Changes in Fluvial Erosion with Stream Chemistry of Cohesive Streambank Soils

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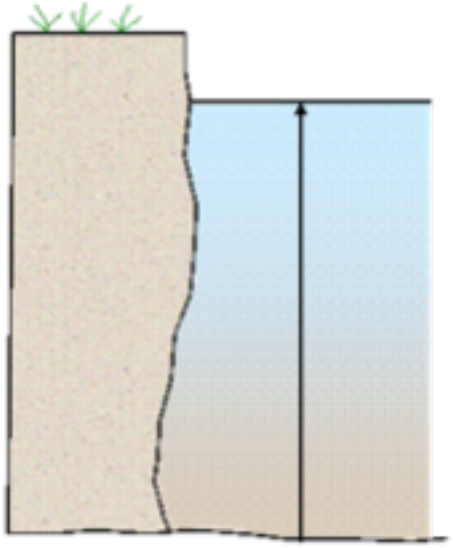
How does bank retreat (typically) occur?

Subaerial Processes/ Erosion

Freeze-thaw and wet-dry cycling weaken soil

Fluvial Entrainment



Soil entrained during high flows

Bank Failure

Mass failure from slope instability

Why is bank retreat important?

1. Required for channel meandering
2. Critical part of evolution of incised channels
3. Net bank sediment yields constitute 70% of Piedmont watershed sediment yields in Chesapeake Bay watershed*

Chesapeake Bay, USA (NASA)

* Donovan M, A Miller, M Baker, A Gellis. 2015. Sediment contributions from floodplains and legacy sediments to Piedmont streams of Baltimore County, Maryland. Geomorphology 235: 88-105.

Eastern US streams have a history of human impacts

1600-early 1900s – Hillslopes denuded

These sediments are now stored in the floodplains of headwater streams

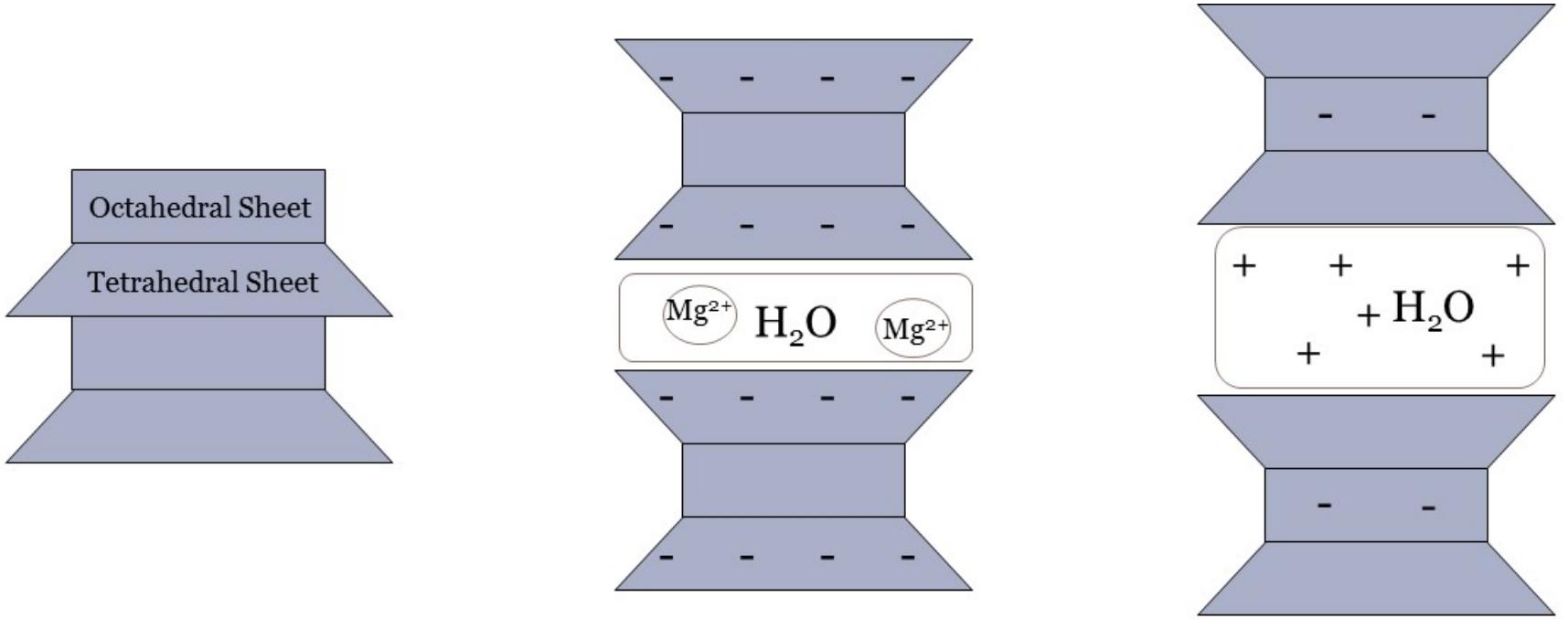
In eastern US streams, channel incision is frequently limited by bedrock and/or culverts

