

# Deep Time in the Upper Mississippi Valley Karst

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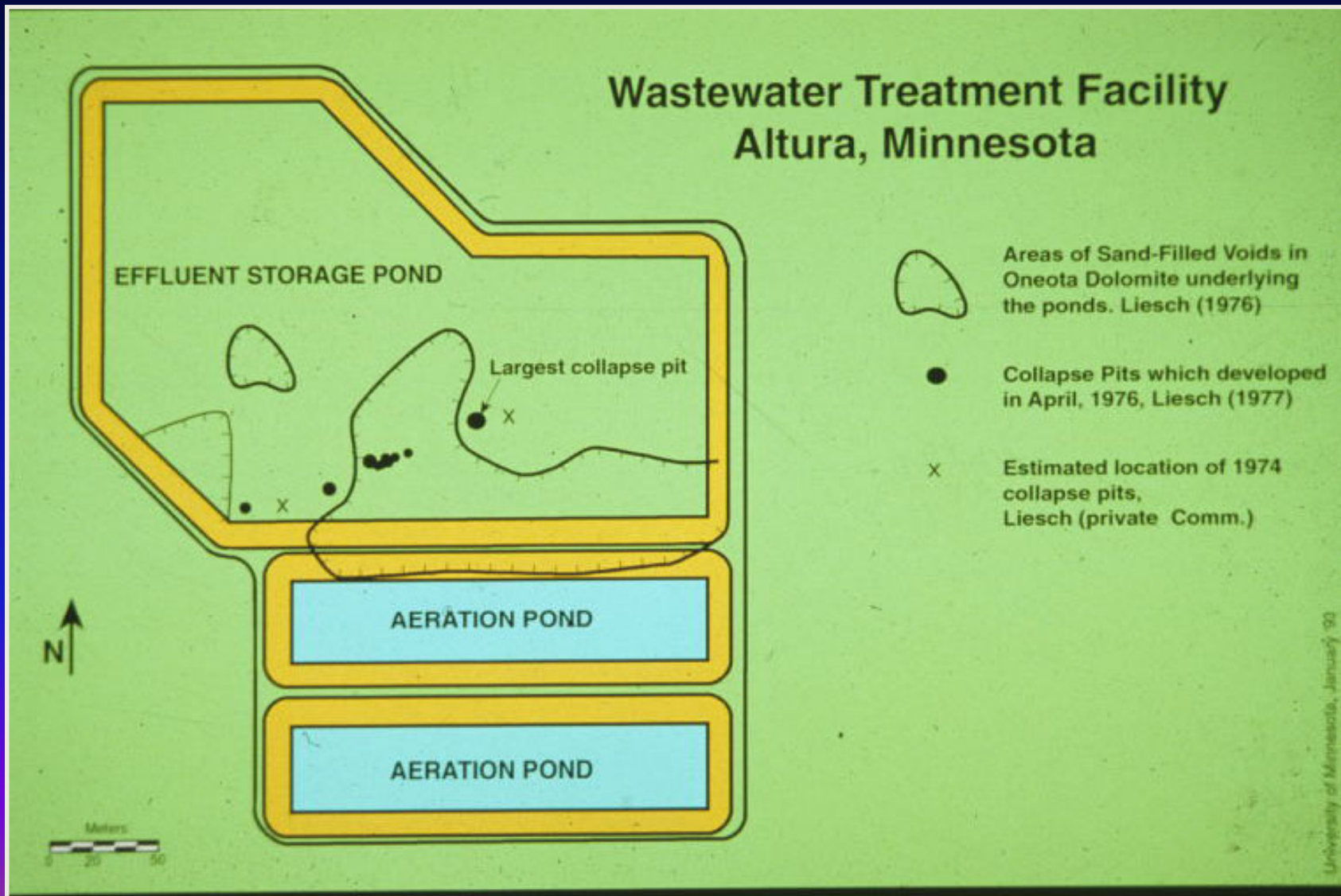
Brooklyn Center, MN



