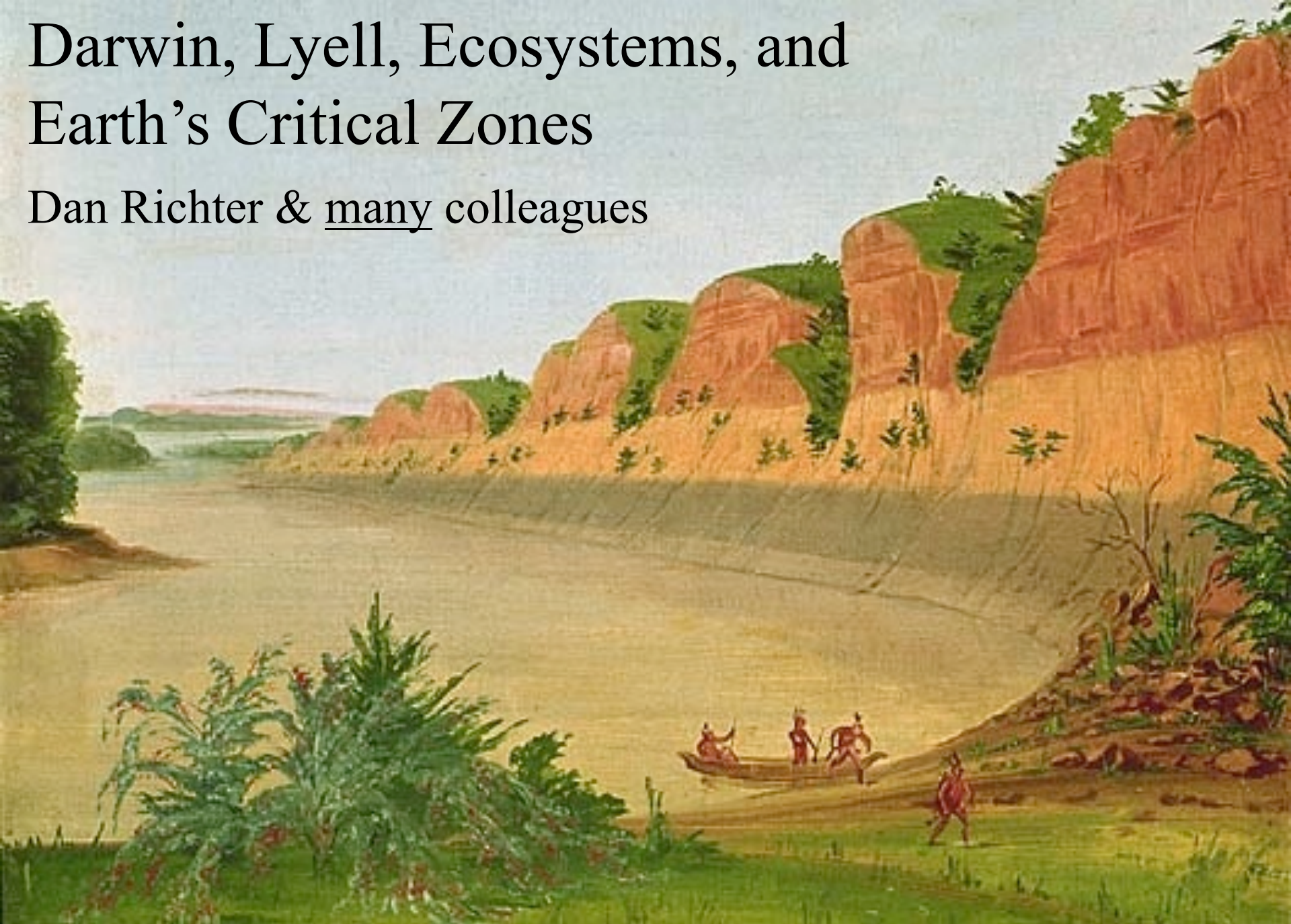


# Darwin, Lyell, Ecosystems, and Earth's Critical Zones

Dan Richter & many colleagues



*Southside of the Missouri River, George Catlin, 1832*

*“...the overlapping of the real world”*

There are not many differences more significant than that between thinking in discrete, defined class concepts and that of thinking in terms of continuity; of the shading of everything into something else, of the overlapping of essences, so that the notion of species comes to seem not applicable to fluency, the universal overlapping of the real world.

A.O. Lovejoy (1936)

## Generic thesis-

In the Anthropocene, while we need disciplines & sub-disciplines to grow scientific specialization, more staples on the scientific menu should be projects motivated by the overlapping of disciplines.

*We have so much to teach & learn from each other!*

## *Objectives of SEFOP2018—*

*Celebrate the collaboration that is the Friends of the Pleistocene movement!!! since 1934!!!*

*Celebrate the new 21<sup>st</sup> century science known as critical zone science, especially with its overlapping & collaboration of disciplines, its biogeoscientific approach*



