

WHAT'S SO CRITICAL ABOUT THE CRITICAL ZONE?

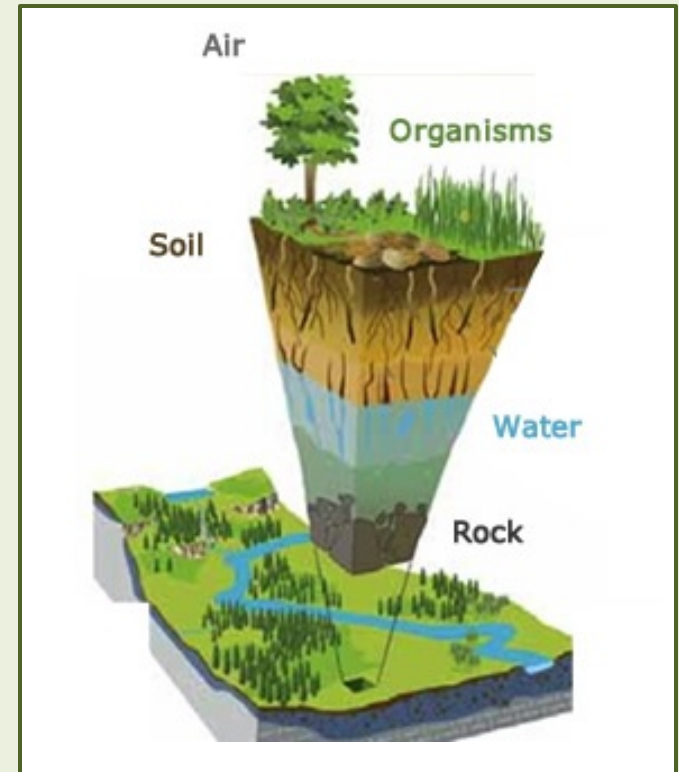
NEW INSIGHTS FROM A GROWING NETWORK

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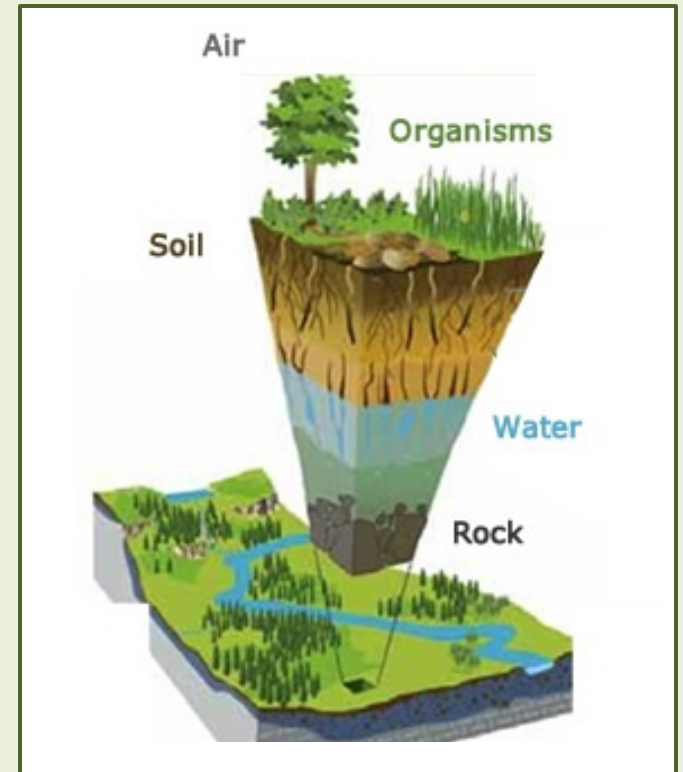
*College of Earth, Ocean and Atmospheric Sciences
Oregon State University*



criticalzone.org

THE CRITICAL ZONE: WHERE ROCK MEETS LIFE

The Critical Zone lies between rock and sky...where water, atmosphere, ecosystems, soils, and rock interact. It is essential to life on Earth, including food production and water quality.



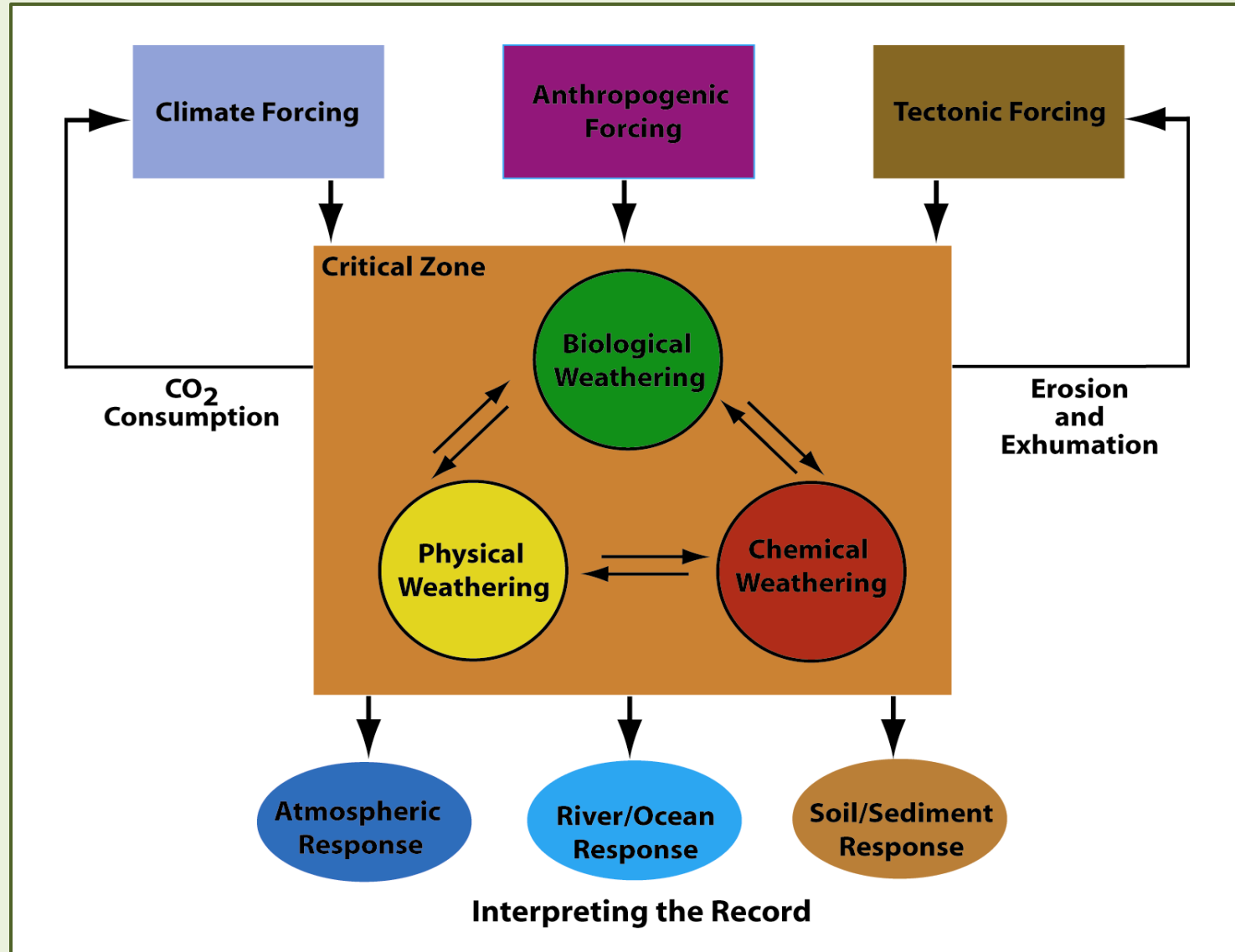
Despite the Critical Zone's importance to terrestrial life, it remains poorly understood:

- How does the CZ form?
- How does it function?
- How will it change in the future?



- **Critical Zone Observatories** are environmental laboratories established in 2007 to study the chemical, physical and biological processes that shape the Earth's surface. CZO research seeks to understand the couplings of these processes across temporal and spatial scales by monitoring and modeling at the watershed.
- **The National CZO Program** is a community resource. It serves the international scientific community through research, infrastructure, data, and models.

OVERARCHING CONCEPTUAL MODEL FOR INTEGRATING GEOLOGY, ECOLOGY, BIOGEOCHEMISTRY, HYDROLOGY AT CZOs



FOUR DRIVING QUESTIONS

Atmosphere

How do processes that **nourish ecosystems** change over human and geologic time scales?

What processes control **fluxes** of carbon, particulates, and reactive gases over different **timescales**?

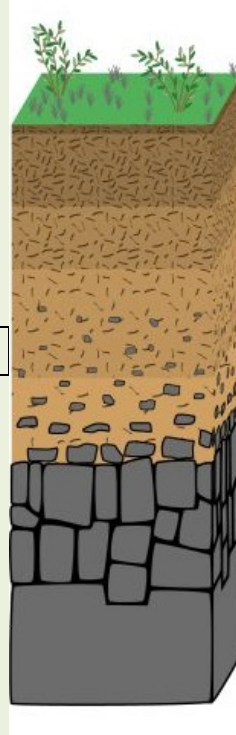
Nutrients

How do biogeochemical processes govern long-term **sustainability** of water and soil resources?

Landform Evolution

How do variations in and **perturbation** to chemical and physical weathering processes impact the Critical Zone?

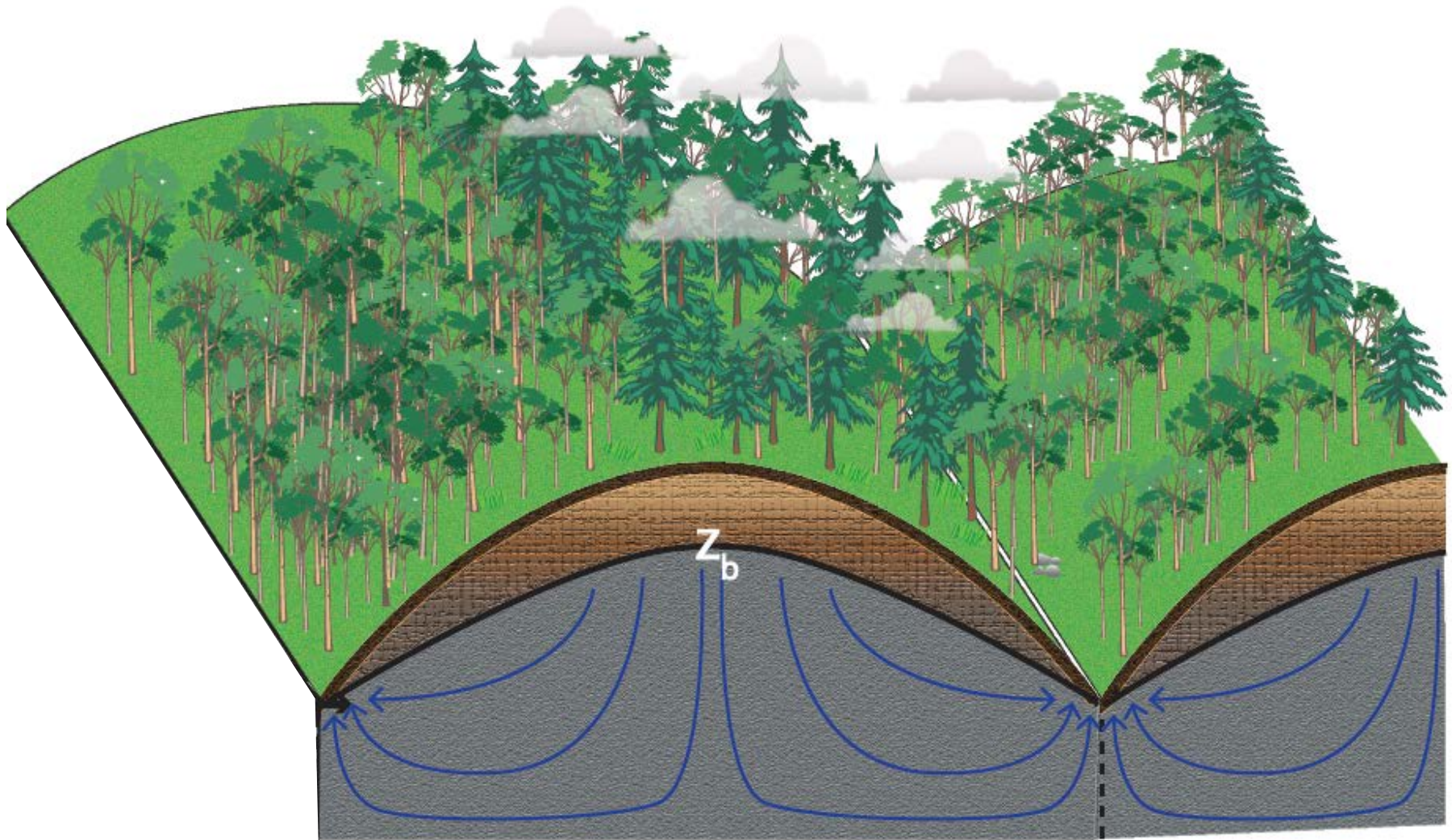
Chemistry of Water



CZO SITES: ★ SIX ORIGINAL ★ FOUR NEW



NEW PERSPECTIVES FROM CZ SCIENCE



Rempe and Dietrich, in press

CLASSIC VIEW: Water flows vertically then laterally through the porous medium constituting the critical zone