# Altura, MN 1976



# Altura, MN – 1974, 1976

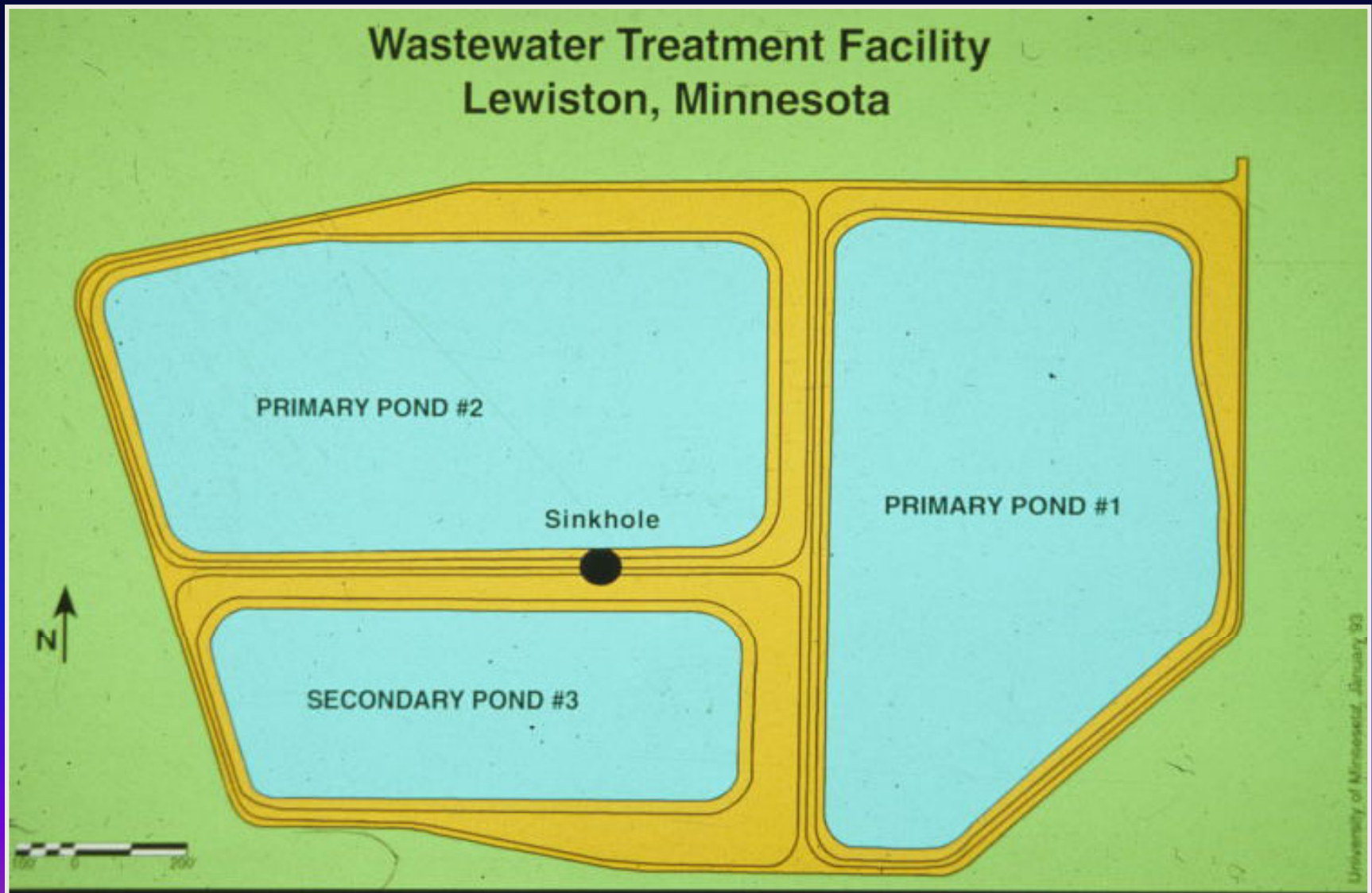




# Lewiston, MN 1991



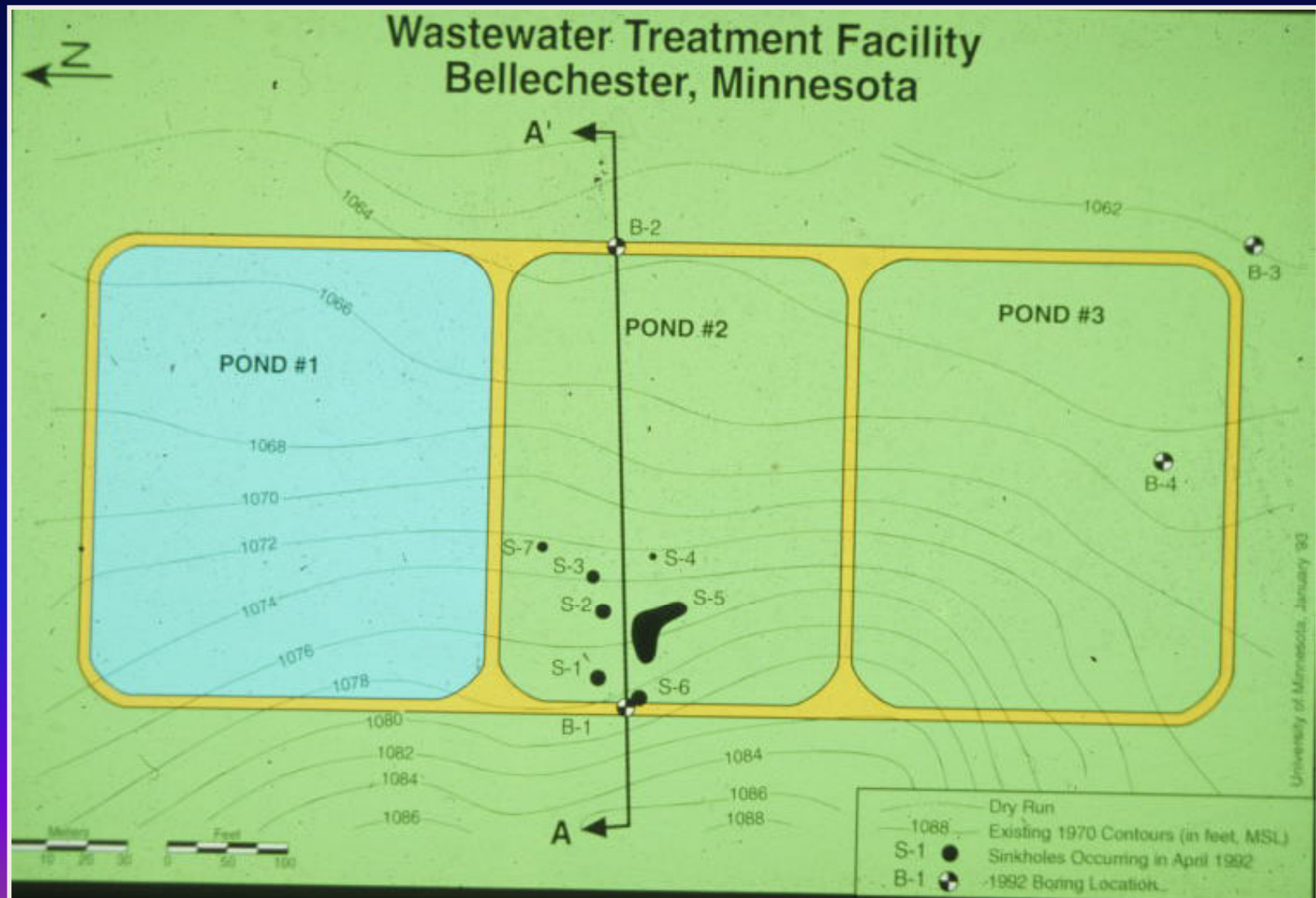
# Lewiston, MN – 1991




# Bellechester, Mn 1992



# Bellechester, MN – 1992

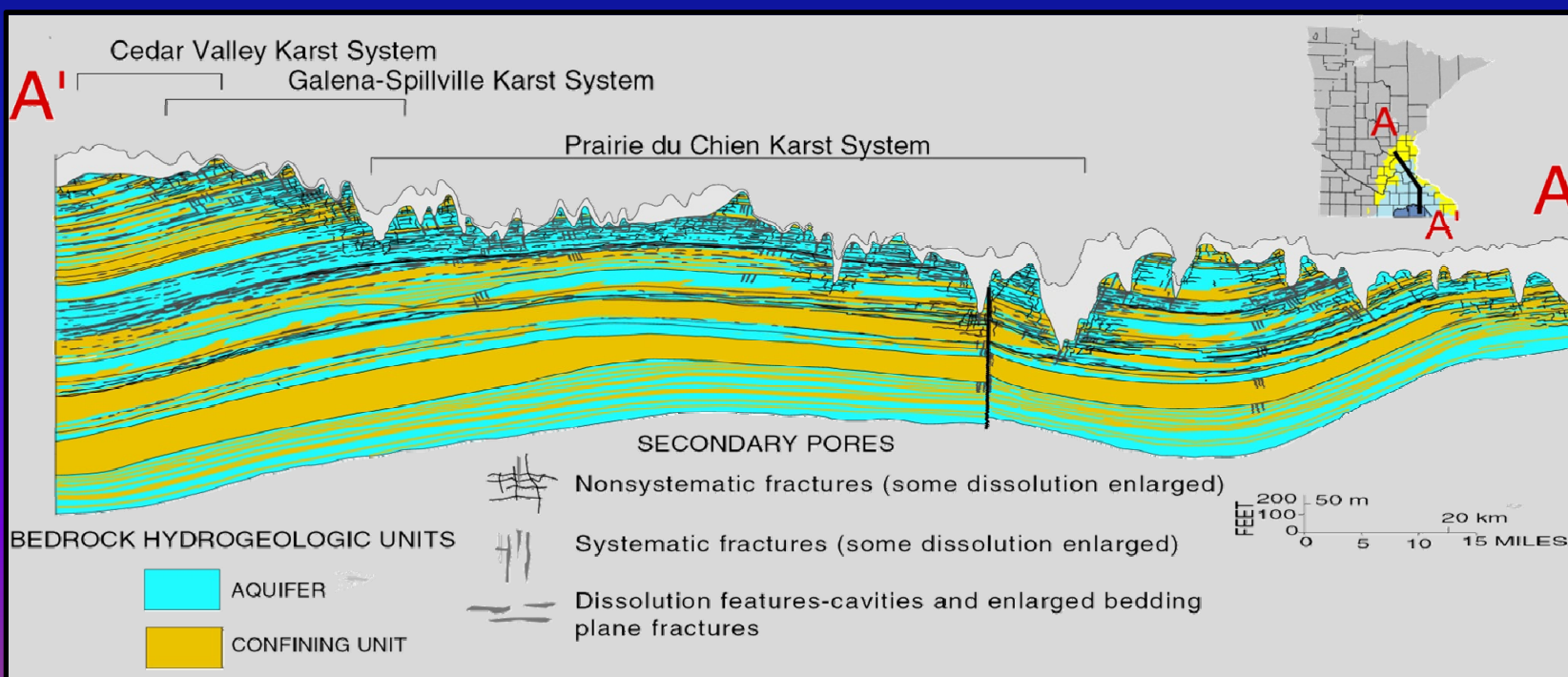
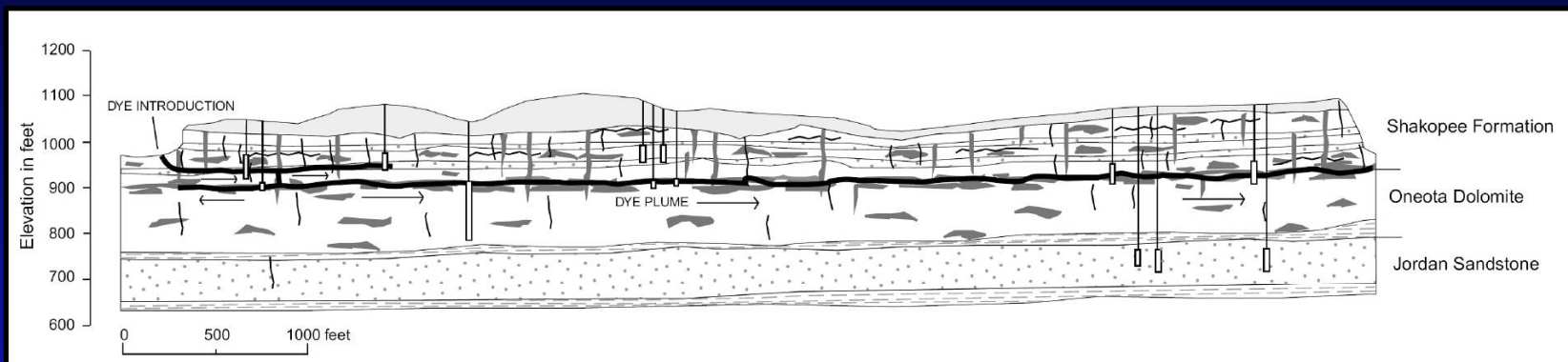


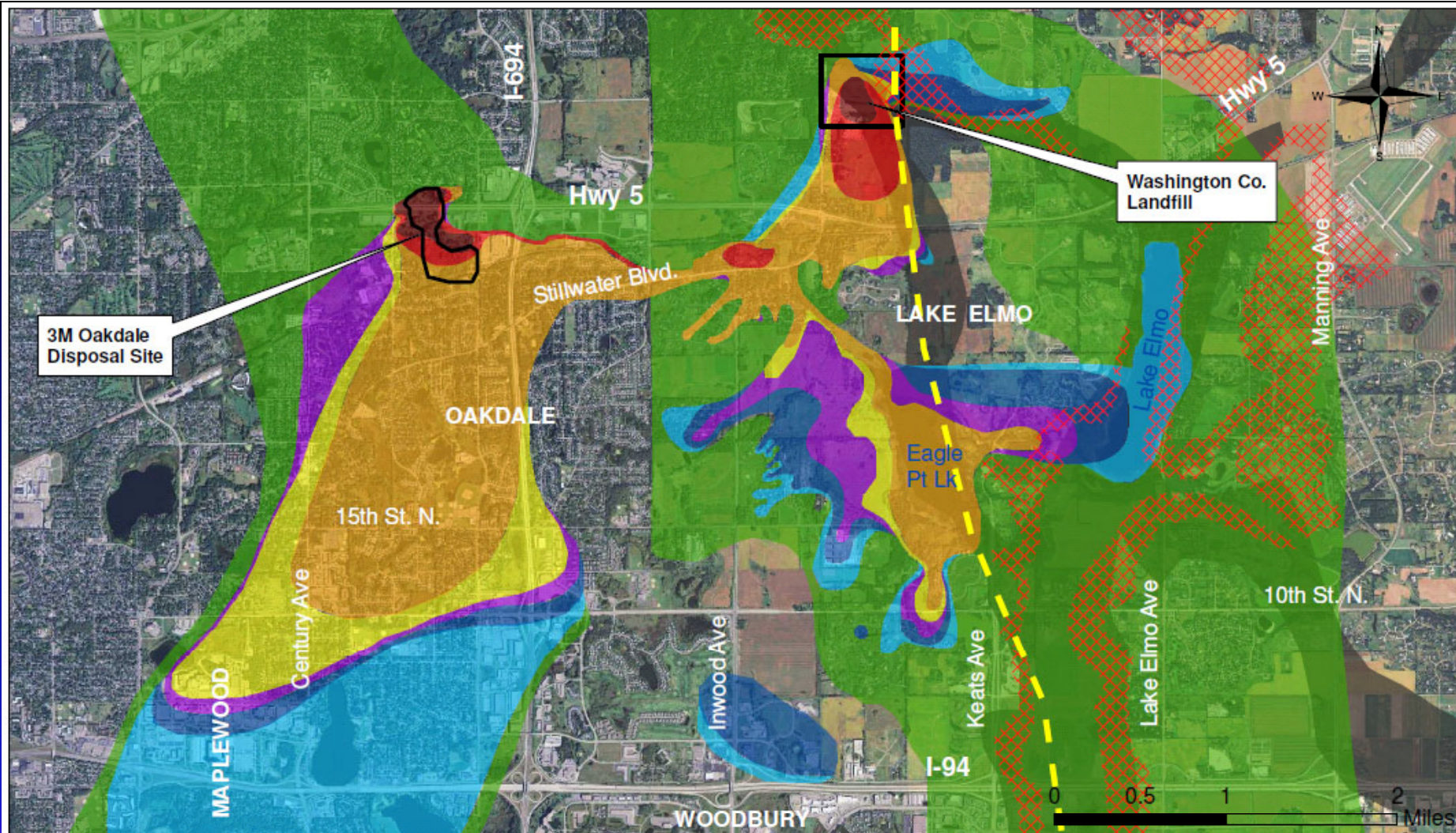
- Were these collapses random, unpredictable, “acts of God”? 
- Or could these collapses have been predicted – and therefore avoidable events which resulted from known or knowable karst hydrogeologic information?
- It is probable that the individuals and organizations who designed, permitted and built these structures did not seriously consider karst processes.