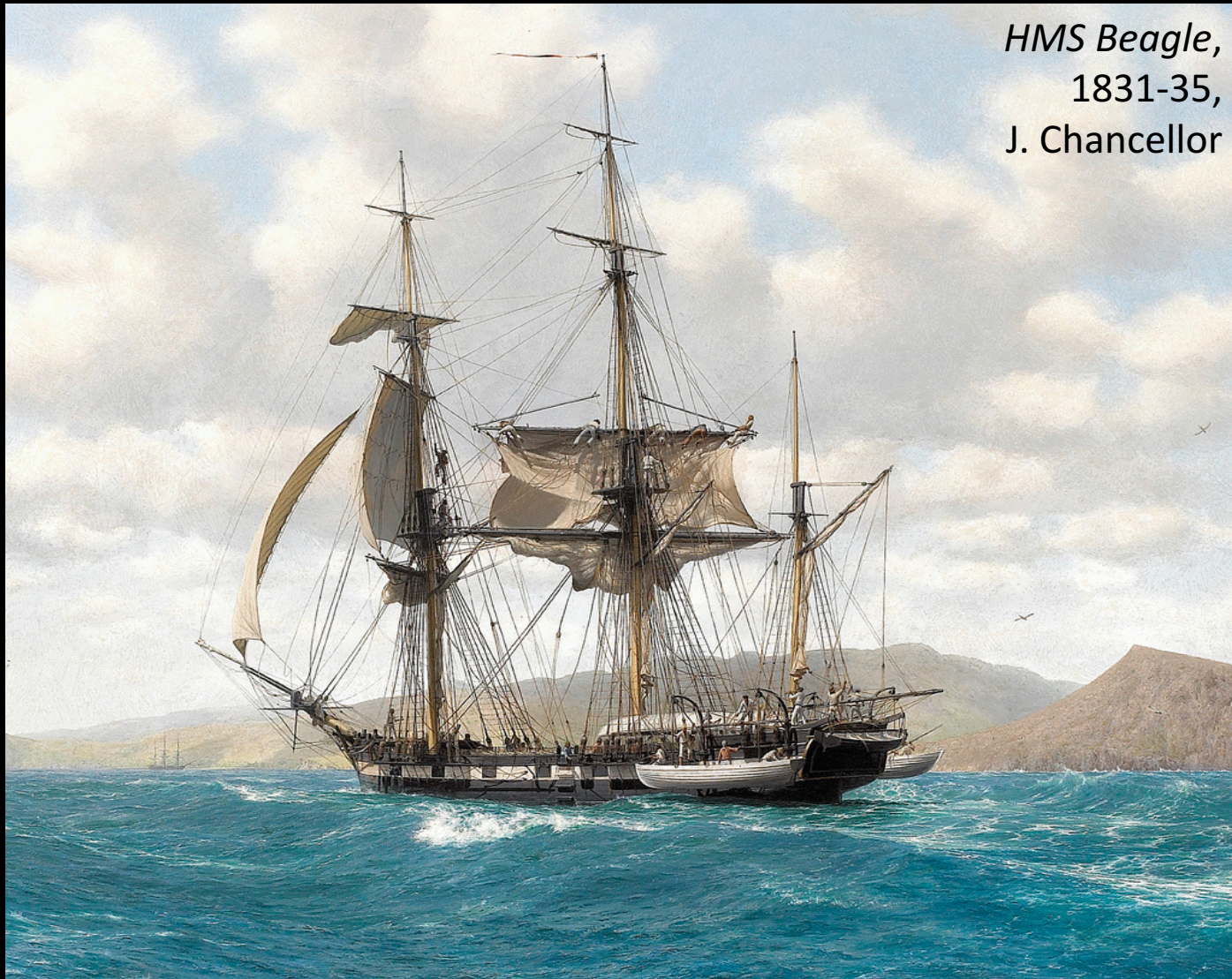
Who better to credit with this interdisciplinary frame of mind than Alexander von Humboldt, gentle explorer of So. America, 1799-1804; author of *Kosmos*, a 5-volume science of the natural world & the human place in it



F. Church, *Chimborazo*, >6000 m Andes' mountain nearly scaled by Humboldt



Second only is Darwin who relied heavily on the expertise of others, most especially geologist, Charles Lyell, whose three-volume *Principles of Geology* Darwin read and re-read in the *Beagle's* small library throughout the five-year voyage.



*HMS Beagle,*  
1831-35,  
J. Chancellor



Tierra del Fuego



Darwin's ideas on biological evolution were possible only because of Lyell, & Darwin's understanding that geology & biology completely overlapped

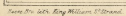
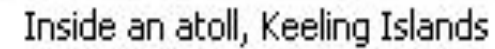
In a letter, Darwin exclaimed, "my books come half out of Lyell's brains." (Horner 1844)



On the Galapagos, Darwin mis-identified his finches, as blackbirds, wrens, grossbeaks, & finches! Darwin relied on ornithologist John Gould for corrections.



Darwin's *Coral Reefs* (1842) is a celebration of the biogeosciences, & is described as “not just a book about reefs, it is a book which sweeps across the ecology and geology of the whole world” (Chancellor 2008)



By 20<sup>th</sup> c, complexities in biology & geology promoted a division into disciplines, with participants welcoming focused scope & training

This division remains cemented today by university departments, professional societies, funding agencies, & journals.

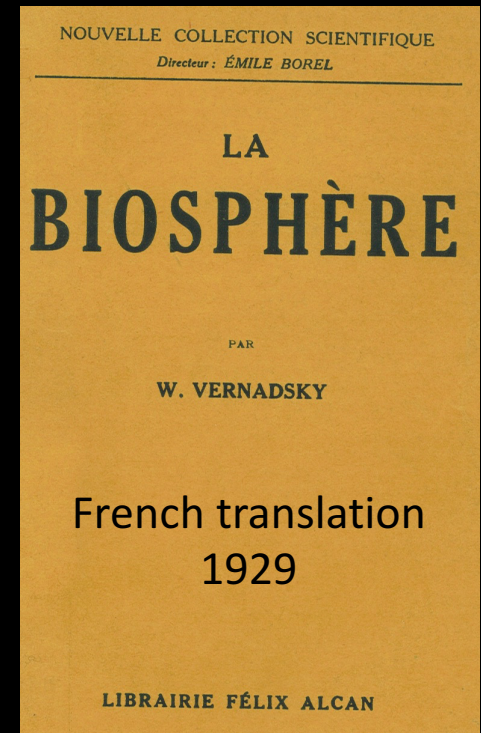
### **Some Notable Exceptions:**

Thomas Huxley, who lectured on what he called “the geological & biological including the very special, “On a piece of chalk”

Vladimir Vernadsky, whose 1920s *Biosphere* went untranslated into English until the 1960s

Vasily Dokuchaev, Vernadsky’s mentor, “patriarch of soil science”

Arthur Tansley and G.E. Hutchinson, two interdisciplinary biologists, who birthed the ecosystem concept





Tansley (1935) & Hutchinson (1940) defined ecosystem  
“in the sense of physics, as *the indivisible system*  
of biota & environment”

Tansley called the ecosystem “one physical system”  
and to have components that “overlap, interlock and  
interact with one another over space and time”

Hutchinson's young student Ray Lindeman may have described the ecosystem best:

“The constant organic–inorganic cycles ... (are) so completely integrated that to consider ... a lake primarily as a biotic community appears to force a ‘biological’ emphasis upon a more basic functional organization.”

