LEACHING POTENTIALS OF COAL SPOIL: EFFECTS OF ROCK TYPE AND DEGREE OF WEATHERING

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APPALACHIAN COALFIELDS

Past surface mine pre-mining analytics focused on:
(1) AMD potential, and (2) Revegetation potential

Now we need to consider:

(3) TDS POTENTIAL

RECLAIMED VALLEY FILL

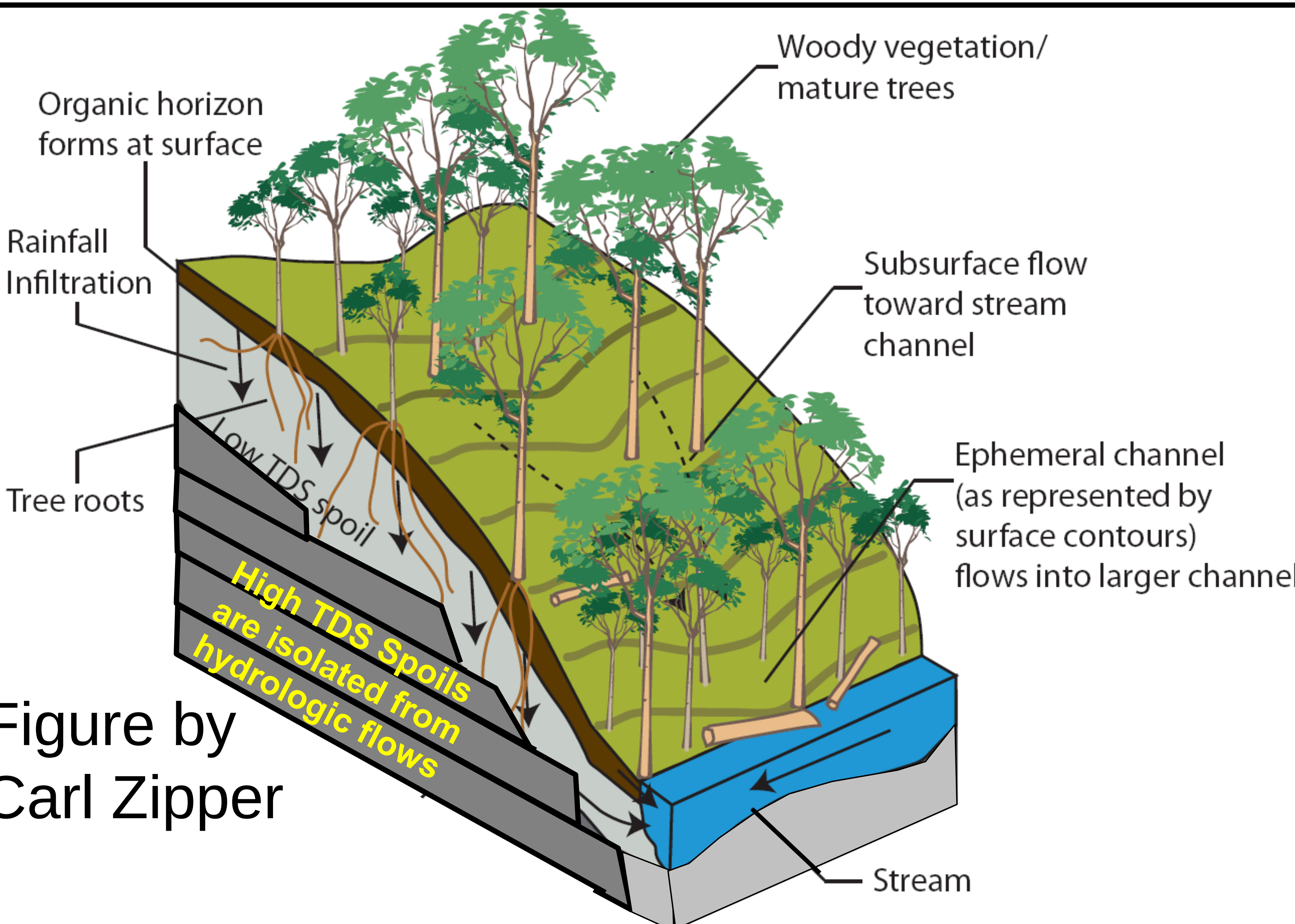


Figure by
Carl Zipper

OBJECTIVES

1) To characterize the potential leaching behavior of mine spoil materials, in terms of:

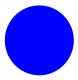
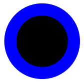
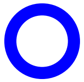
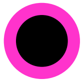
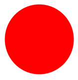
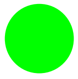
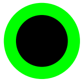
- pH
- EC
- Major cation and anion composition

2) To evaluate leaching behavior with respect to:

- rock type
- degree of weathering

METHODS

Column leaching conducted on 55 diverse spoil samples from lower to middle-Pennsylvanian age strata:

ROCK TYPE	WEATHERING	# OF SAMPLES	CODE
Sandstone	unweathered	13	
	(un)weathered	5	
	weathered	3	
Mudstone	unweathered	11	
	(un)weathered	2	
	weathered	4	
Black shale	unweathered	4	
Mixed spoil	unweathered	6	
	(un)weathered	7	

(un)weathered – partially weathered or mix of weathered and unweathered material

METHODS

BULK SAMPLES (2 5-gal buckets) were each:

- Spread out to air-dry.
- Passed through a 1.25 cm (0.5”) sieve.
- Coarse fraction was crushed to <1.25 cm.
- All material was thoroughly re-blended.
- Subsamples (1200 cm^3, with mass recorded) were collected (cone and quarter) for column leaching, to determine pore volume (within columns), and to determine coarse particle size distribution.
- Subsamples were collected and crushed as appropriate for basic characterization including saturated paste pH/EC and total-S.

COLUMN SETUP

Capped with 5 cm sand

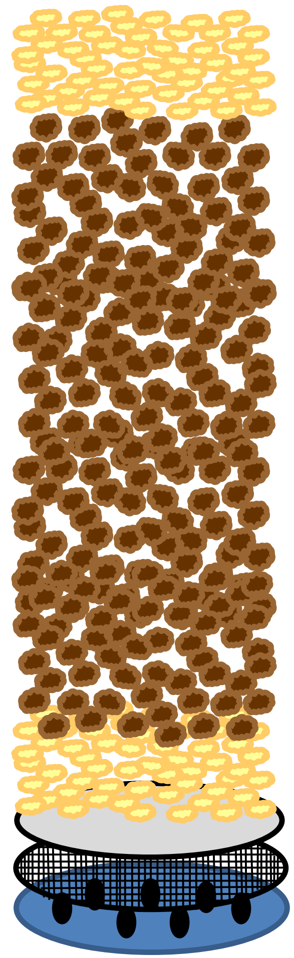
- Sample volume: 1200 cm^3
- Inside diameter = 7.5 cm
- Height of spoil = ~ 27 cm
- Inside bottom of column:

  -- 5 cm (2”) sand

  -- Whatman #1 filter

  -- 0.1 mm nylon mesh

  -- perforated plastic disc



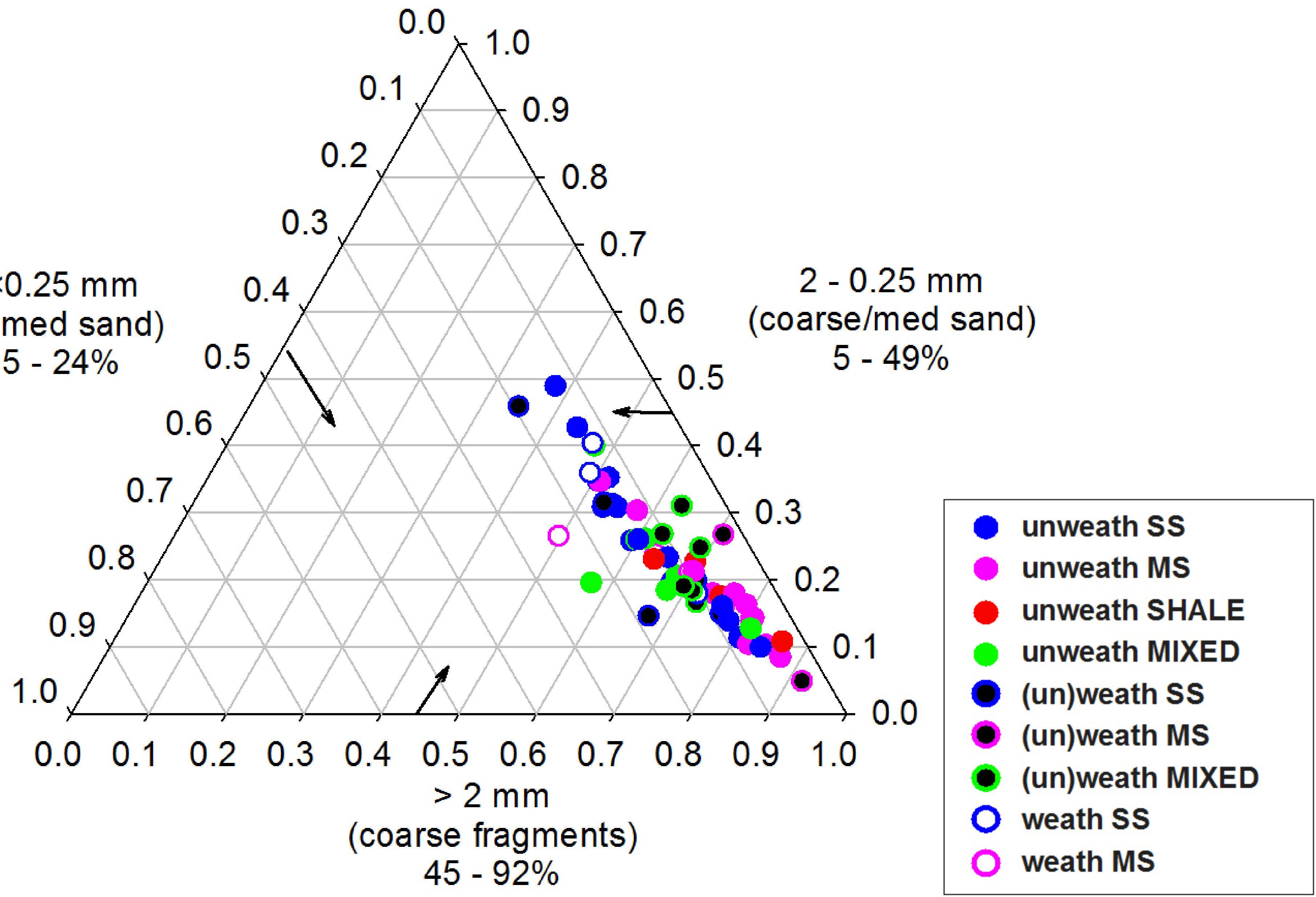
- PVC pipe nipple and Tygon tubing for drainage


EMERGENCY
FIRST AID KIT

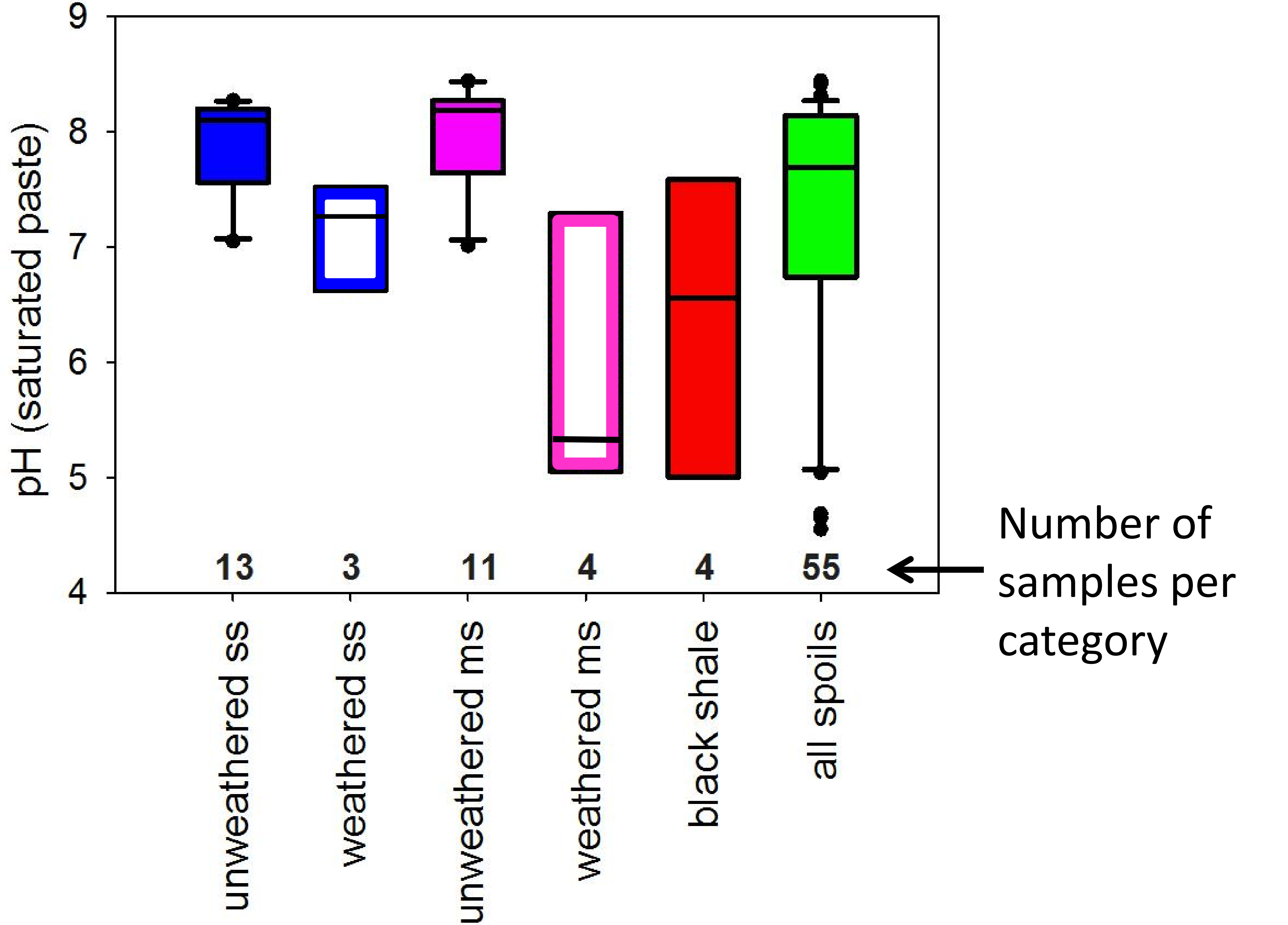
METHODS

- Each spoil material was run in triplicate (3 columns/material)
- Unsaturated: samples initially moistened to maximum water holding, then any amount added = amount drained.
- Leaching solution: synthetic acid rain with pH=4.6
  Contains very low amounts of $CaSO_4$, K_2SO_4, Mg_2SO_4, NaCl, $NaNO_3$, NH_4NO3, $(NH_4)_2SO_4$, H_2SO_4, HNO_3, H_3PO_4)
  (Recipe from Halvorson and Gentry, 1990)
- Simulated rainfall was applied 2x/week (Mon/Thurs)
- Each rainfall event = 125 ml (~2.5 cm; 1”)
- Leachate (~125 ml) collected after ~24 hrs (Tues/Fri).
- Samples analyzed for: pH, EC, cations, bicarbonate, sulfate, and chloride

