Evaluating acid rock drainage from road cuts in Tennessee

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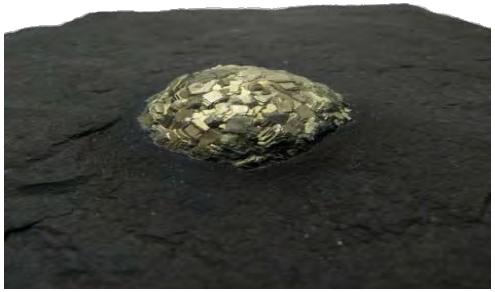
In cooperation with
Tennessee Department of Transportation

14th Annual Technical Forum
Geohazards Impacting Transportation in Appalachia

Problem

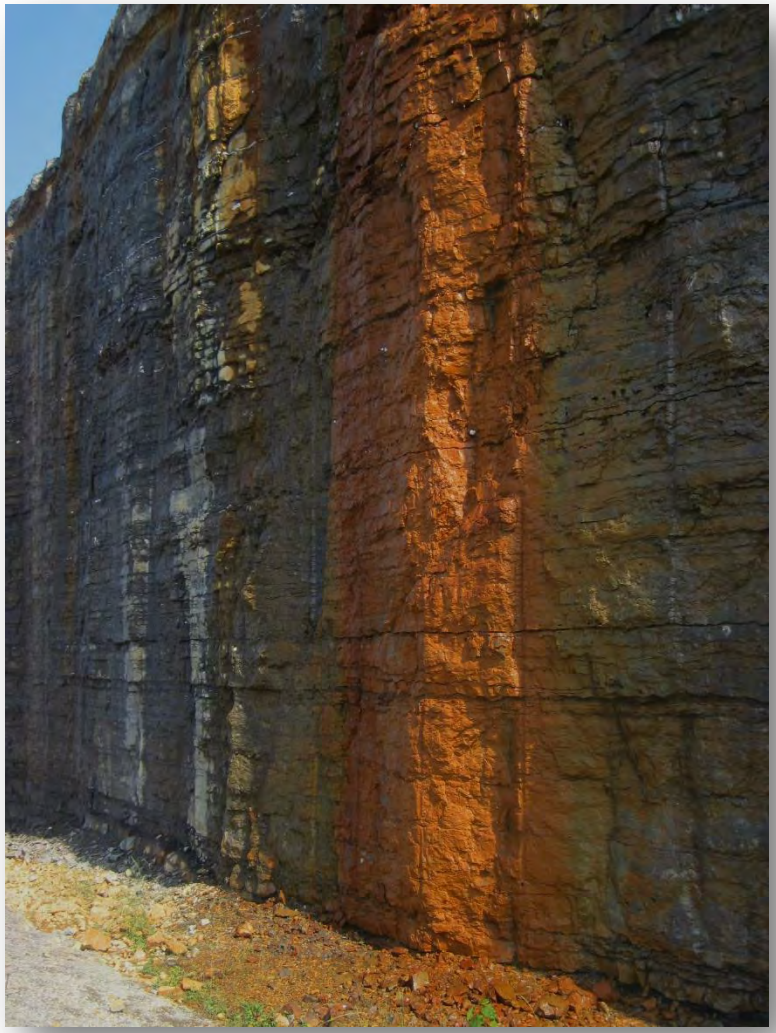
Acid rock drainage from pyrite bearing formations in road cuts and road construction

- Low pH and high trace metal concentration
- Occurrence and transport from the site
- Reduce the impact of contaminants on the environment



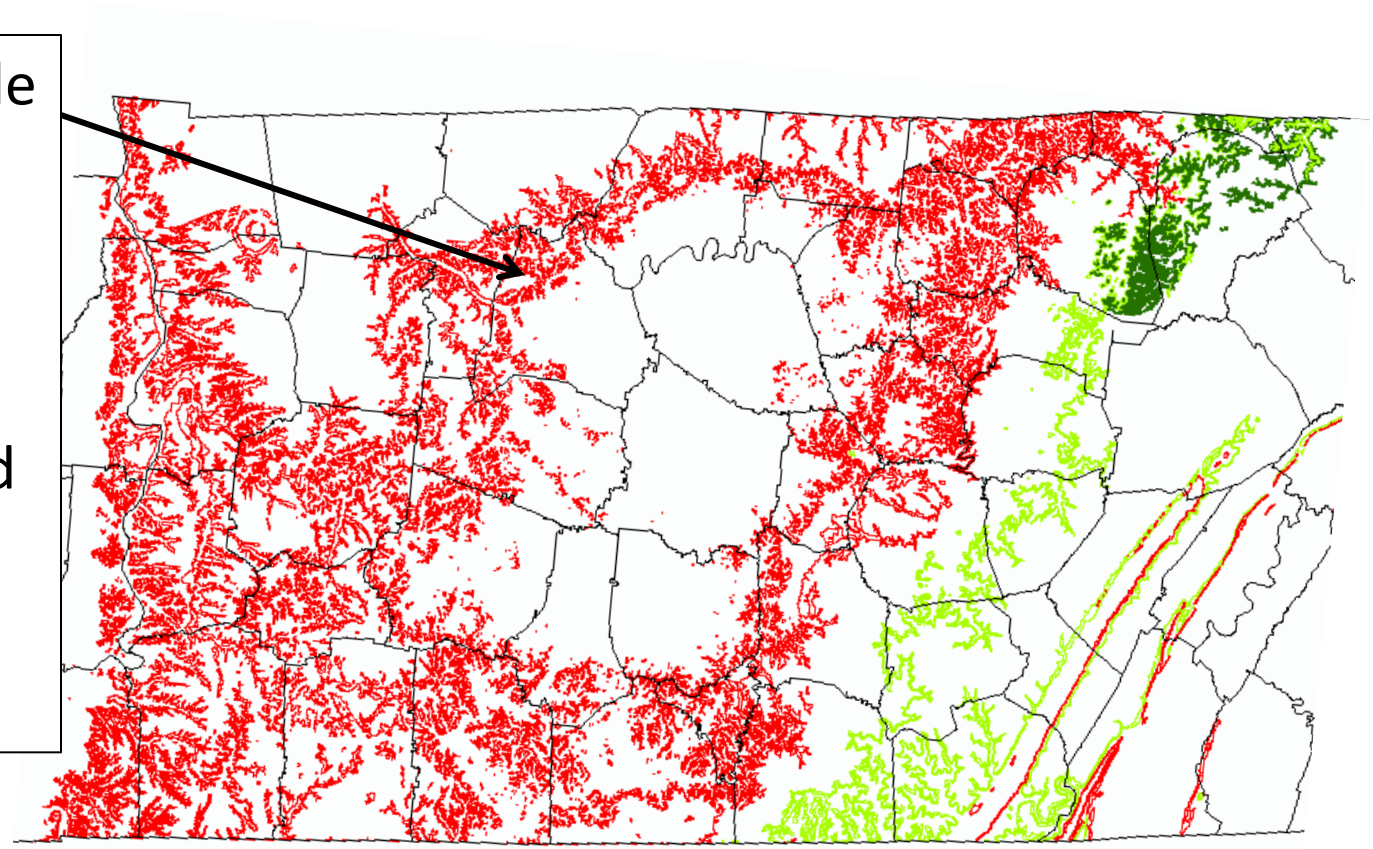
Objectives

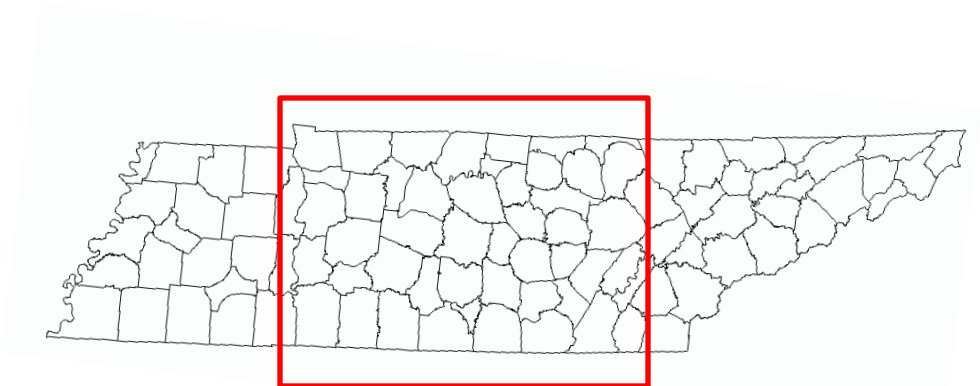
- Evaluate controls on acid-rock drainage
- Define mechanisms of water and oxygen transfer
- Evaluate microbial activity that affect pyrite oxidation