…so channel widening is common

The goal of this study was to quantify changes in fluvial erosion rates with changes in stream chemistry

- Temperature
- pH
- Deicing salt

Cohesive soils are dominated by inter-particle attraction



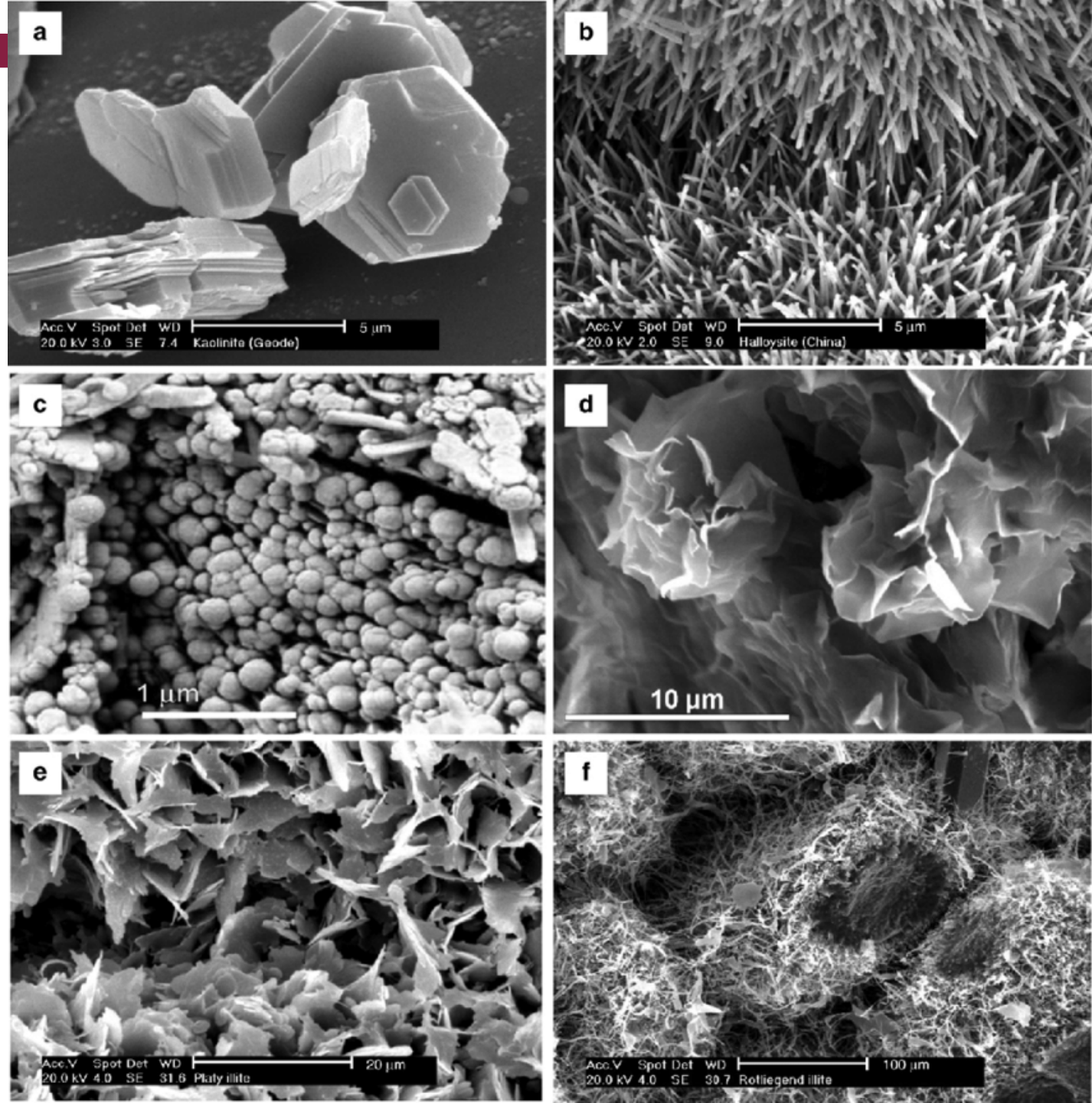
Kaolinite
(Non-Expansive)