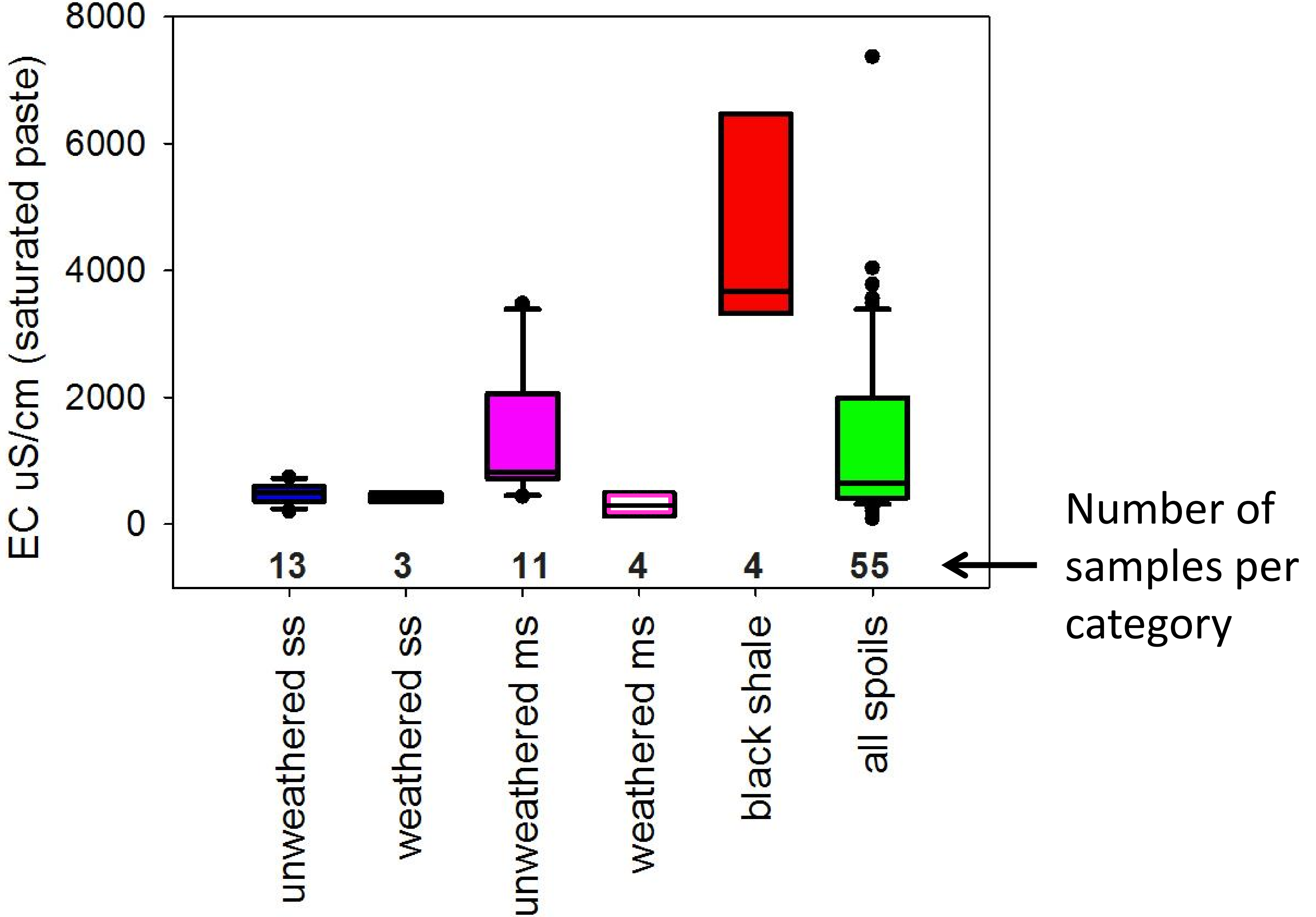
PARTICLE SIZE IN COLUMNS



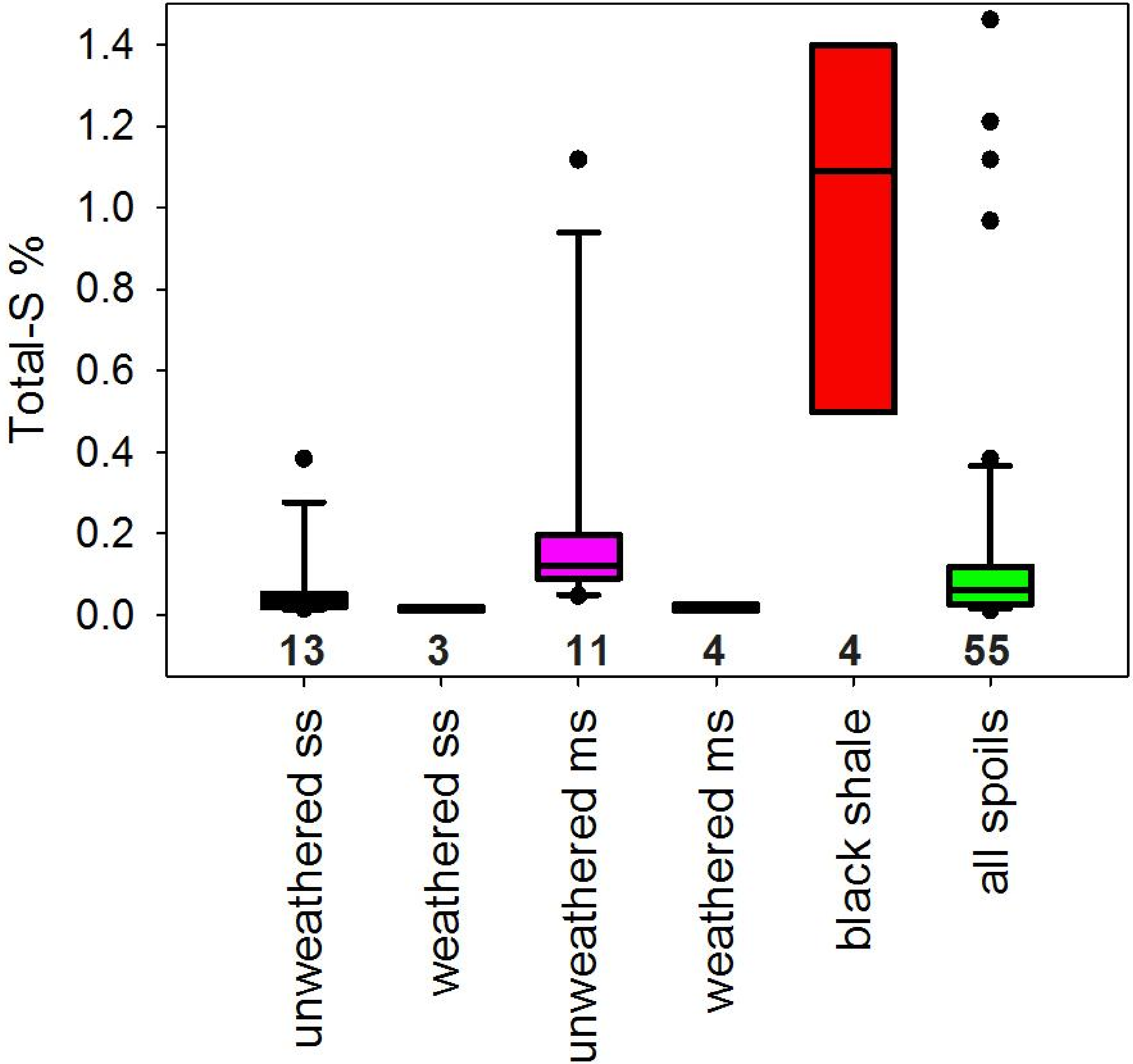
Saturated paste pH



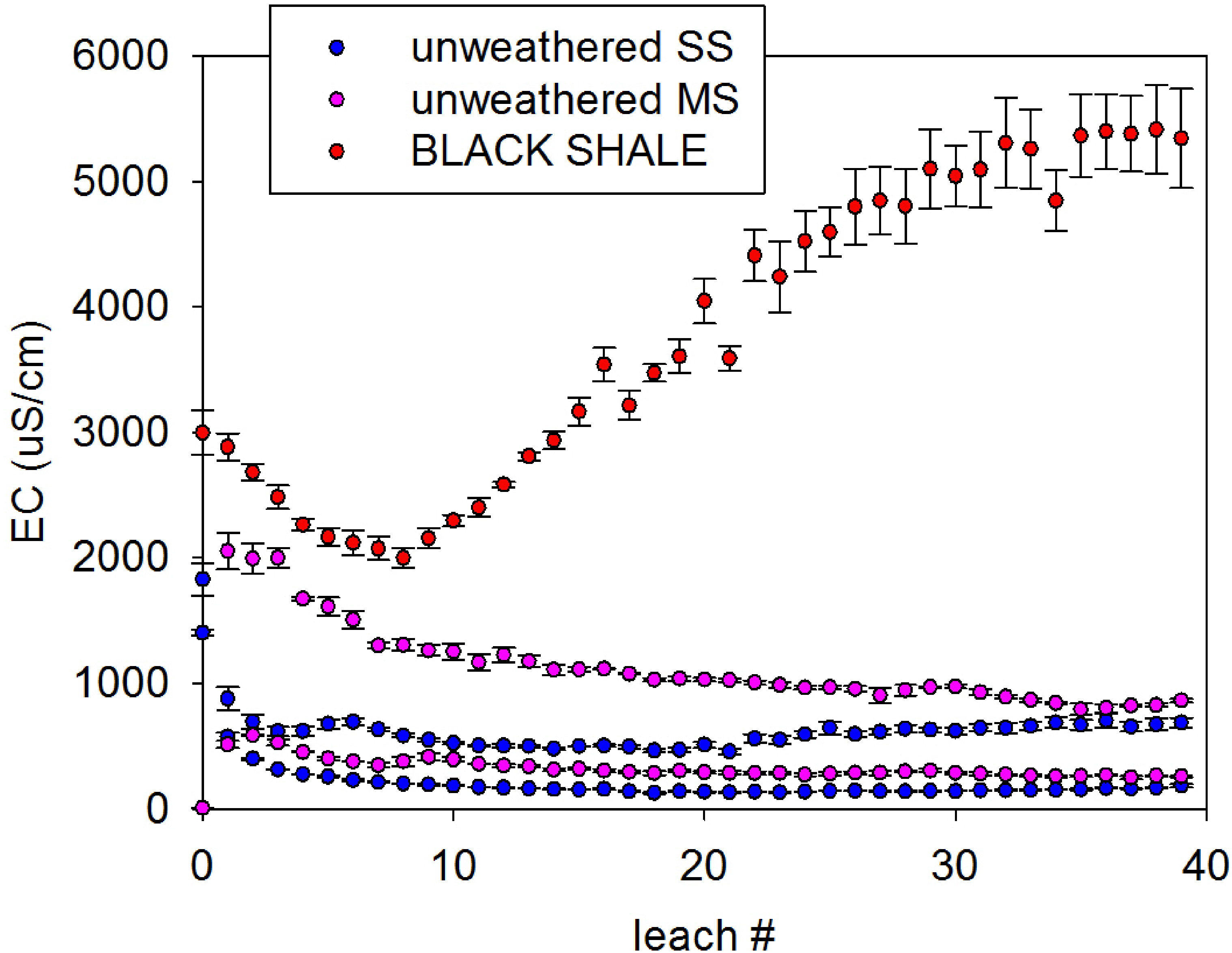
Saturated paste EC



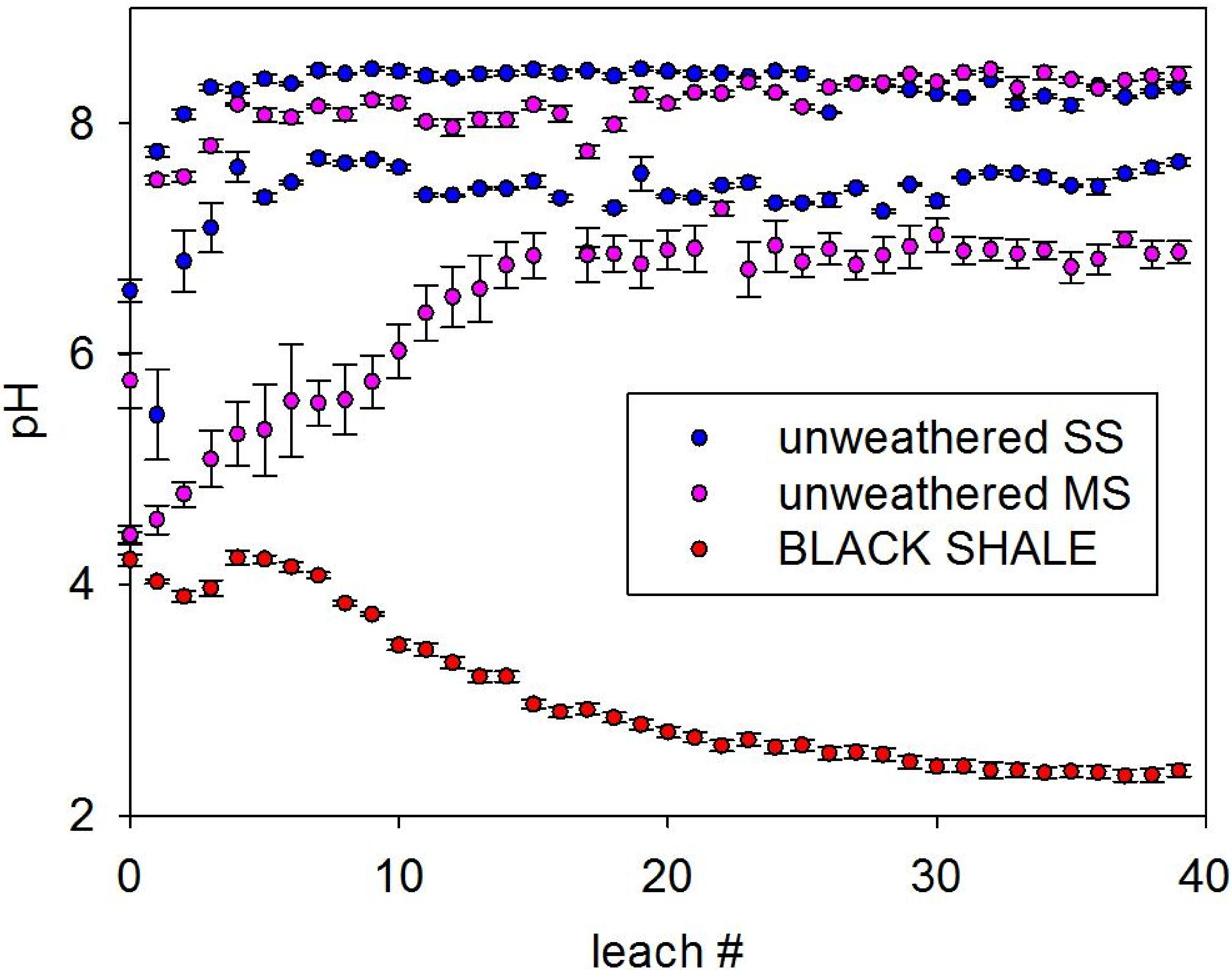
Total Sulfur



THREE REPLICATES PER MATERIAL