# Observations

- All three of the catastrophic WWTF lagoon collapses occurred at precisely the same stratigraphic interval – the top of the New Richmond Sandstone Member of the Shakopee Formation.
- That stratigraphic interval is now known to be part of a major, regionally correlated, karst high transmissivity zone.

# Prairie du Chien High Transmissivity Zone





## PFOA and Subcropping of High Transmissivity Zone

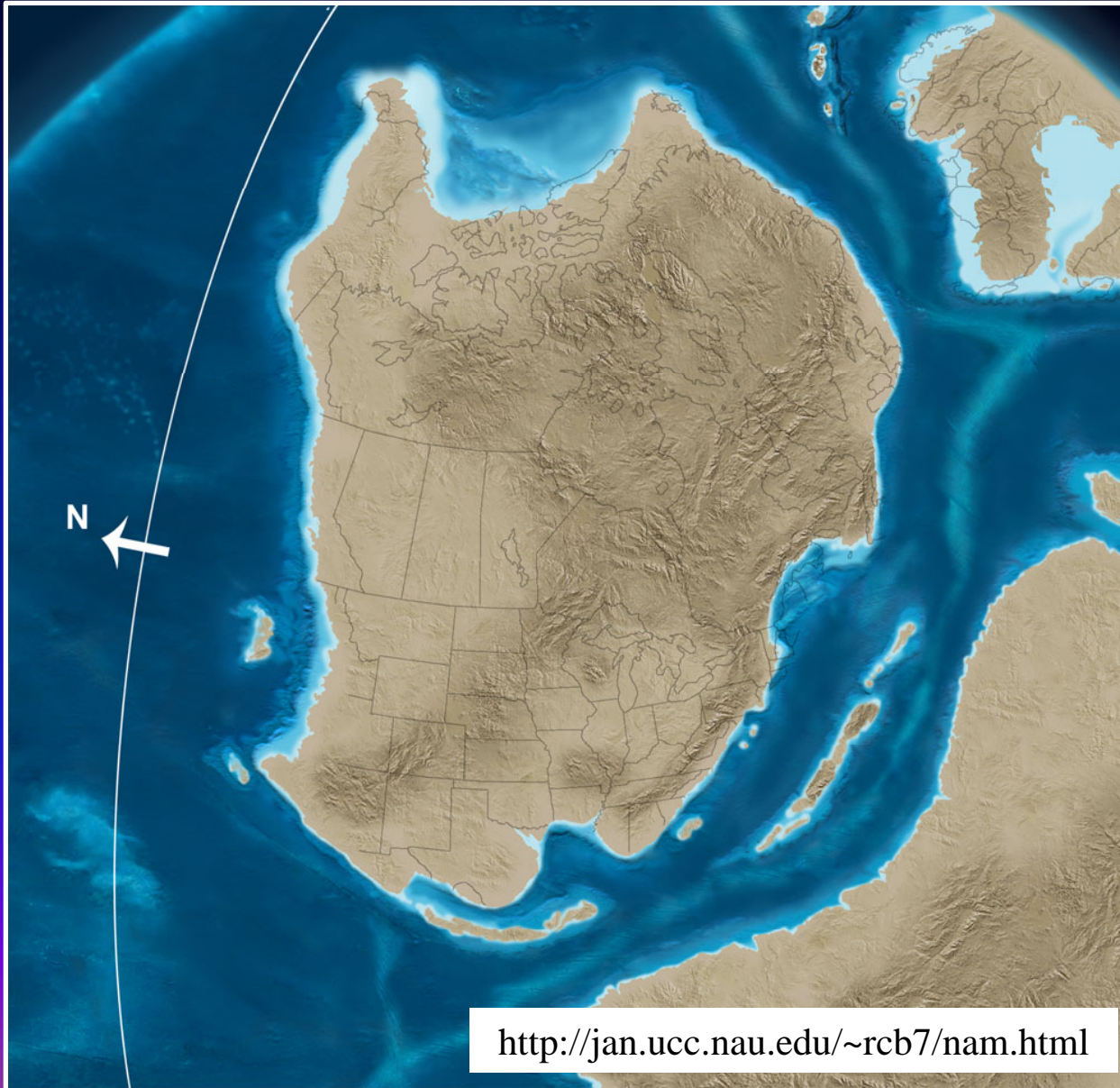
### Legend

PFOA exceeds HRL (>10 ppb)	PFOA 50-75% HRL (0.15 - 0.23 ppb)	Approx. location groundwater divide
PFOA exceeds HRL (1-10 ppb)	PFOA 25-50% HRL (0.075 - 0.15 ppb)	Area of HTZ Subcrop
PFOA exceeds HRL (0.3-0.99 ppb)	PFOA less than 25% HRL (0.01 - 0.075 ppb)	bedrock valley
PFOA 75-100% HRL (0.23 - 0.3) ppb	PFOA not detected	

NOTES: Map combines data from all aquifers, actual concentrations in any area may vary; blank spaces indicate no sample data