Chattanooga Shale

15-30 ft thick
Trace metals
Radionuclides
Disseminated and clustered pyrite



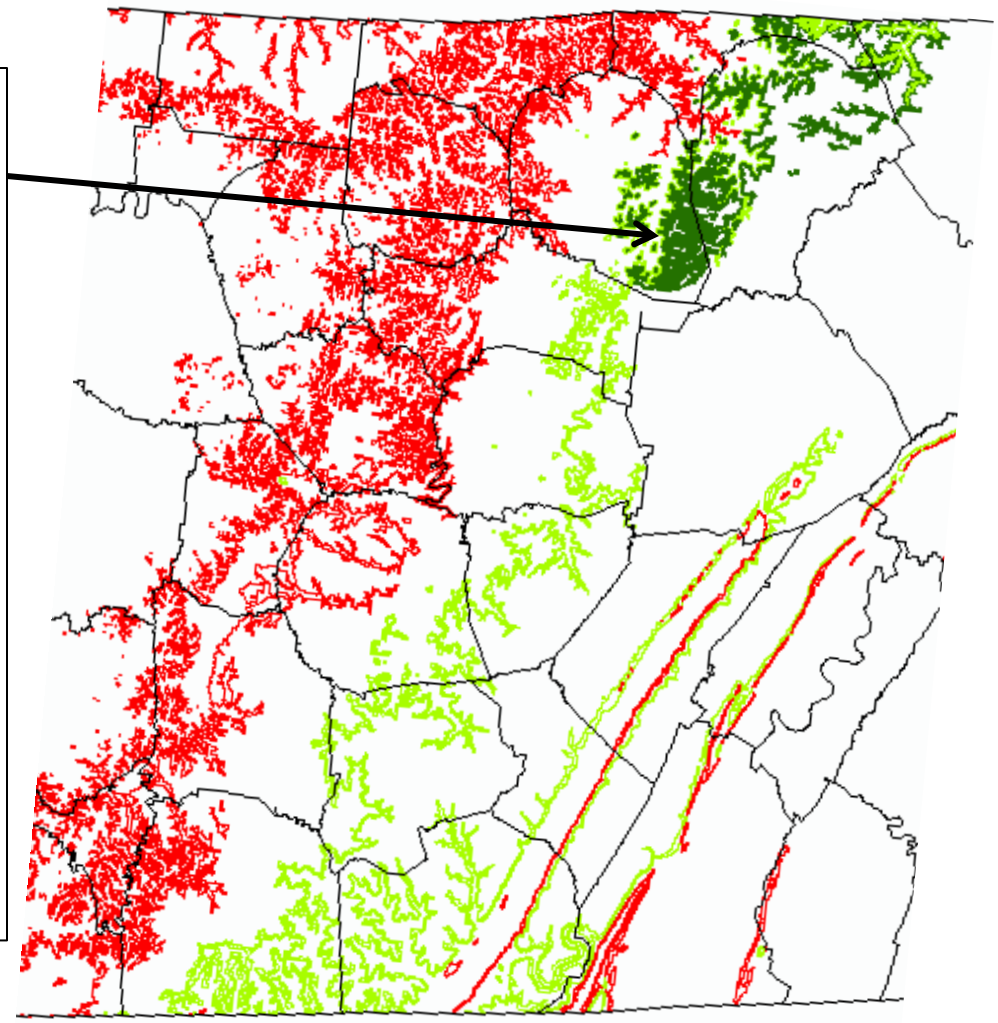


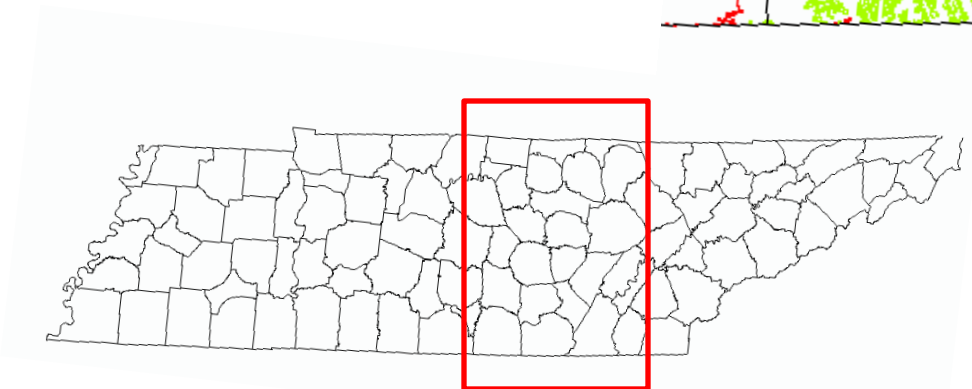
Fentress Formation

Up to 300 feet thick

Lower unit has multiple coal/shale sequences with high pyrite -- variable

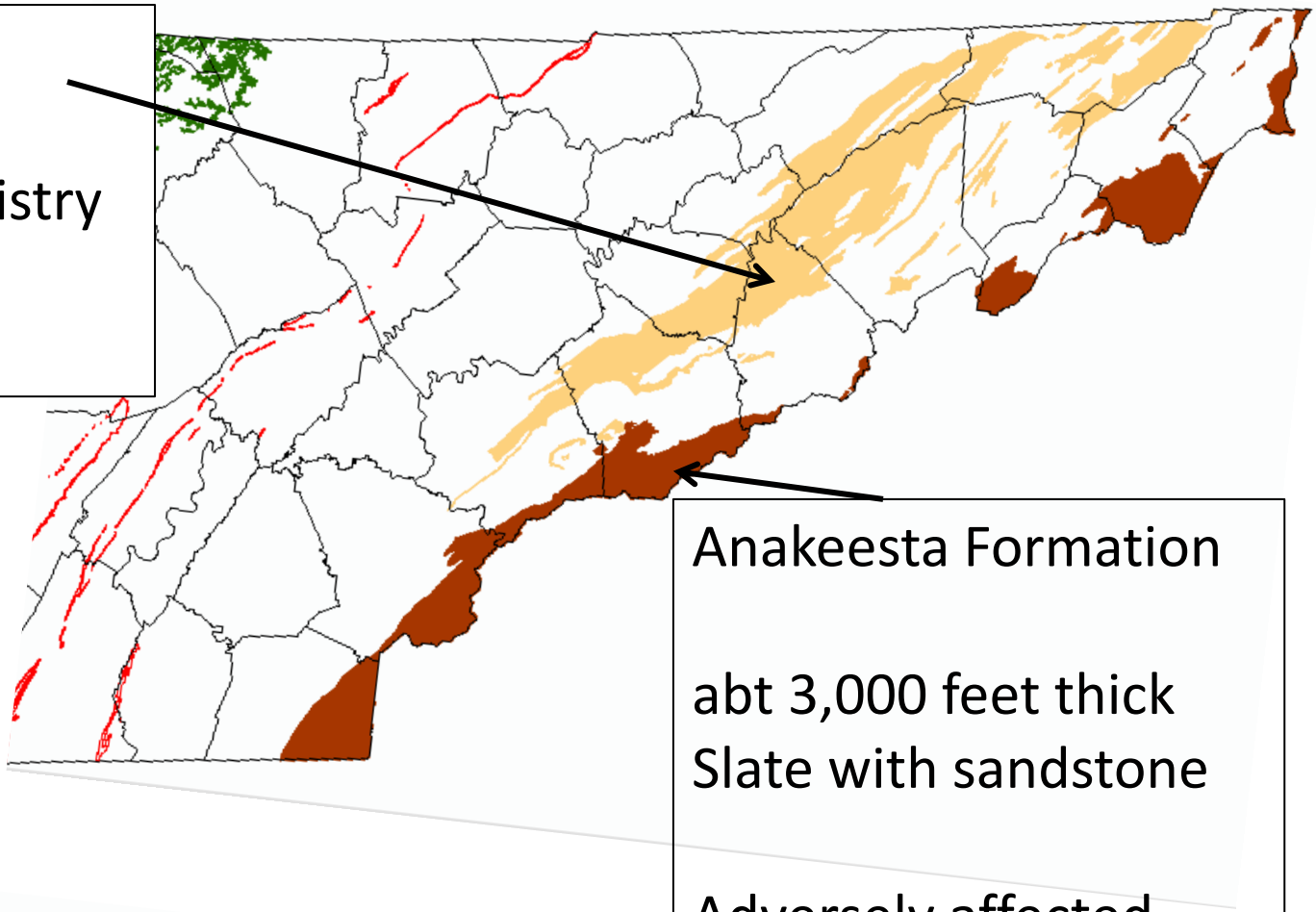
Problem primarily in NW Cumberland Plateau





Sevier Shale

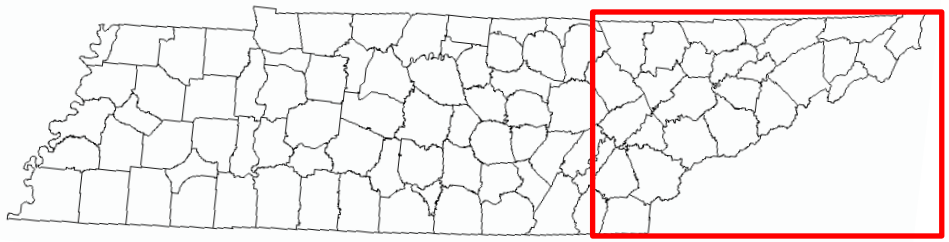
Variable geochemistry
Locally high pyrite



Anakeesta Formation

abt 3,000 feet thick
Slate with sandstone

Adversely affected ecosystems in GRSM stream



Approach - Field

- Literature review
- Reconnaissance and HASP
- Identify 4 sites for sampling and evaluation
  - Access
  - Indication of ARD
  - Hydrology
  - Secondary sulfate mineralization
- Analysis for water and rock chemistry and microbial activity (sample wet and dry periods)

Approach - Lab

- Geochemical reaction tests
- Bacterial tests to determine type present
- Microcosm test to evaluate microbial effect and control on pyrite oxidations
- Storage / rinse out of metals from SSM