VERY GOOD REPLICATION

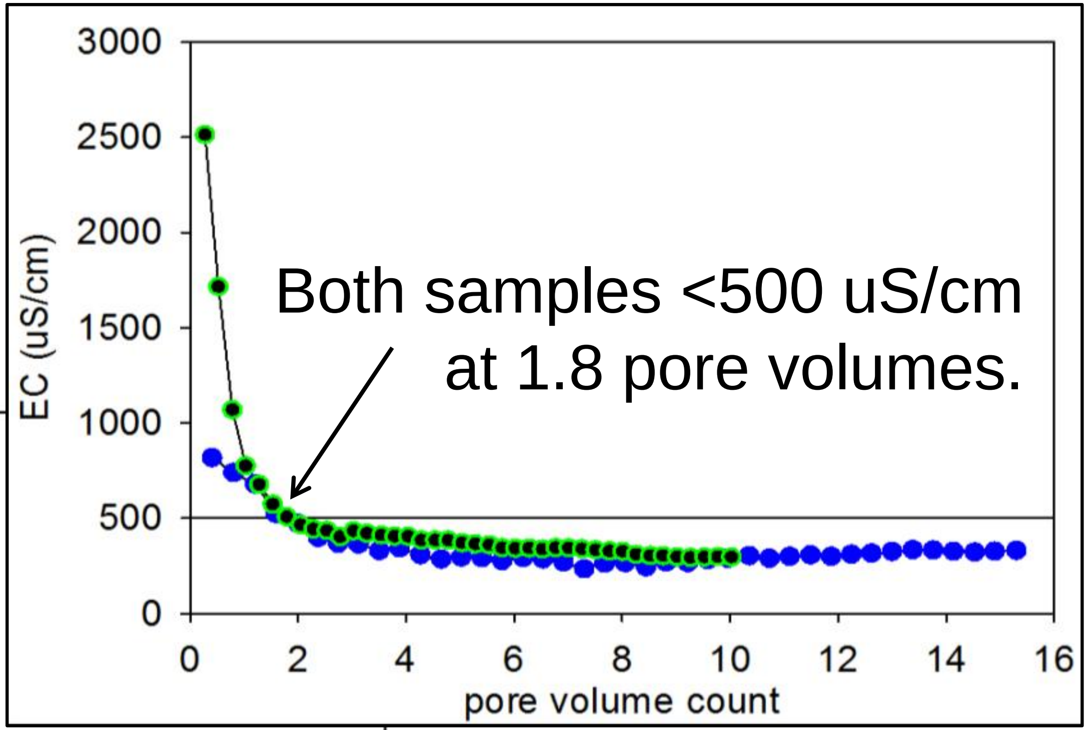


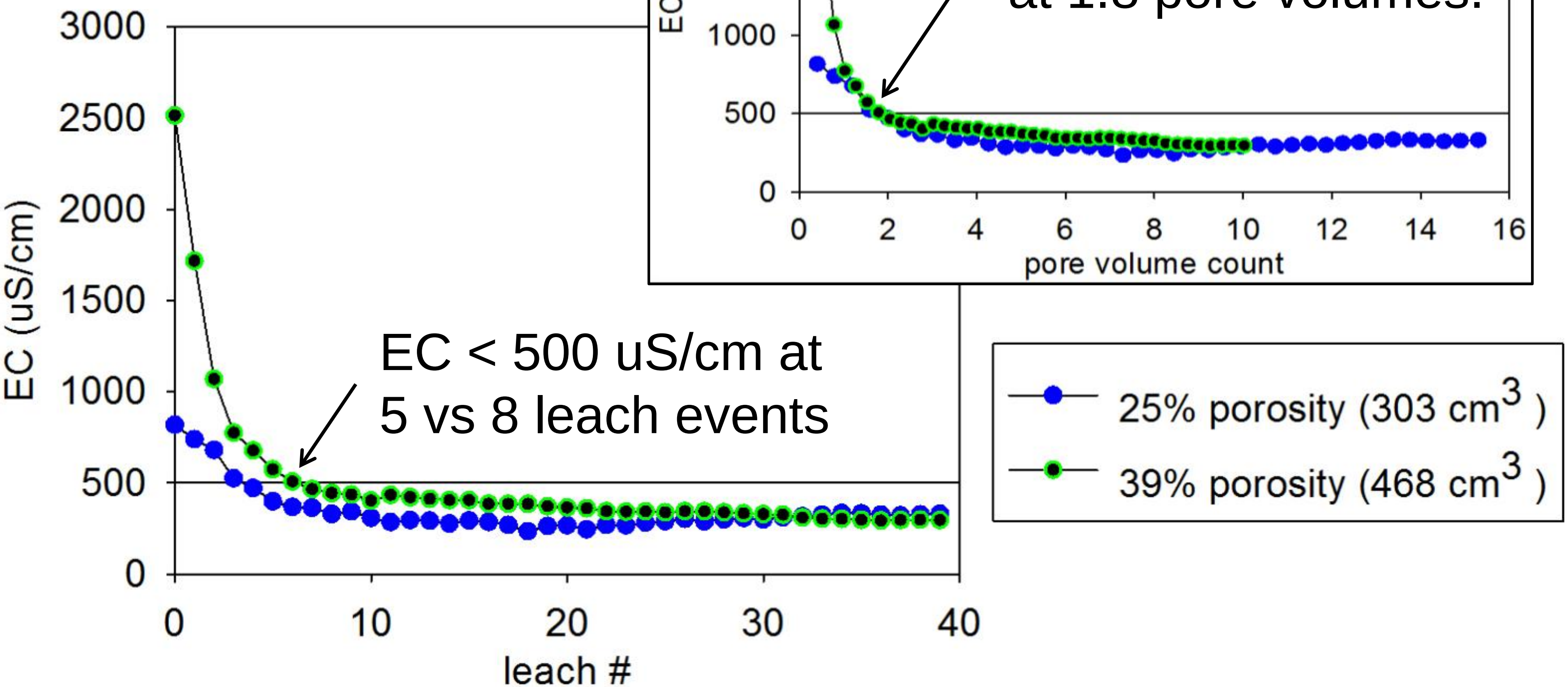
THREE REPLICATES PER SPOIL
VERY GOOD REPLICATION

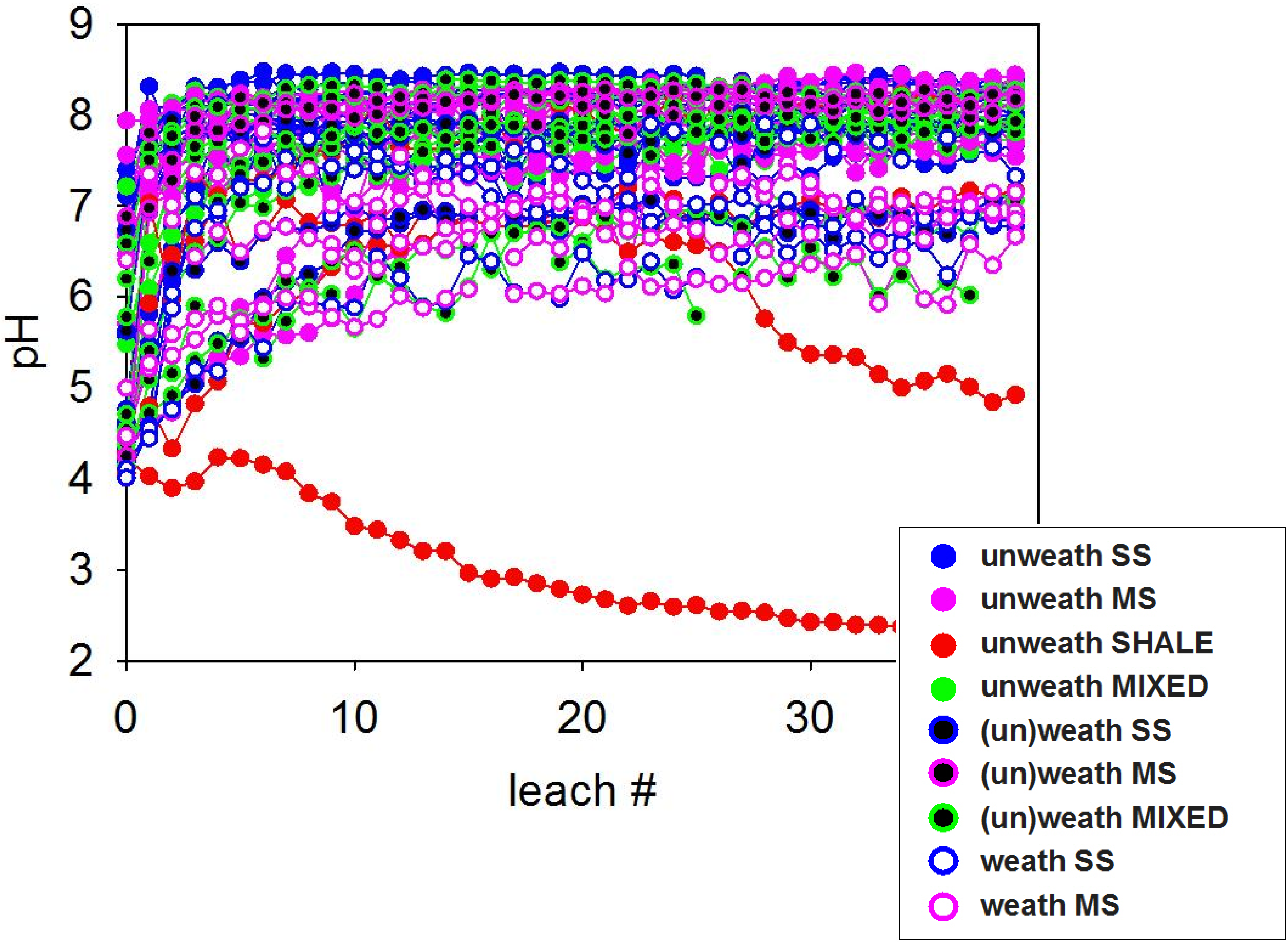


A NOTE ABOUT PORE VOLUMES

Most samples had porosity between 25 – 45%.