BEVEN AND GERMANN: WATER FLOW IN SOIL MACROPORES

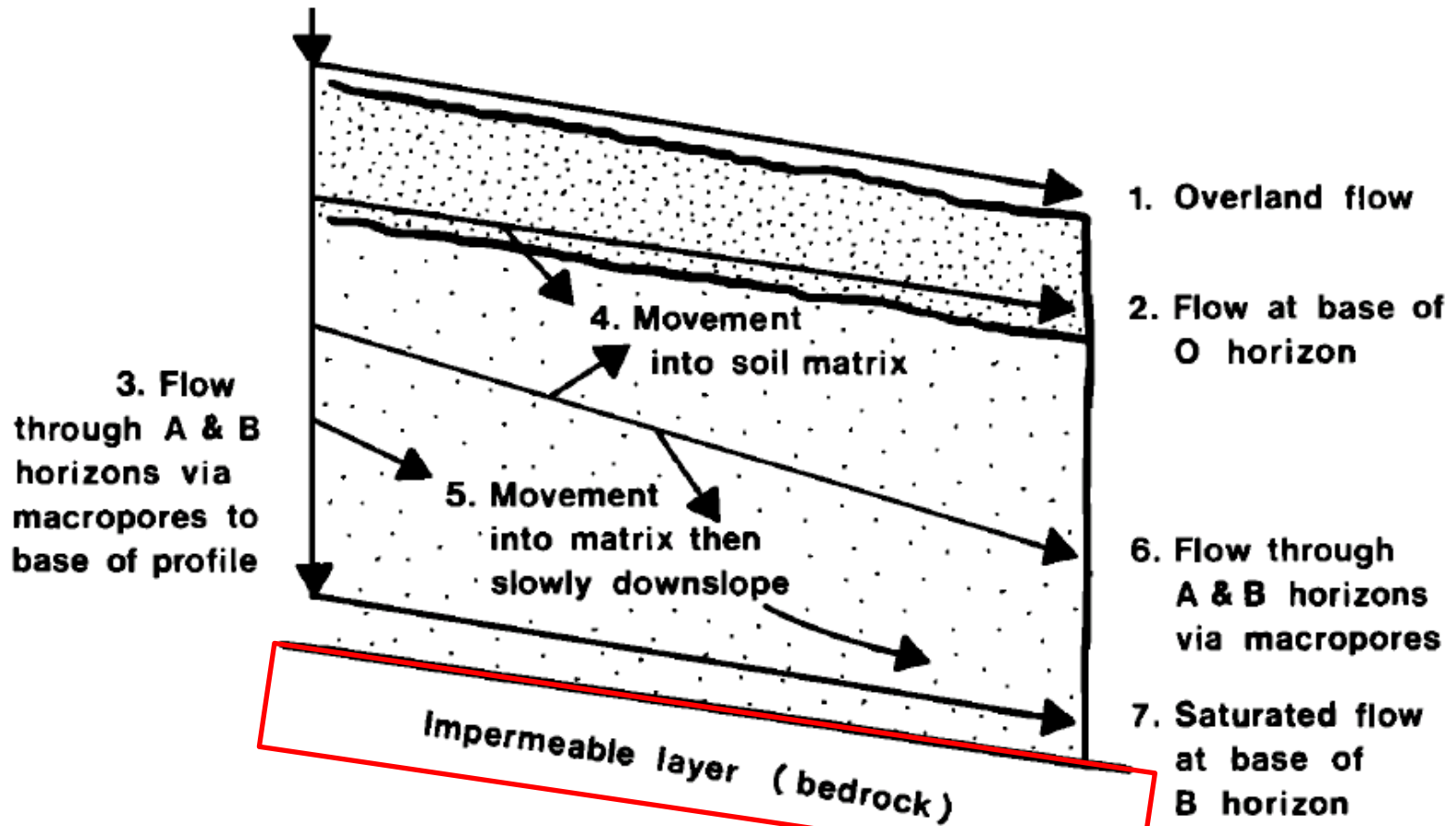
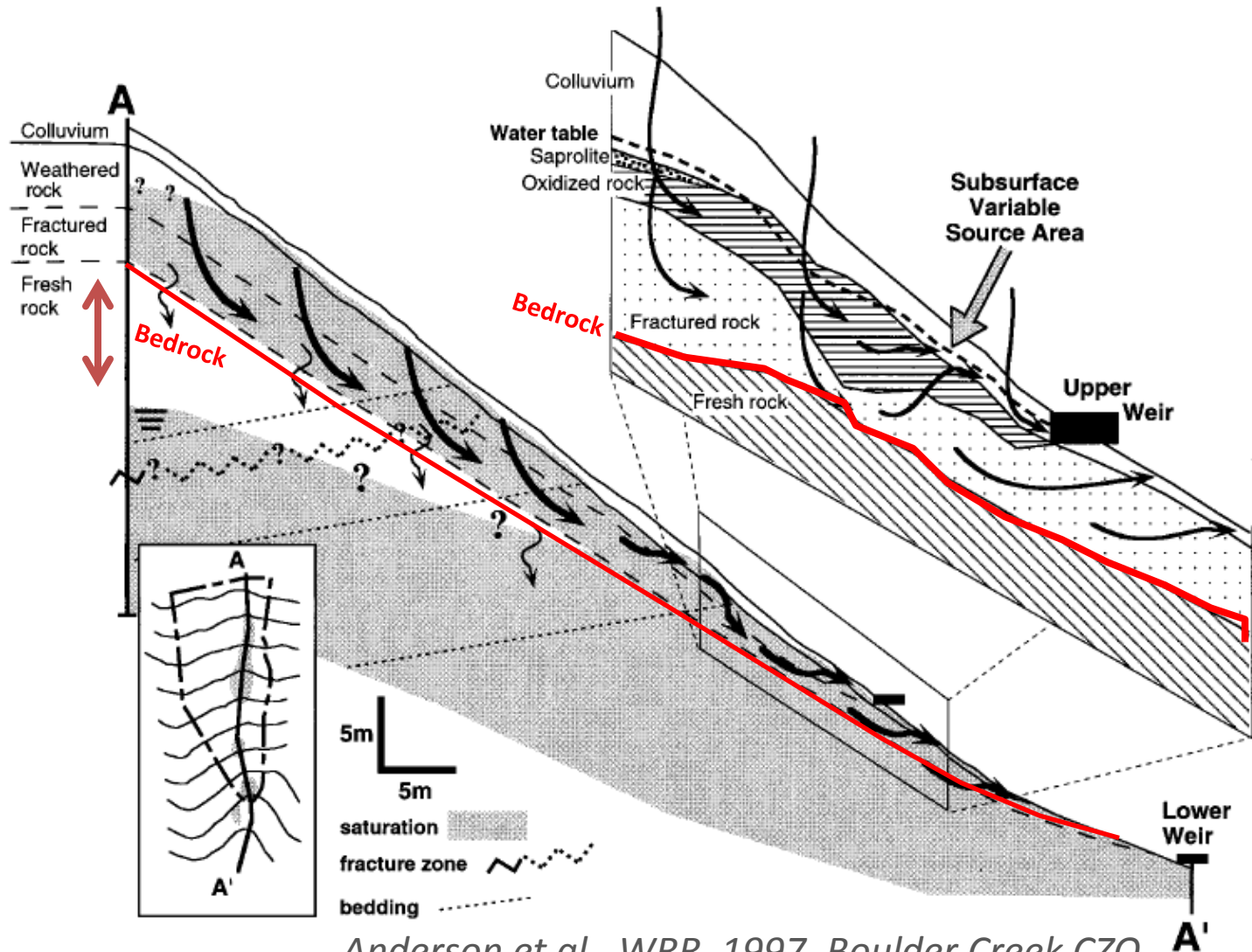


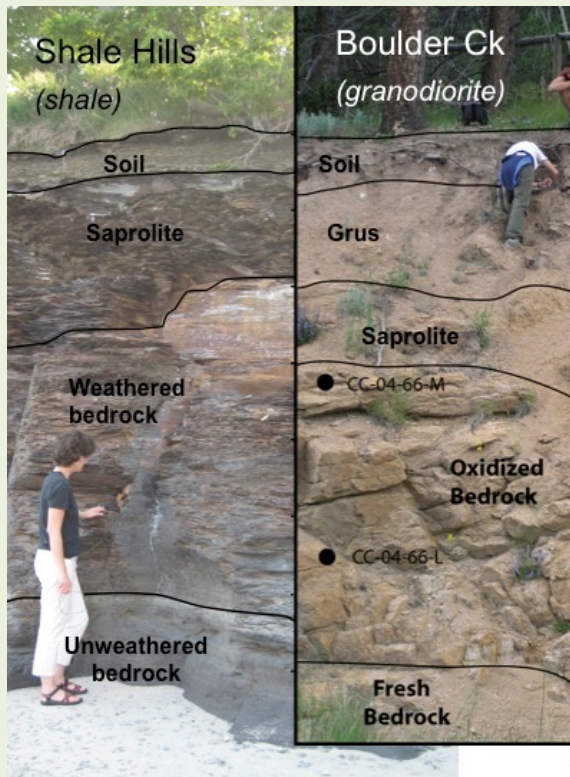
Fig. 8. Flow paths for the movement of water through a shallow forest soil with macropores (after Mosley, 1982).

DEEPER VIEW: Water moves multi-directionally over different timescales

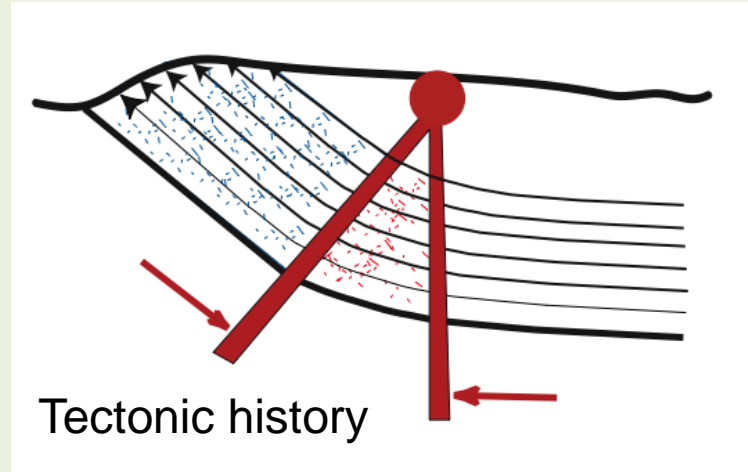


FRACTURED VIEW: Fracture spacing due to various processes is an important control on critical zone architecture:

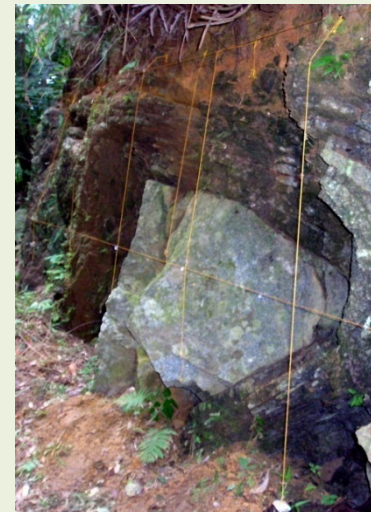
Lithology



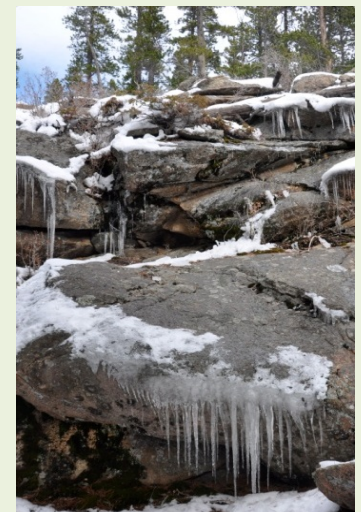
Molnar et al. (2007)