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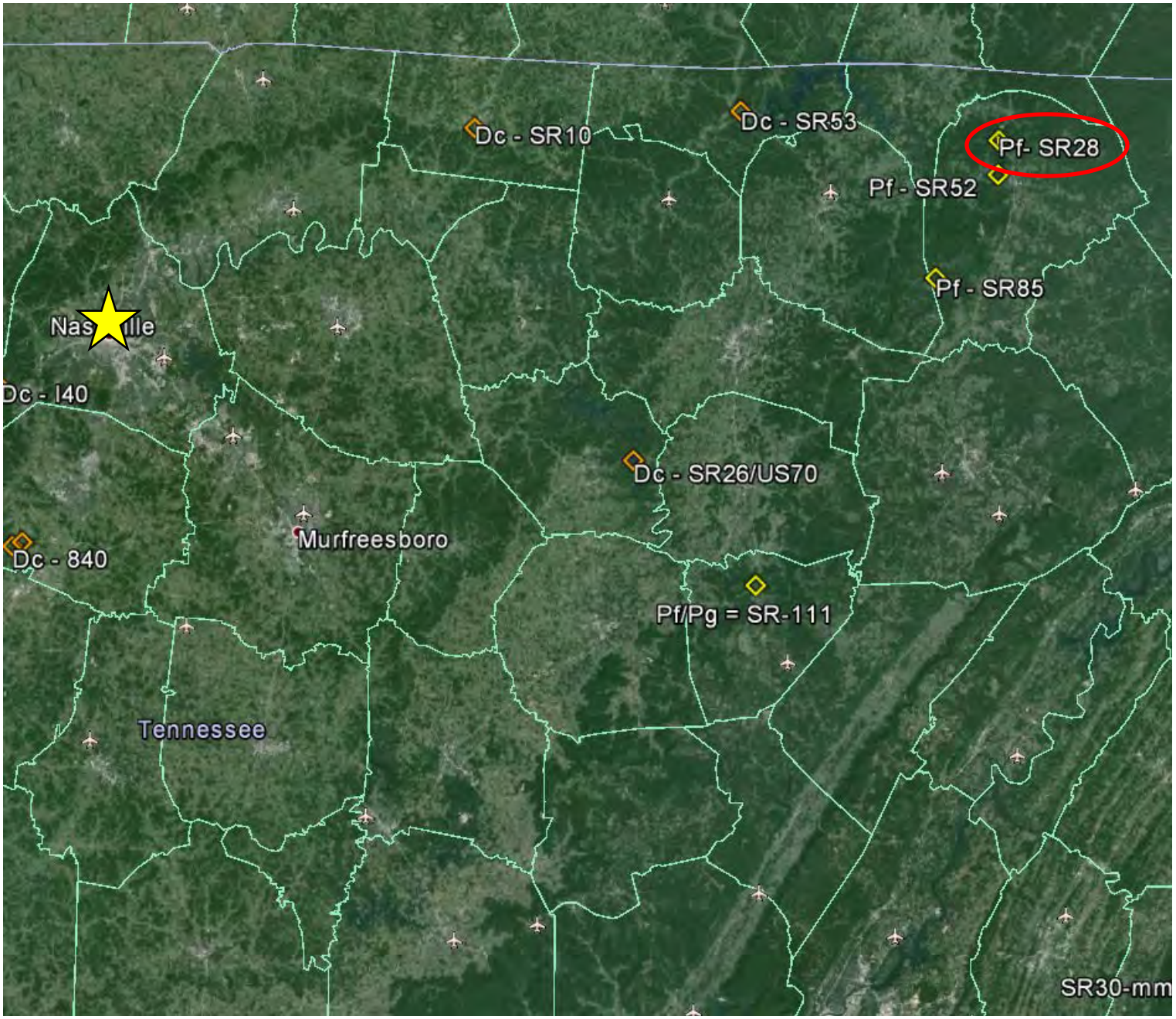

Dc - SR10
Dc - SR53
Pf- SR28
Pf - SR52
Pf - SR85
Nas ille
Dc - I40
Dc - SR26/US70
Murfreesboro
Dc - 840
Pf/Pg = SR-111
Tennessee
SR30-mm

Fentress County
Fentress Formation

Large spoil pile / disposal area

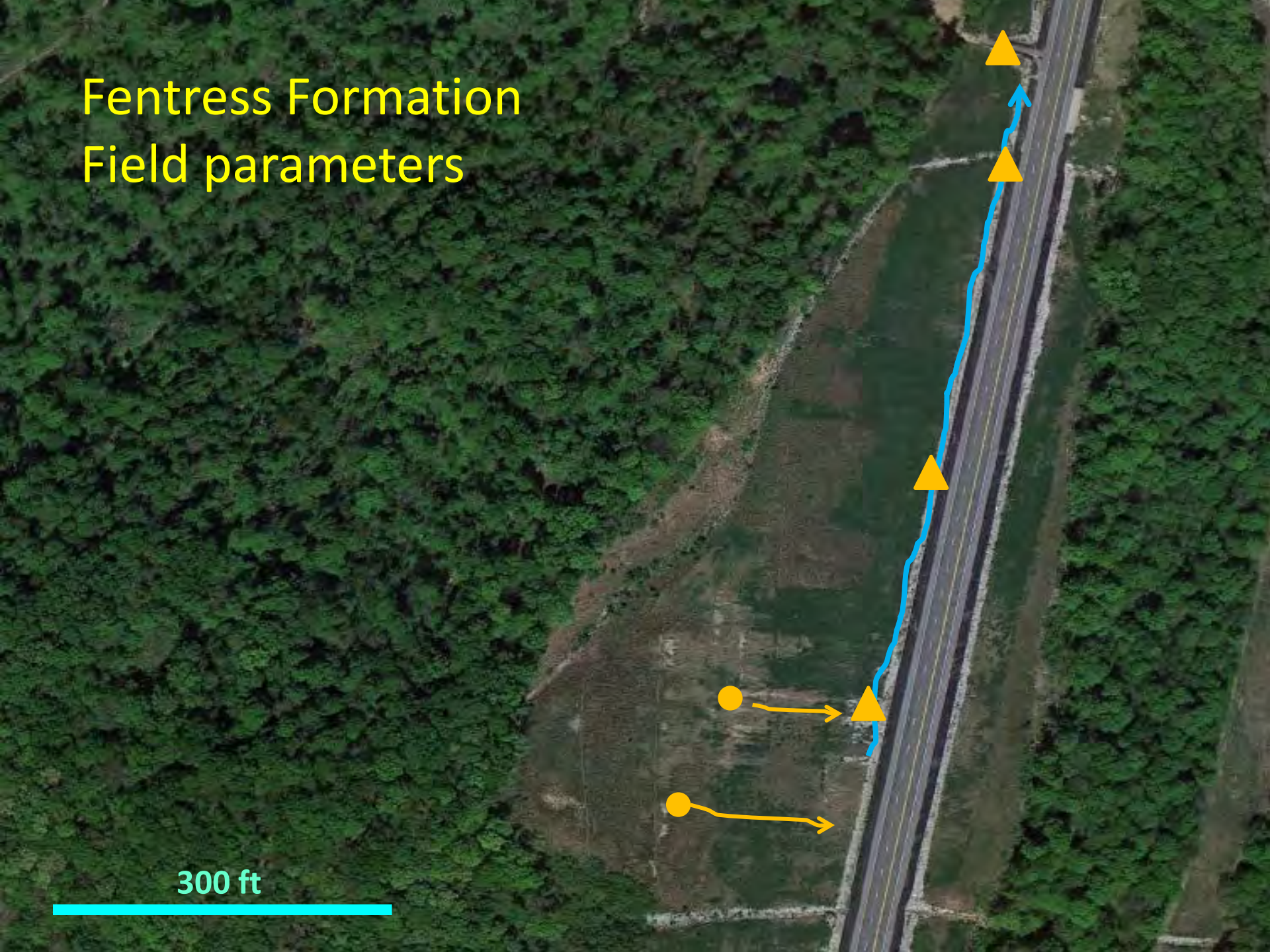
Seeps occur along
coal/underclay sequence in cut