Lindeman's Cedar Bog, MN



*A contemporary critique of ecosystem ecology suggests room for much scientific development! (with recognition for exceptions)*

1. Interdisciplinarity – Ecosystem ecology remains biological, & rarely achieves the interdisciplinary scope envisioned by its framers
2. Depth & Volume – the subsurface ecosystem is too rarely studied
3. Time – Despite LTERs, ecosystem science remains focused on short time scales

# *1. An interdisciplinary critique of ecosystem ecology*

Biologists overwhelmingly dominate ecosystem science

Physicists, chemists, and Earth scientists have but secondary roles

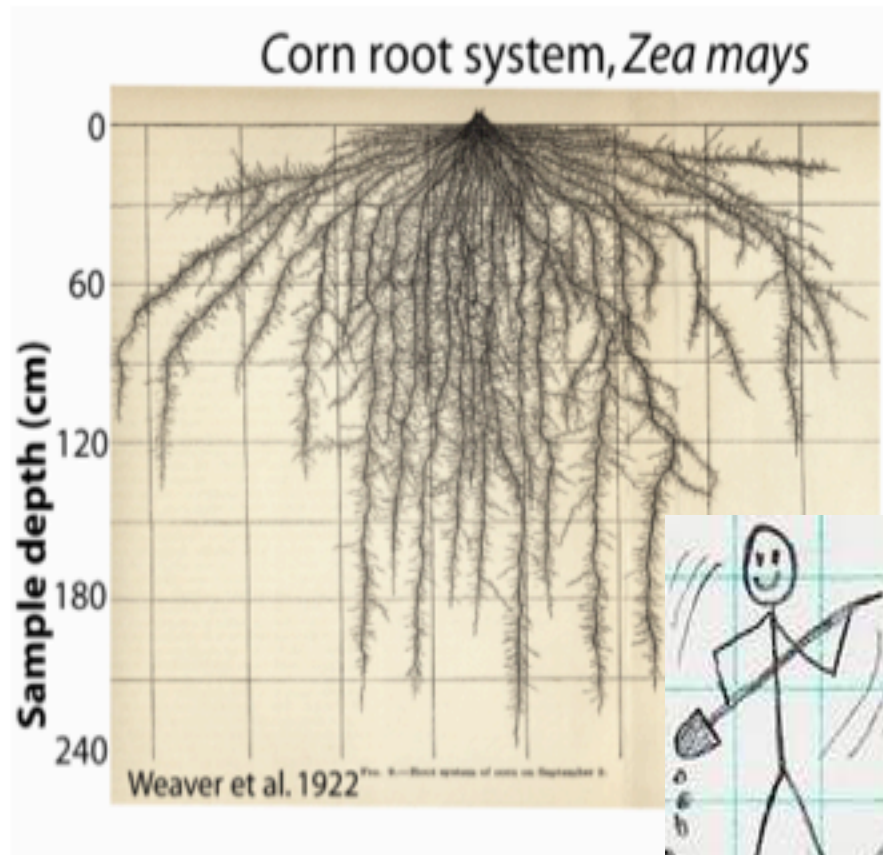
Despite early recognition that ecosystems are overlapping systems, “of a higher order than the biome”, ecosystems too often taken to be the biologist’s construct

## 2. *A depth & volume critique of ecosystem ecology*

Despite decades of significant work by watershed-ecosystem scientists, above- & belowground ecologists infrequently interact & belowground ecosystems are superficially studied

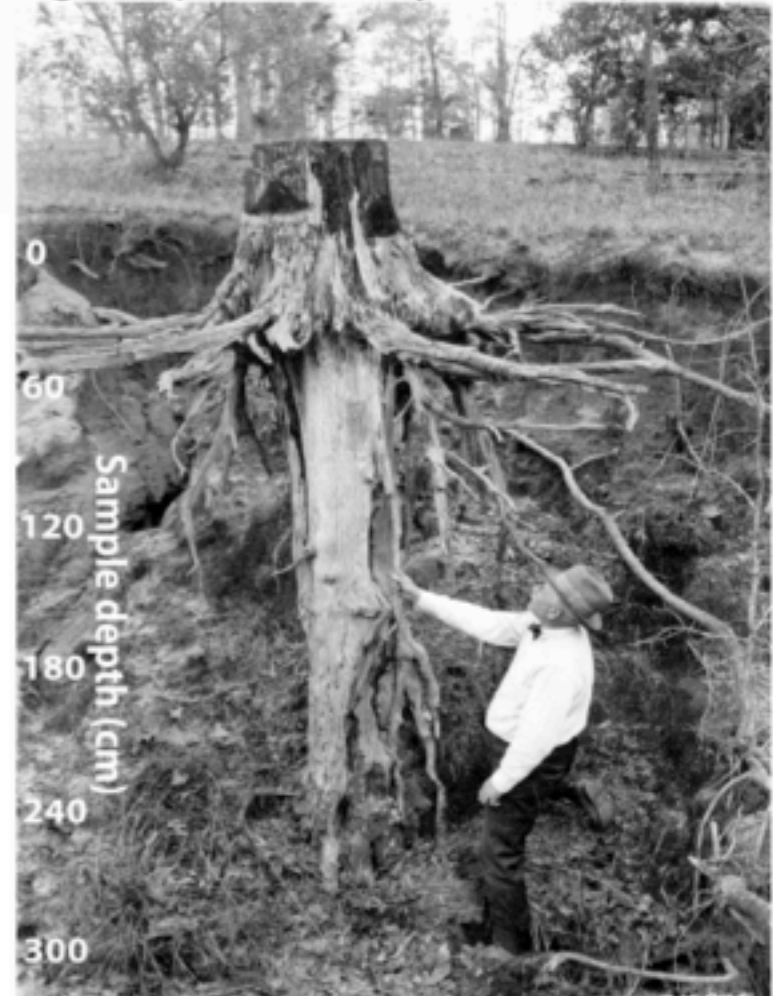


While it has long been observed that plants & animals inhabit & affect large soil volumes ,