Prying by trees

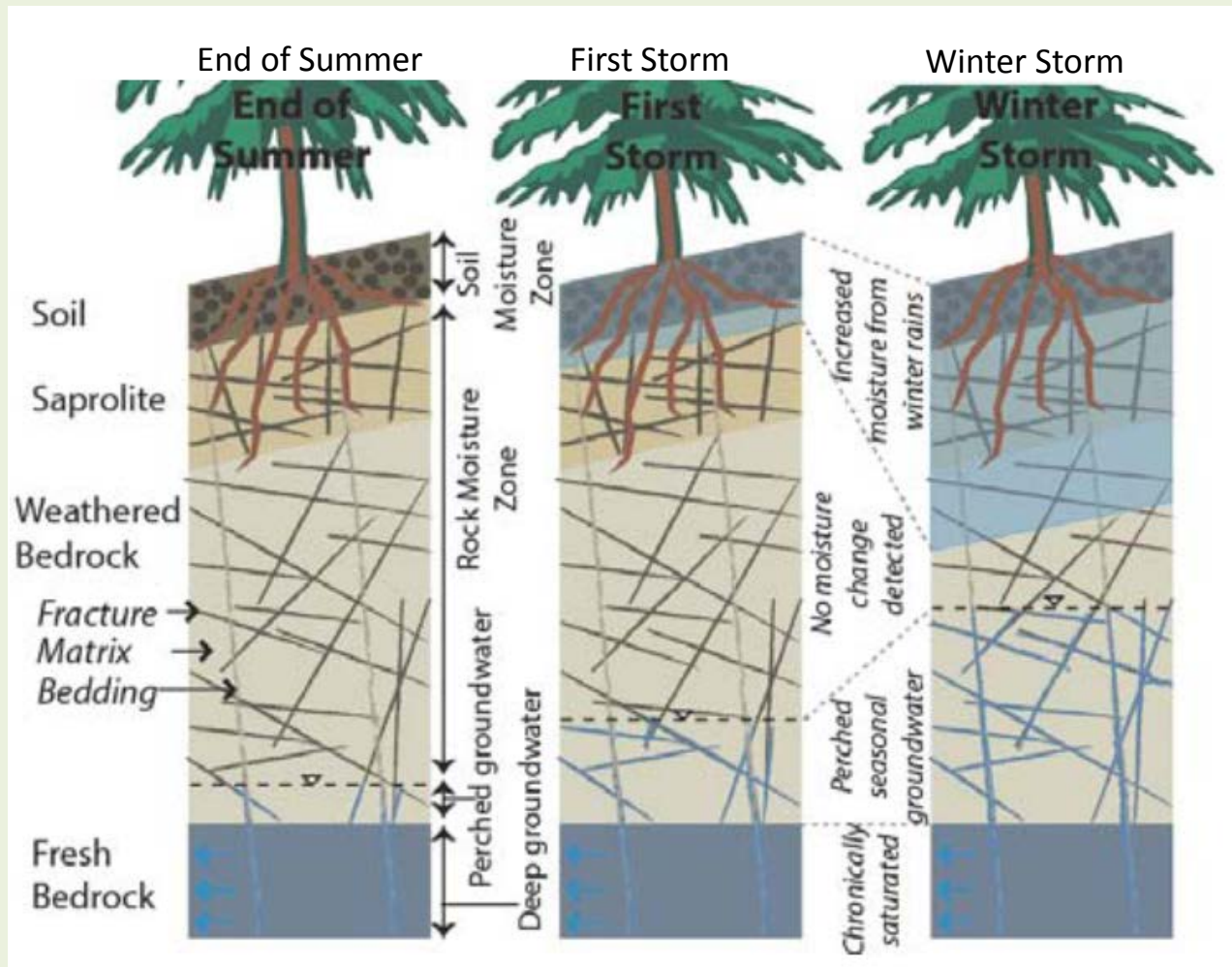


Chemical alteration

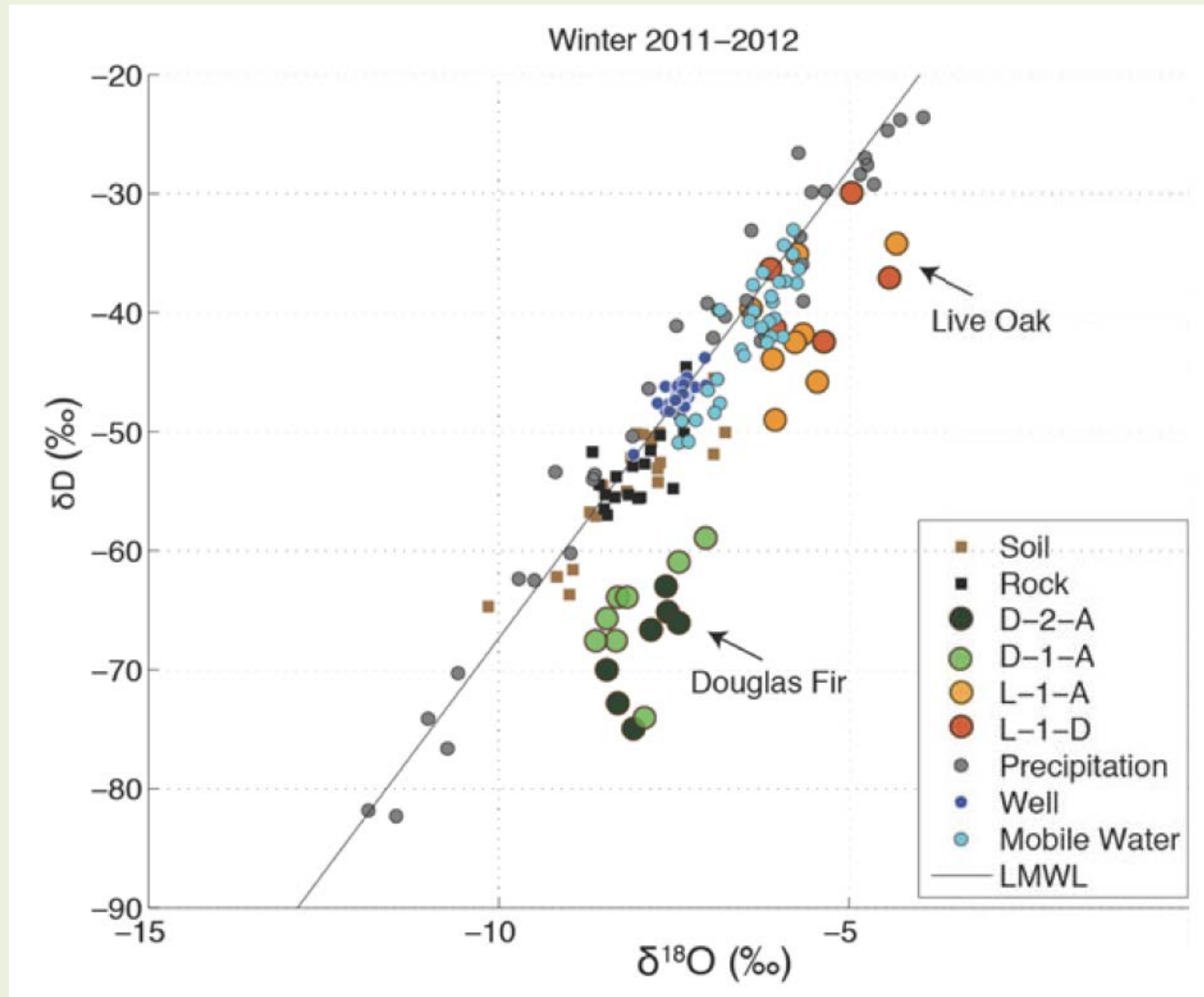


Thermal processes

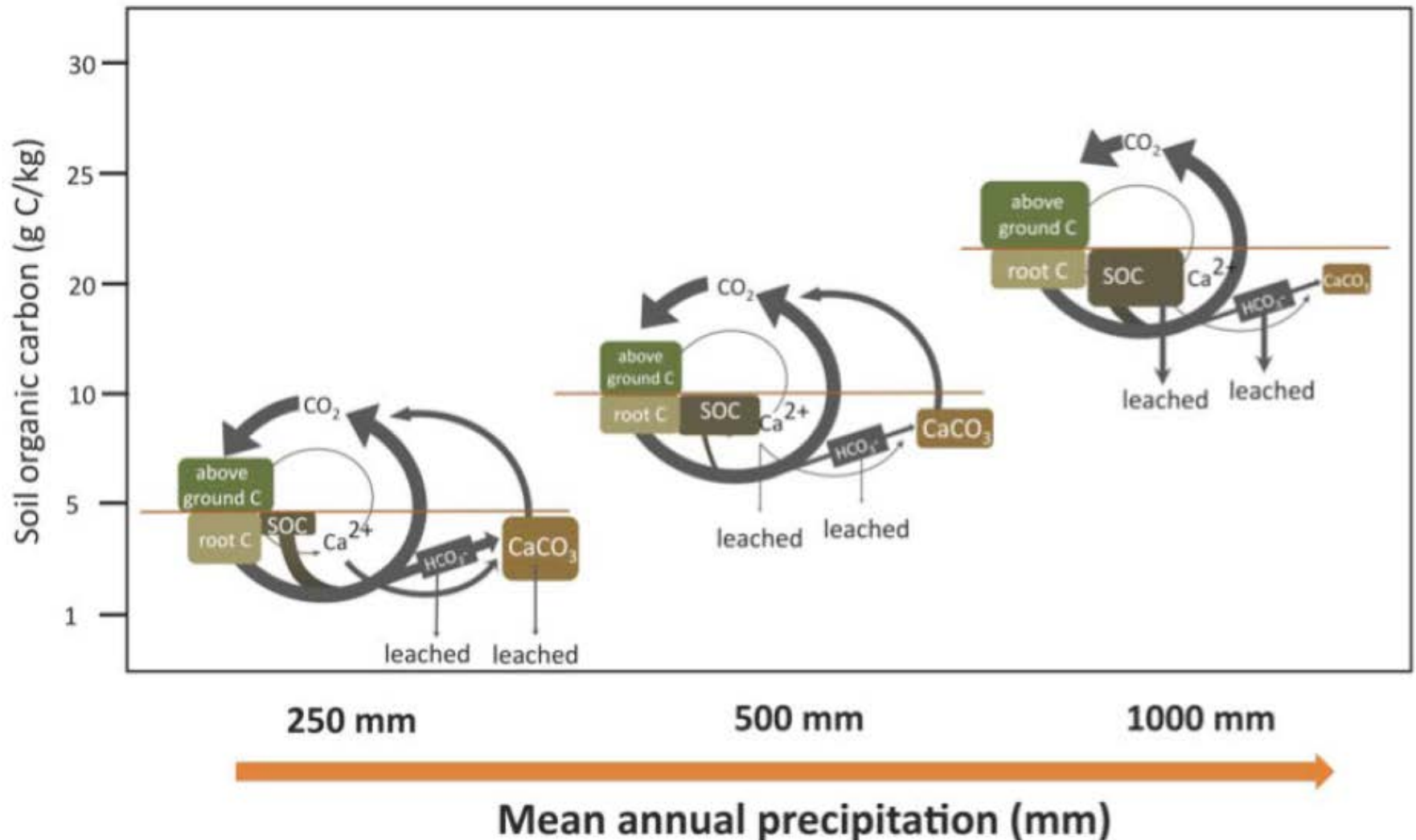
FRACTURED VIEW²: Permeability does not vary predictably with depth, and important factors (fractures, depth to bedrock, roots and extent of unsaturated zone) vary seasonally



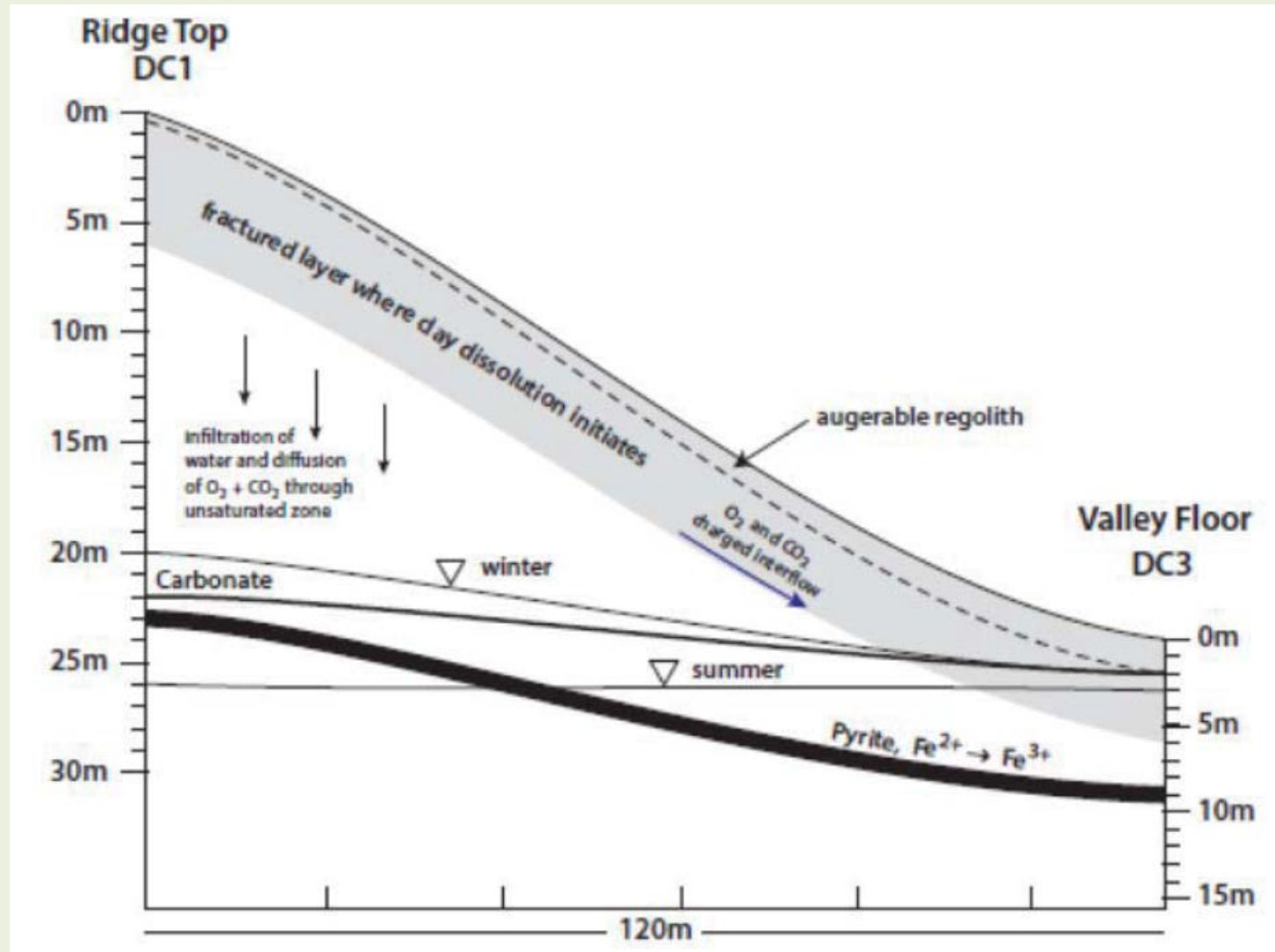
VIEW FROM THE TREES: species use isotopically distinct water despite growing adjacent to each other