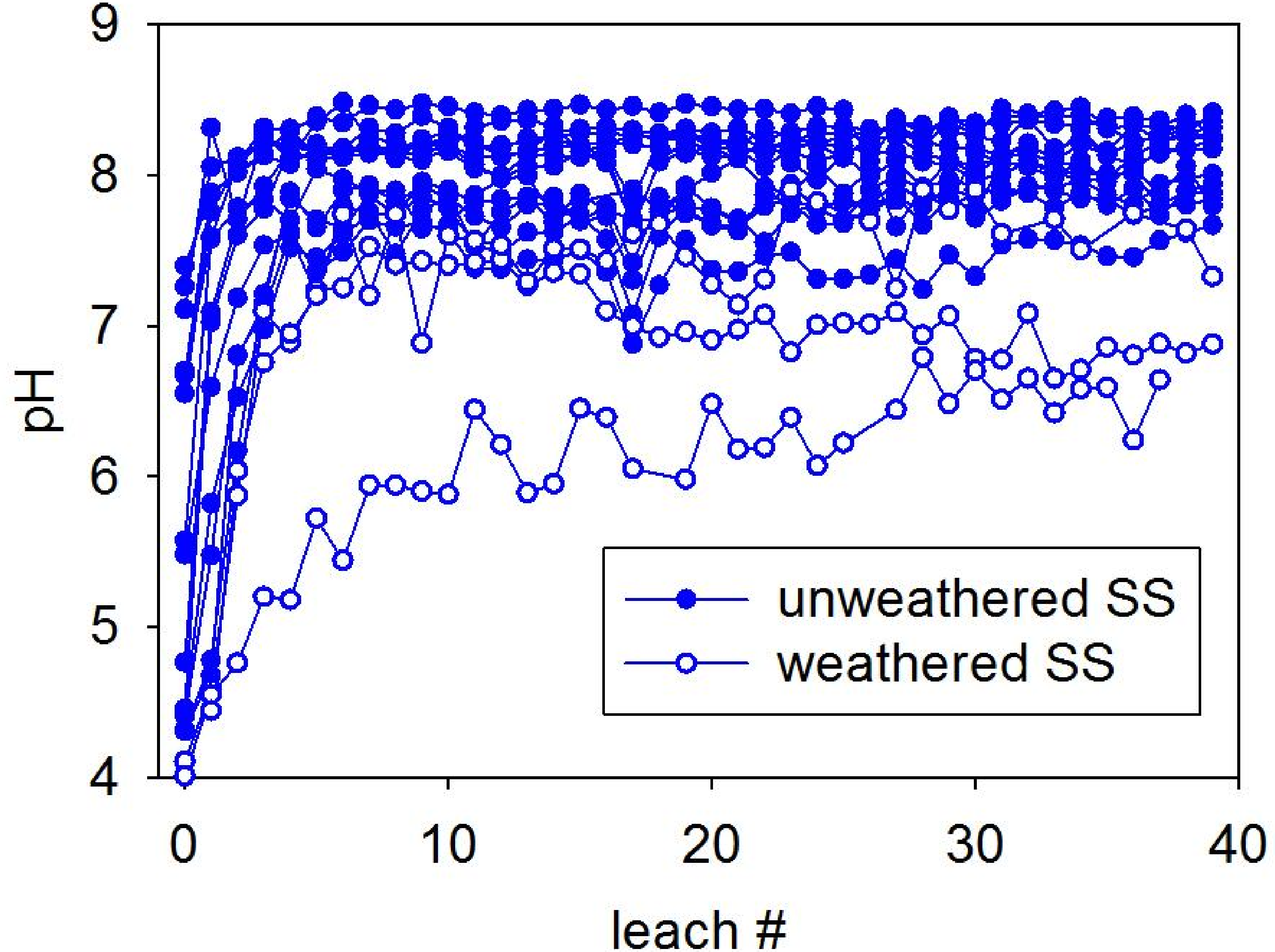




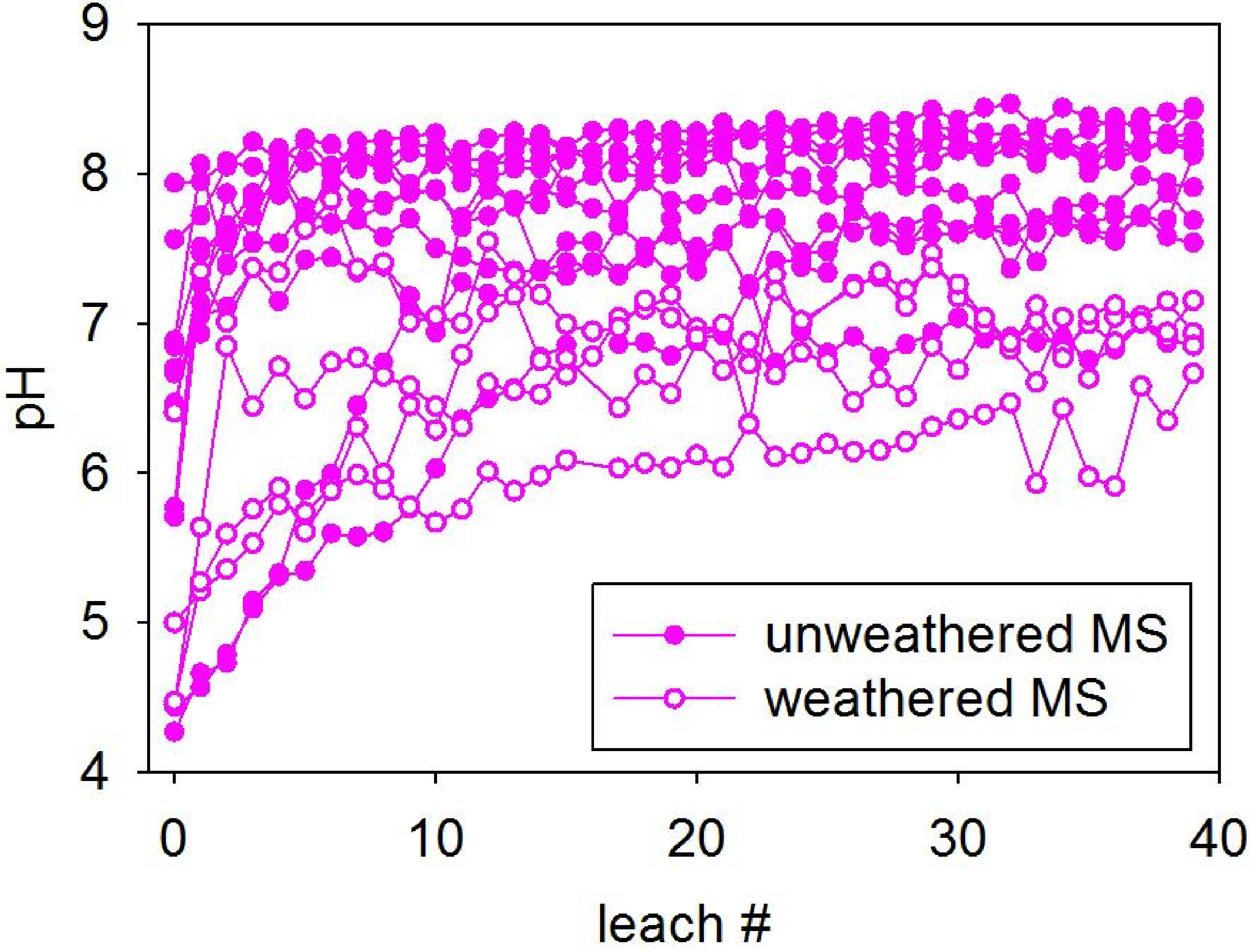


pH
9
8
7
6
5
4
3
2
0
10
20
30
leach #
unweath SS
unweath MS
unweath SHALE
unweath MIXED
(un)weath SS
(un)weath MS
(un)weath MIXED
weath SS
weath MS

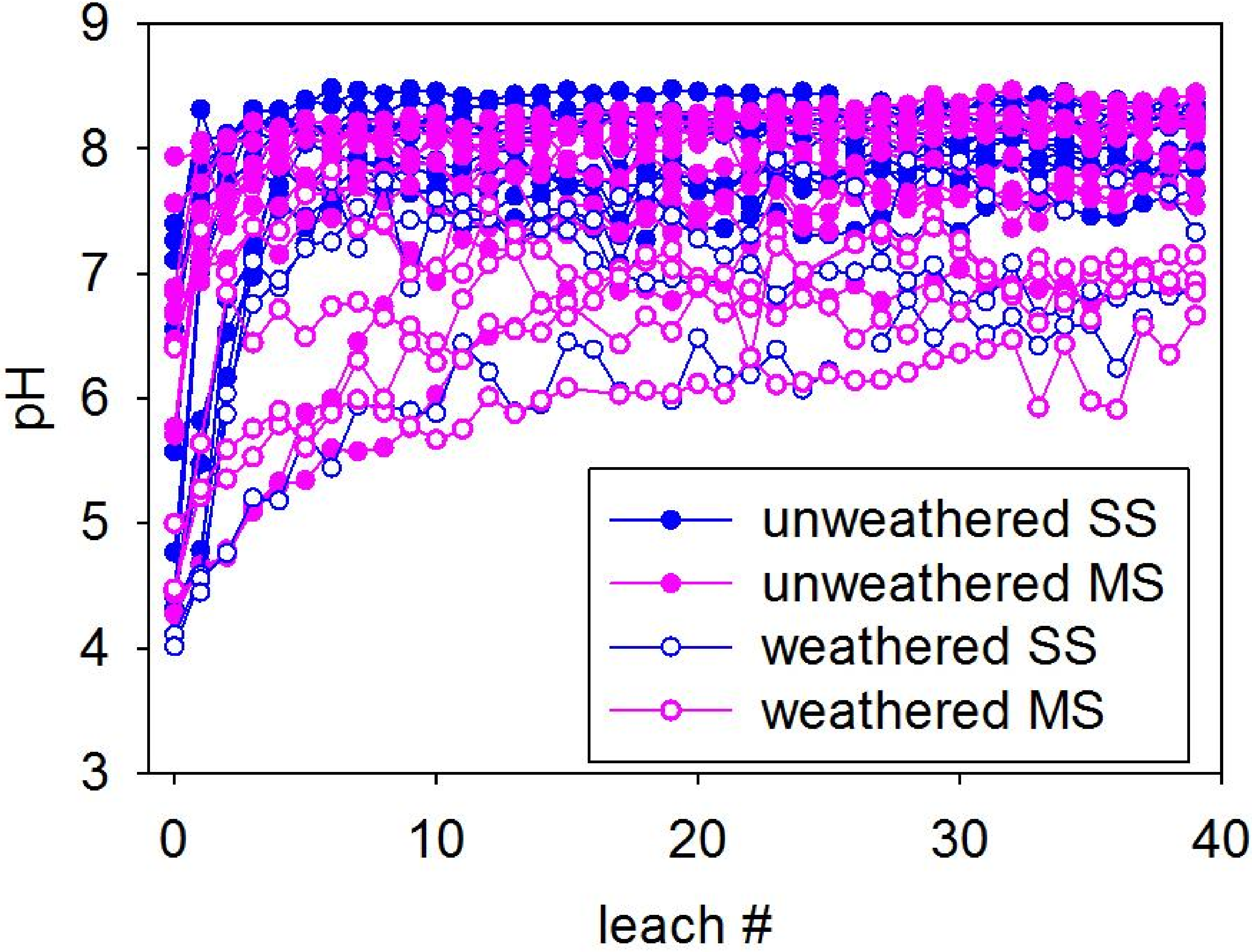
SANDSTONE: Weathered spoils tend to equilibrate at lower pH values than unweathered spoils.