Fentress County
Fentress Formation

Large spoil pile / disposal area

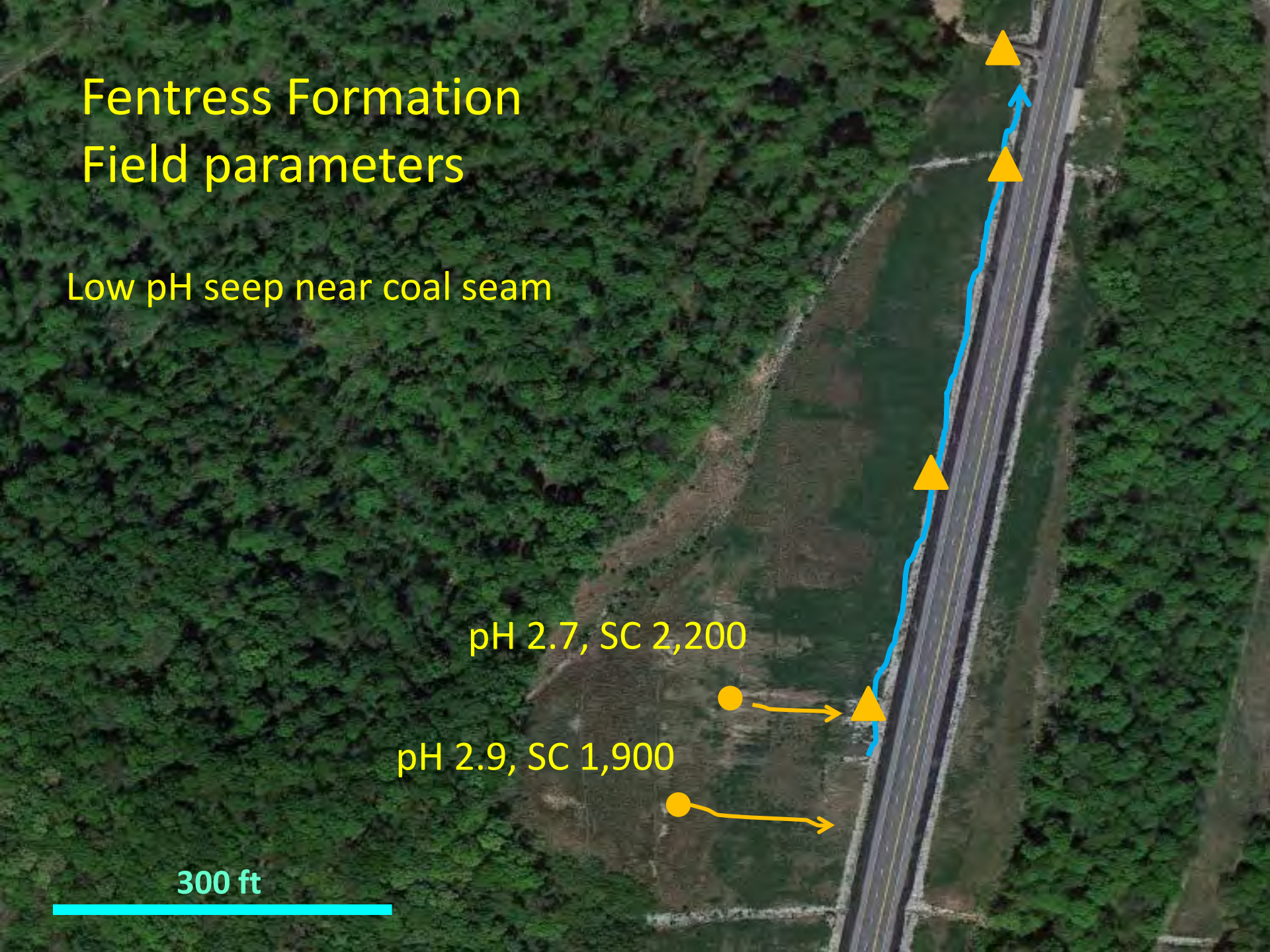
Seeps occur along coal sequences in cut

Fentress Formation
Field parameters



Fentress Formation
Field parameters

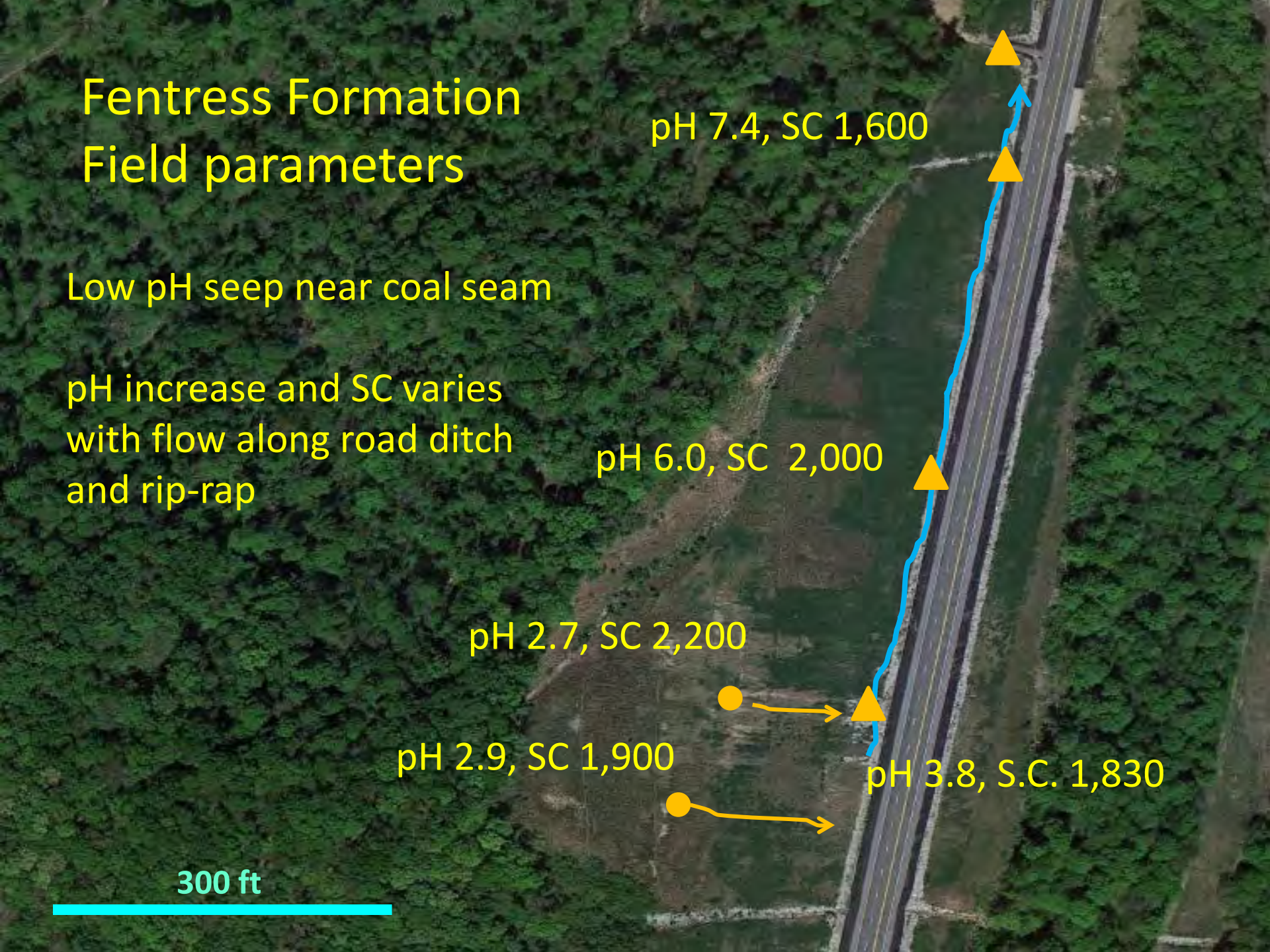
Low pH seep near coal seam



Fentress Formation
Field parameters

Low pH seep near coal seam

pH increase and SC varies with flow along road ditch and rip-rap




Clarksville
Dc - SR10
Dc - S
Nas ille
Dc - I40
Dc - SR26/US7
Murfreesboro
Dc - SR50
Dc
Dc - 840
Pf/Pg = SR-1
Tennessee
64
Dc - US64
Dc - US64

Chattanooga Shale – Williamson Co

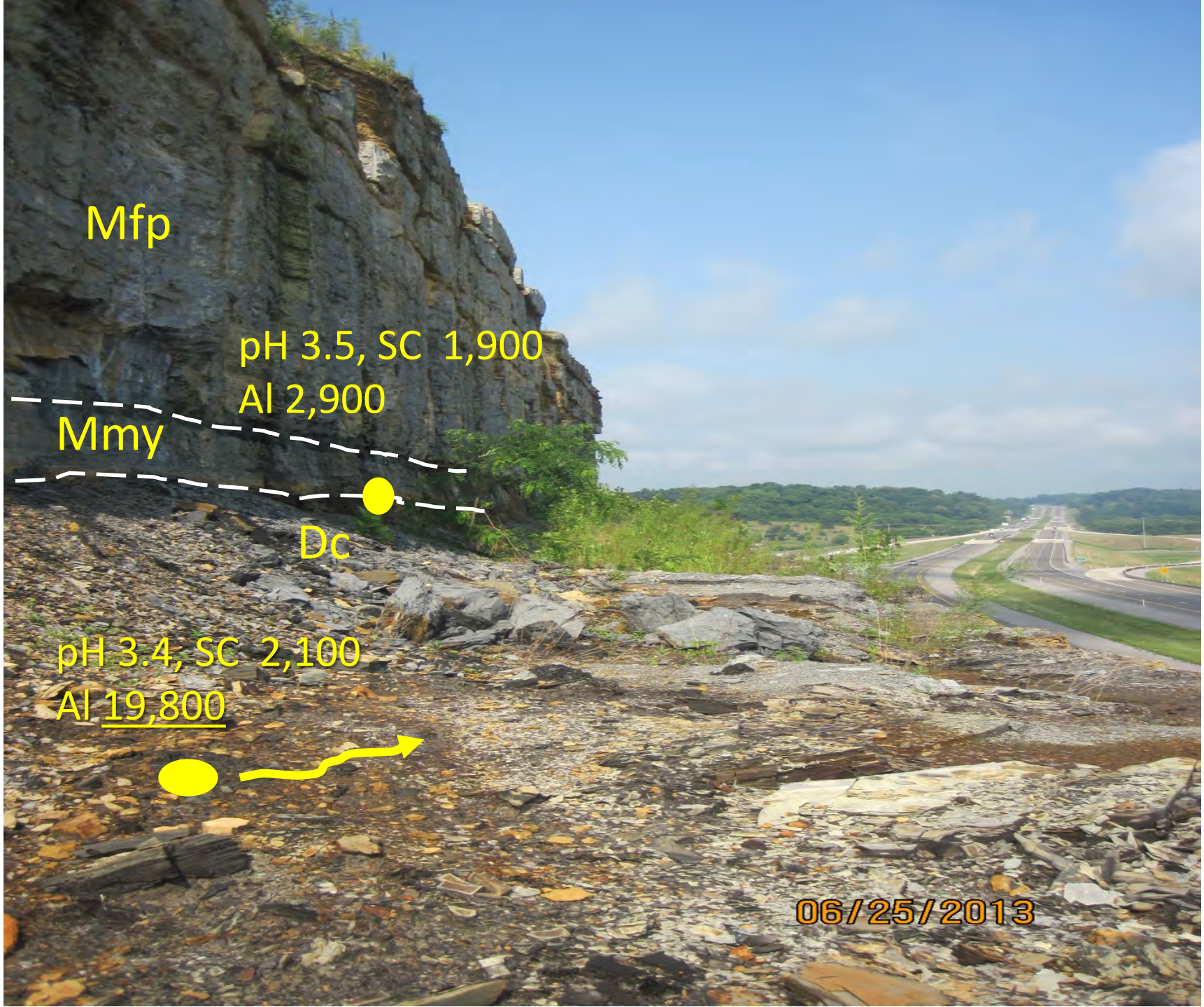
Long lateral exposure of shale

Vertical exposure on bench cut

Shale breakdown at base of cut

Multiple seeps;
- overlying Fort Payne
- top of Chattanooga
- shale rubble
- underlying limestone