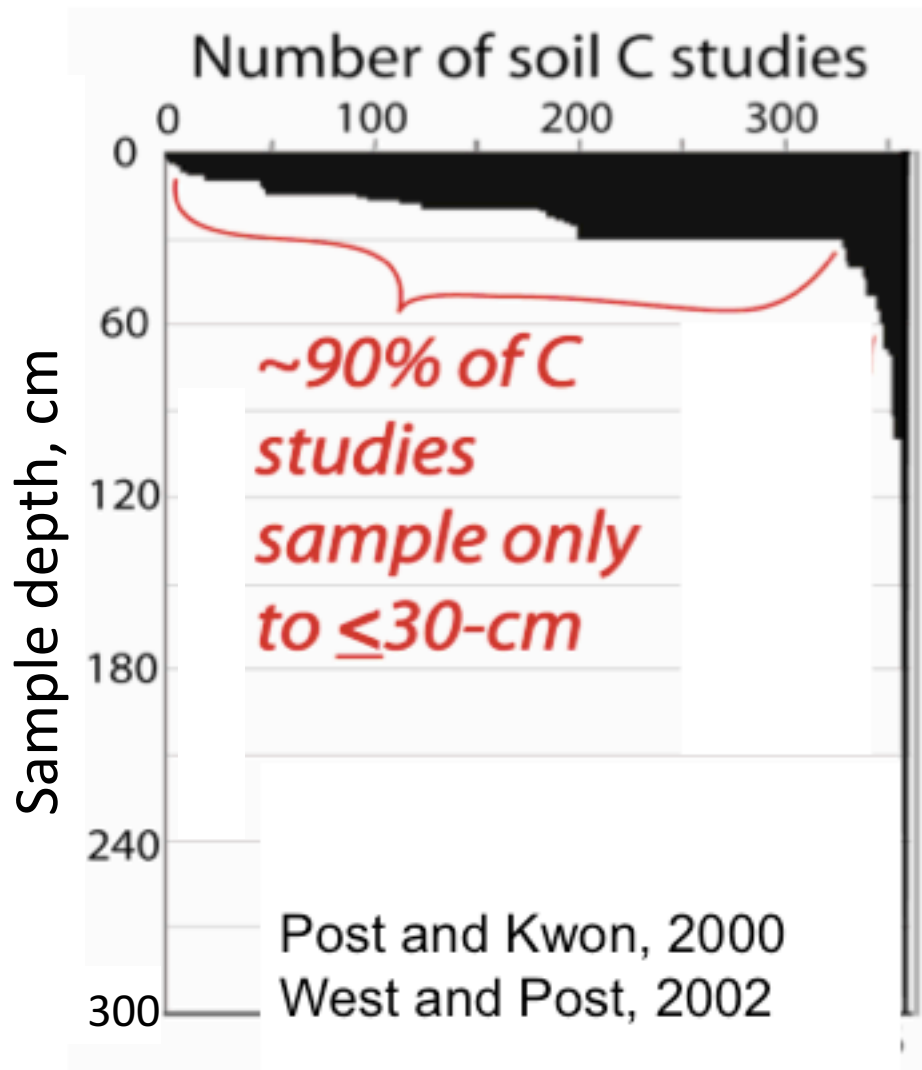


to scale

Longleaf pine root system, *P. palustris*



ecosystem ecologists superficially study the subsurface  
belowground ecosystem! eg, soil carbon



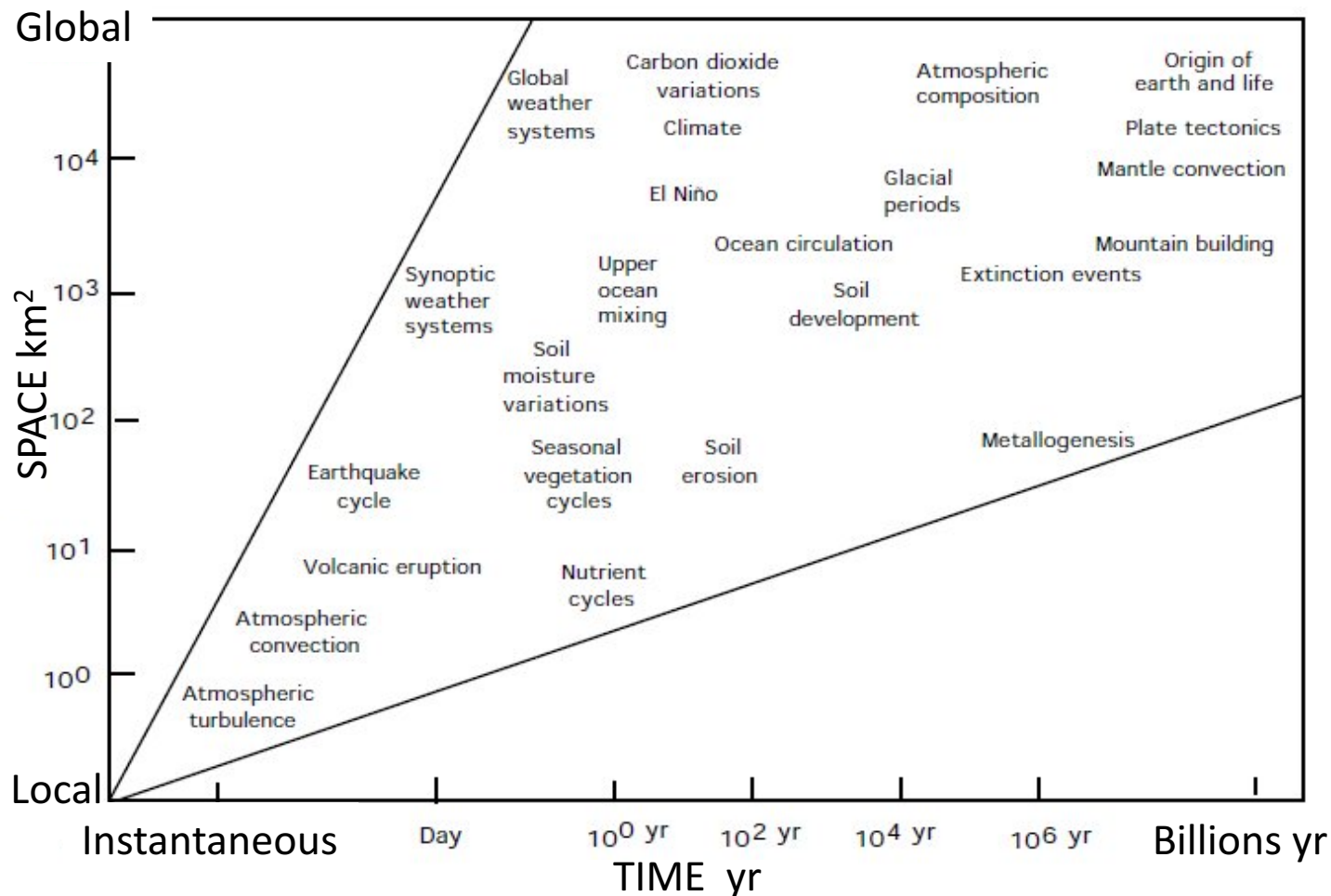
*Maximum sampling depth of >360 studies of how land-use alters soil organic matter and carbon*

There may be an uptick in recent years, but even still!