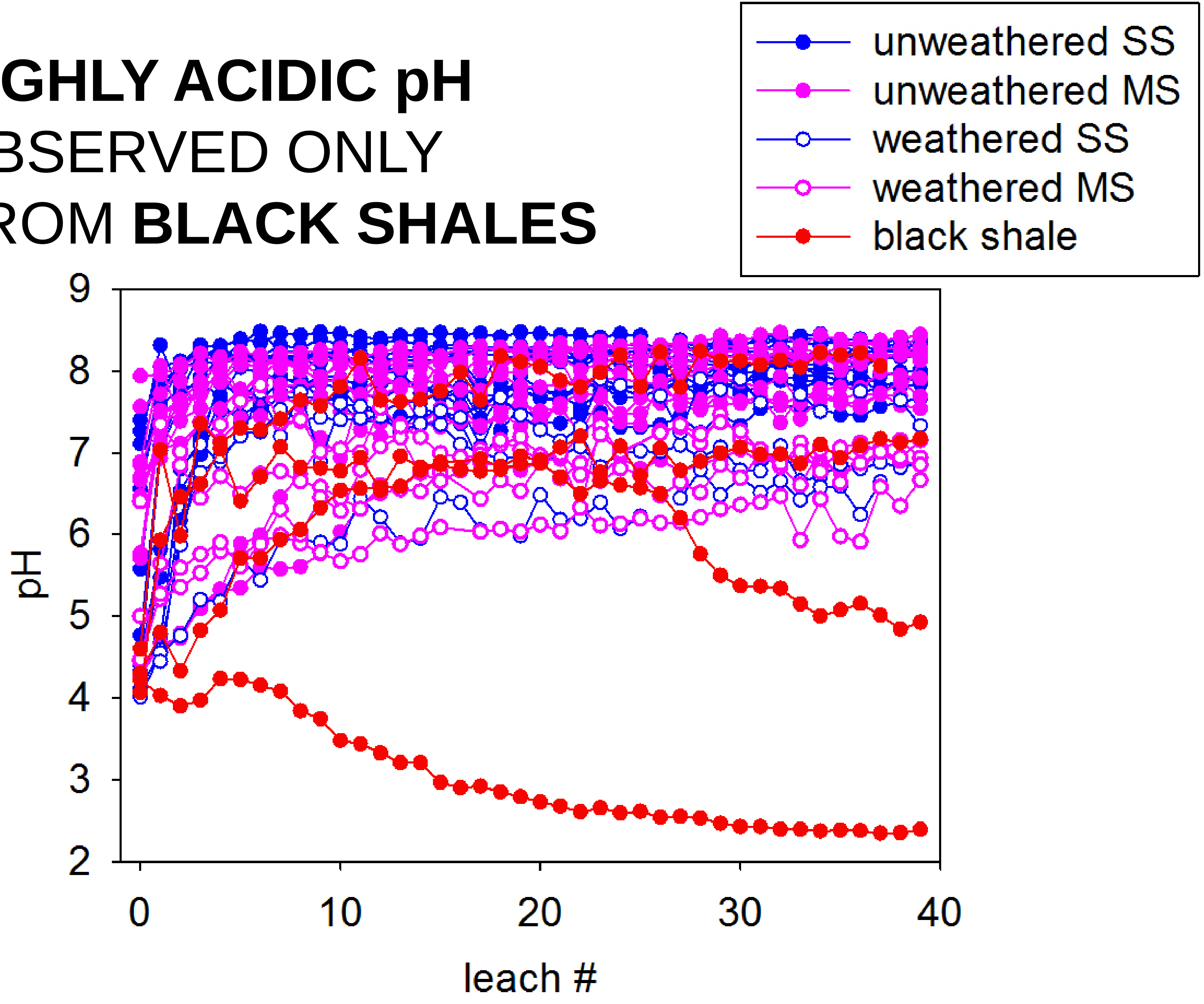
MUDSTONE: Weathered spoils tend to equilibrate at lower pH values than unweathered spoils.

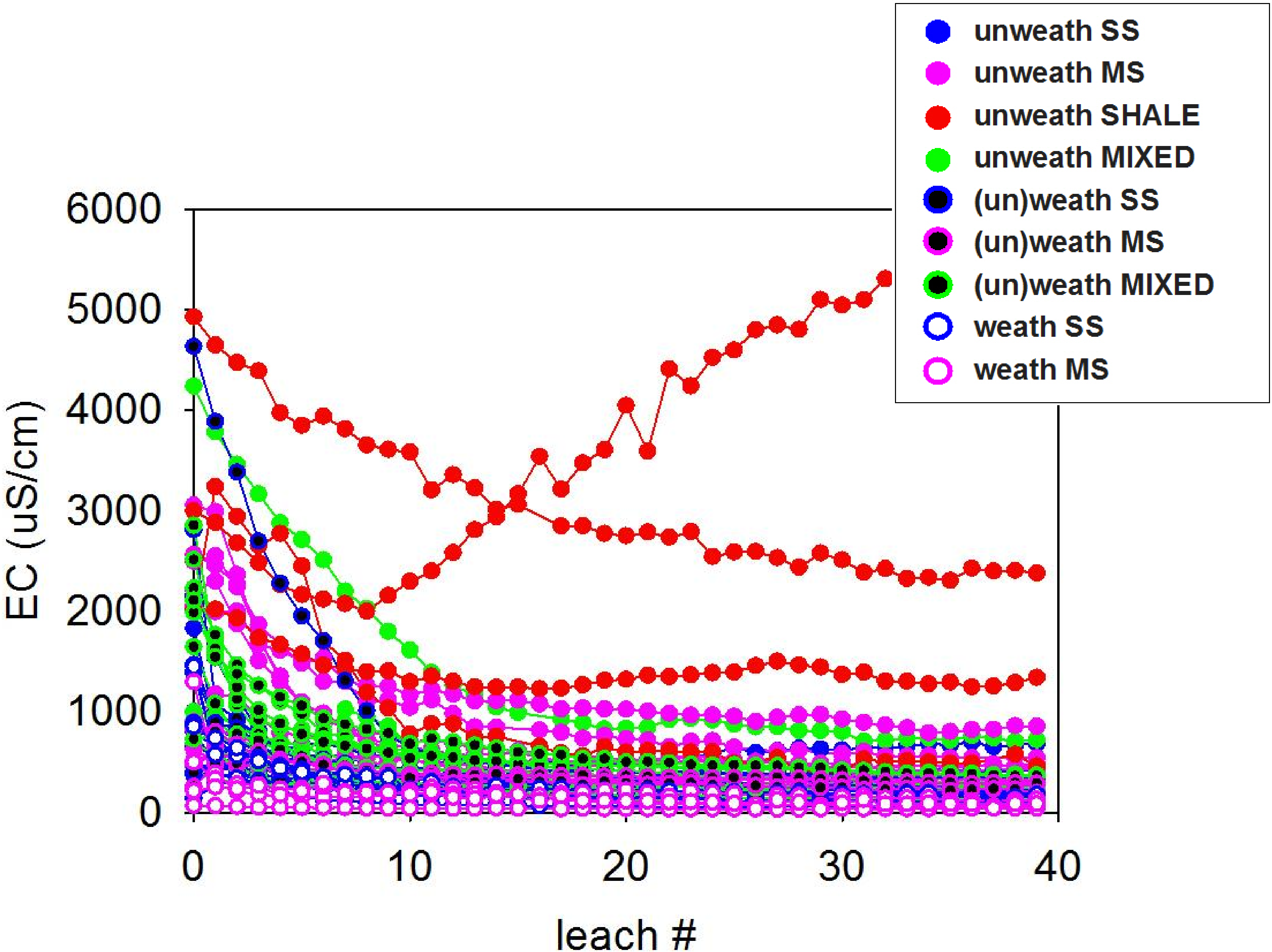


OVERALL NO MAJOR pH DIFFERENCES BETWEEN SANDSTONES AND MUDSTONES



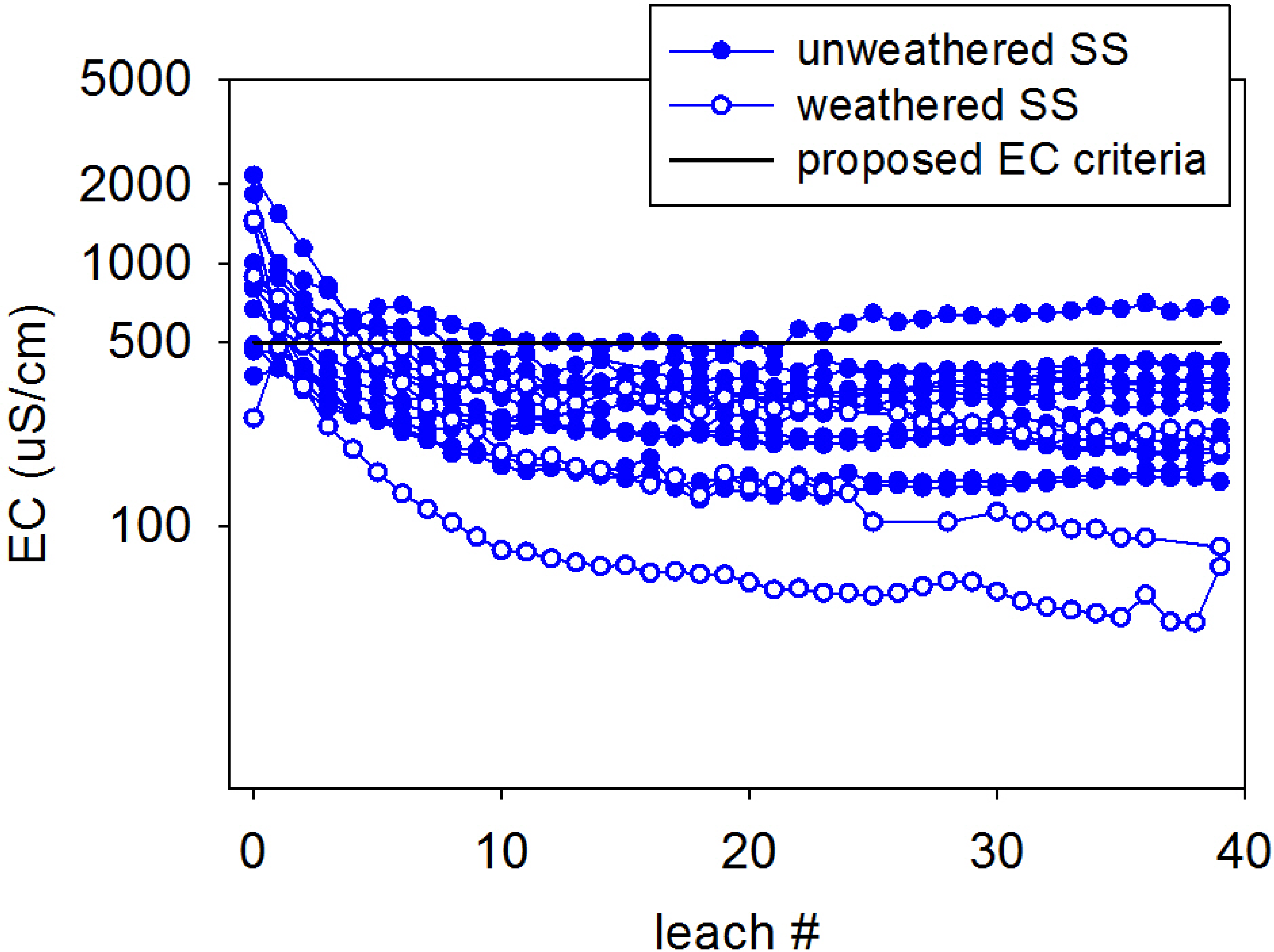
HIGHLY ACIDIC pH OBSERVED ONLY FROM **BLACK SHALES**



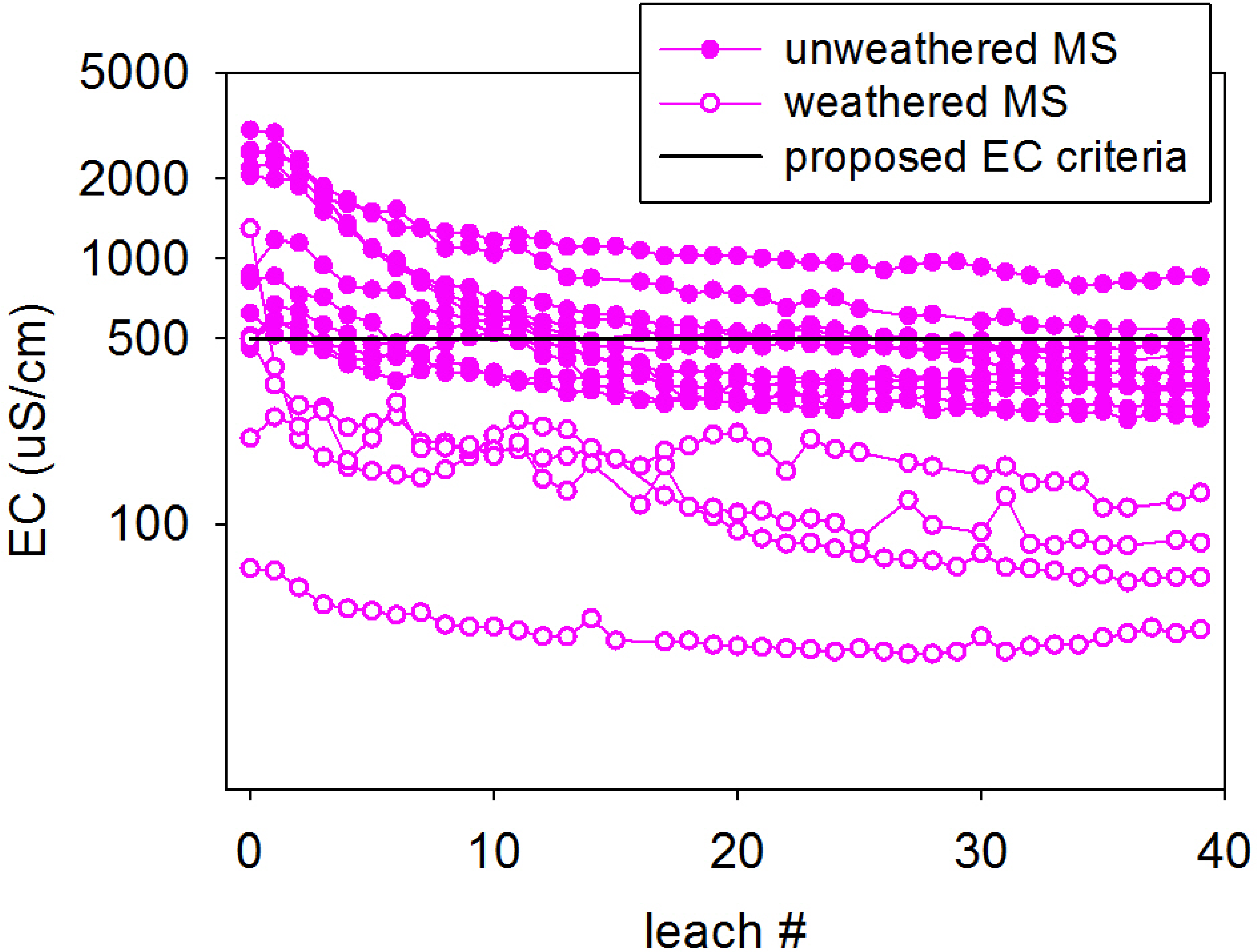


unweath SS
unweath MS
unweath SHALE
unweath MIXED
(un)weath SS
(un)weath MS
(un)weath MIXED
weath SS
weath MS
EC (uS/cm)
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
leach #

SANDSTONE: All weathered and most unweathered samples equilibrated to <500 uS/cm.

