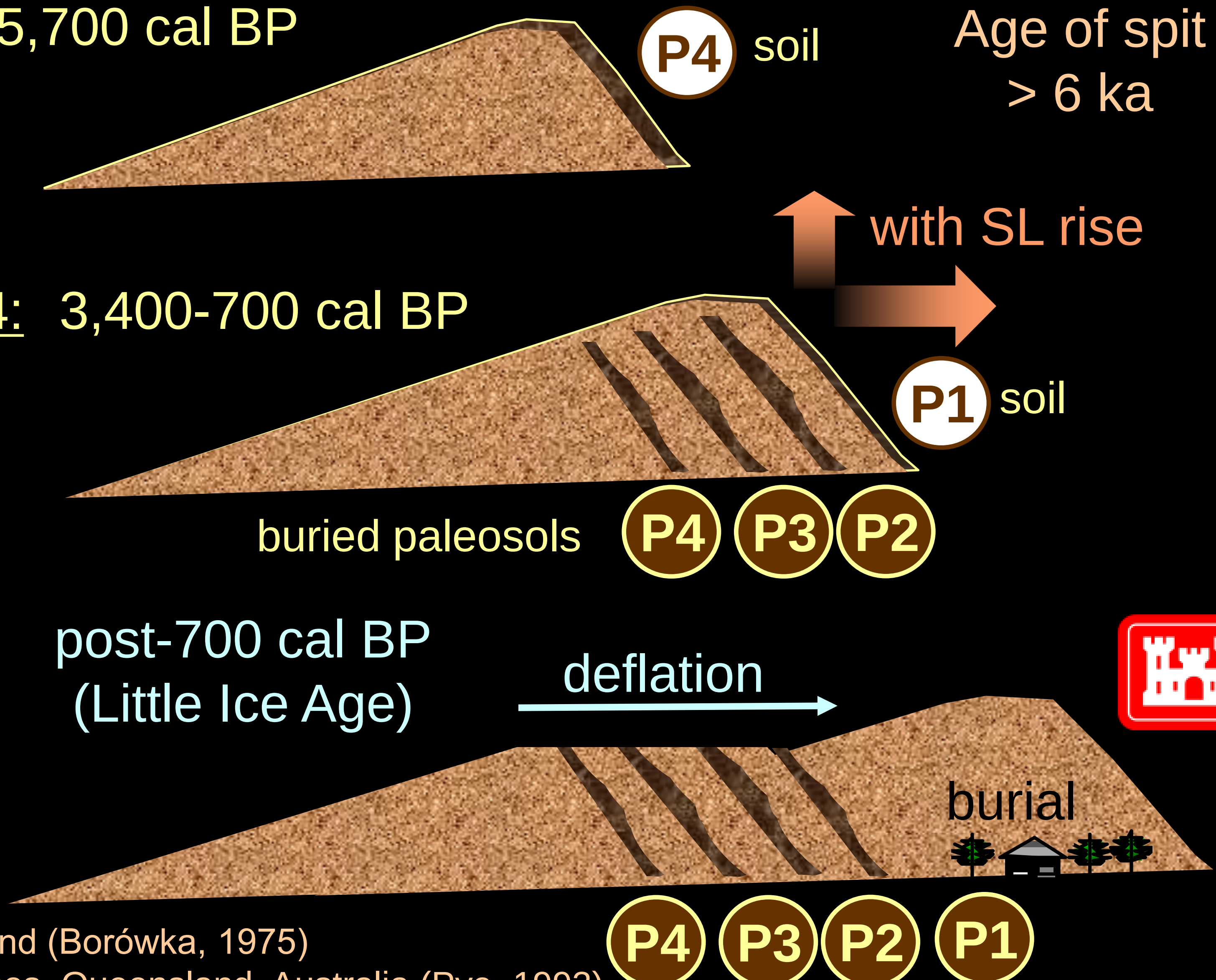


Activity-Stability Phases

Phase 1: ~5,700 cal BP

Phases 2-4: 3,400-700 cal BP

Phase 5: post-700 cal BP (Little Ice Age)

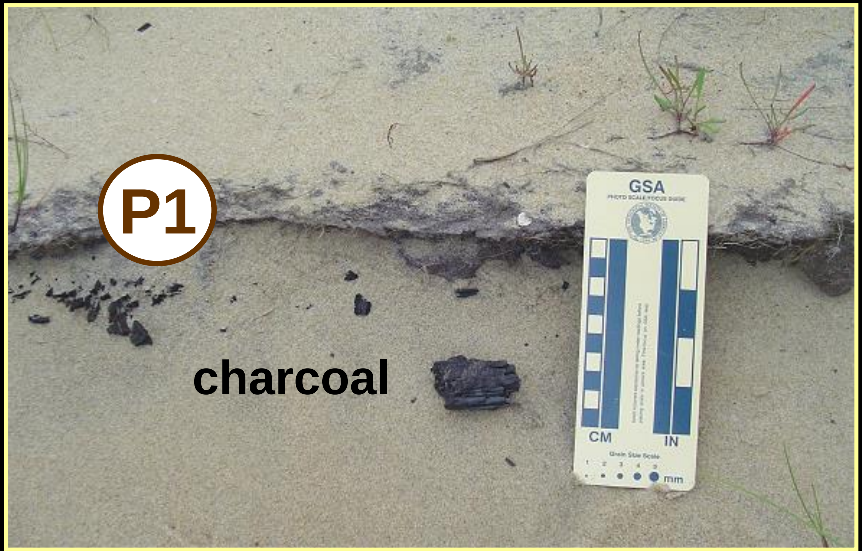


Similar evolution:

Łeba dunes, Poland (Borówka, 1975)

Cape Flattery dunes, Queensland, Australia (Pye, 1993)

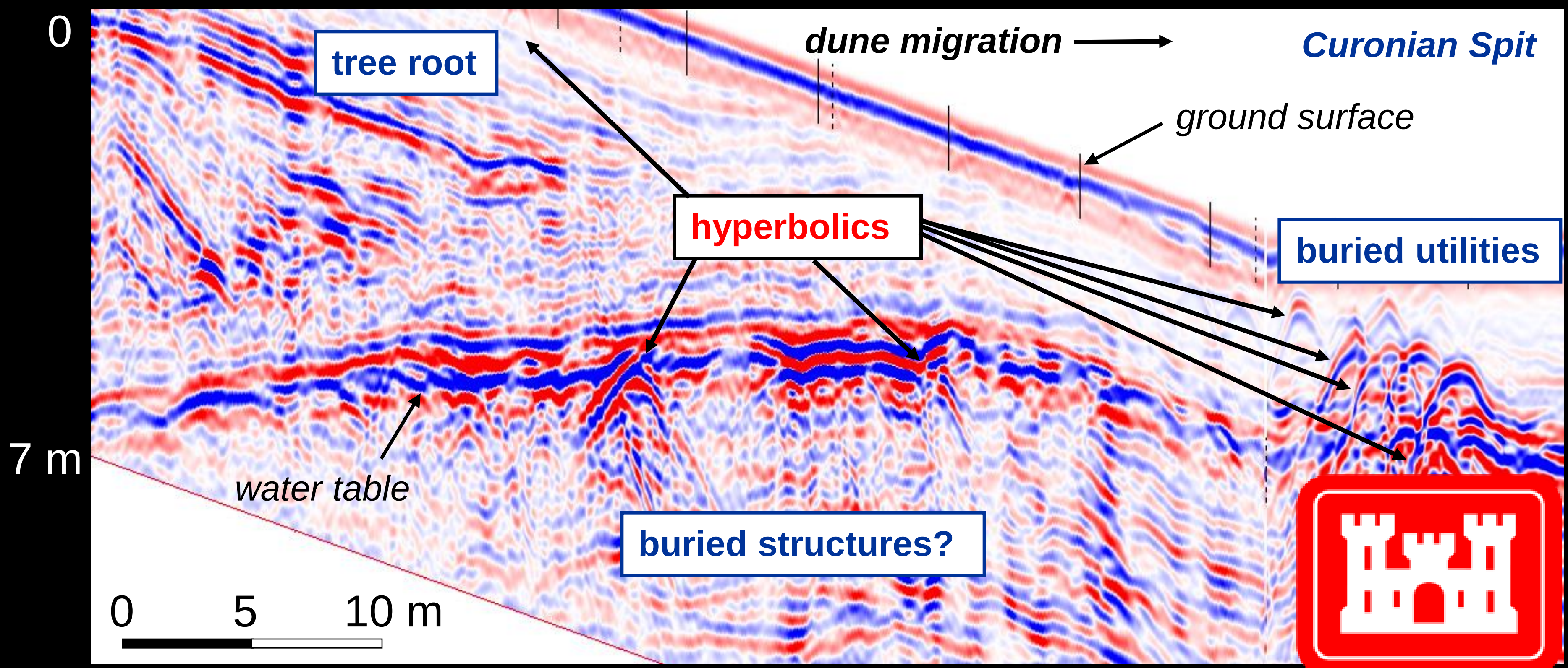
Reactivation of aeolian activity: Triggers