Vermiculite
(Semi-Expanding)

Montmorillonite
(Fully Expanding)

The type of clay in a soil plays a major role in erosion

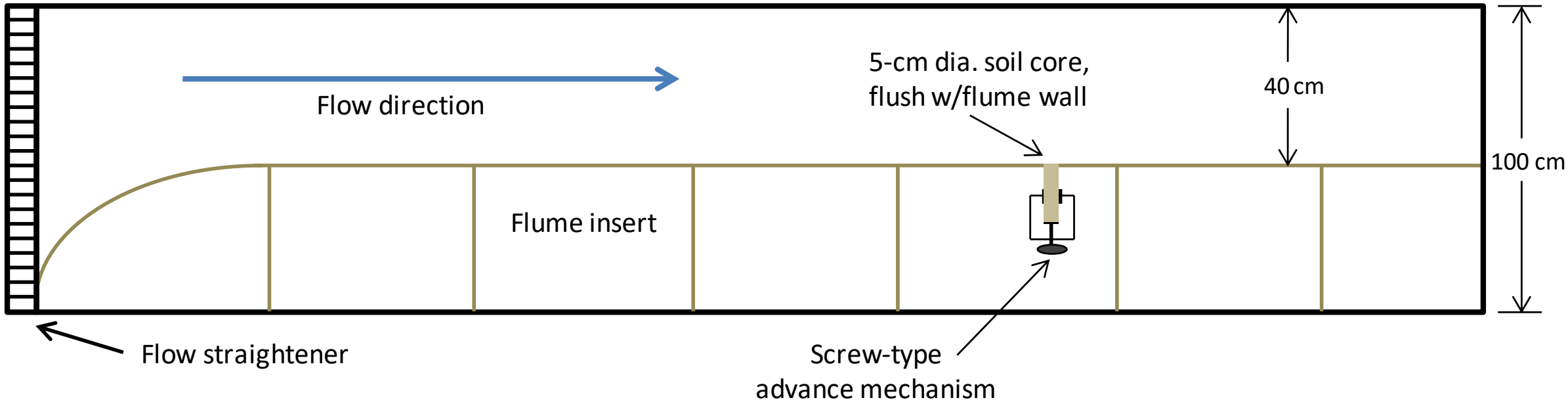
(a) Kaolinite
(b) Tubular crystals of halloysite
(c) spheroidal crystals of halloysite
(d) Montmorillonite
(e) Flaky illite
(f) Fibrous illite