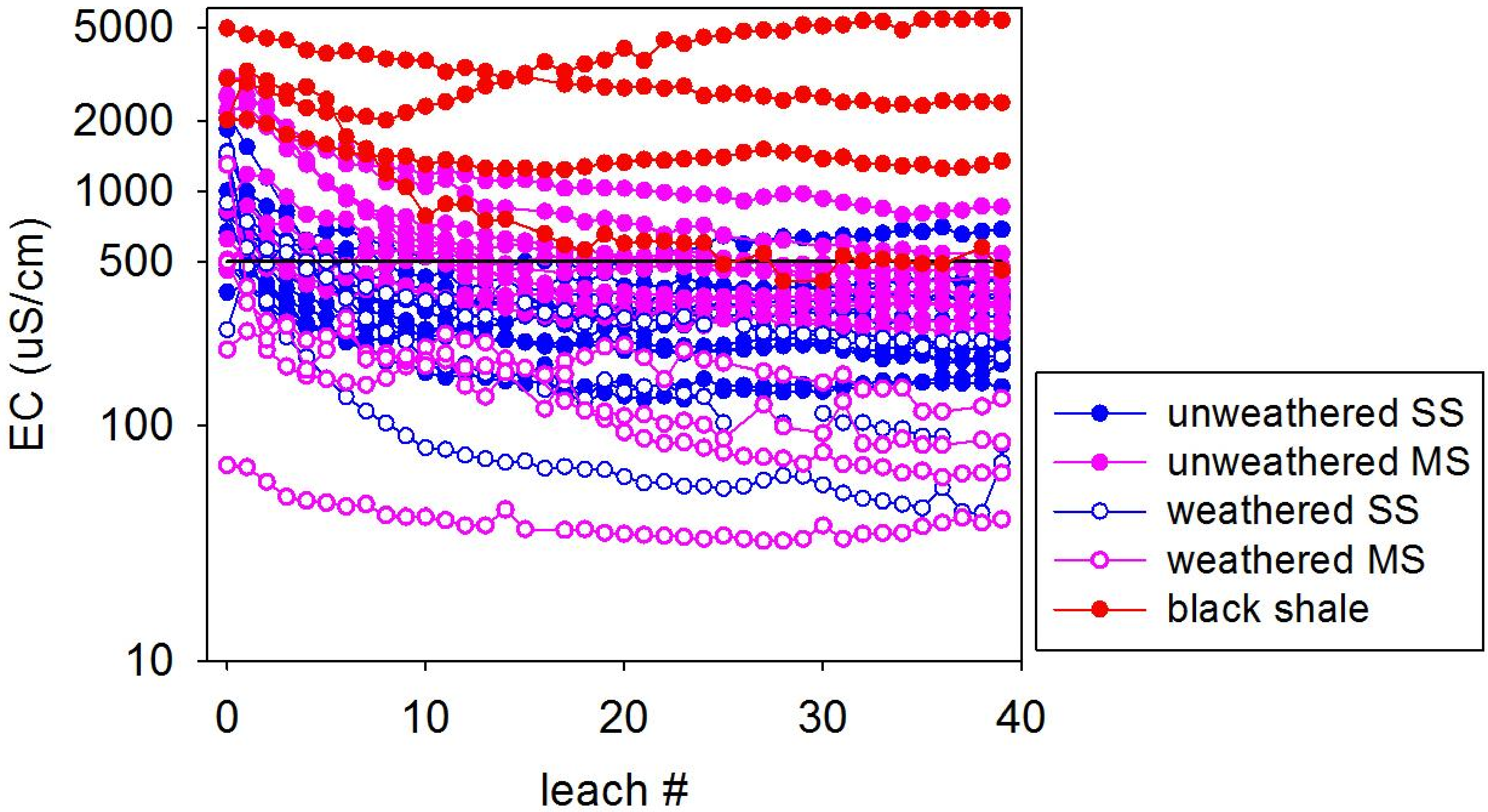


MUDSTONE: All weathered and several unweathered samples equilibrated to <500 uS/cm.

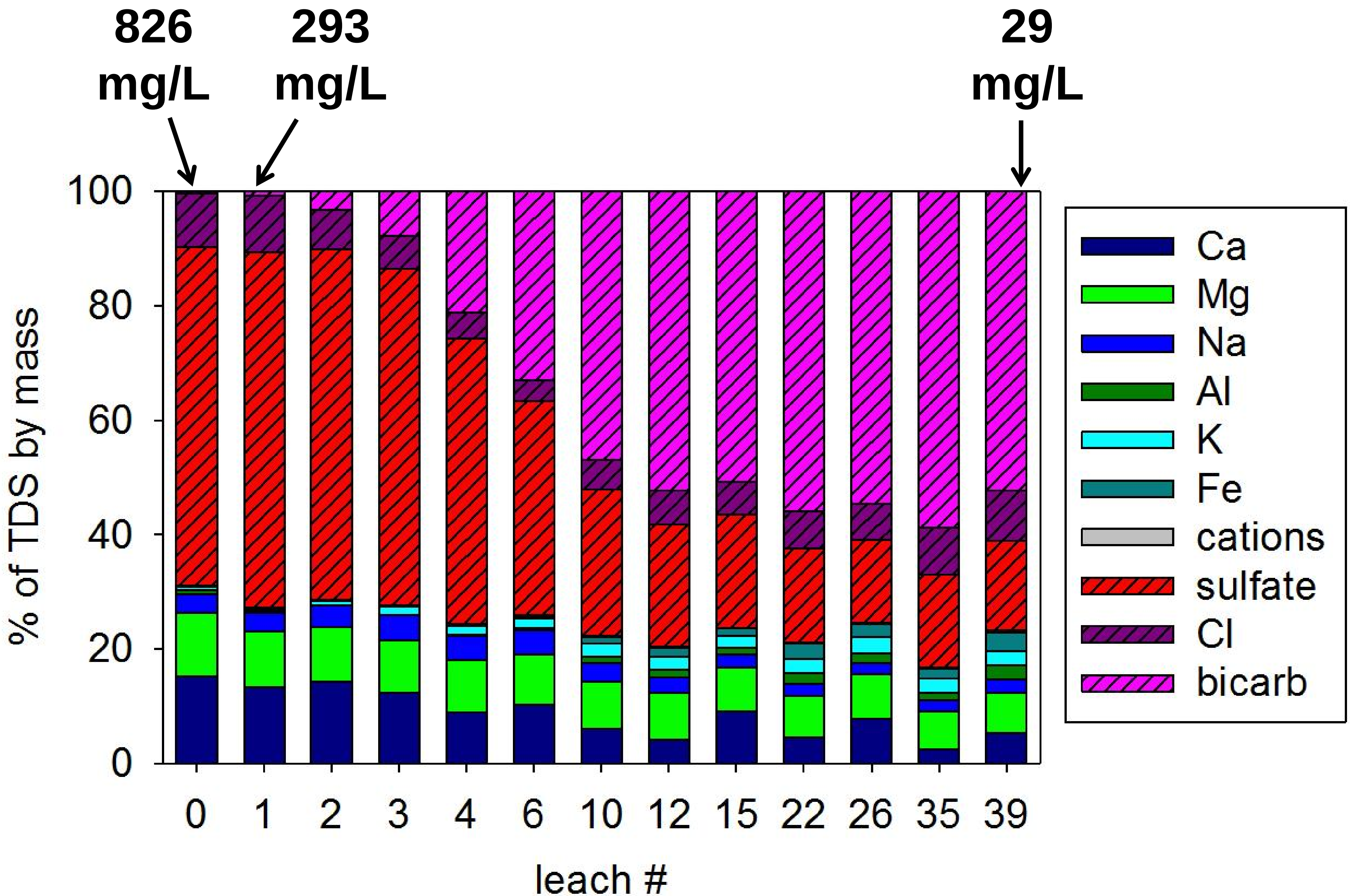


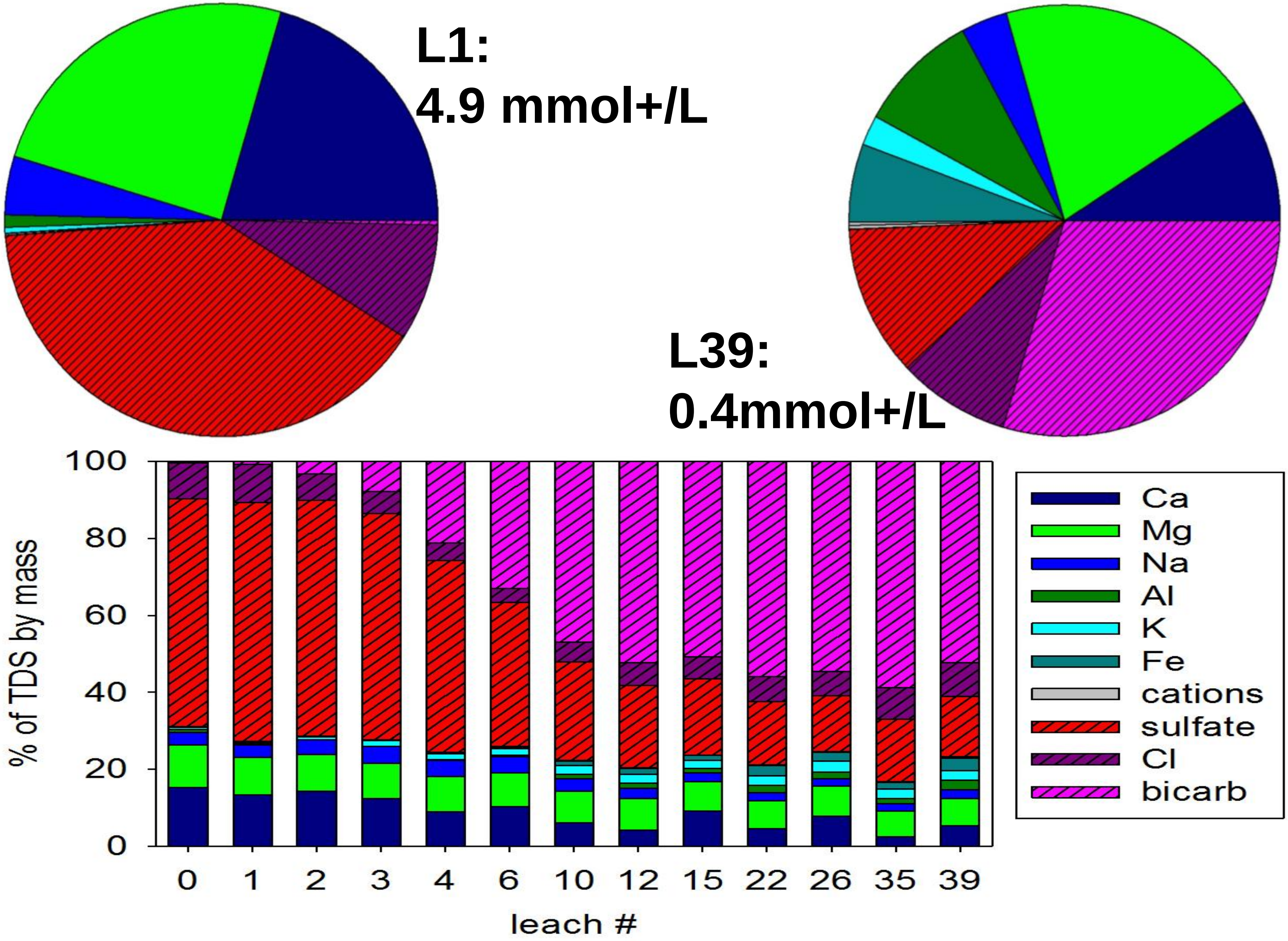
Overall: finer grain size = higher EC/greater TDS.