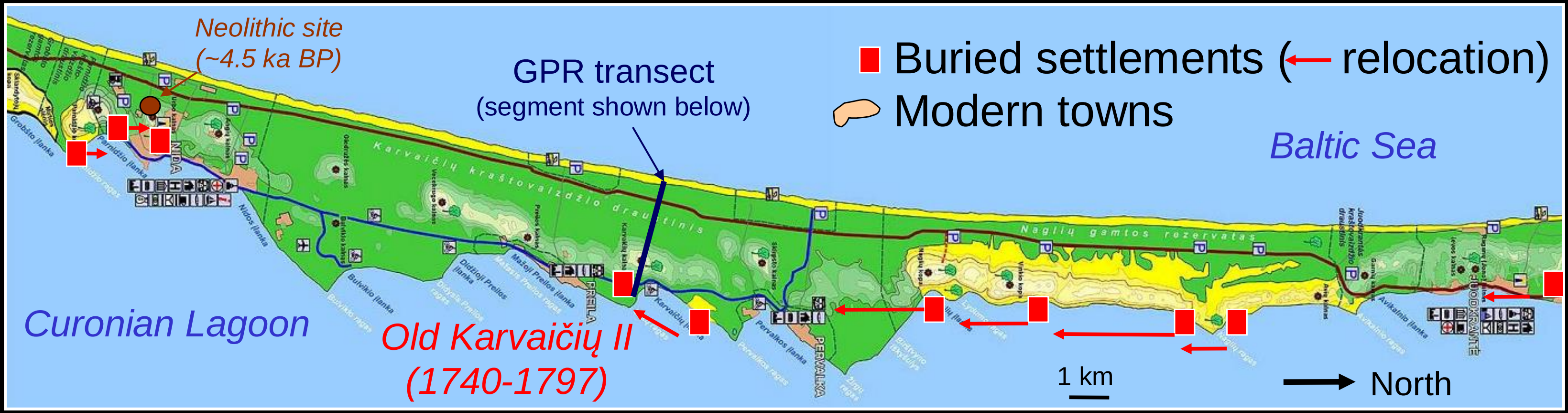
Storms, disease, deforestation

Fires (natural and man-made)

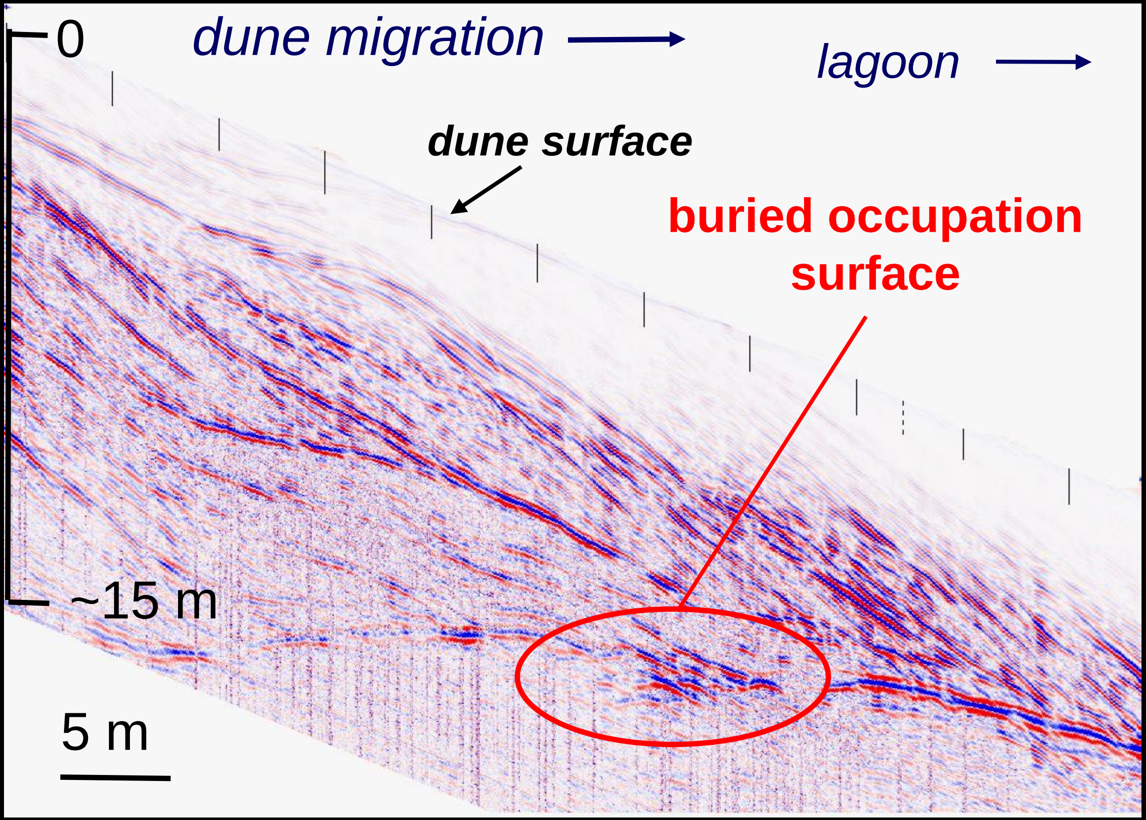
Buried Landscapes and Structures



Human-Landscape Interaction



GPR near Old Karvaičių II (1700-1797)



Summary

Extreme Events – key mechanism of landward sand transfer

- Integrated approach:
  - onshore-offshore geophysics
  - groundtruth: deep cores (5-10 m in sand)
  - multi-dating techniques

- New opportunities to reconstruct and quantify:
  - Beach/shoreface gradients (texture/depth/wave energy)
  - Extent and chronology of erosion (storm impact)
  - Quantitative storm hindcasting based on geological indicators
  - Shoreline retreat rates (vulnerability to SL rise)
  - Channel distribution (onshore-offshore links, stability)
  - Channel dimensions (tidal prism, longshore transport)
  - Dune stratigraphy (regional climate, sediment supply, sand invasion)


Paldies ~ Thank You
Research Support