Meg Mobley et al. 2015

### 3. *A temporal critique of ecosystem ecology*

Despite the success of LTERs, “Long-term Ecological Research”, ecosystems change over deep time as well as the decadal



Space-time diagrams illustrate the essential overlap of ecologists & Earth scientists

Given these critiques of ecosystem ecology, Earth scientists' proposed critical zone science in 2001, expanding upon on the ecosystem concept

Earth's critical zone (Jordan, Ashley et al. 2001):

Life-support system that integrates & connects climate & soil to the deepest of mineral weathering

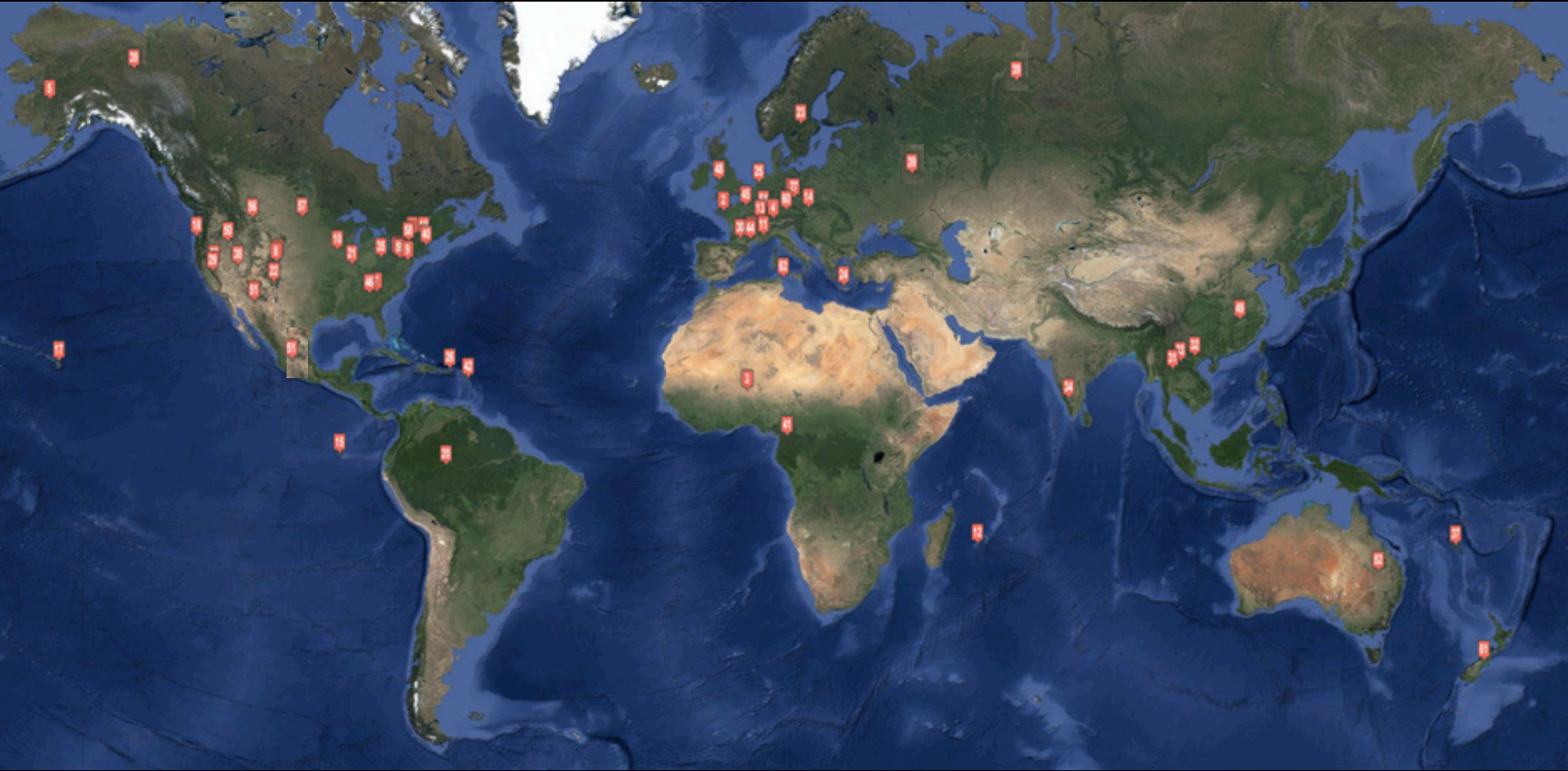
Fluids: atmosphere to groundwater

Time: all bio- & geo- time scales

Slogan: “tree top to bedrock”



Since 2001, an international CZO movement in Earth & ecological observatory science: Many are “volunteers”



Map modified from Banwart et al. 2013  
Visit: [CRITICALZONE.ORG](http://CRITICALZONE.ORG) & [CZEN.ORG](http://CZEN.ORG)