Only one BLACK SHALE equilibrated ~500 uS/cm

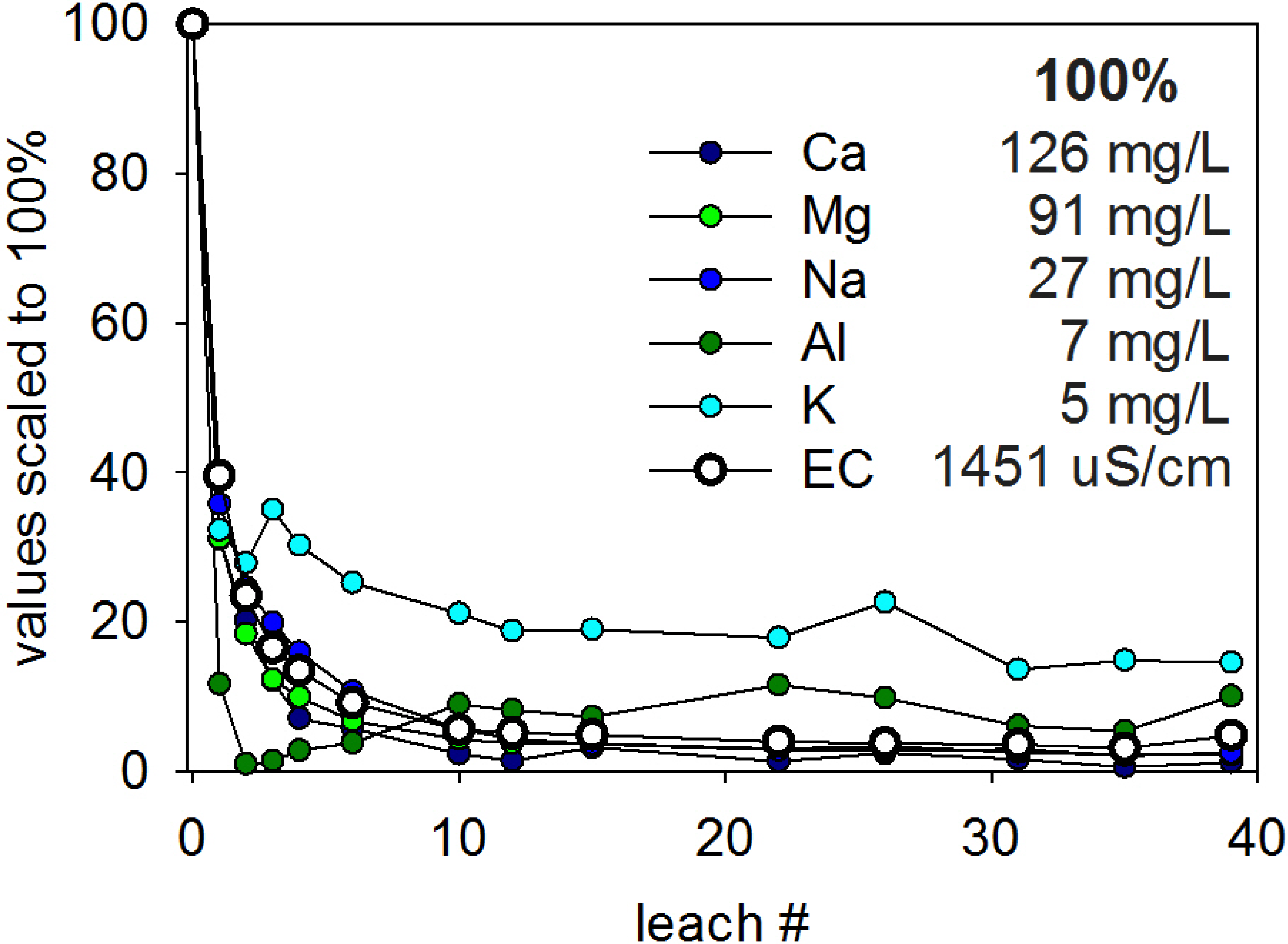


TDS ELEMENTAL COMPOSITION: weathered SS

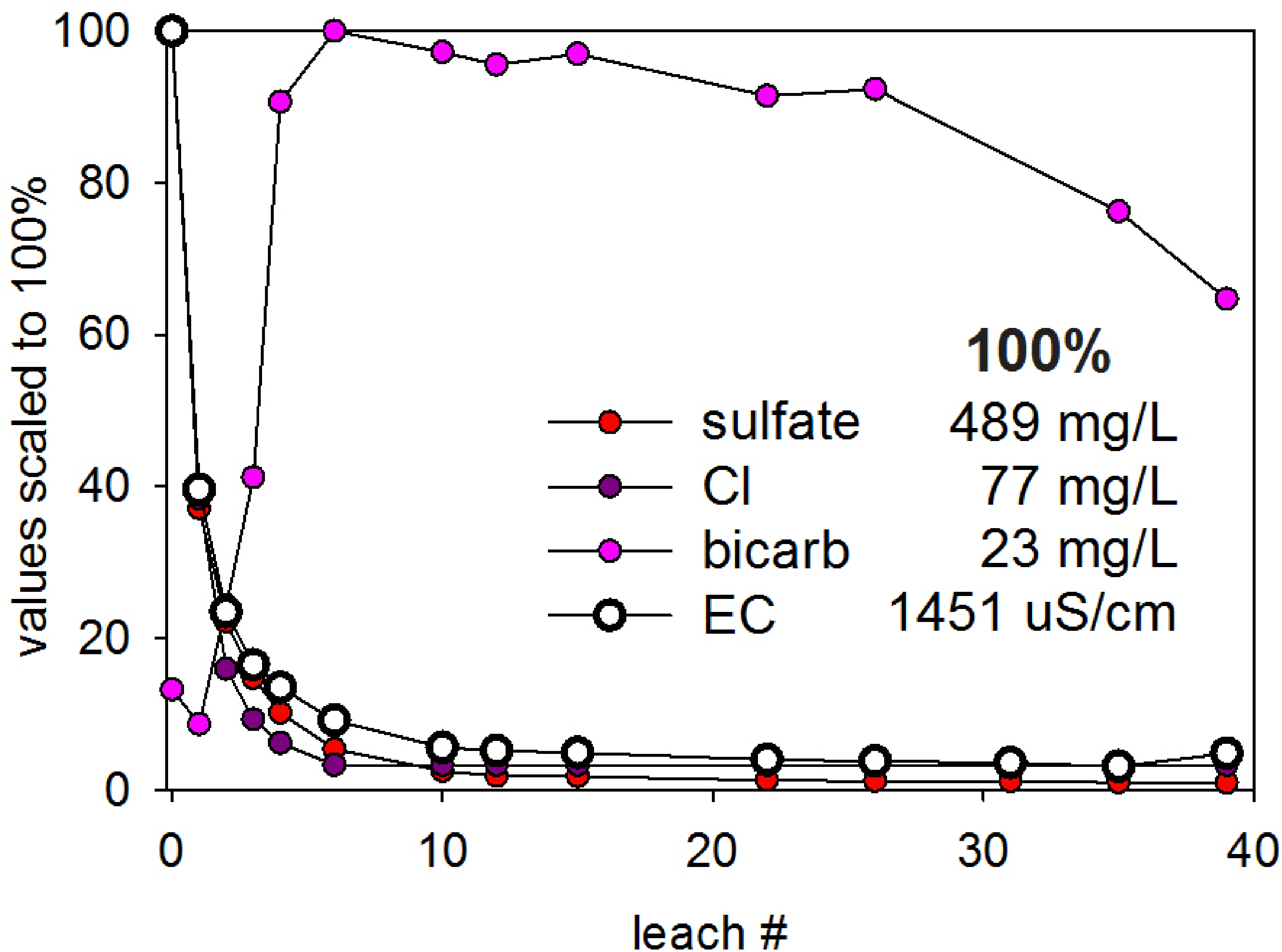



L1:
4.9 mmol+/L
L39:
0.4mmol+/L
% of TDS by mass
100
80
60
40
20
0
0
1
2
3
4
6
10
12
15
22
26
35
39
leach #
Ca
Mg
Na
Al
K
Fe
cations
sulfate
Cl
bicarb

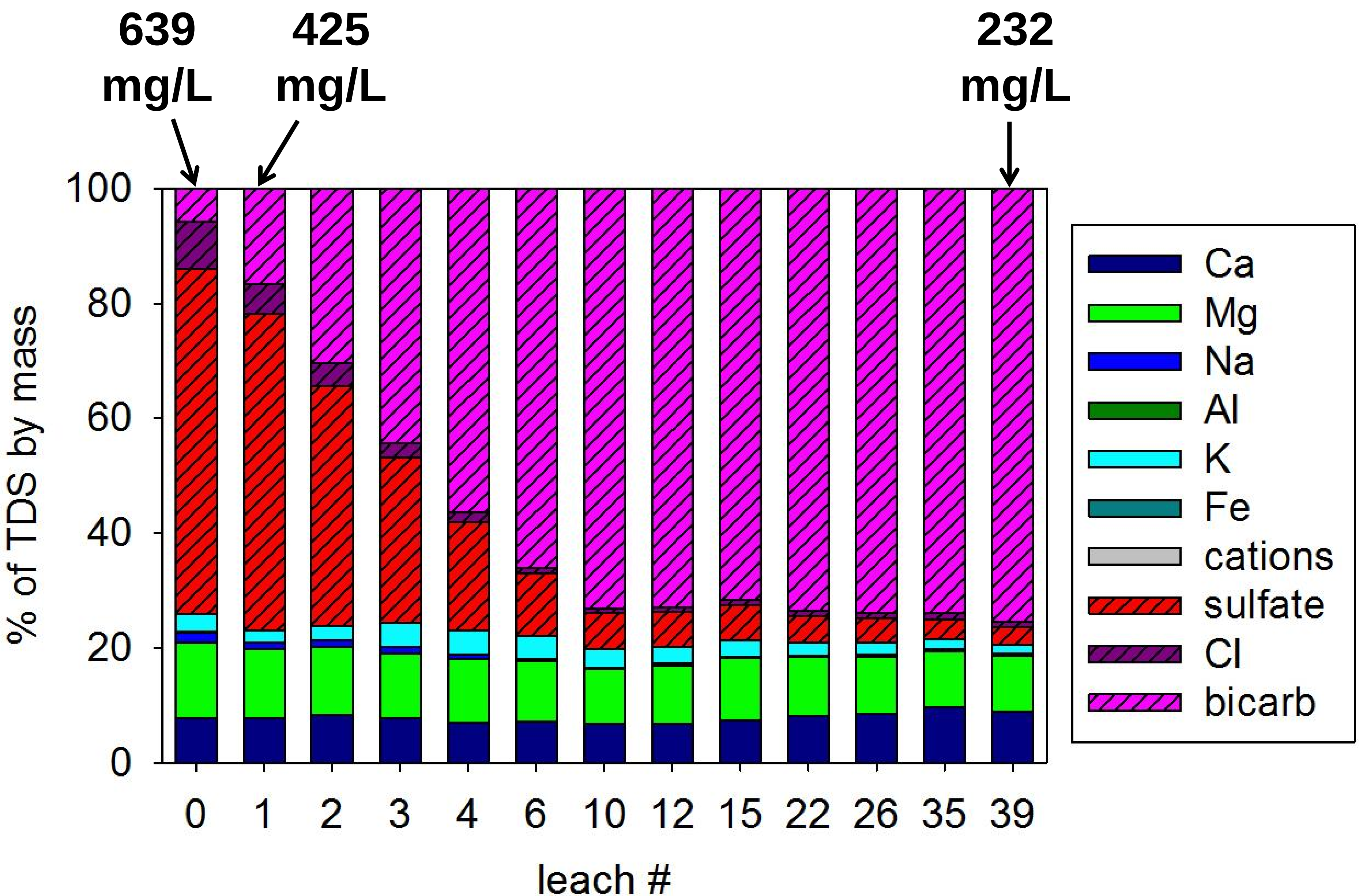
TDS RELATIVE ELUTION OVER TIME: MAJOR CATIONS
weathered SS



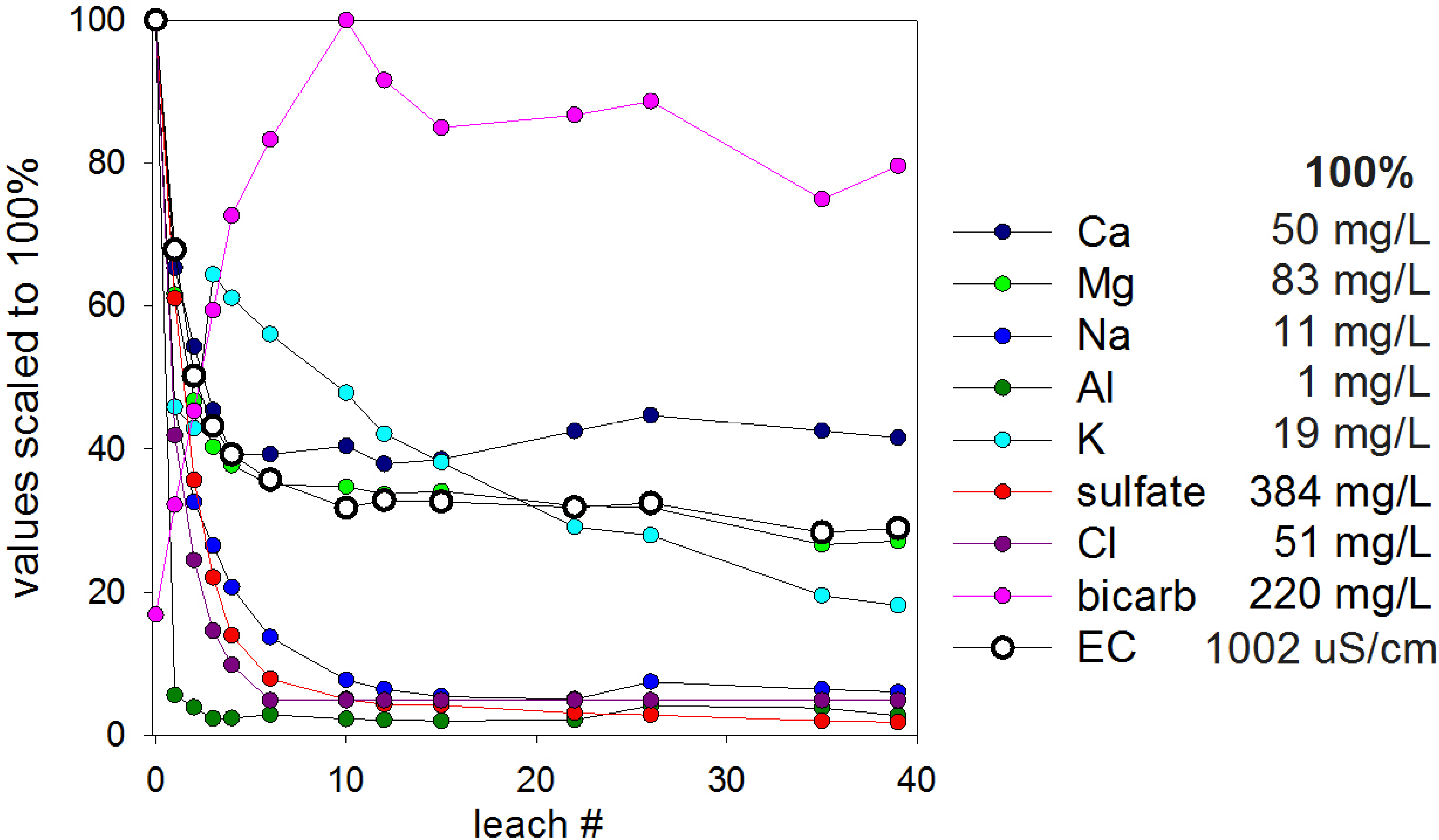
TDS RELATIVE ELUTION OVER TIME: MAJOR ANIONS
weathered SS