MDH - 9/25/2011

# 550 Myr – Precambrian



UMV above sea level

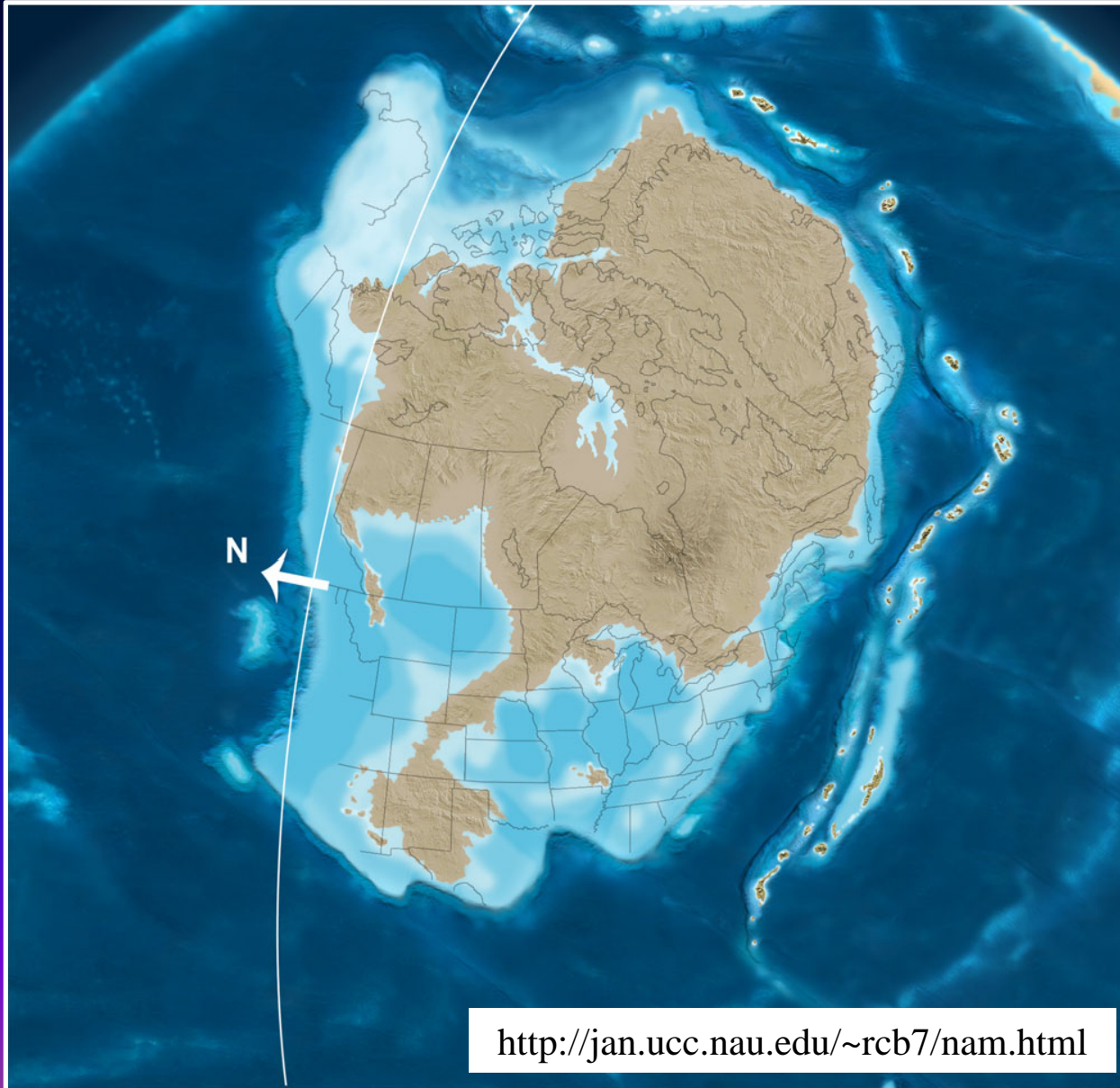
Tropical conditions

South of Equator.