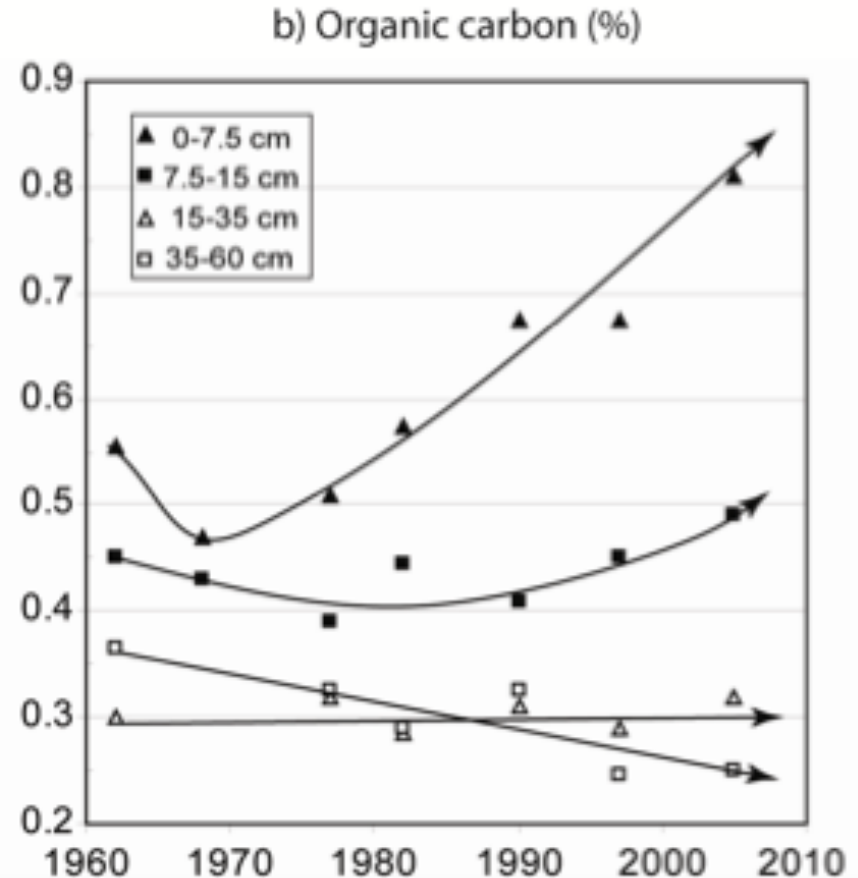
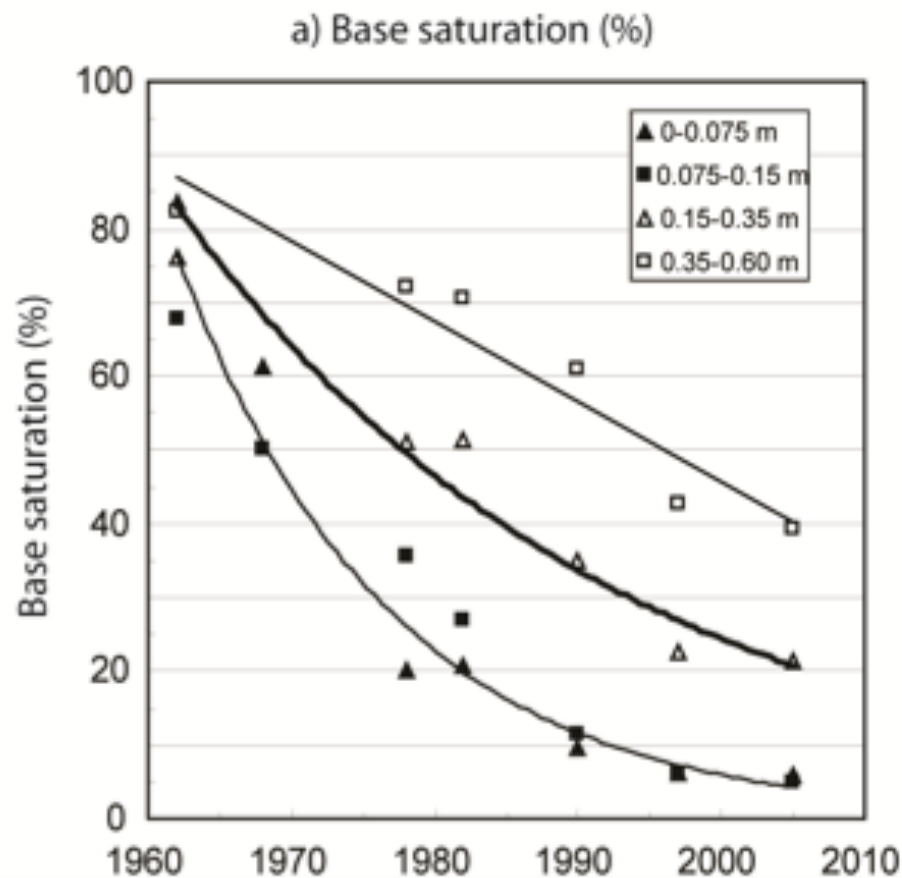
Conclude with how one ecological station was re- & up-instrumented as a critical zone observatory

Calhoun LT Soil-Ecosystem Experiment,

initiated in 1957 by USFS scientists to learn how forest ecosystems change over decades time

- Many dozens of ecosystem papers by many authors
- A biogeochemistry book, *Understanding Soil Change* (2001)
- 9 PhDs on biogeochemical cycling of chemical elements C, N, P, cations, Si, Al, Fe, & trace metals

Iconic data sets produced, from a 60-yr field experiment with sample archive we can document how long cultivated, eroded cotton fields are transformed by the growth of pine trees



A lesson: while forests ameliorate the soil in important ways, trees demand much from the soil, in some ways that are surprising

# Calhoun watersheds, abandoned by forest ecosystem ecologists in the 1960s, have been re- & up-instrumented by critical zone scientists since 2013



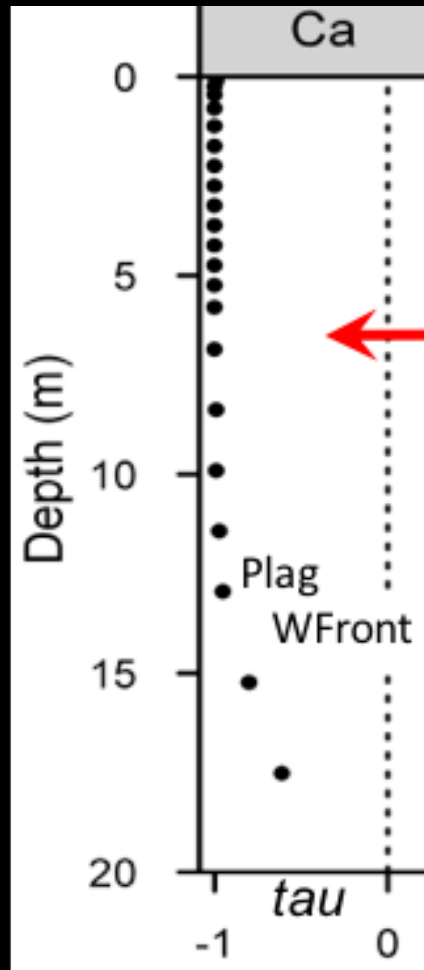
Hydrologic records now span 1948 to 1962 as USFS, 2014 to >2018 as the CCZO!!