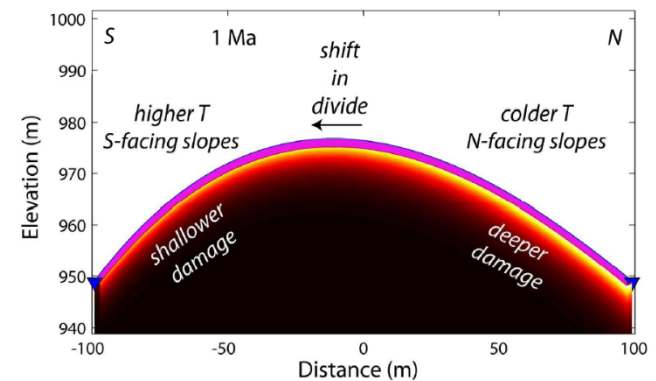
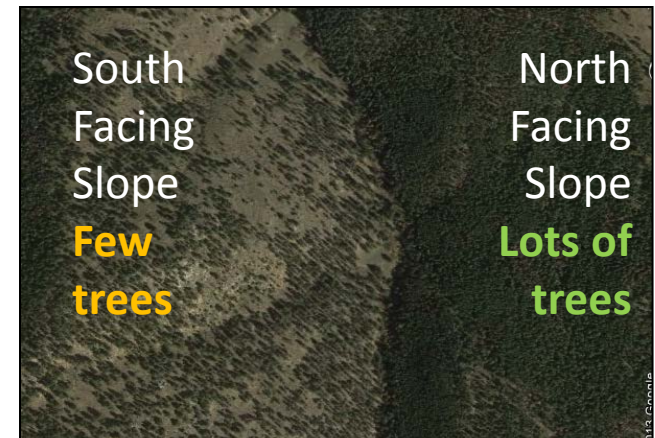
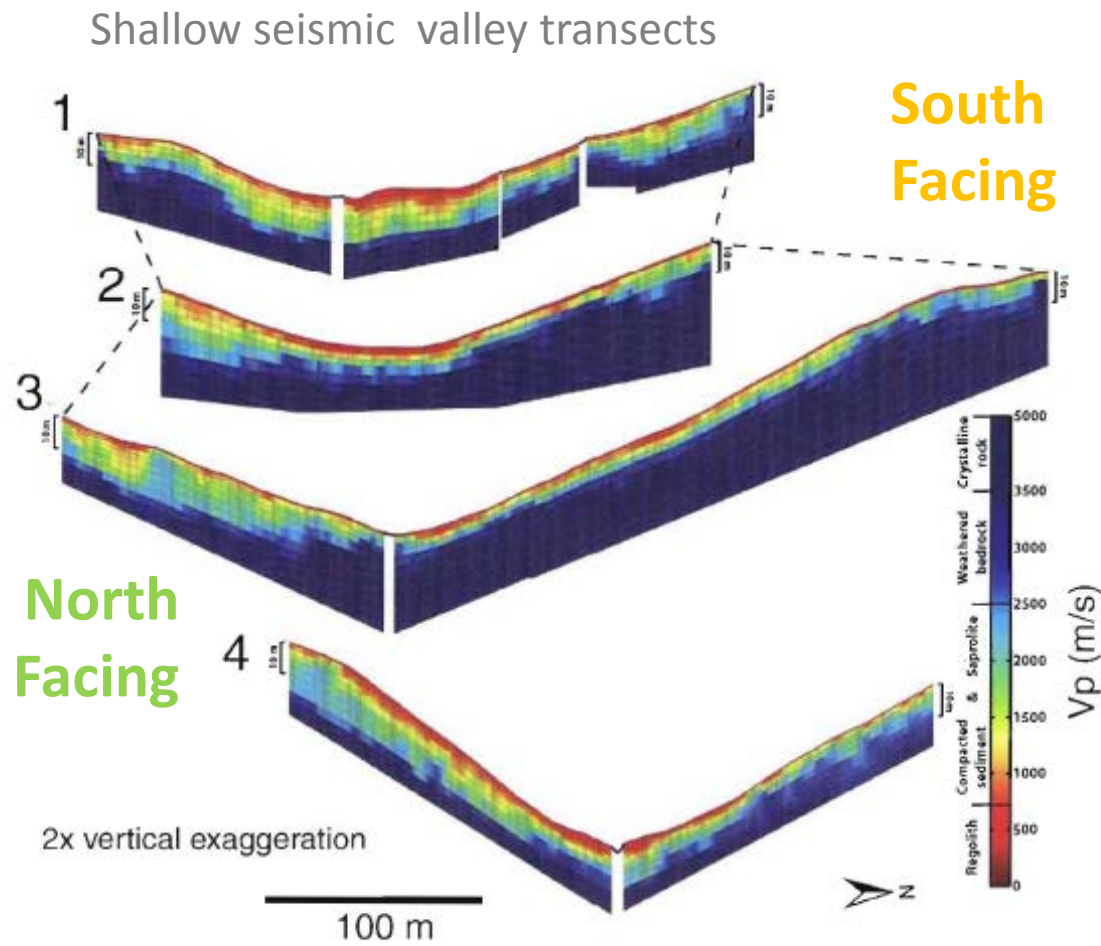
NOT A CARBON COPY: Key critical zone processes vary along environmental gradients



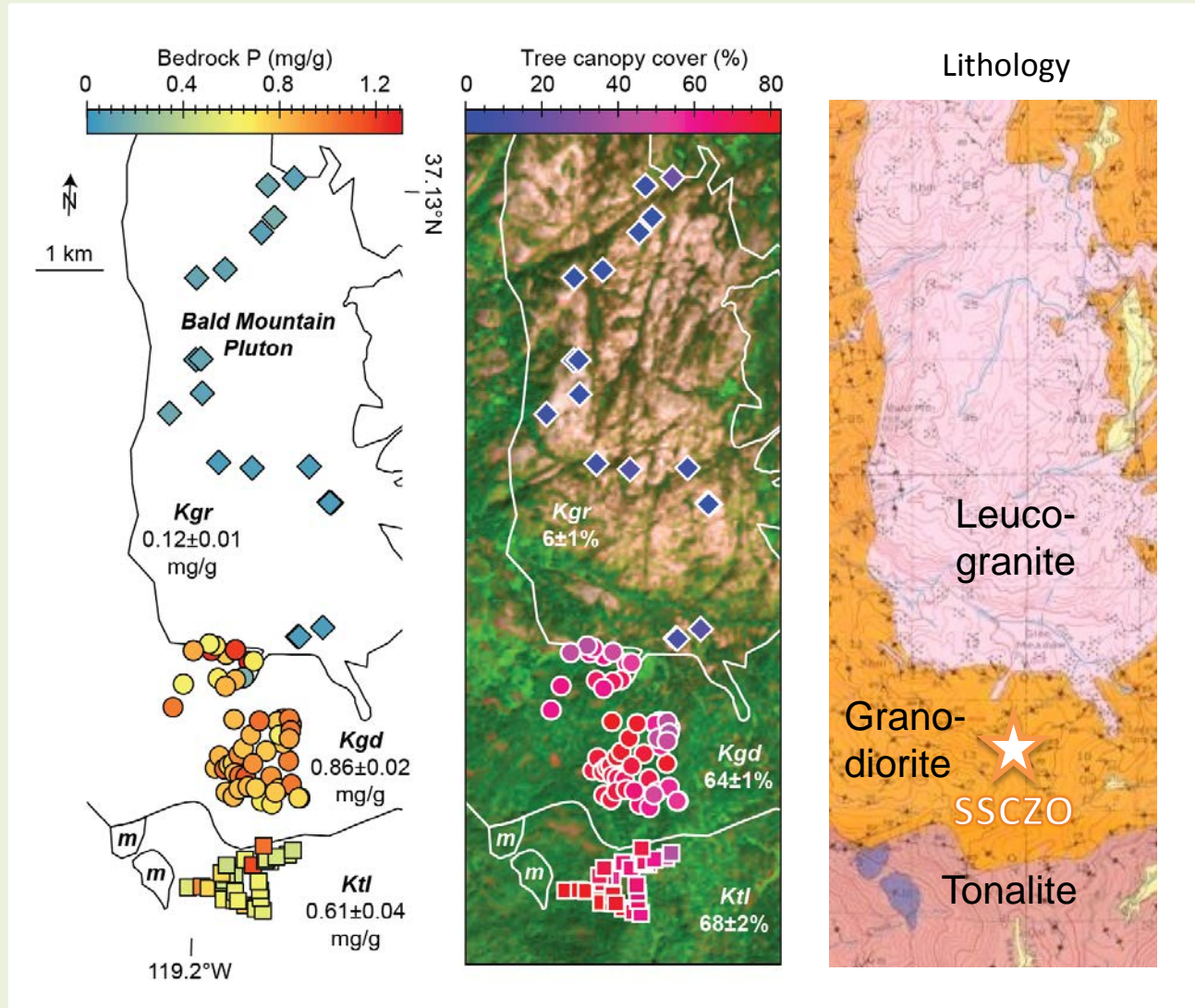
CRYPTIC PATHWAYS: Hydrological & chemical flowpaths and weathering fronts don't always conform to surface topography



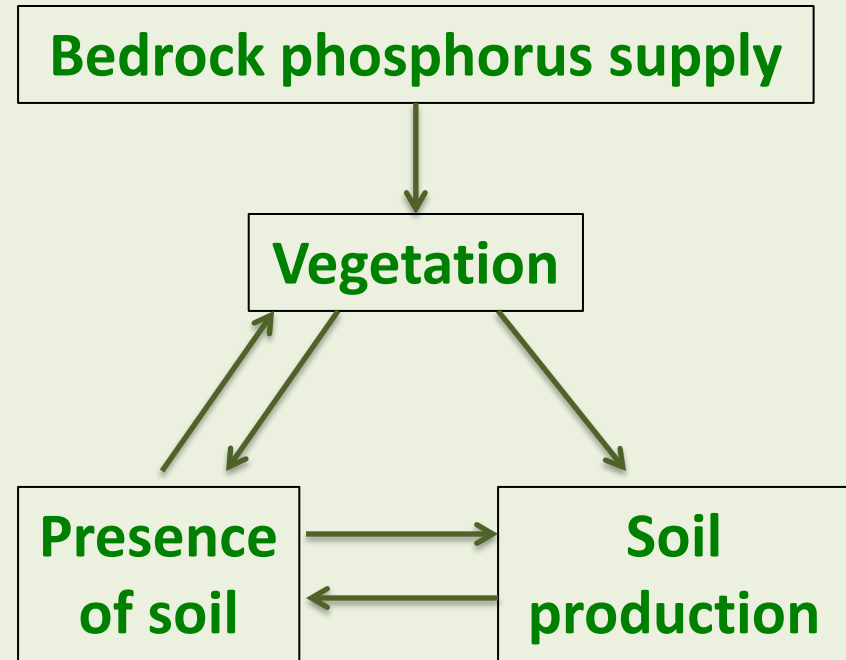
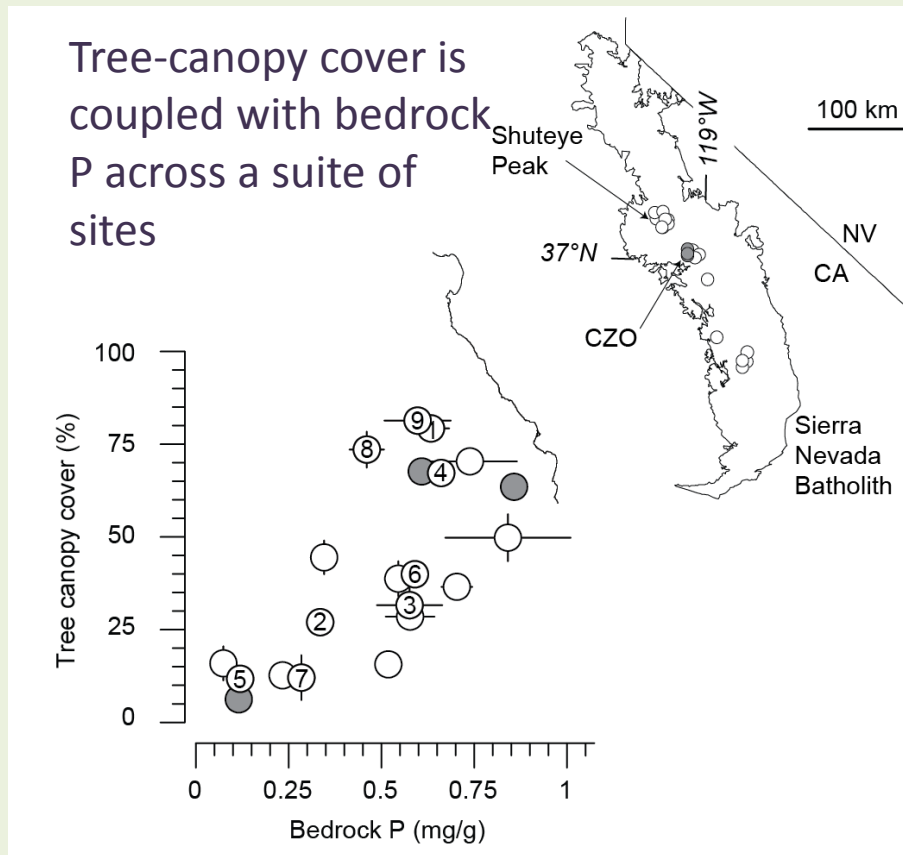
NORTH AND SOUTH: Depth of critical zone integrates vegetation, aspect, climate



TREES CARE ABOUT GEOLOGY: Vegetation patterns reflect differences in bedrock geochemistry (endogenous)