Eroding

<http://jan.ucc.nau.edu/~rcb7/nam.html>

# 500 Myr – Late Cambrian



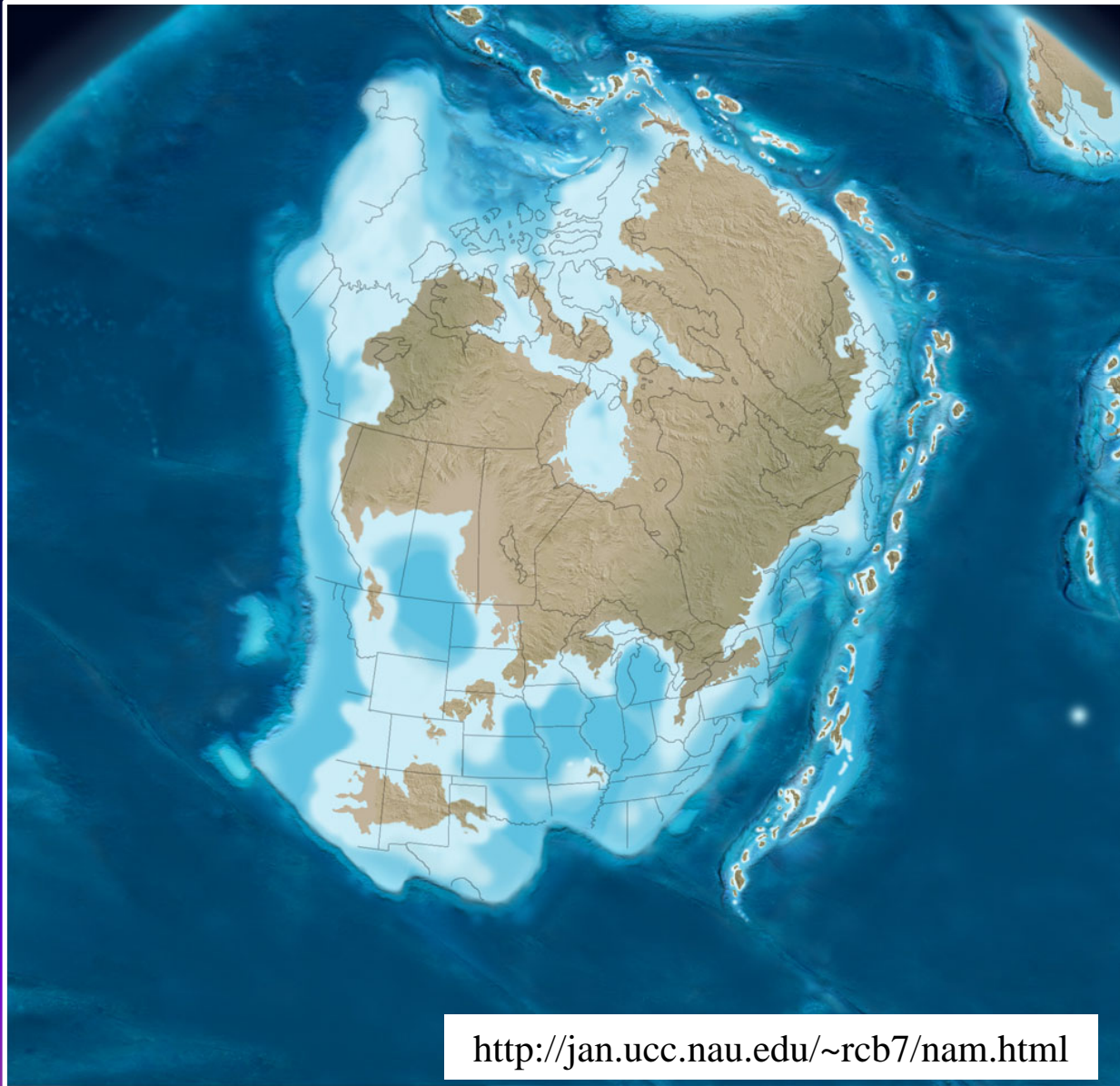
<http://jan.ucc.nau.edu/~rcb7/nam.html>

Warm Tropical Seas  
advancing and  
retreating across  
UMV

South of Equator.

Depositing  
carbonates,  
sandstones and  
shales

# 485 Myr – Early Ordovician



<http://jan.ucc.nau.edu/~rcb7/nam.html>

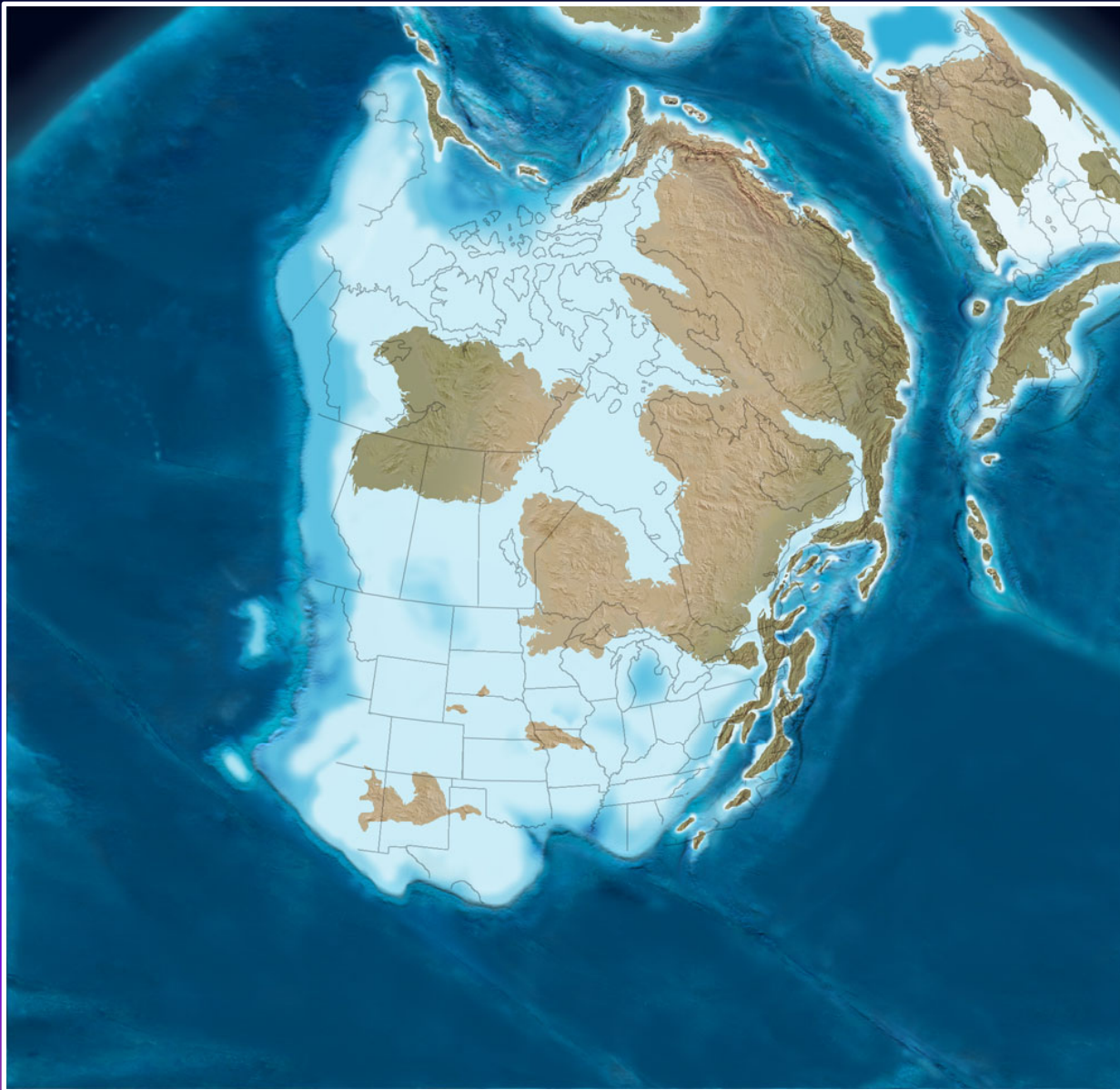
Warm Tropical Seas  
advancing and  
retreating across  
UMV