Some of the world's Few studies of the ecohydrology of severely disturbed & Eroded land

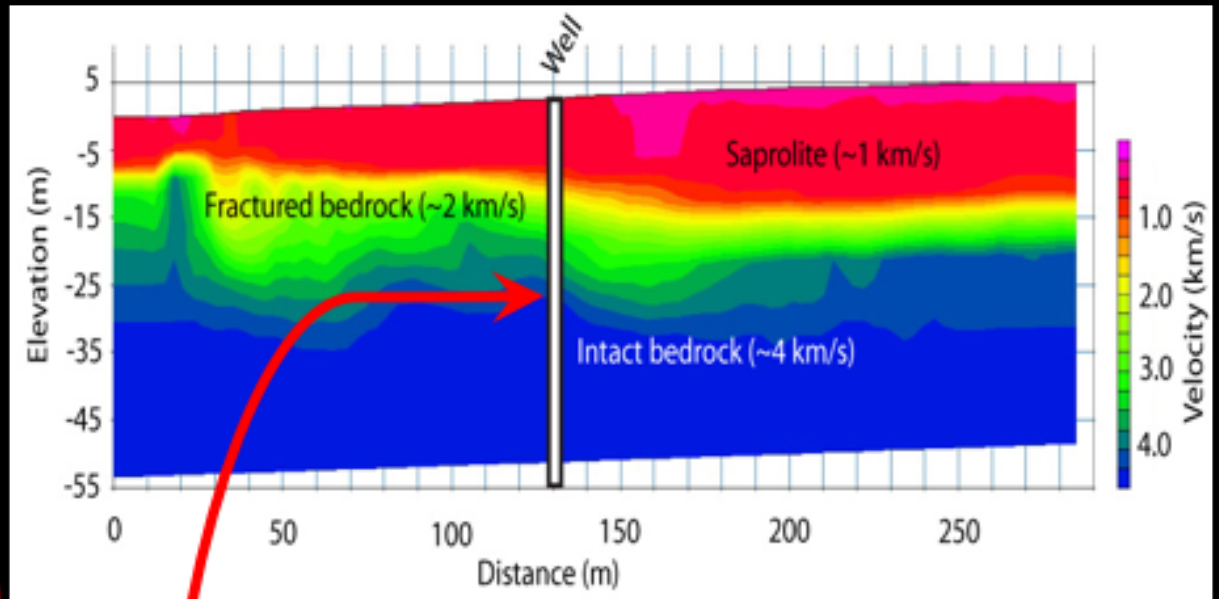
Photo: 2013



We core boreholes, the first 70-m thru soil, saprolite, fractured rock, & granitic gneiss; & with clay mineralogists, geochemists, & geophysicists, worked to understand the biogeochemistry of a Piedmont's full weathering profile



Seismic velocities across the landscape, Holbrook et al. submitted



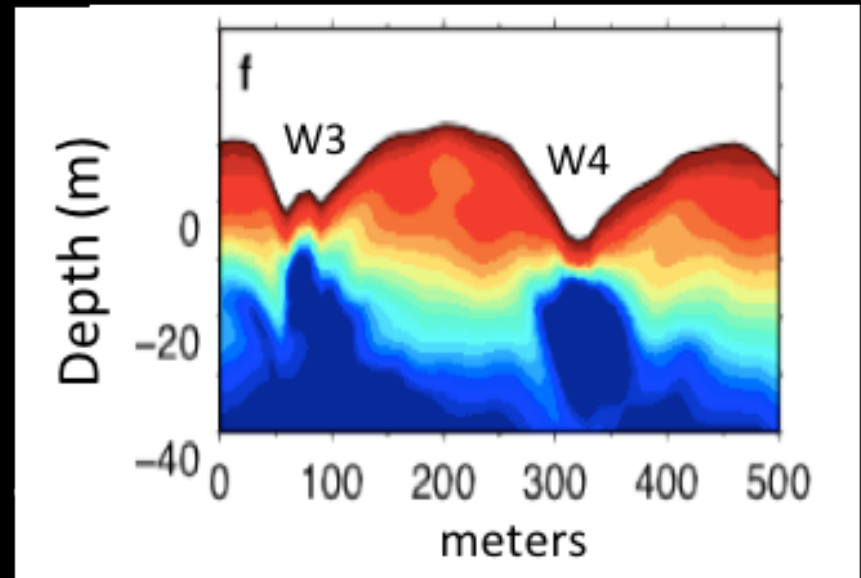
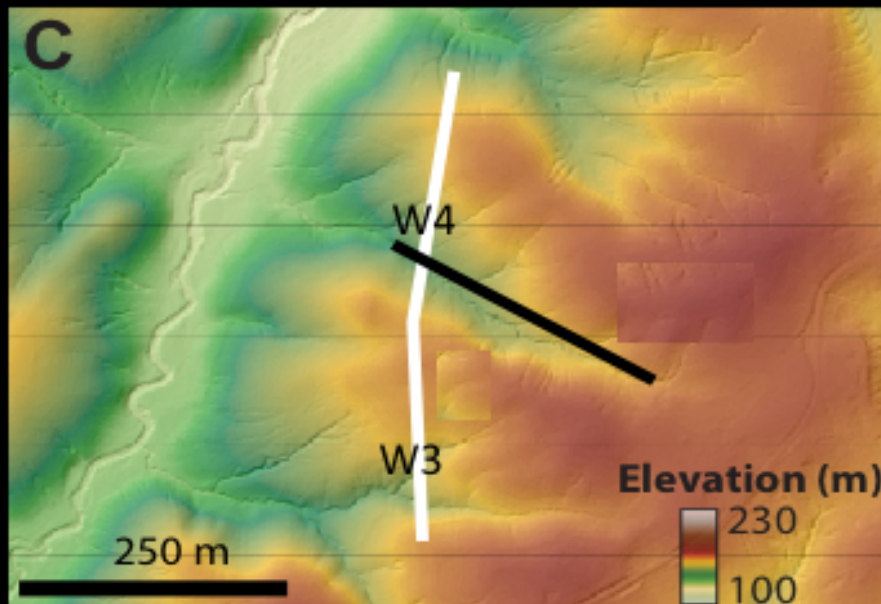
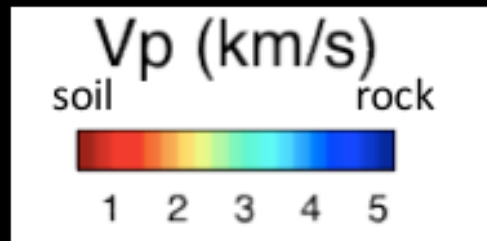
- $^{10}\text{Be}$  residence time >2 million y!
- Weathering fronts 12-40-m!
- pH ~4 to 12-m!

Element mass balances

• Bacon et al. 2012 *GEOLOGY*

# Seismic velocity & resistivity map topographies of weathering & porosity – how regional & local stresses precondition rock for the critical zone!!

Sonic velocities (km/s) of WyCEHG



Calhoun's “bowtie” illustrated in St.Clair et al. 2016



But let us conclude with several stories about G.K. Gilbert & his colleagues, Dutton & Powell, starting with Gilbert who in 1877 made a simple but profound comment about soil:

“Over nearly the whole of the earth's surface, there is a soil, and wherever this exists we know that conditions are more favorable to weathering than to transportation.”