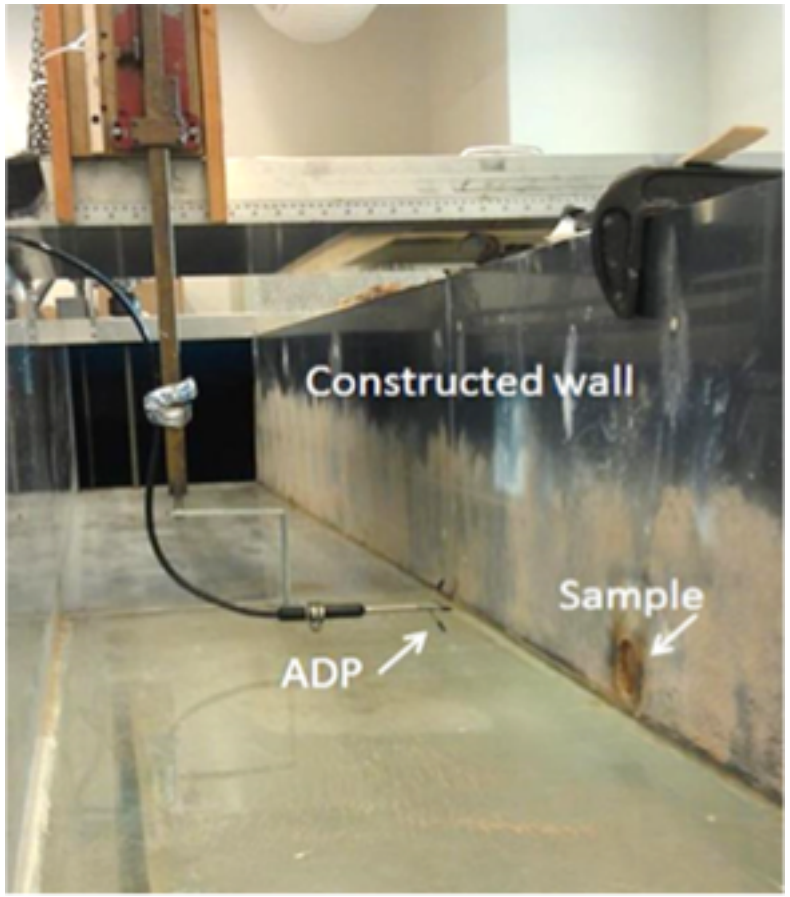
Industrial Clays - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/SEM-images-of-clay-minerals-a-pseudohexagonal-crystals-of-kaolinite-b-tubular_fig4_311583515 [accessed 30 May, 2018]

Images courtesy of The Clay Minerals Society and the Clay Minerals Group of the Mineralogical Society (Images of Clay Gallery, available at www.minersoc.org/pages/gallery/claypix/index.html).

Remolded, 5-cm diameter cores of two natural soils were tested in an 8-m recirculating hydraulic flume



Water temperature, pH, and salt concentration were varied



- Water temperatures of 10, 20, and 30˚C
- pH of 6 and 8
- NaCl concentrations of 0 and 5000 mg/l
- 3 replicates for each soil-T-pH-salt combination

- Velocity profiles and distance to sample measured with a Vectrino II ADCP
- Sample advanced after every 1 mm of erosion
- Shear velocity determined using rough law of wall ($u^* = \sqrt{\tau/\rho}$)
- Shear stress ranged from 0.2—6.5 Pa

Two natural soils were tested

Vermiculite-dominated

- 40% sand, 40% silt, 20% clay
  - 35% hydroxyl interlayered vermiculite
  - 10% vermiculite
  - 10% mica
  - 15% kaolinite
  - 13% quartz
  - 10% chlorite
  - 6% smectite