06/25/2013


Mfp
pH 3.5, SC 1,900
Al 2,900
Mmy
Dc
pH 3.4, SC 2,100
Al 19,800
06/25/2013


pH 7.6, SC 1,250
Al <20
06/25/2013

SSM on Chattanooga Shale

Mineralization occurring as edge rind on chips and within shale plates


Clarksville
Dc - SR10
Dc - S
Nas ille
Dc - I40
Dc - SR26/US7
Murfreesboro
Dc - SR50
Dc
Dc - 840
Pf/Pg = SR-1
Tennessee
64
Dc - US64
Dc - US64

Chattanooga Shale - Hickman county

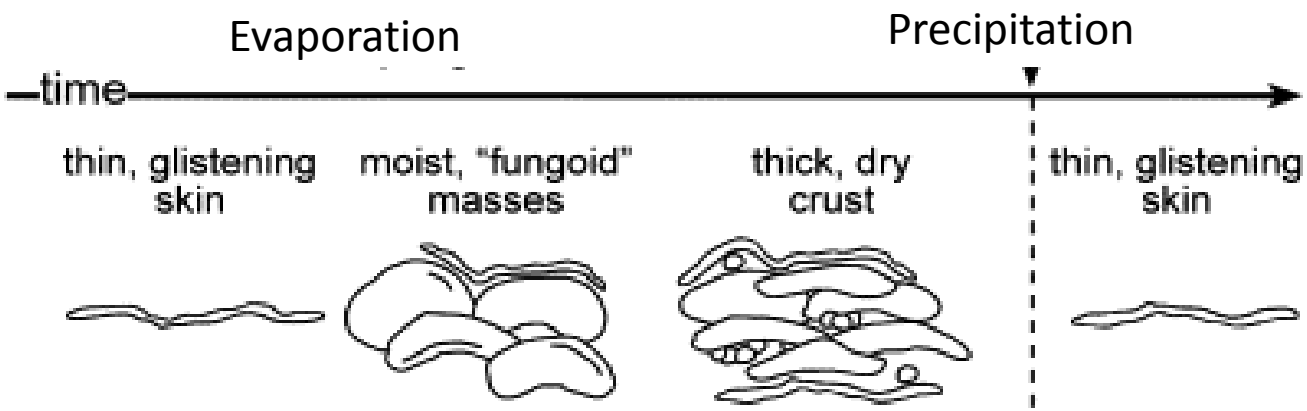
SSM at Hickman

Mineralization covers nearly full face of road cut.

Multi-colored – different metal accumulation (??)

Potential source of low pH and high metal

Little water – almost none in January 2014



Gypsum → Anhydrite → increasing trace metals
(accumulation)

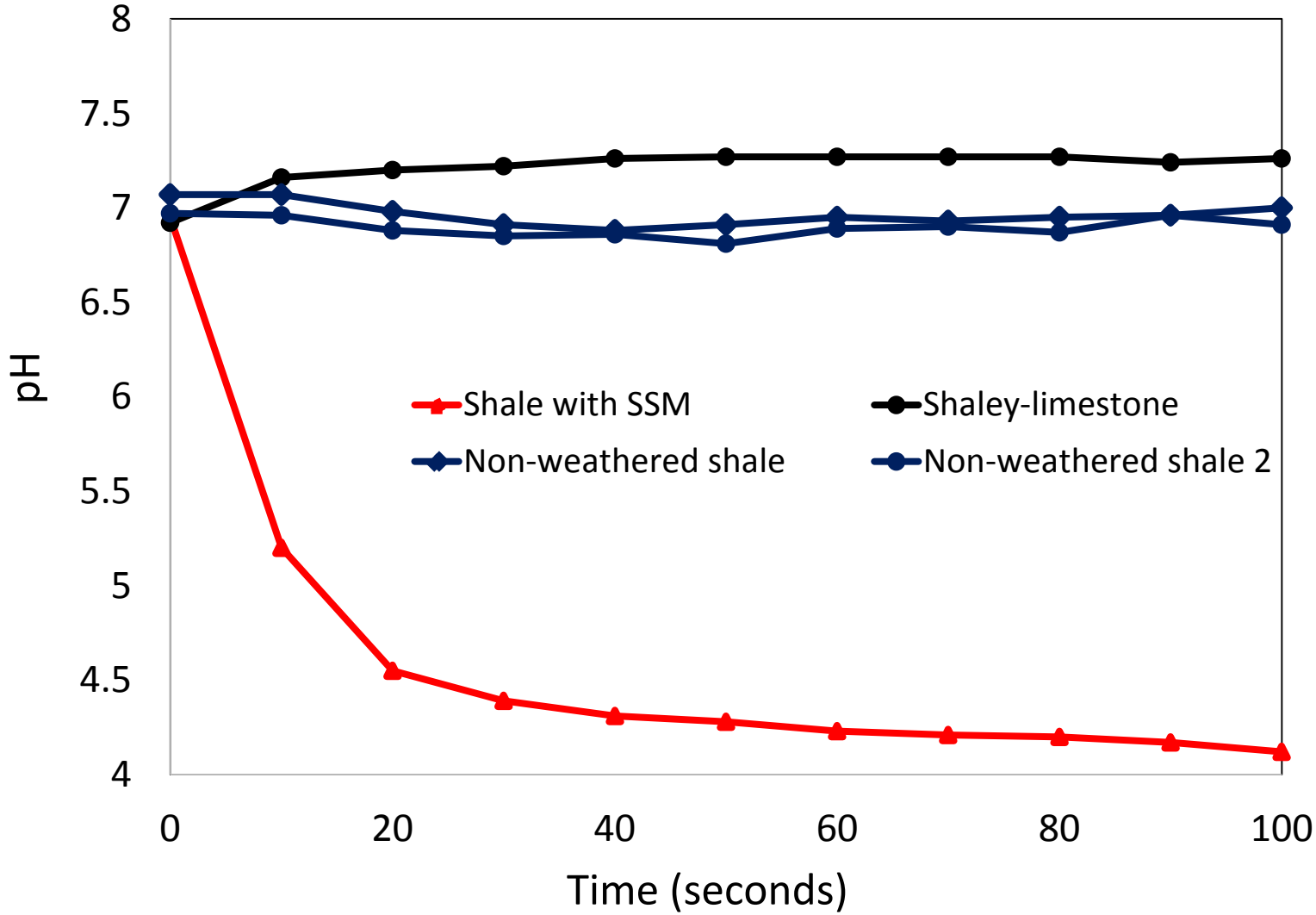
SSM Dissolution → gypsum → ??
(release)

1. Compare pH lowering potential of weathered and unweathered shales

Batch Experiment

- 150 ml of three representative shale samples used
- Weathered, shaley-limestone, and unweathered
- Electronic mixer and mounted pH probe was used