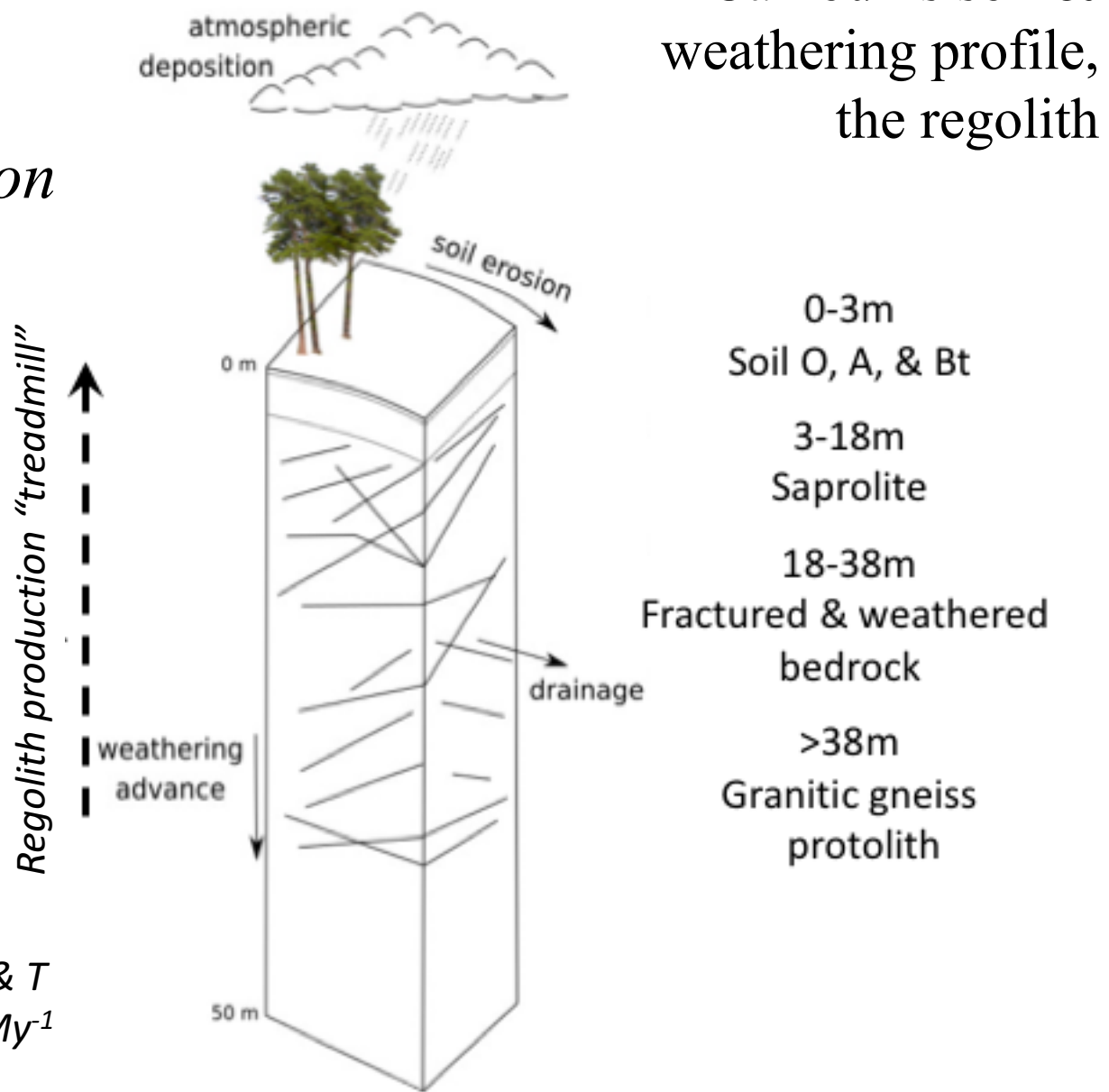
Soil, a fundamental planetary and local attribute

Remarkably, Gilbert's work on soil (regolith) went uncirculated until mid-20th c. geomorphologists re-discovery (Jahn 1954 & 1968, Carson & Kirby 1972)

Gilbert's simple & elegant expression of *regolith production*

“across most of earth's surface, there is soil”, thus, a net  $W > T$

*Rates of W & T*  
 $\sim 1 \text{ to } 10 \text{ m My}^{-1}$



Contemplating on where his ideas about soil, weathering, and erosion came from... he remarked, “these principles were derived or enforced by the study of the Colorado Plateaus.”

By which Gilbert meant the far flung and absolutely remarkable collaborations led by John Wesley Powell (Pyne, 1980)



No. 91. Mr. Gilbert on Billy.

“Mr. Gilbert on Billy”

Conclude this introduction with Gilbert & Powell, as they show us how to work as critical zoneists ...

According to Clarence Dutton, an equal to Gilbert & Powell, the grand exploration of the American West by these remarkable scientists was conducted...

“With a bond of affection and mutual confidence which made this study in a peculiar sense a labor of love, this geological wonderland was a never-ending theme of discussion; *all observations and experiences were commonstock*, and ideas were interchanged, amplified, and developed by mutual criticism and suggestion. The extent of my indebtedness to them I do not know. Neither do they.”

We have no better words to describe what Earth science's new critical zone science is all about! Welcome to the Critical Zone!

# IMPORTANT NOTICES:

1. We are part of a BIG FOP TEAM! We have periodic rest room breaks planned through the day, though the woods are not a bad rest area either!
2. We must consolidate riders in our vehicles. A number of vans with empty seats are available for your use. *Carpool, carpool, carpool.* Try to coordinate your riders tonight, but we will also consolidate riders at our 2<sup>nd</sup> stop in the morning, at Padgett's Creek Baptist Church parking lot, where you can park your car. The church is convenient to the Calzone Science Partee (at Sedalia Camp Ground) at day's end.
3. Camping should ONLY be in campsites near Bombing Range Road! The campground area beyond the red gate is restricted for partee activities only!
4. After the last field site Sat afternoon, we will proceed directly to the Calzone Science Partee. Thus, in the morning, bring your water, snacks, lunch, & evening's drinks for the entire day. Master planner and world-class lab manager, Paul Heine, will be serving dinner at the "Top of the Hill" at Sedalia Camp Ground, at ~630pm. We can not camp in this area. (See p.41, for LiDAR image).



# Critical zoneists in the Anthropocene