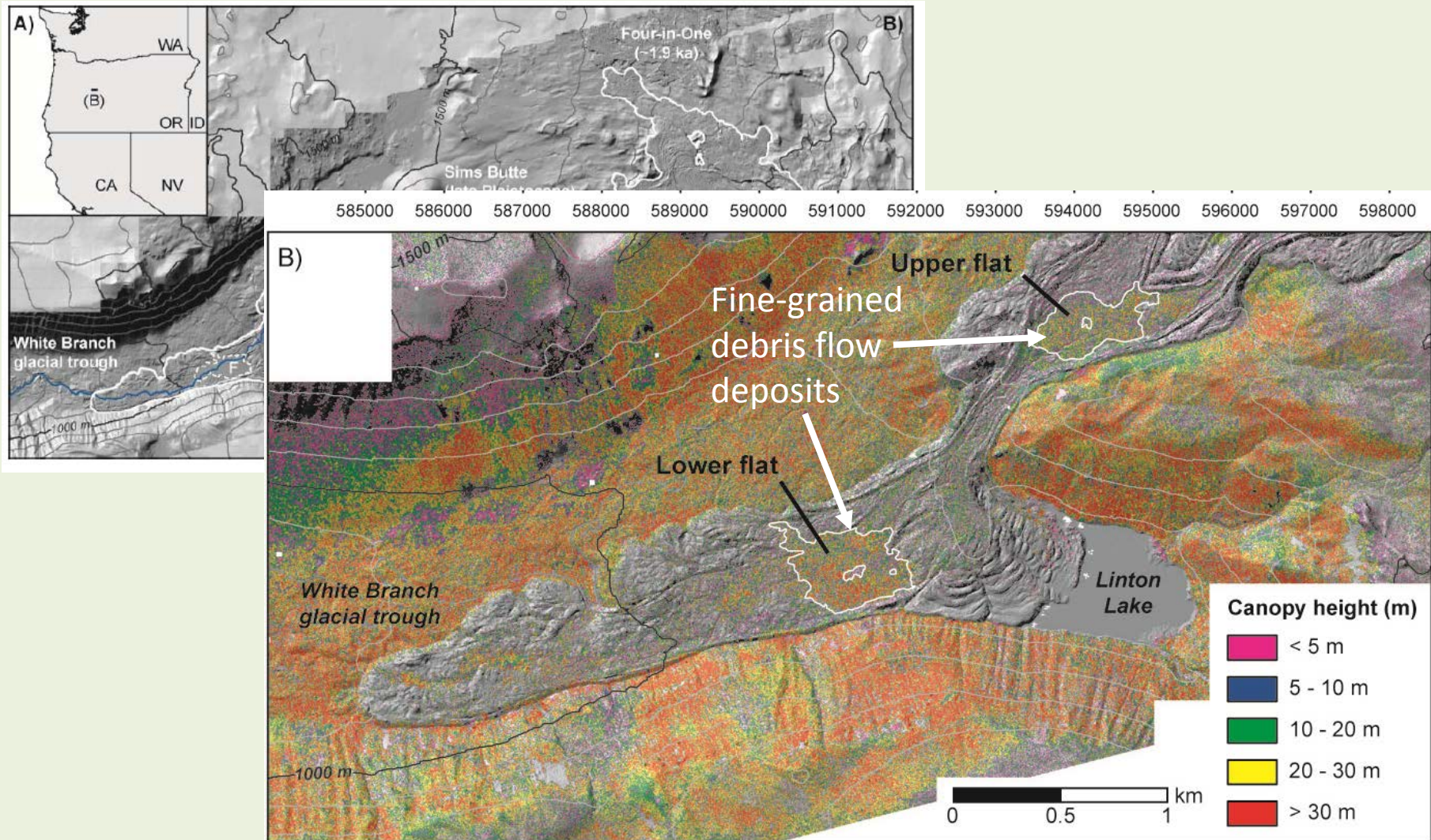
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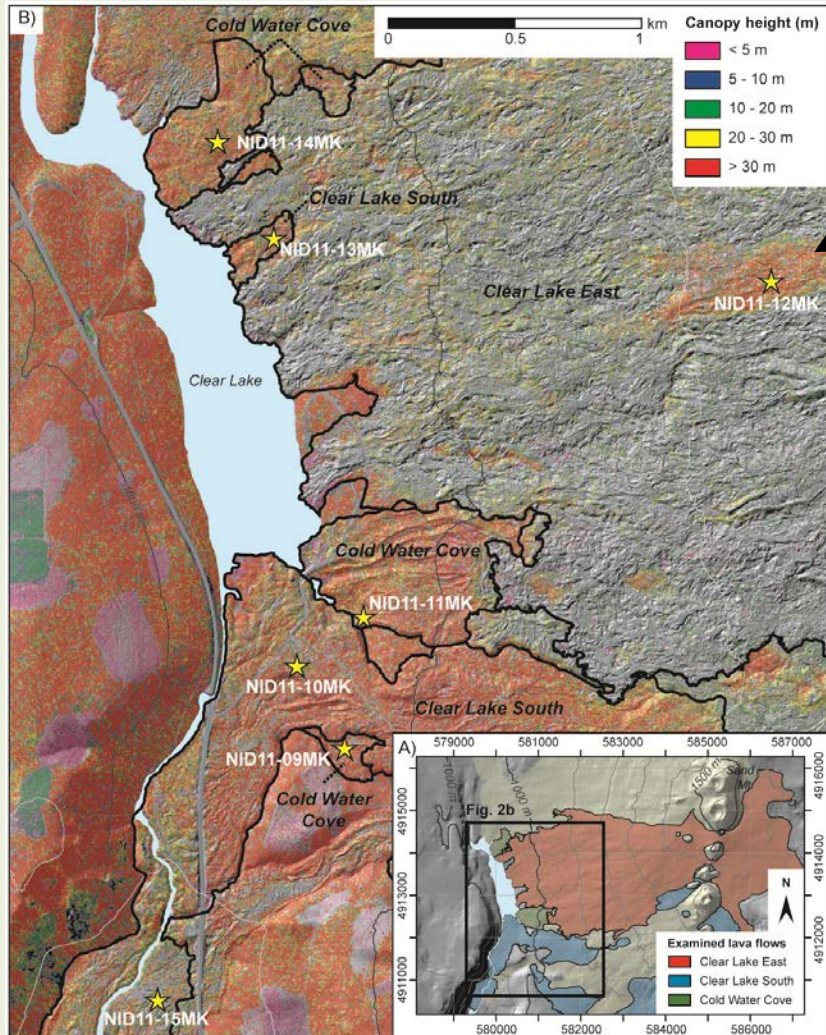
Hahm et al. 2014, Southern Sierra CZO

Hypothesis: Bedrock phosphorus provokes a weathering limitation on erosion and thus landscape evolution through its influence on vegetation. OR IS SOMETHING ELSE AT PLAY?

SPACE INVADERS: Extra-CZ-ial controls on vegetation pattern and soil depth (exogenous)



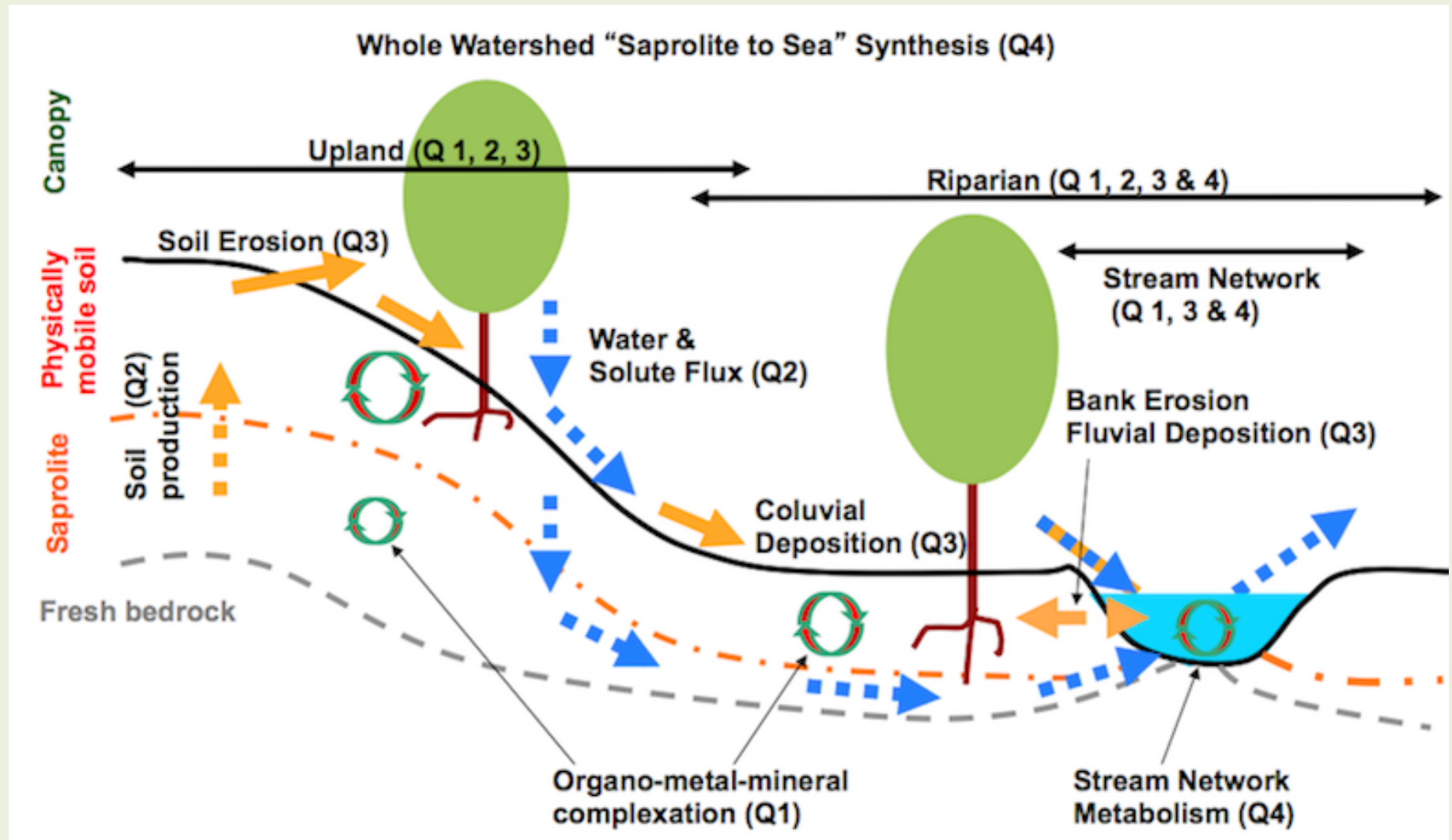
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Tephra blanket

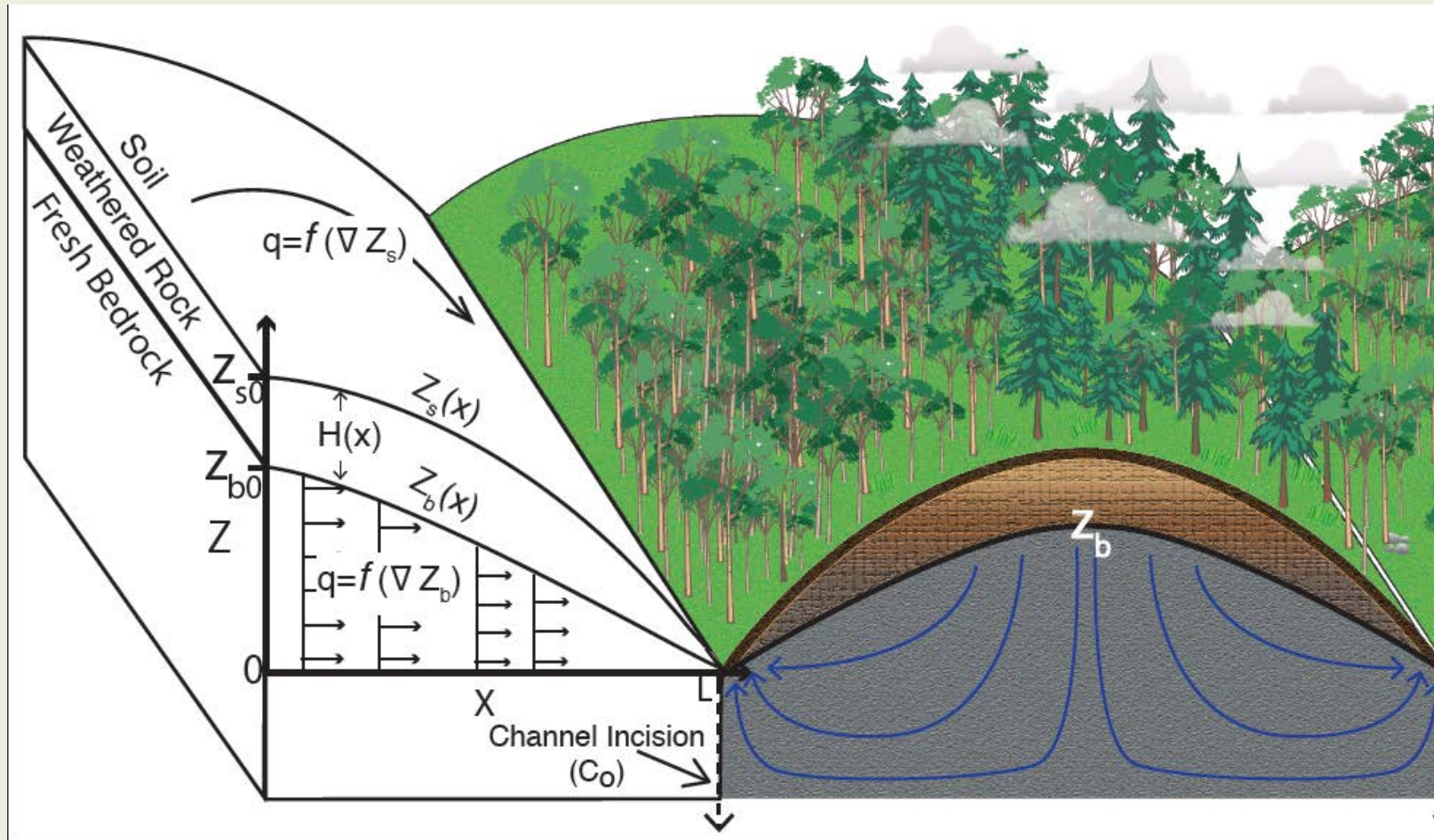
Hypothesis: Presence of exogenous fine-grained substrate can jump-start soil formation, vegetation succession and forest development