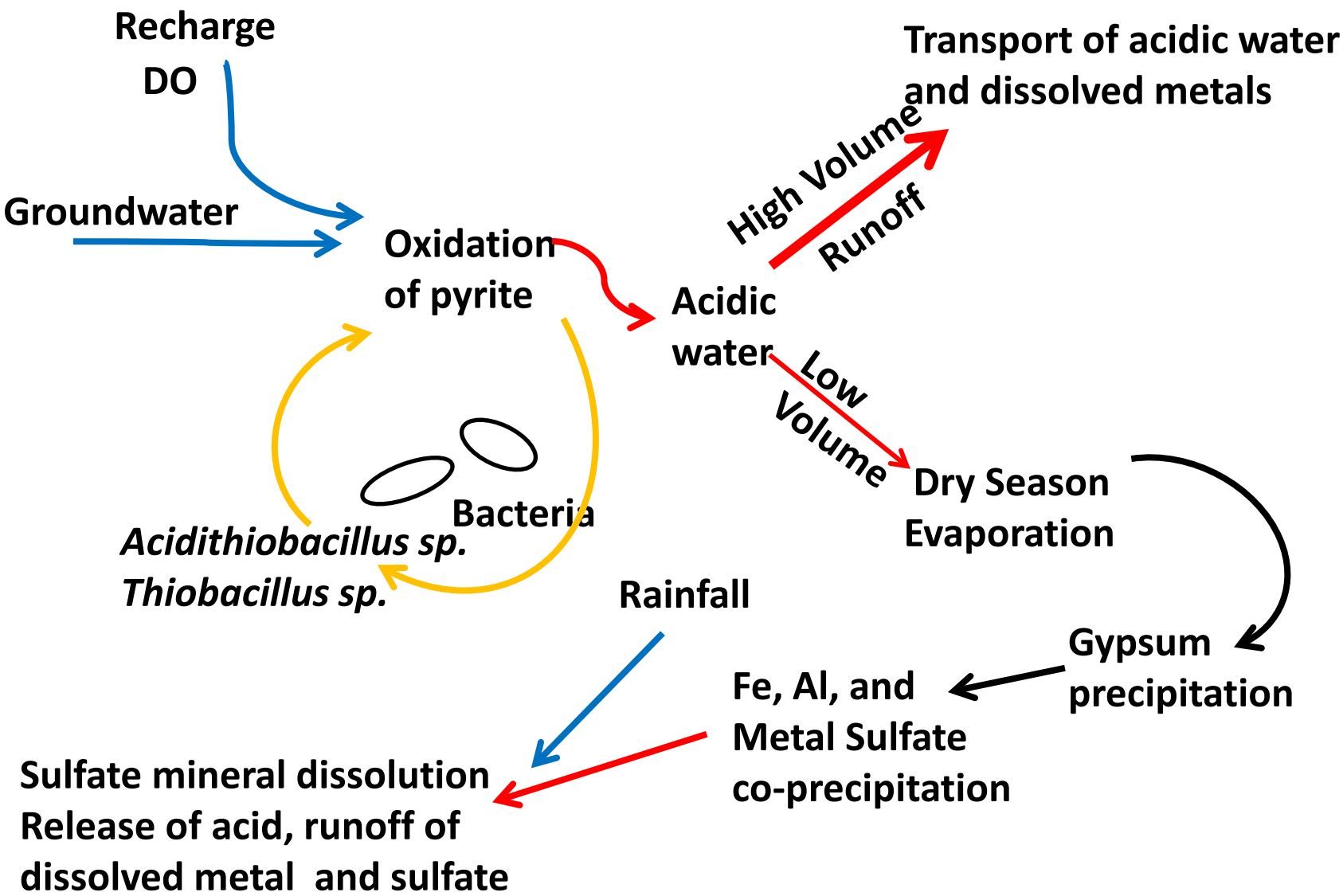
1. Compare pH lowering potential of weathered and unweathered shales



Summary

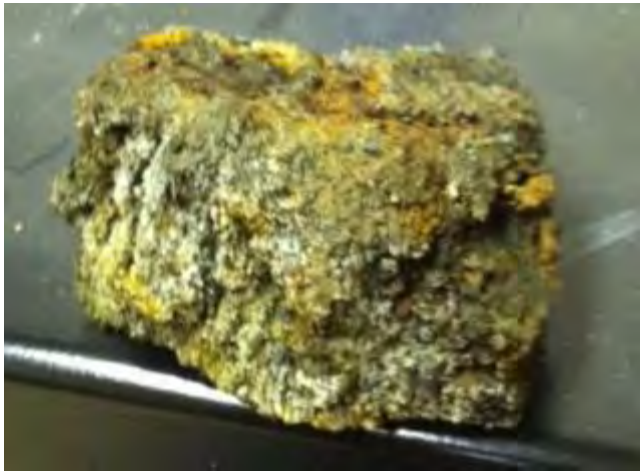
- Cooperative investigation with TDOT to evaluate ARD from road cuts.
- Primary pyrite-bearing formations are Chattanooga Shale, Fentress Formation, and Anakeesta units.
- Low pH and high trace metals, very high Al from Dc seep
- SSM can result in rapid change in pH and metals

Questions ??


Recharge
DO
Groundwater
Oxidation
of pyrite
Acidic
water
High Volume
Runoff
Transport of acidic water
and dissolved metals
Low
Volume
Dry Season
Evaporation
Gypsum
precipitation
Fe, Al, and
Metal Sulfate
co-precipitation
Bacteria
Acidithiobacillus sp.
Thiobacillus sp.
Rainfall
Sulfate mineral dissolution
Release of acid, runoff of
dissolved metal and sulfate

Highway 840

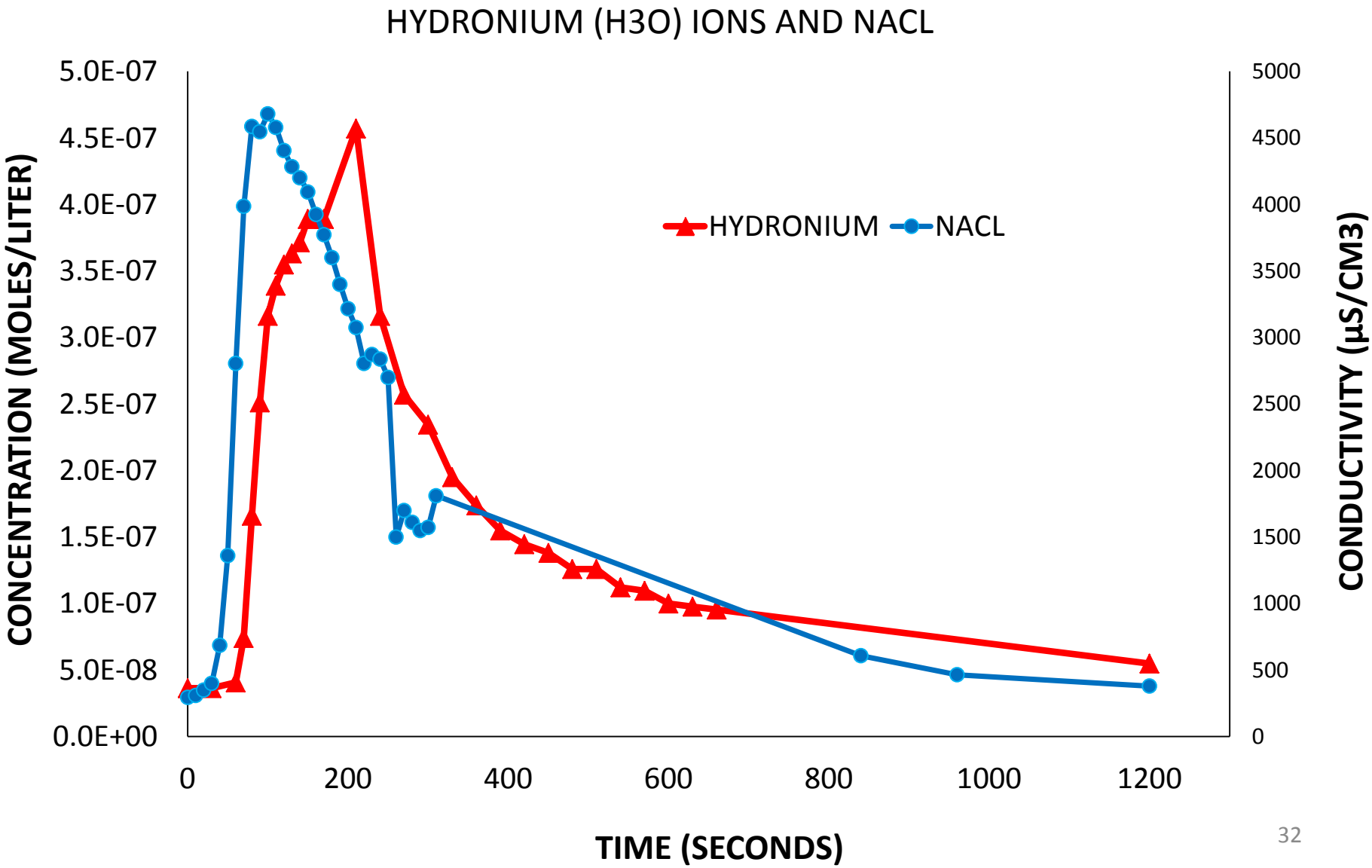
Secondary Sulfate Minerals (SSM)