Equatorial

Depositing  
carbonates, sandstones  
and shales

Sub aerial erosion  
surfaces –  
syndepositional karst

# 450 Myr – late Ordovician



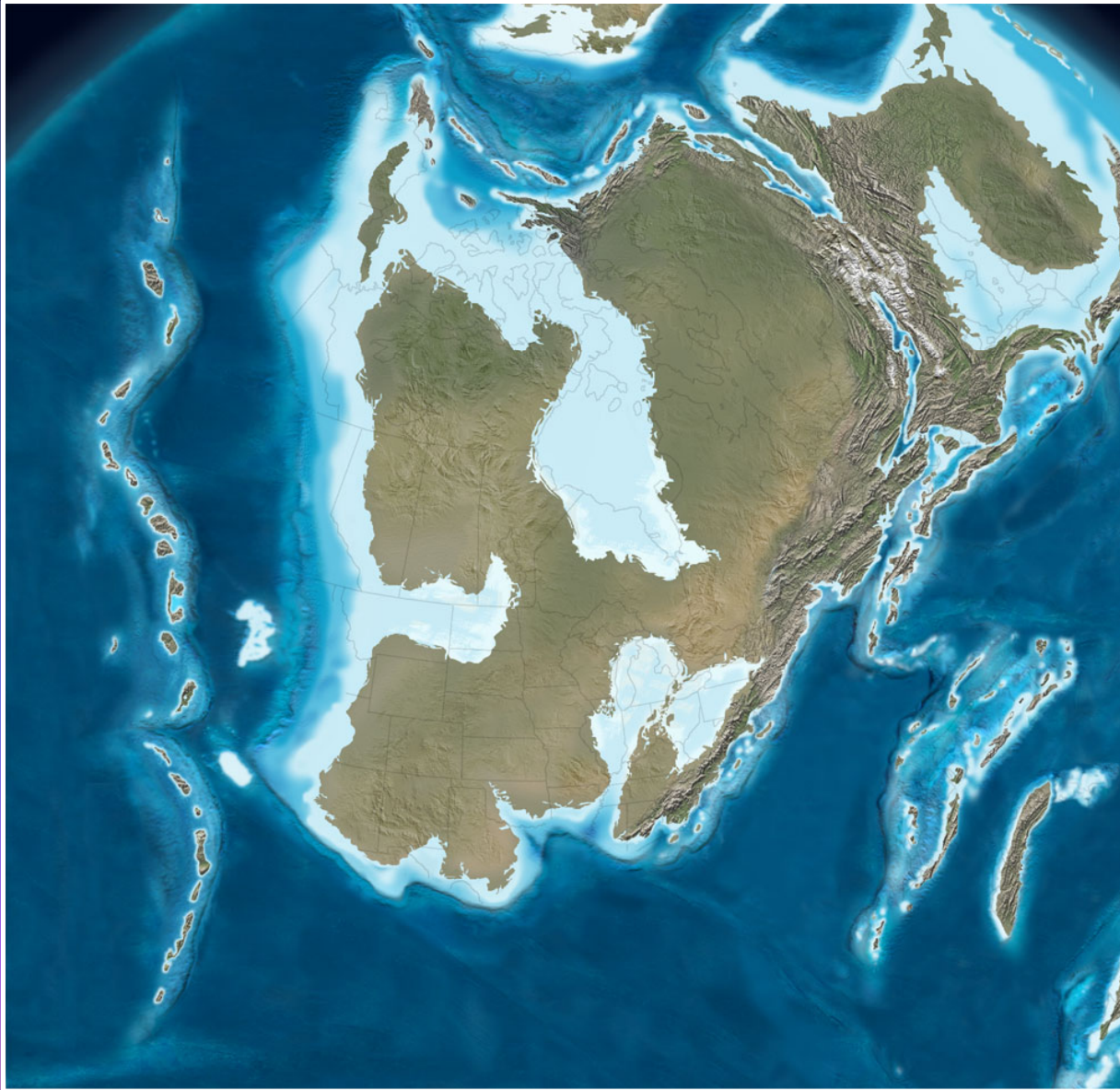
Warm Tropical Seas  
advancing and  
retreating across  
UMV

Equatorial

Depositing  
carbonates, sandstones  
and shales

Sub aerial erosion  
surfaces –  
syndepositional karst

# 4020 Myr – Late Silurian



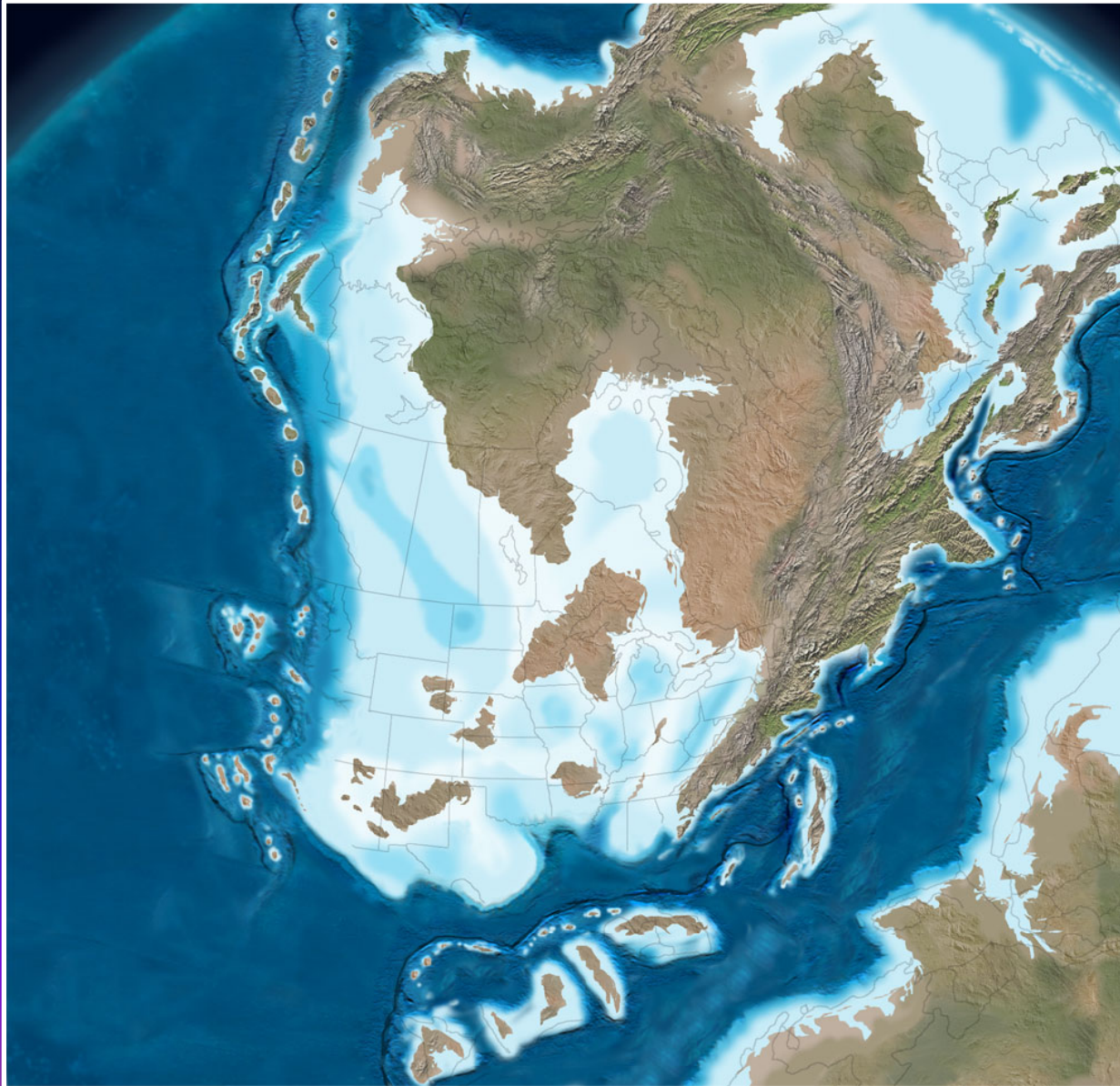
Warm Tropical  
Subaerial conditions  
in UMV