TYING IT ALL TOGETHER: EVERYTHING COUNTS



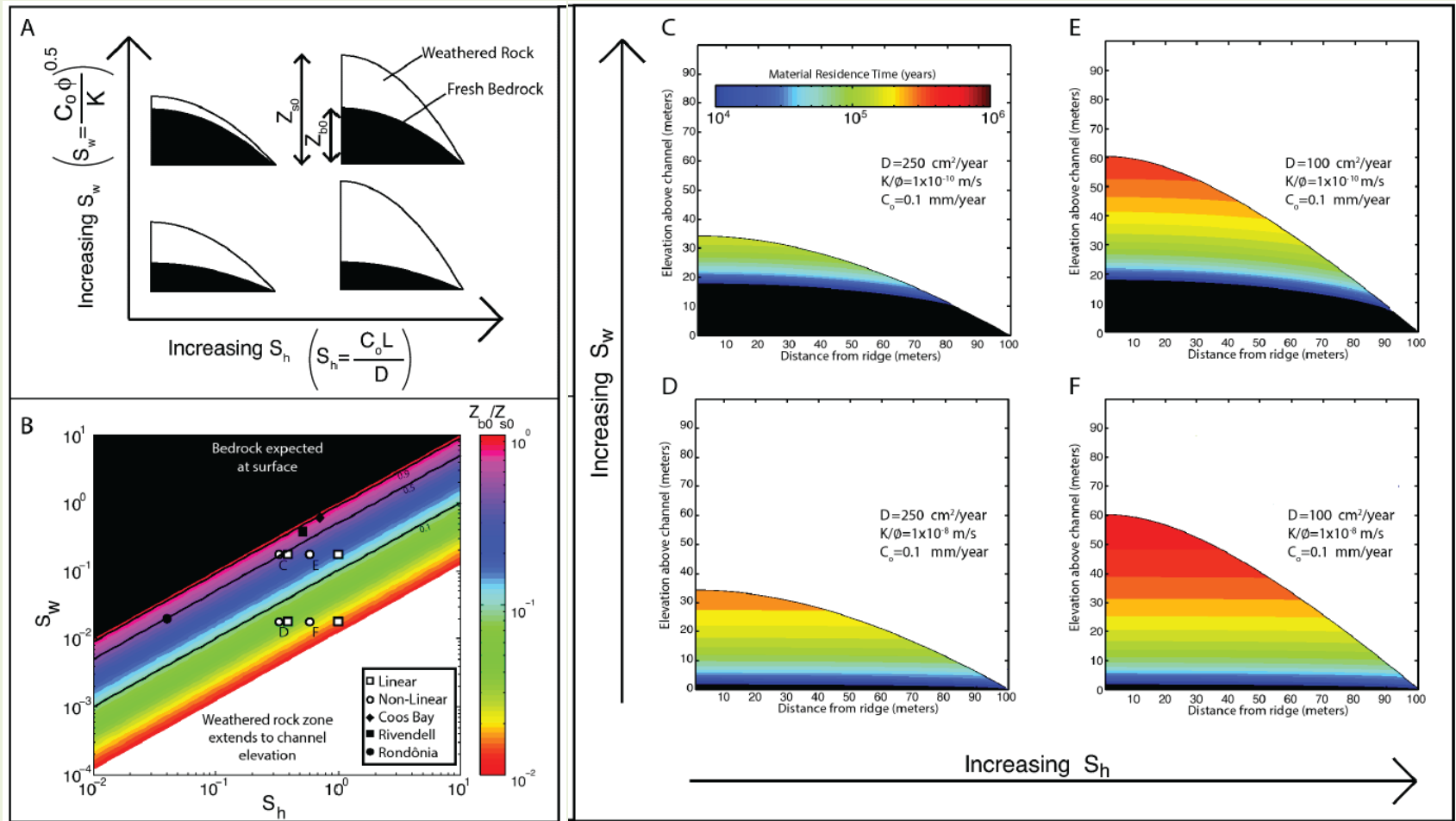
MOVING TOWARDS THEORIES OF CZ DEVELOPMENT:

De-watering of deep bedrock controls CZ development



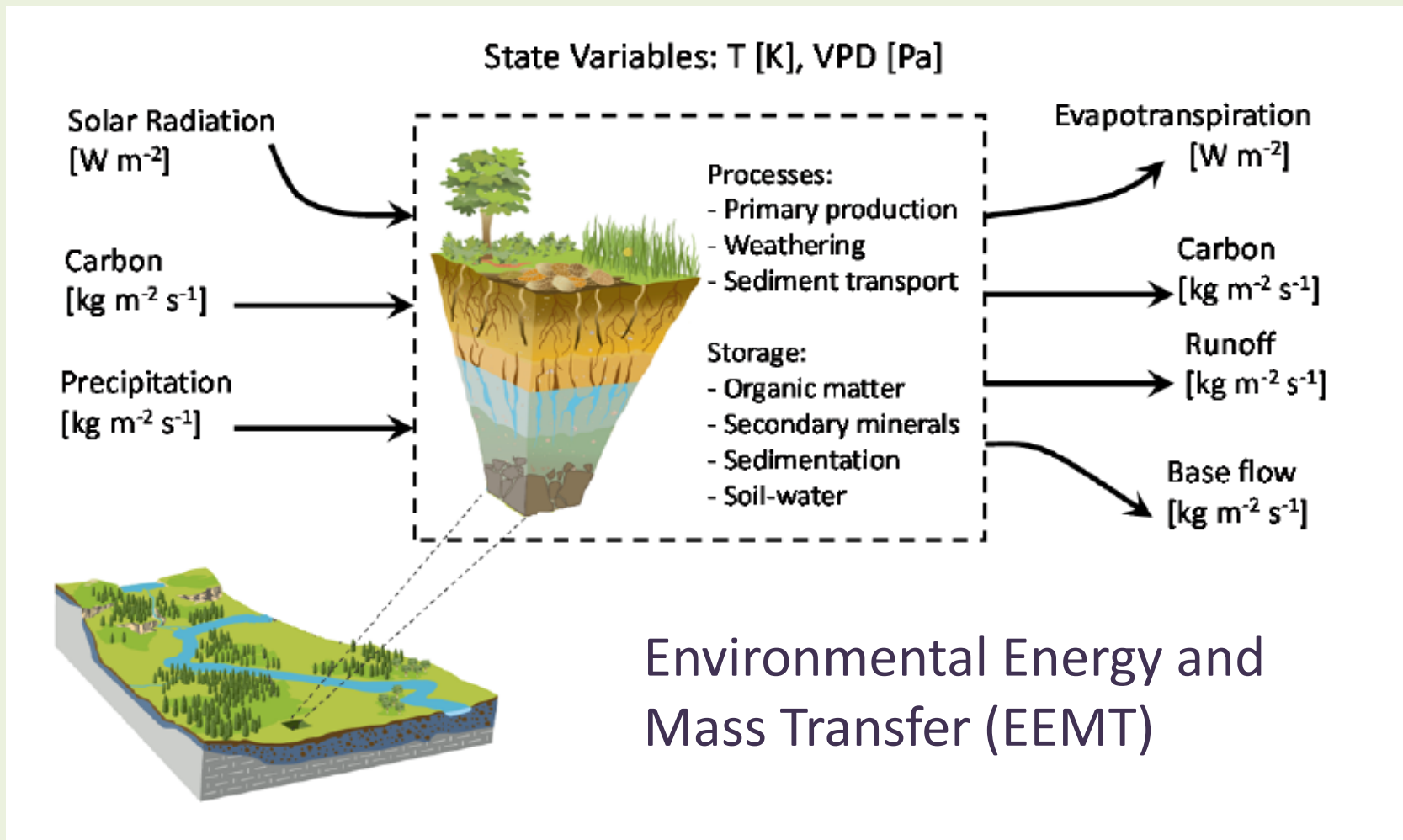
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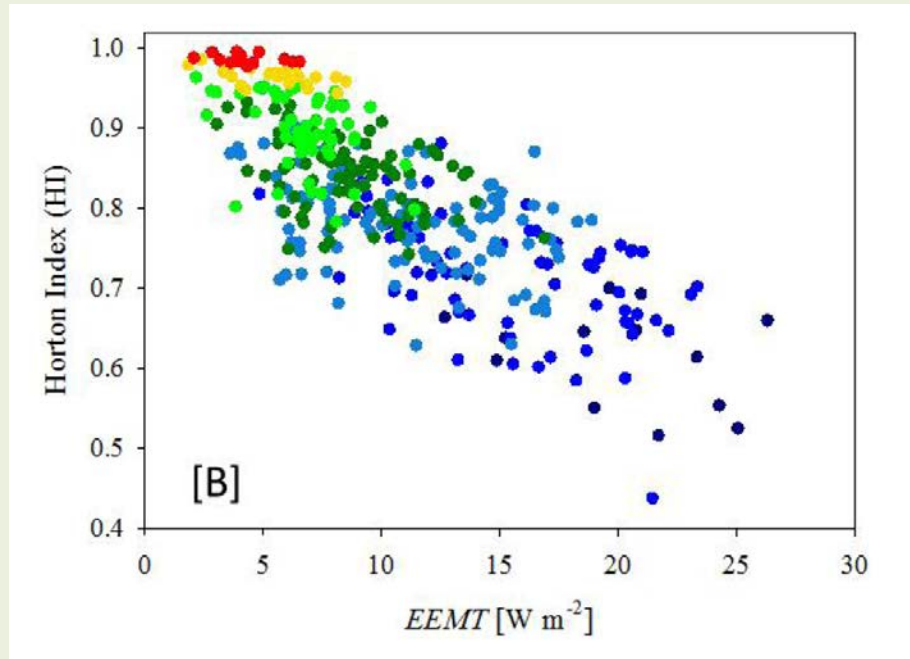
MOVING TOWARDS THEORIES OF CZ DEVELOPMENT:

Energy flux sets the tempo of CZ development and vegetation water use

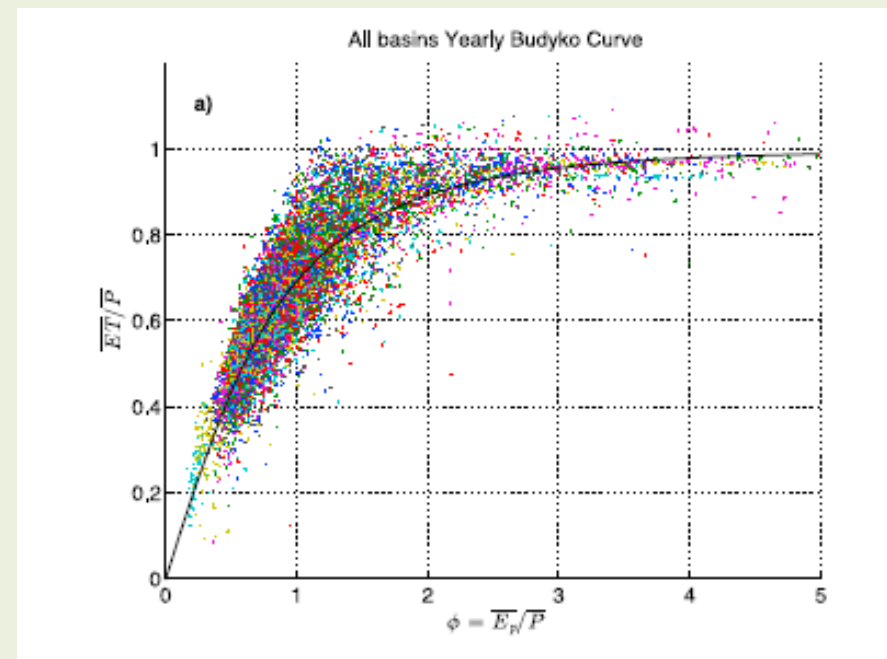


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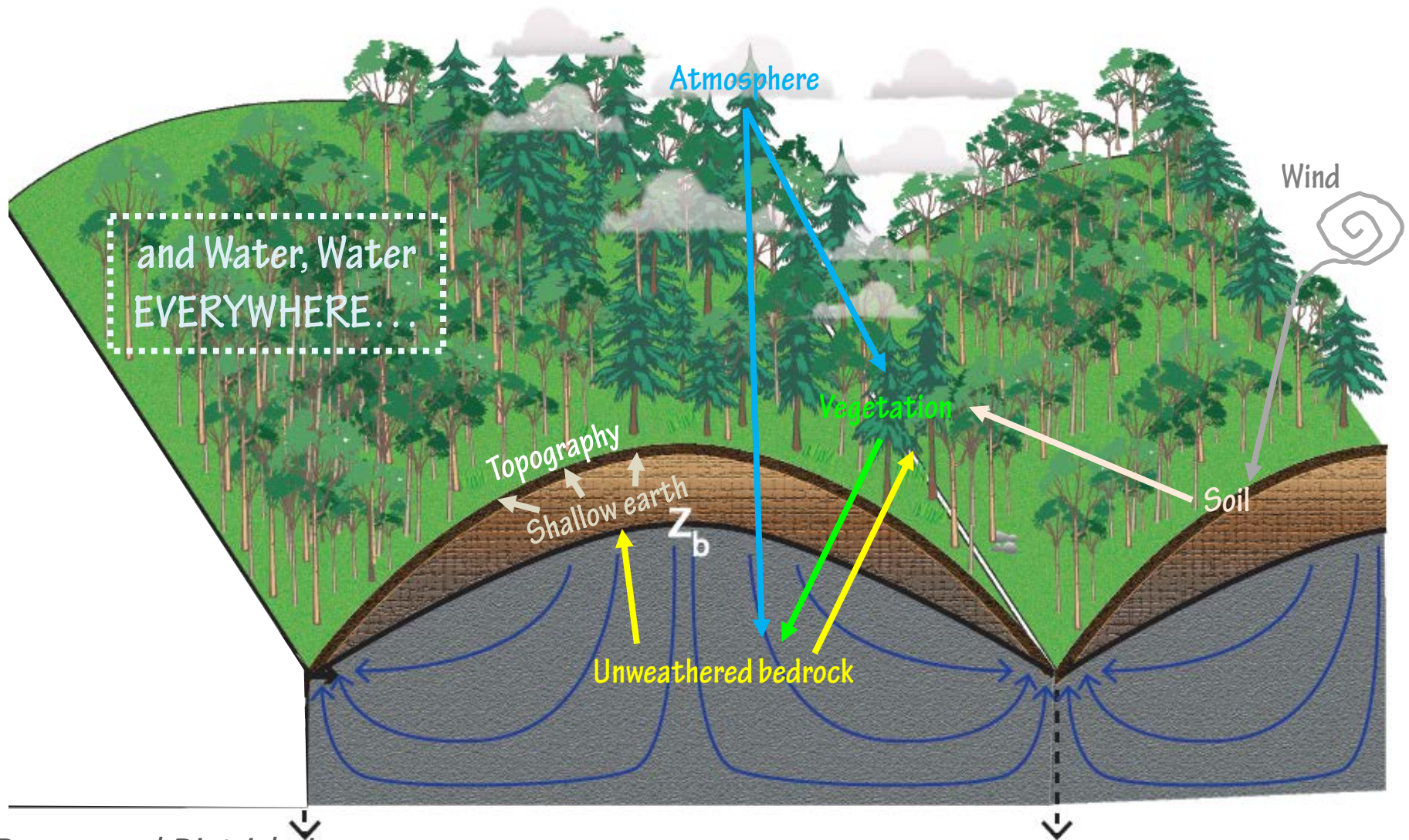