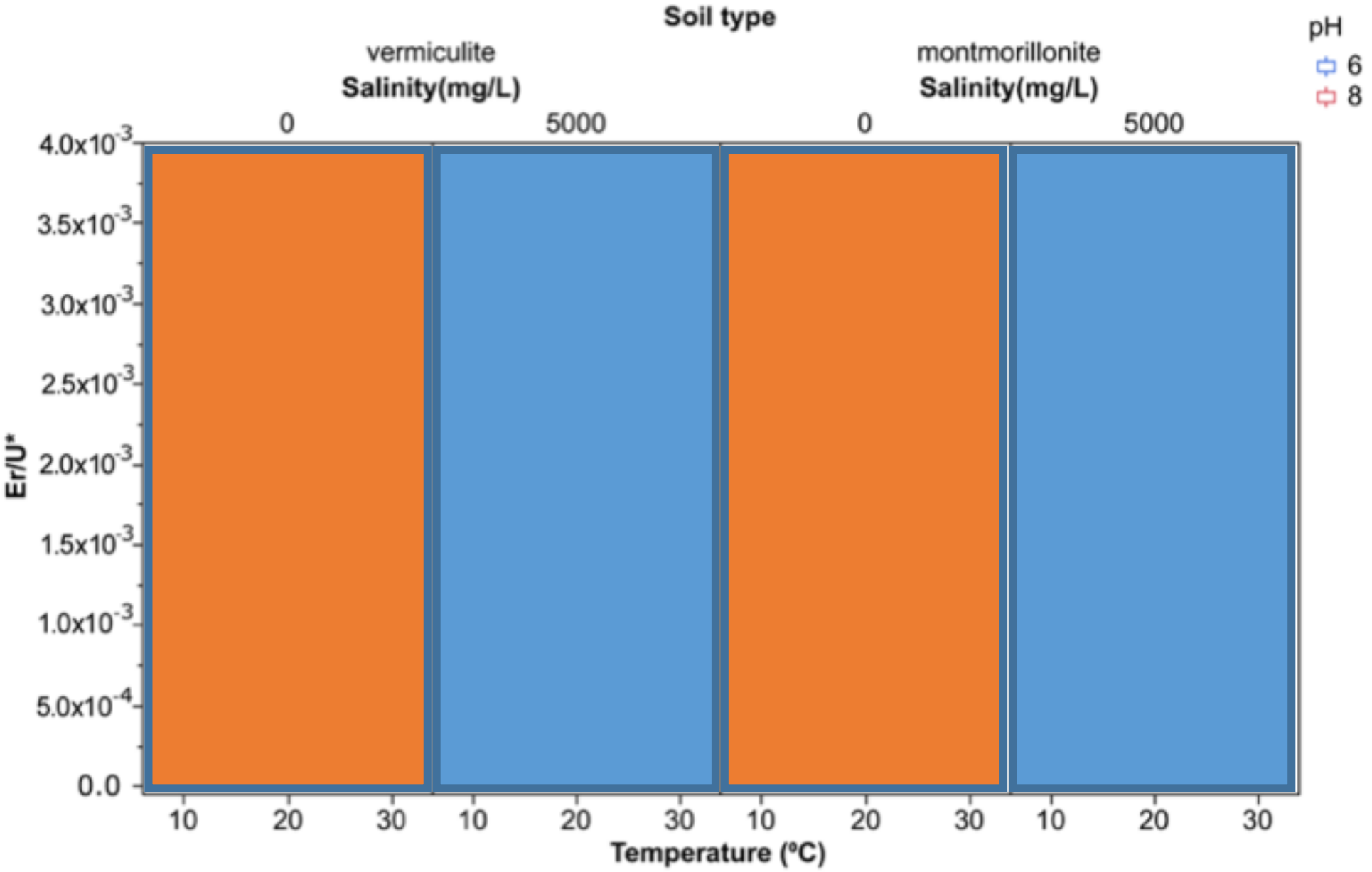
Montmorillonite-dominated

- 47% sand, 42% silt, 11% clay
  - 35% kaolinite
  - 25% montmorillonite
  - 20% mica/illite
  - 15% hydroxyl-interlayered vermiculite
  - 3% chlorite
  - 2% quartz