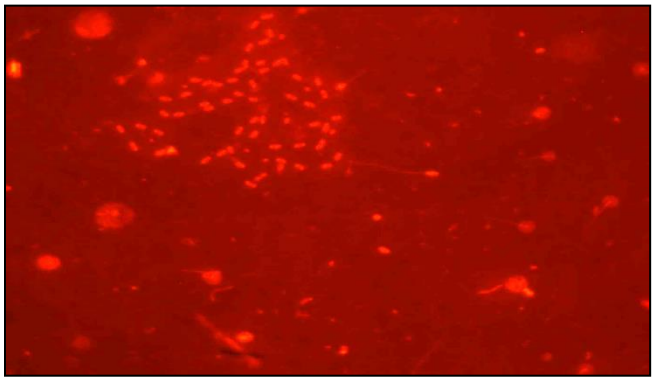
Weathered

Unweathered

Flume run results



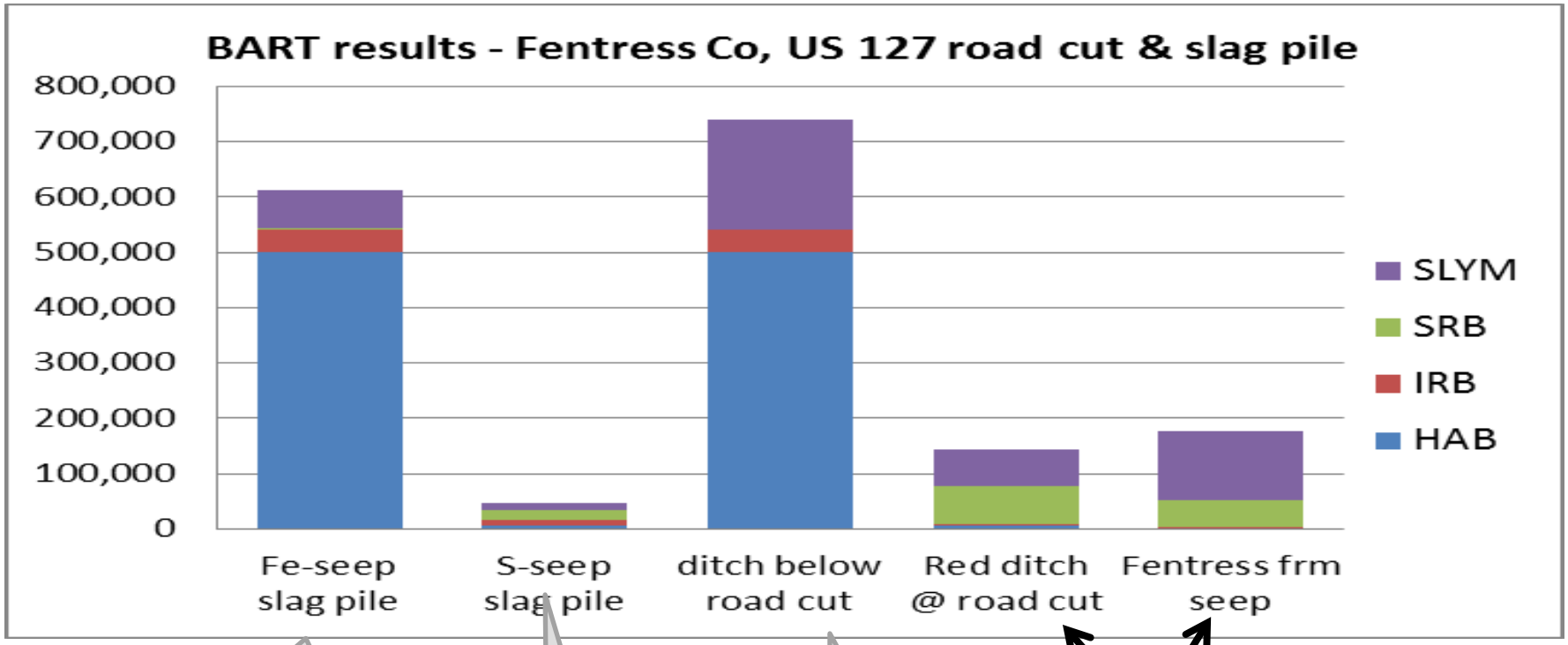
Bacteria Types



BACTERIA TYPE	SIGNIFICANCE OF BACTERIA TYPE
Total aerobic heterotrophic bacteria (**HAB**)	Aerobic heterotrophic bacteria are efficient at metabolizing carbon food, are desired for aerobic degradation processes and to initially deplete competing electron acceptors for anaerobic processes.
Iron-related bacteria (**IRB)**	Iron-reducing bacteria are relatively efficient at biodegrading petroleum hydrocarbons and other simple organics. Active in aerobic processes with ARD
Sulfate-related bacteria (**SRB**)	Sulfate-reducing bacteria function in strongly reducing conditions and typically use fermentation products as food. Sulfur-oxidizing bacteria use sulfide as a food source.
Acid-producing bacteria (**APB)**	Bacteria that switch to fermentation metabolism when O_2 is limiting, producing organic acids by-products, acetate & lactate
Slime forming bacteria (**SLYM**)	SFB are a consortium of bacteria that tend to form biofilms by adhering to hard surfaces. This is critical for maintaining bacteria populations in the subsurface.

Bacteria

Identifying bacteria types – Biological Activity Reaction Test (BART)