EEMT vs. Horton Index

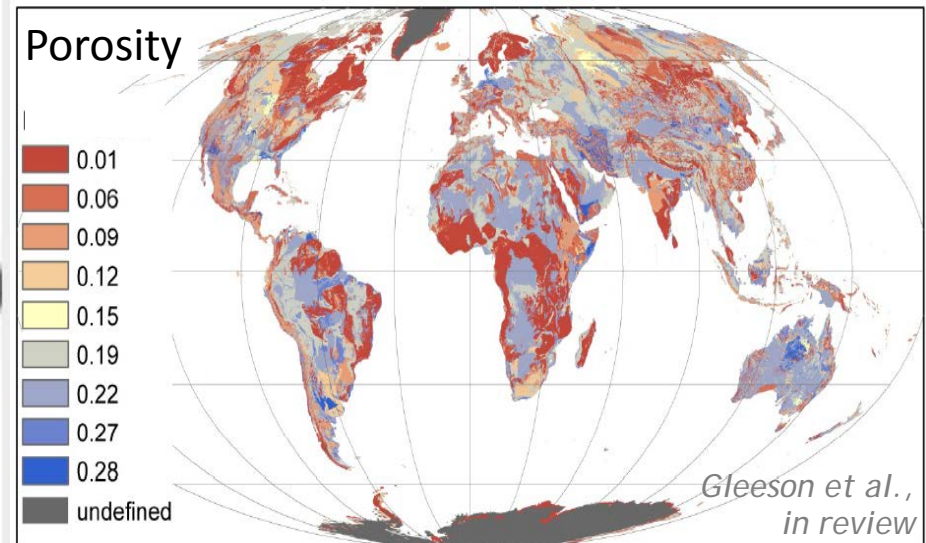
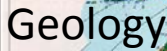


Budyko Curve

THE EVOLVING BIG PICTURE



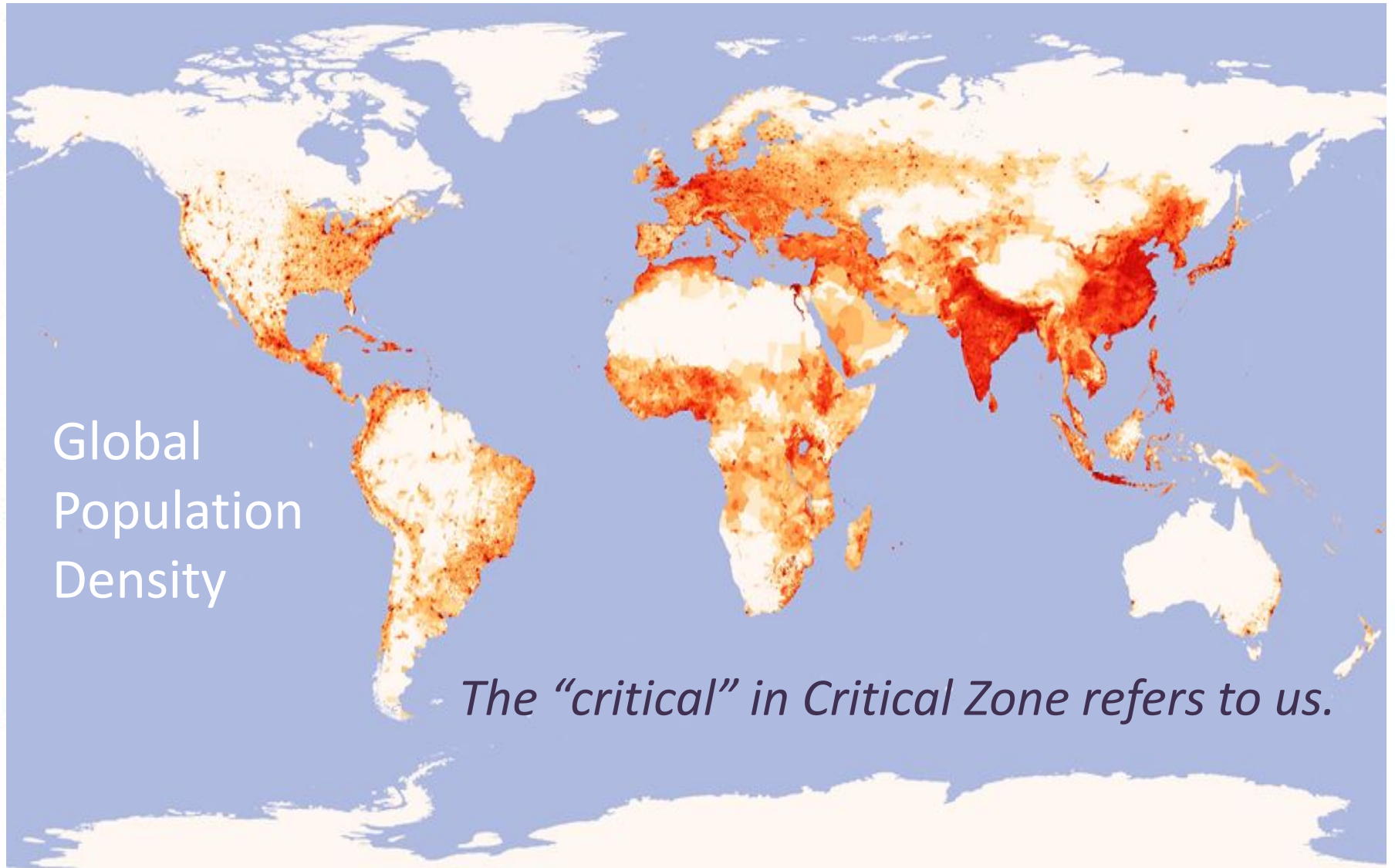
Climate



WHAT TRUMPS WHAT WHERE?



WHY SHOULD WE CARE?



Global
Population
Density

The “critical” in Critical Zone refers to us.

THE ANTHROPOCENE: Human forcings accelerate cycling and transport of water, nutrients and sediment through the critical zone.

Calhoun

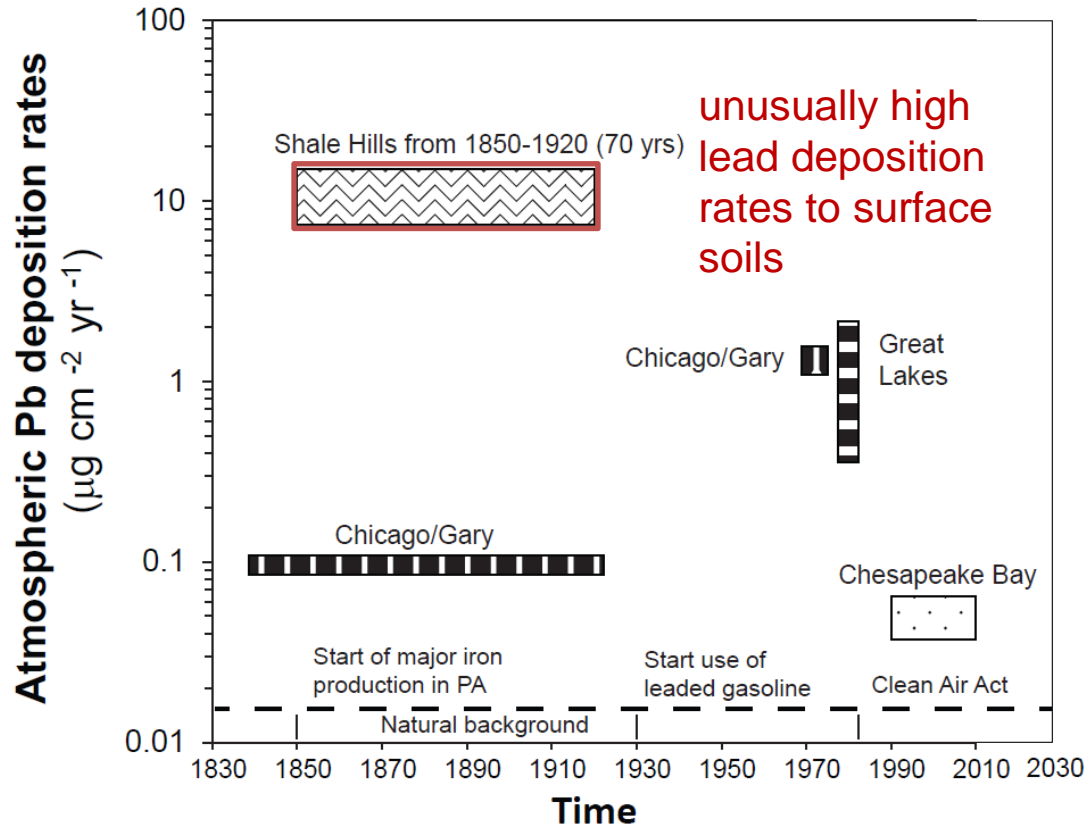


Christina River

IML



THE ANTHROPOCENE: The critical zone remembers...



Coal burning at the Greenwood Furnace produced 4 tons of iron per day (1834-1904)

Ma et al., 2014, in revision; Shale Hills CZO



Flood

Luquillo CZO



Fire

USFS



Drought

Morton Arboretum



Dieback & Mortality

Natural Resources of Canada



Bugs

USFS



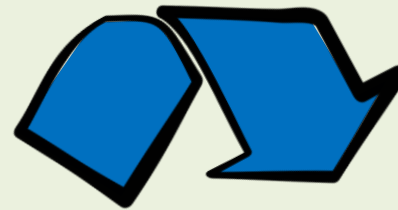
Stressed trees

USGS

Water

Tree growth sequesters more carbon but uses more water

Drought stressed trees more vulnerable to insect attack



As growing season proceeds, soils dry out and trees lose efficiency

Forest become more vulnerable to fire earlier in the summer as fuels dry out



Vegetation (carbon)

Carbon stored in trees is released by wildfires

Disturbance (fire)



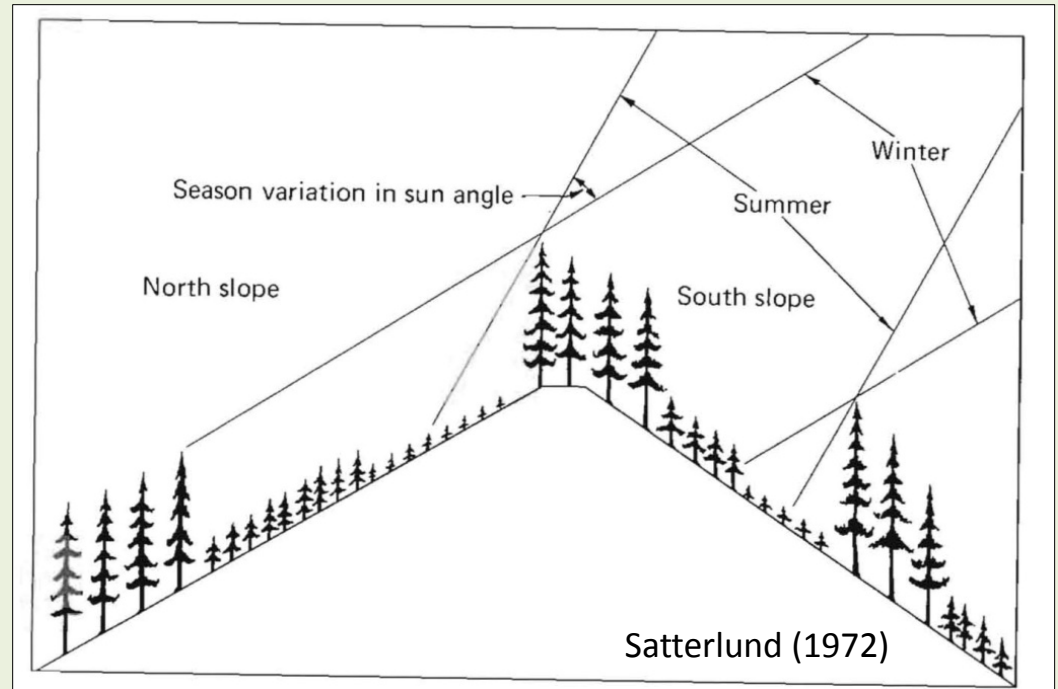
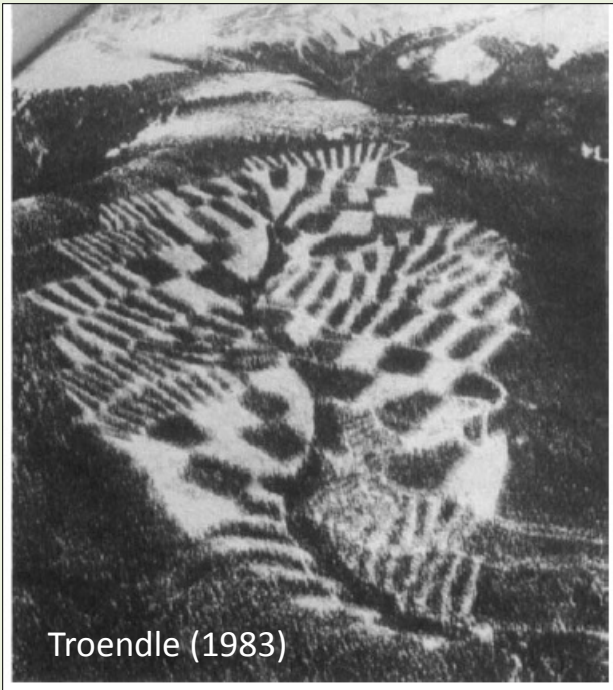
CAN THE CRITICAL ZONE BE MANAGED TO:

- Store more water and carbon?
- Help ecosystems adjust or adapt to a changing environment?
- Reduce natural hazards?

Some strategies...