Soil sample preparation

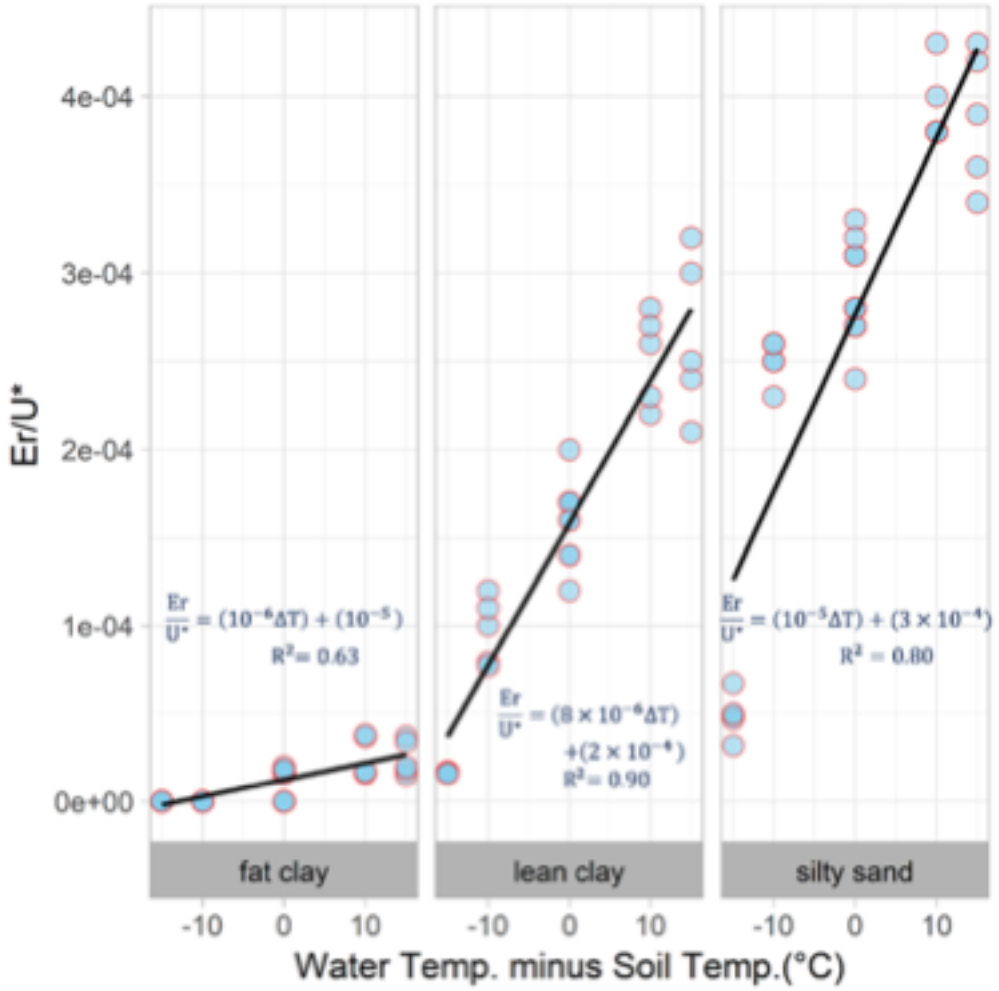
1. Air-dried soils crushed and sieved (2-mm)
2. Dionized water added to bring to test moisture content
3. Compacted into 5-cm x 5 cm aluminum cylinders with a slide hammer
4. Saturated overnight
5. Placed in a pressure plate chamber to bring samples to field capacity (-1/3 bar)
6. Tested within 8 hours of removing from pressure chamber

Clay Type	Bulk Density (g/cm^3)	Soil Moisture Content at Compaction (%)	Hammer Blows Per Layer
Vermiculite	1.5	7.5	4
Montmorillonite	1.3	4.7	3


Soil type
vermiculite
Salinity(mg/L)
0
5000
montmorillonite
Salinity(mg/L)
0
5000
pH
6
8
Er/U*
4.0x10-3
3.5x10-3
3.0x10-3
2.5x10-3
2.0x10-3
1.5x10-3
1.0x10-3
5.0x10-4
0.0
10
20
30
Temperature (°C)

Actually, the heat exchange between the water and the soil affects erosion rates

New research by Akin Akinola



Wrapping it up…

1. Clay type and stream chemistry play a significant role in the fluvial erosion of cohesive streambanks
2. Stormwater regulations should require temperature control in addition to peak flow and volume control to maintain channel stability
3. The change in erosion rate with temperature is directly related to the change in enthalpy of the streambank soils

Questions??

https://en.wikipedia.org/wiki/Carnac_the_Magnificent