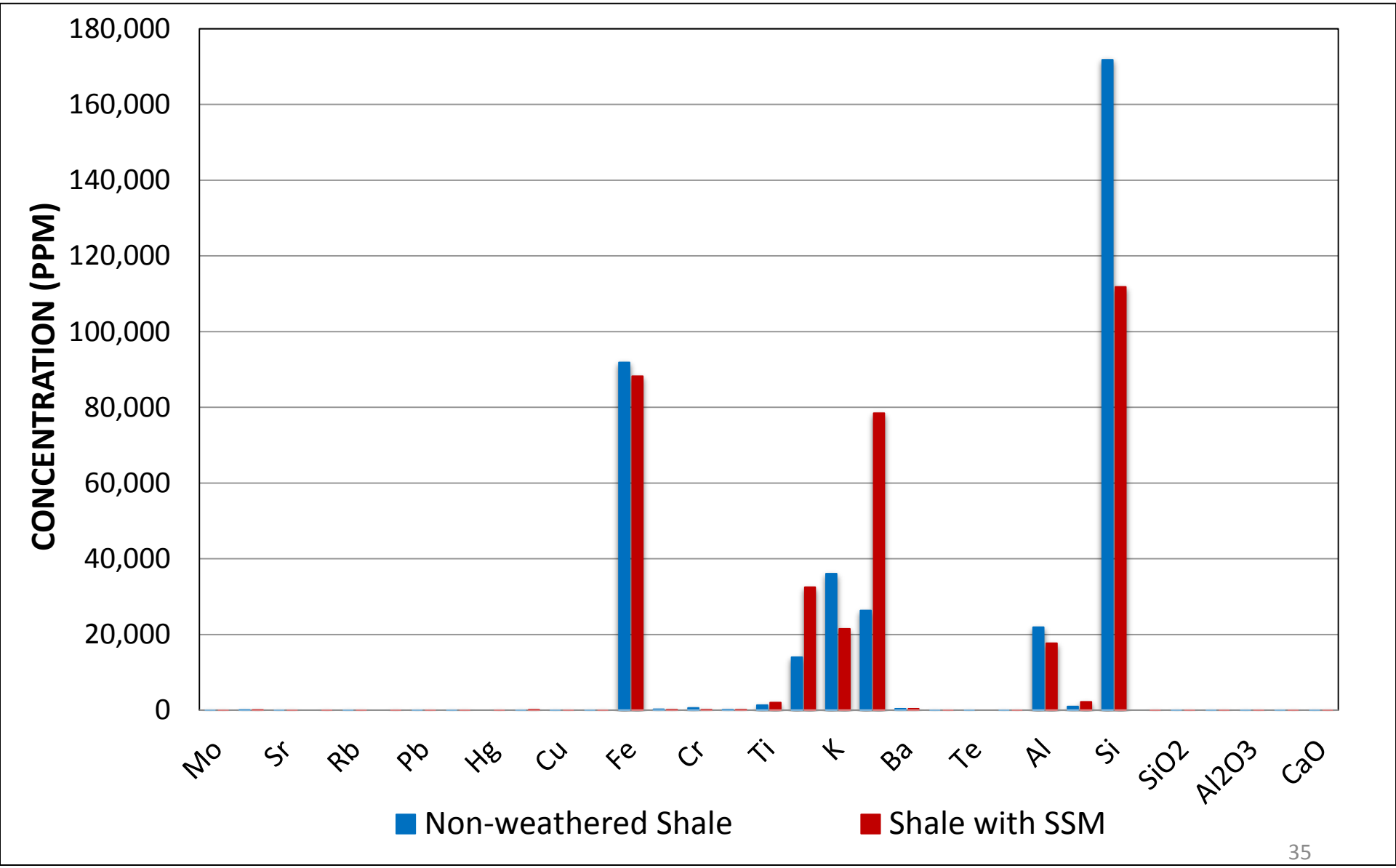
Aerobic, facultative anaerobe

Anaerobic, facultative anaerobe

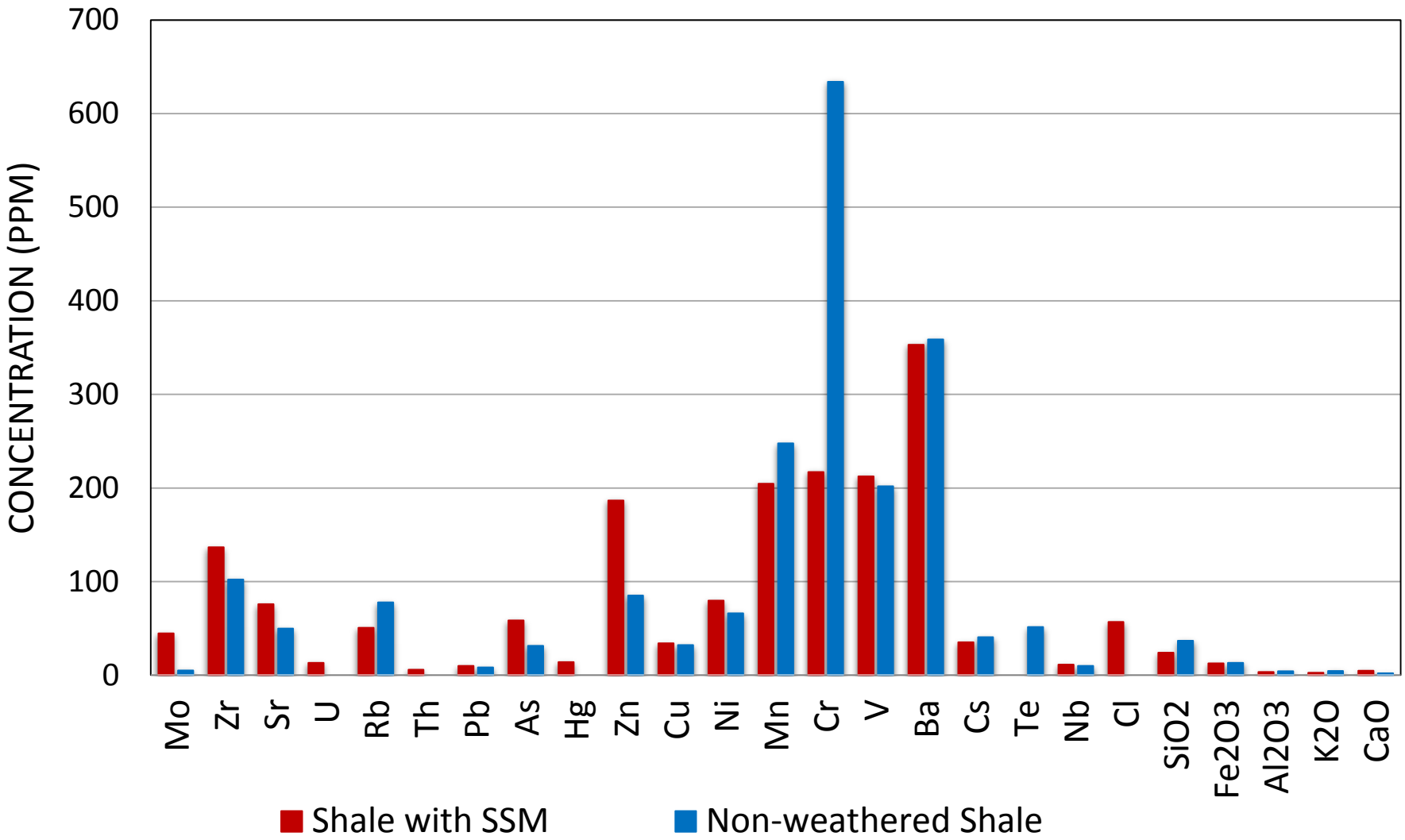
Aerobic,

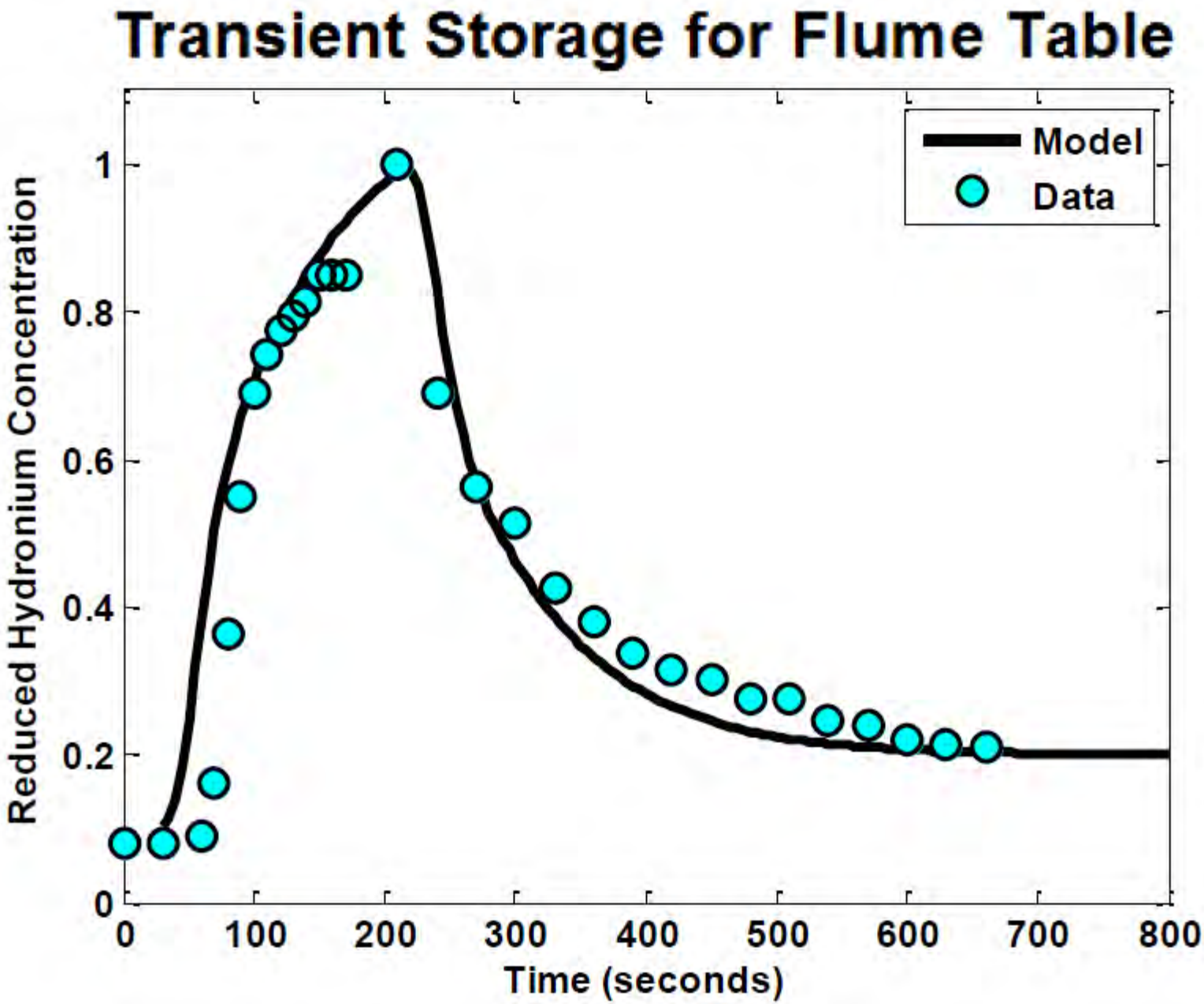
Anaerobic, facultative anaerobe

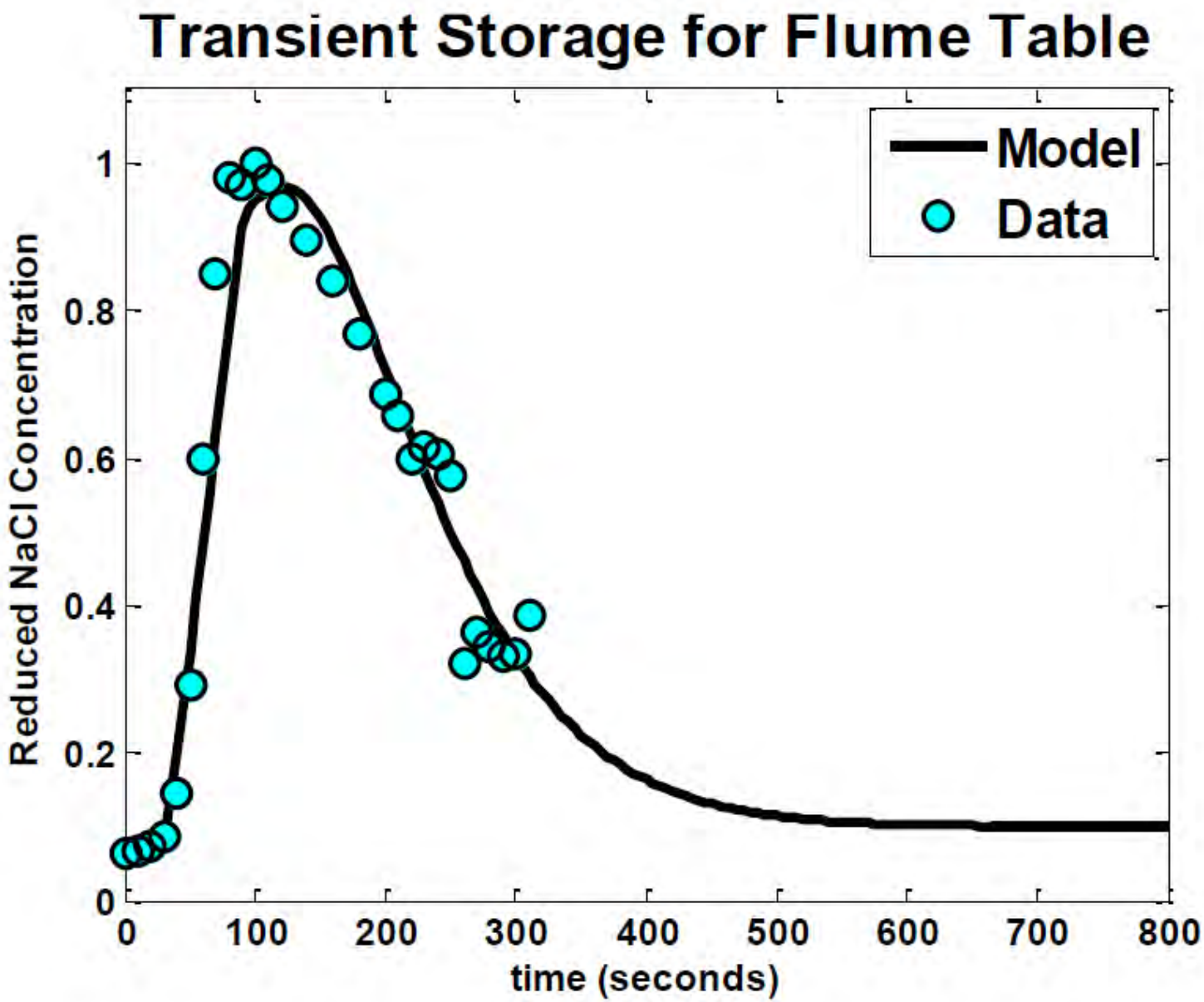
XRF All Concentrations



XRF Lower Concentrations




Transient Storage for Flume Table
Model
Data
Reduced Hydronium Concentration
Time (seconds)
0
0.2
0.4
0.6
0.8
1
0
100
200
300
400
500
600
700
800


Transient Storage for Flume Table
Model
Data
Reduced NaCl Concentration
time (seconds)
0
0.2
0.4
0.6
0.8
1
0
100
200
300
400
500
600
700
800