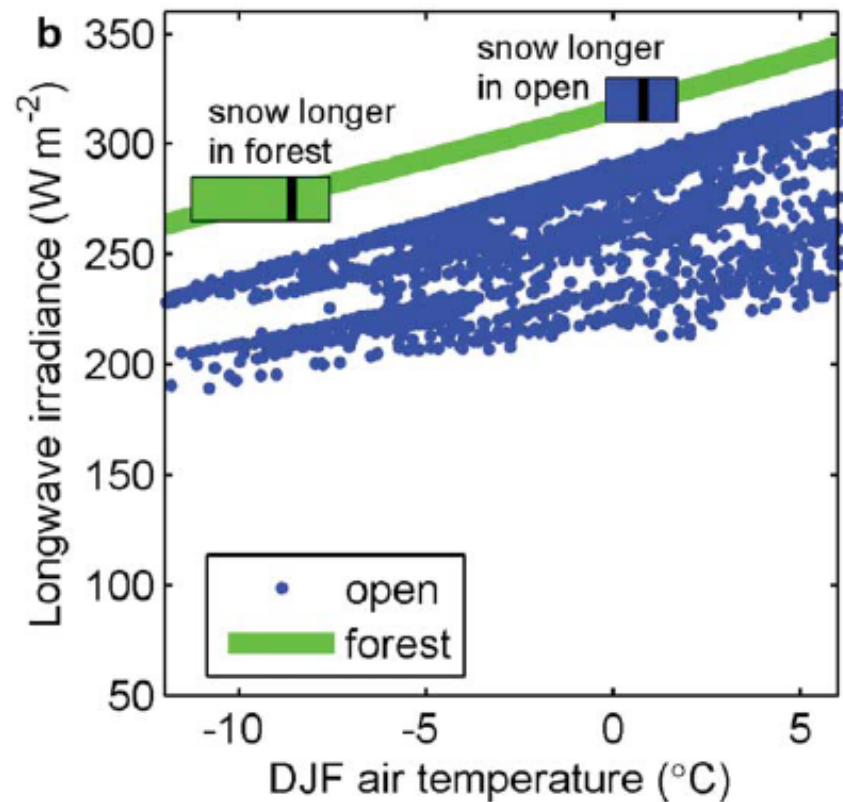
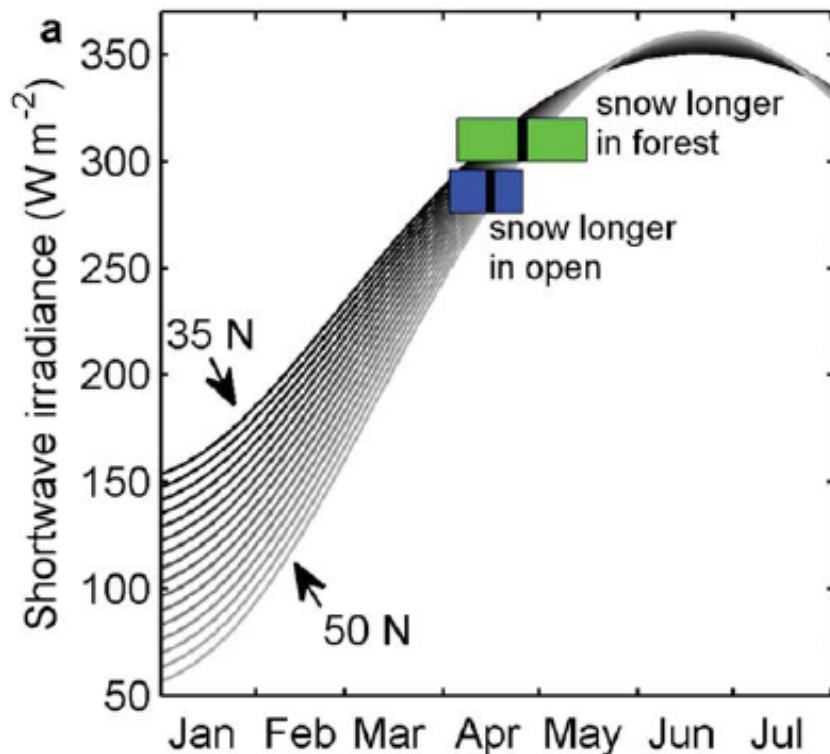
STRATEGY: Maintain snow to sustain soil moisture

- size and shape of openings
- aspect of cutting
- density of thinning



STRATEGY: Maintain snow to sustain soil moisture

But how long snow persists under forest depends on where you are...

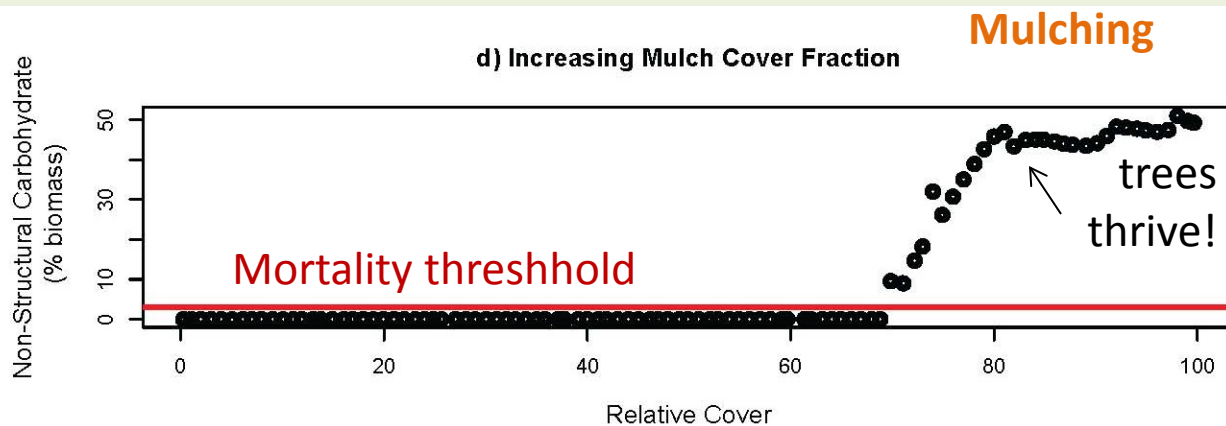


STRATEGY: Maintain soil moisture through mulching



Hatchett et al.(2006)

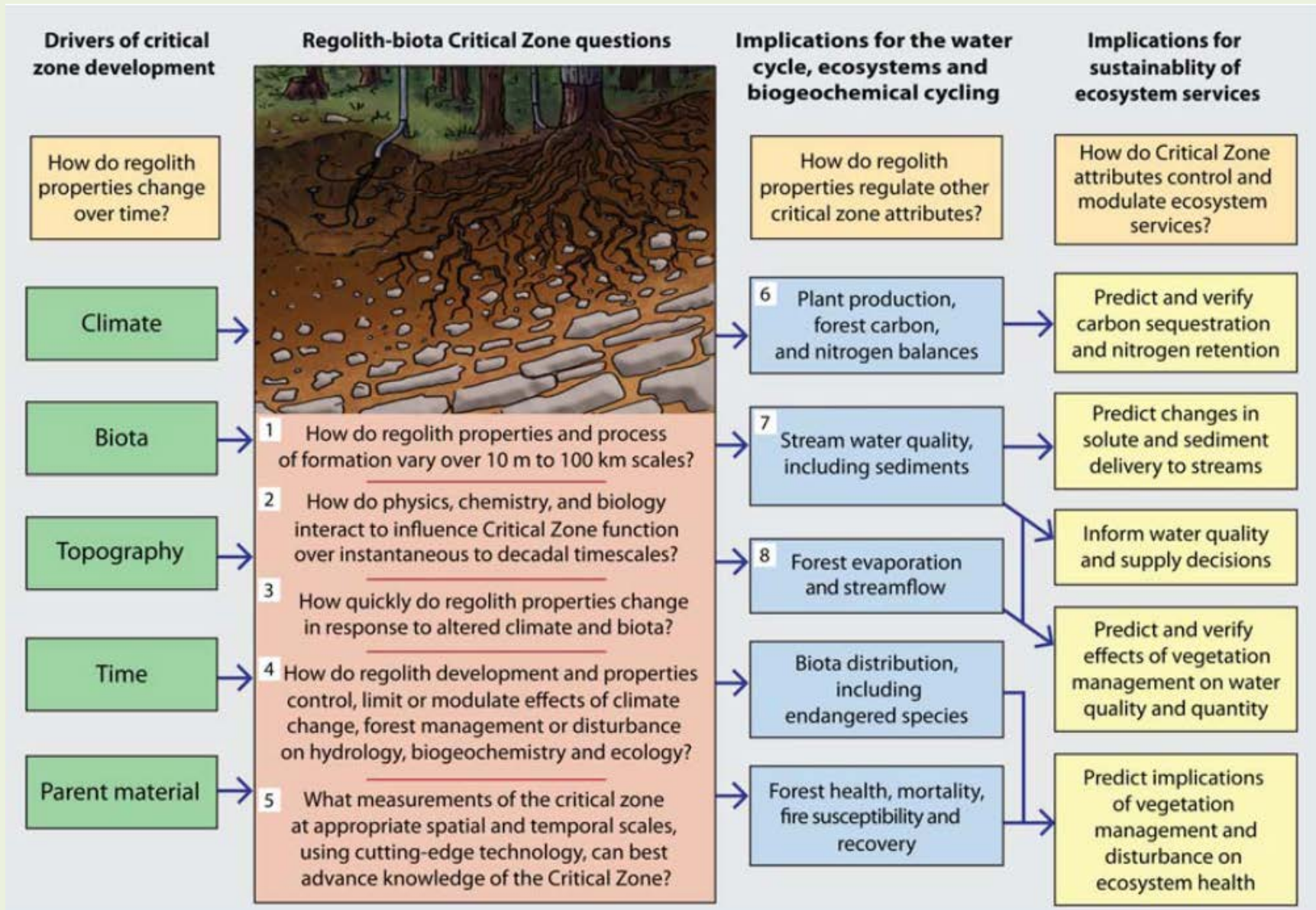
The study area in Tahoma, near Lake Tahoe, *left*, before and, *center*, after mastication treatment; *right*, the masticator grinds forest material into hand-sized chunks.



RHESSys modeling
of carbohydrate
fixation

Grant et al.(2013)

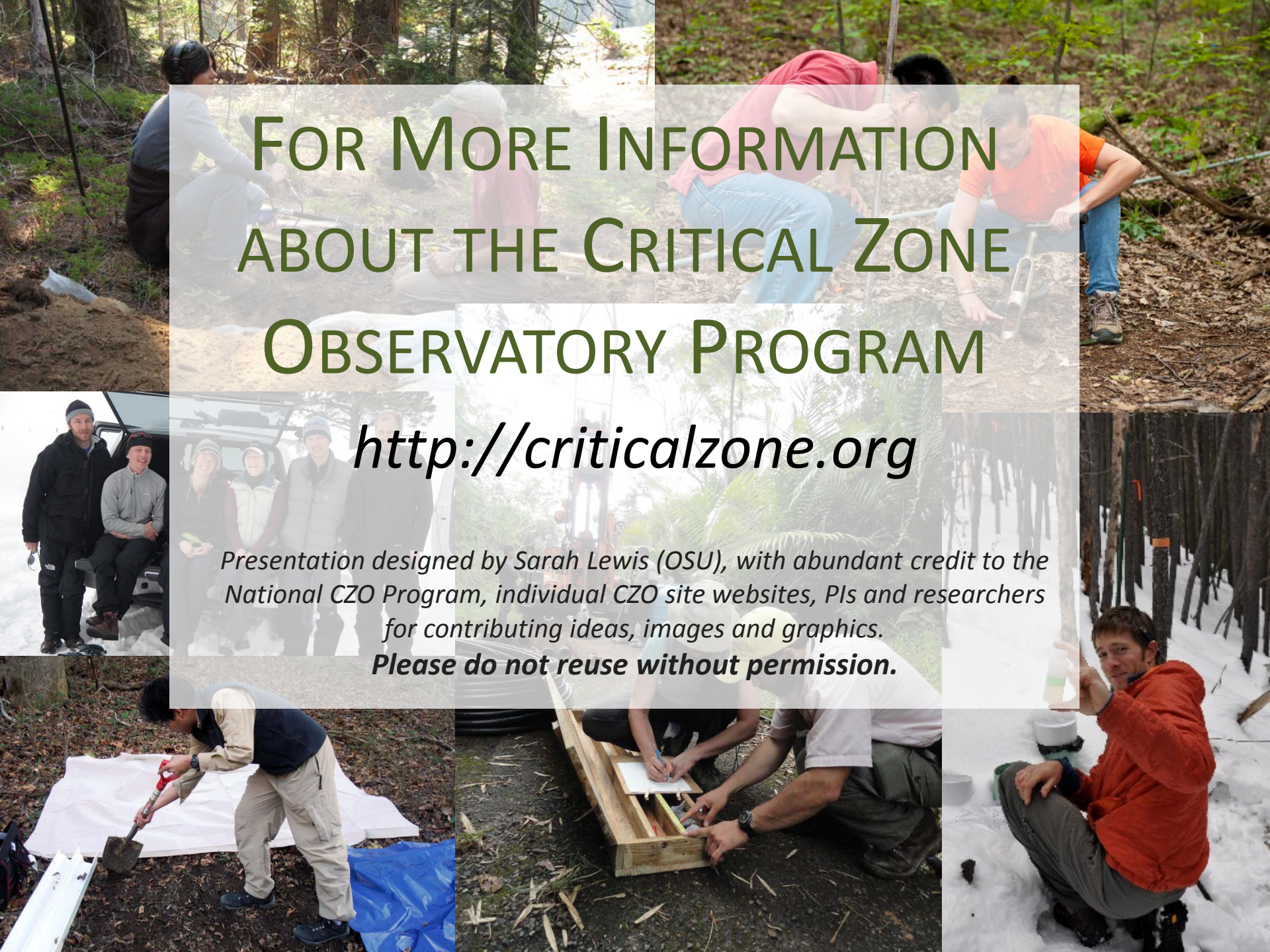
CRITICAL ZONE = ECOSYSTEM SERVICES



SO WHAT IS SO CRITICAL ABOUT THE CRITICAL ZONE (AND CZOs)?

- A growing network
- Representing a portfolio of landscapes
- Addressing fundamental questions
- Generating new scientific perspectives
- And provocative hypotheses
- That address key societal issues
- At a critical time

COME PLAY!



FOR MORE INFORMATION ABOUT THE CRITICAL ZONE OBSERVATORY PROGRAM

<http://criticalzone.org>

Presentation designed by Sarah Lewis (OSU), with abundant credit to the National CZO Program, individual CZO site websites, PIs and researchers for contributing ideas, images and graphics.

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