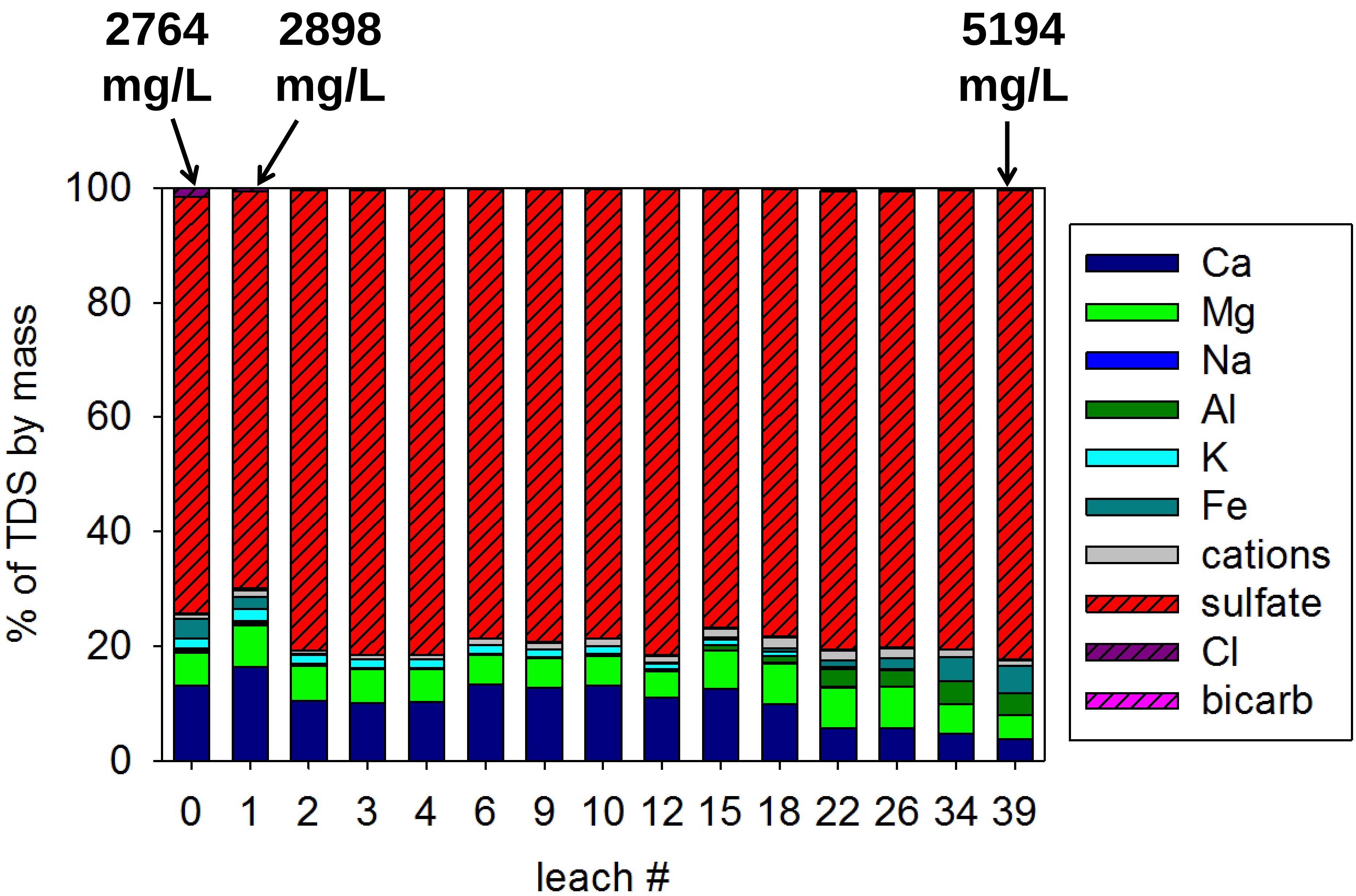
TDS ELEMENTAL COMPOSITION: unweathered SS



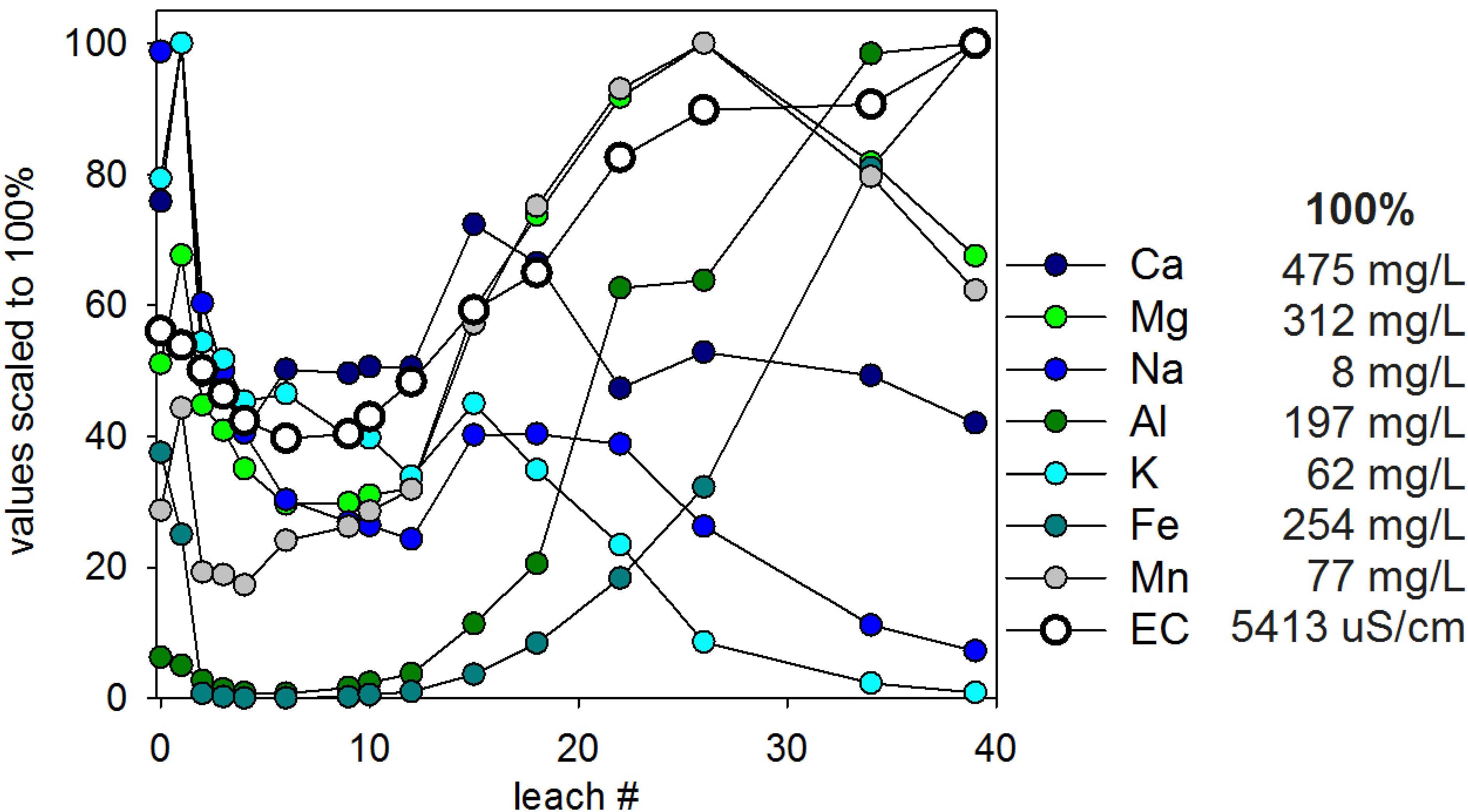
TDS RELATIVE ELUTION OVER TIME - MAJOR IONS
unweathered SS



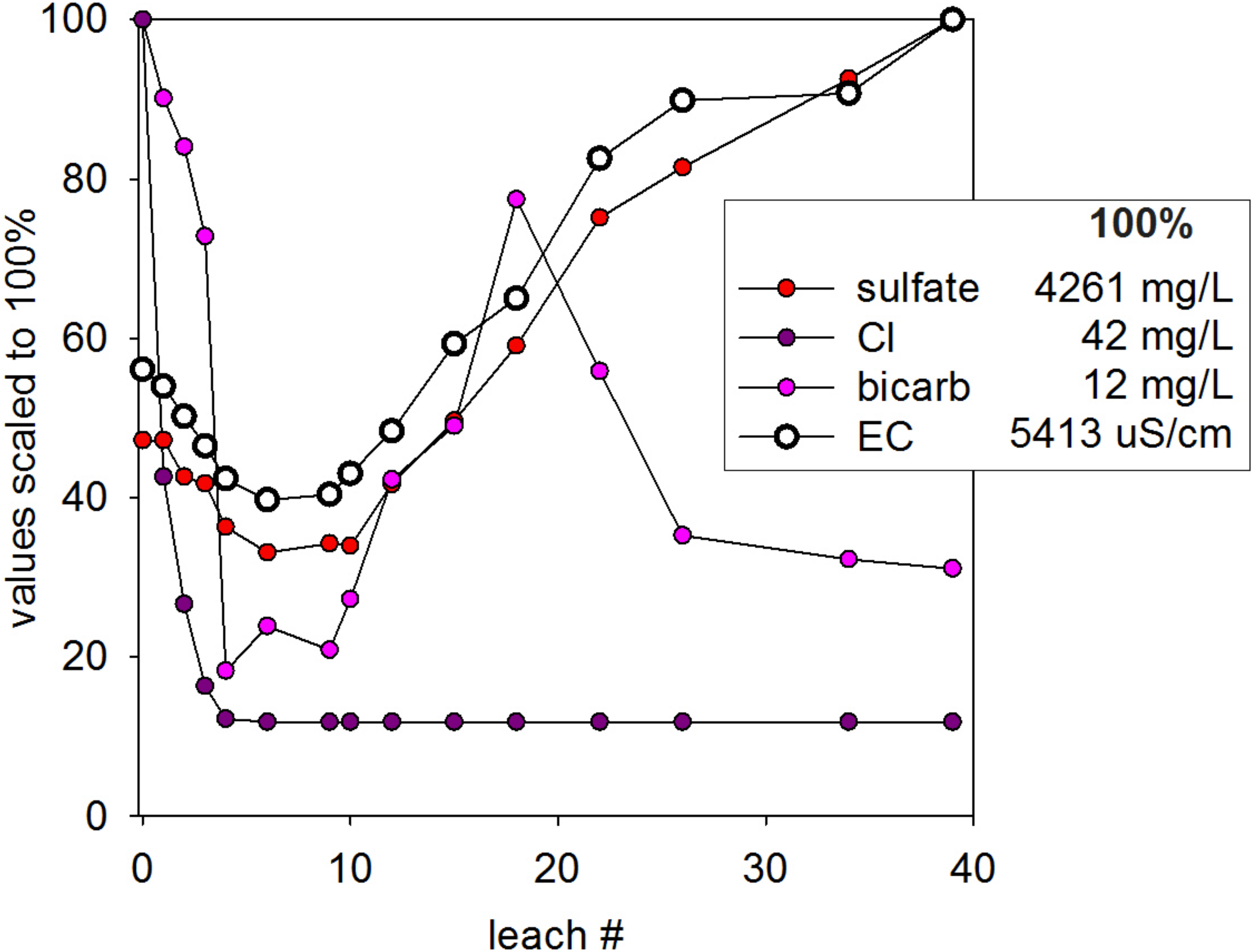
TDS ELEMENTAL COMPOSITION: Black Shale



TDS RELATIVE ELUTION OVER TIME – MAJOR CATIONS
Black Shale



TDS RELATIVE ELUTION OVER TIME - ANIONS
Black Shale



Summary

- TDS elution is directly related to the source strata and extent of historic weathering and oxidation.
- TDS elution appears to increase with decreasing grain size; black shales are the most problematic materials.
- Well-weathered materials typically do not appear to be problematic.

Summary

- For most samples, TDS elution was highest in the first few leach cycles, then dropped rapidly and showed little change after 10 – 15 leach cycles (about 2.5 – 5 pore volumes).

- 48 out of 55 samples evaluated in this study equilibrated to EC < 500 uS/cm.

Summary

- **Elemental cation composition was dominated by Ca and Mg, with lesser amounts of Al, K, Na and Fe.**

- **Elemental anion composition was dominated by sulfate and bicarbonate, with lesser amounts of chloride. For several samples, sulfate was initially dominant, but over time bicarbonate became the dominant anion.**

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