Equatorial

Erosion of carbonates,  
sandstones and shales

Surficial and deep  
karst formation

# 360 Myr – Late Devonian



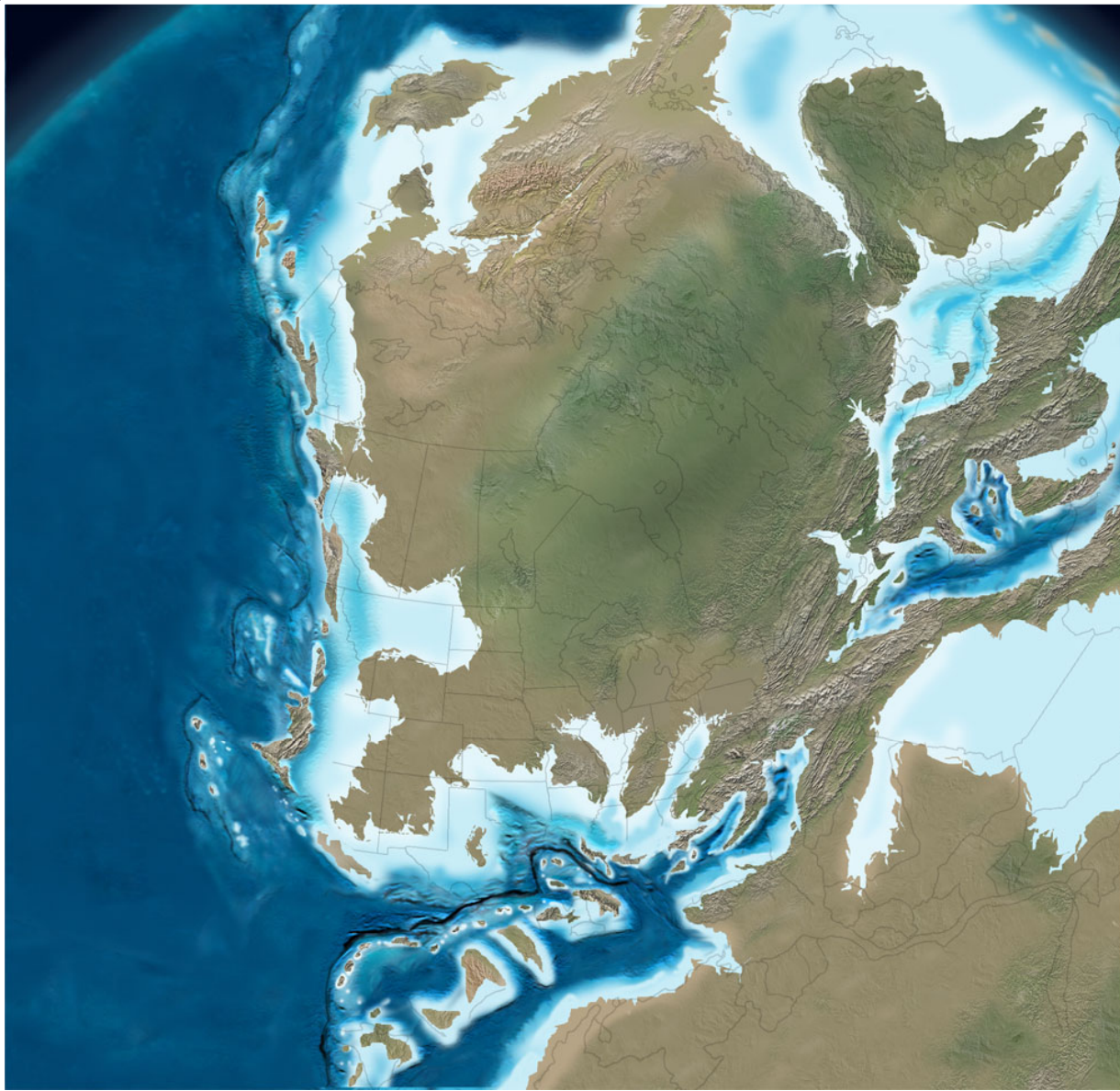
Warm Tropical Seas  
advancing and  
retreating across  
UMV

Equatorial

Depositing  
carbonates, sandstones  
and shales

Sub aerial erosion  
surfaces –  
syndepositional karst

# 325 Myr – Late Mississippian



Warm Tropical Seas  
retreat for the last time  
from UMR

Equatorial

Sub aerial erosion  
next 300 Myr

Formation of shallow  
and deep karst  
features

# 275 Myr – Middle Permian



Alleghenian Orogeny mobilizes heavy metal rich brines which migrate north and deposit the MV Pb/Zn deposits in the UMV at 270 Myr

Galena, sphalerite and other sulfides deposited in pre-existing caves, solutionally enlarged joints and sinkholes.

# 75 Myr – Late Cretaceous



Cretaceous Sea covers  
central plains west of  
UMV karst

Sub aerial erosion

Drainage west to  
Cretaceous Sea way

Formation of shallow  
and deep karst  
features

# 2.5 Myr to ~12 kyr – Pleistocene



Continental glaciers repeatedly cover all but the true Driftless Area of SW Wisc.

Drainages radically rearranged.

“Glacially Deranged Karst”

Much of the epikarst scraped off

Many subsurface features temporarily clogged with sediment

# Conclusions I

- Karst processes began during the original deposition of the sediments in Cambrian/Ordovician time – 400-500 Myr ago.
- Intra-depositional unconformities record periods of sub-aerial weathering and karst activity.
- Above sea level with surface and ground water circulation for past 300+ Myr.
- 270 Myr lead & zinc ores deposited in well formed caves and solution enlarged joints.

# Conclusions II

- Radical rearrangement of ground water flow paths when the Mississippi River drainage established.
- Pleistocene glacial cycles.
  - Removal of much of the epikarst
  - Major sea level fluctuations – changing base level
  - Back filling with sediments of many karst conduits.
- Holocene/Anthropocene effects.