Weathering and Erosion: How Landscapes Wear Down

- Everyday evidence and deep-time evidence: landscapes are always changing
- Weathering breaks rock in place; no movement is involved
- Erosion removes and transports the broken material away
- Two linked processes, but not the same thing
- Roadmap: process families, rates, landforms, human stakes, classroom applications
- Accessible core for students and adult learners, plus educator extensions



Background: Landscapes in Balance

- Landscapes are a tug-of-war: uplift and rock formation versus wearing down (denudation)
- Relative time versus deep time: a storm's change versus millions of years
- Rock cycle: weathering → erosion → transport → deposition → burial → new rock, plus uplift
- Name misconceptions early: erosion is not always fast; dissolution is weathering
- Why it matters: soils, infrastructure, hazards, water quality, food security



Physical Weathering:
Breaking Rock Without Changing Its Chemistry

Frost wedging: water expands ~9% on freezing; strongest where temperatures cross 0 °C repeatedly

Salt weathering (haloclasty): crystals grow in pores and cracks; honeycomb tafoni on coasts and deserts

Thermal stress and exfoliation: day–night cycling, wildfire heating, and pressure release/sheet jointing

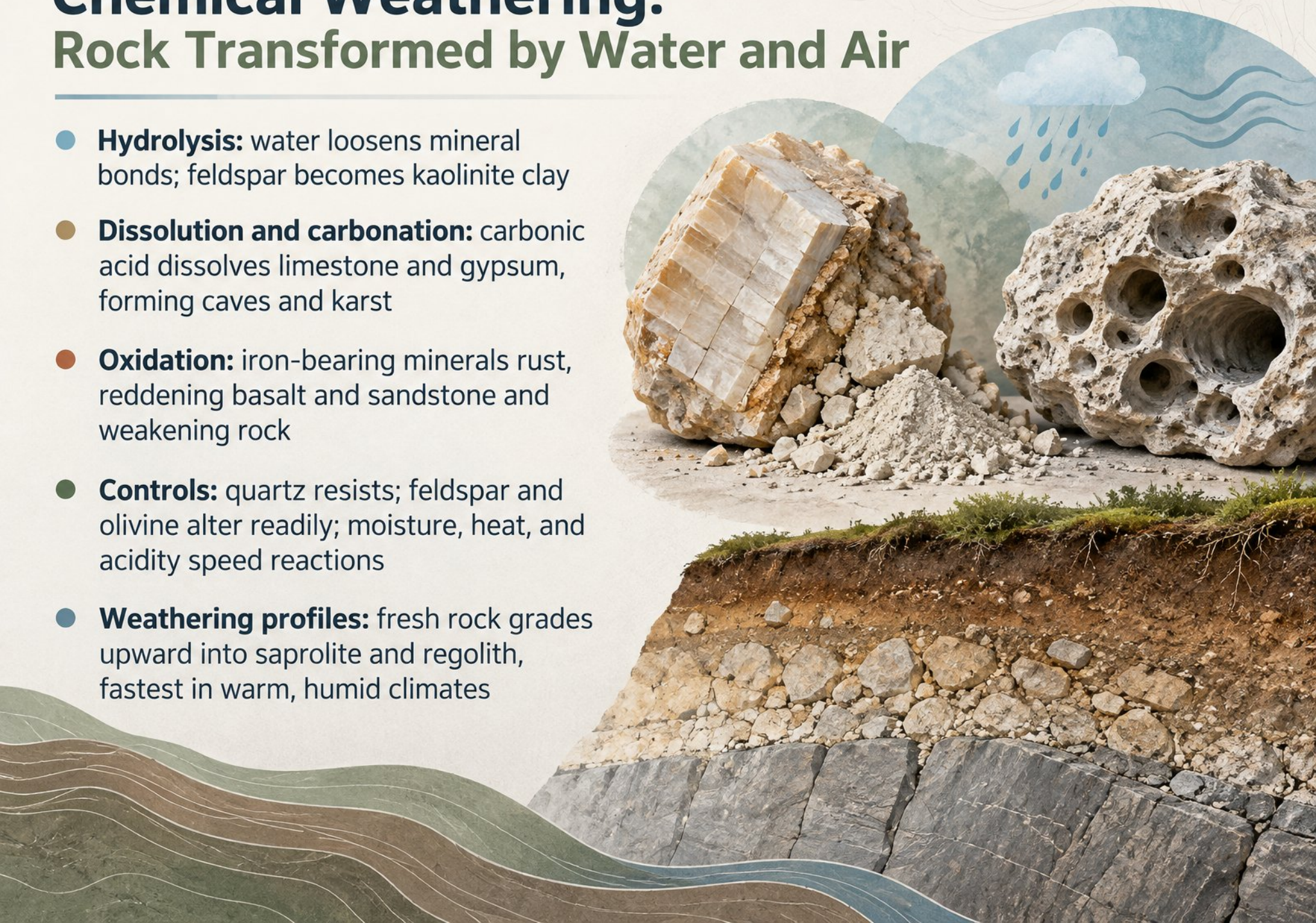
Abrasion: rock-on-rock collisions in water, wind, and gravity-driven falls

Root wedging and biological prying exploit joints, bedding planes, and porosity



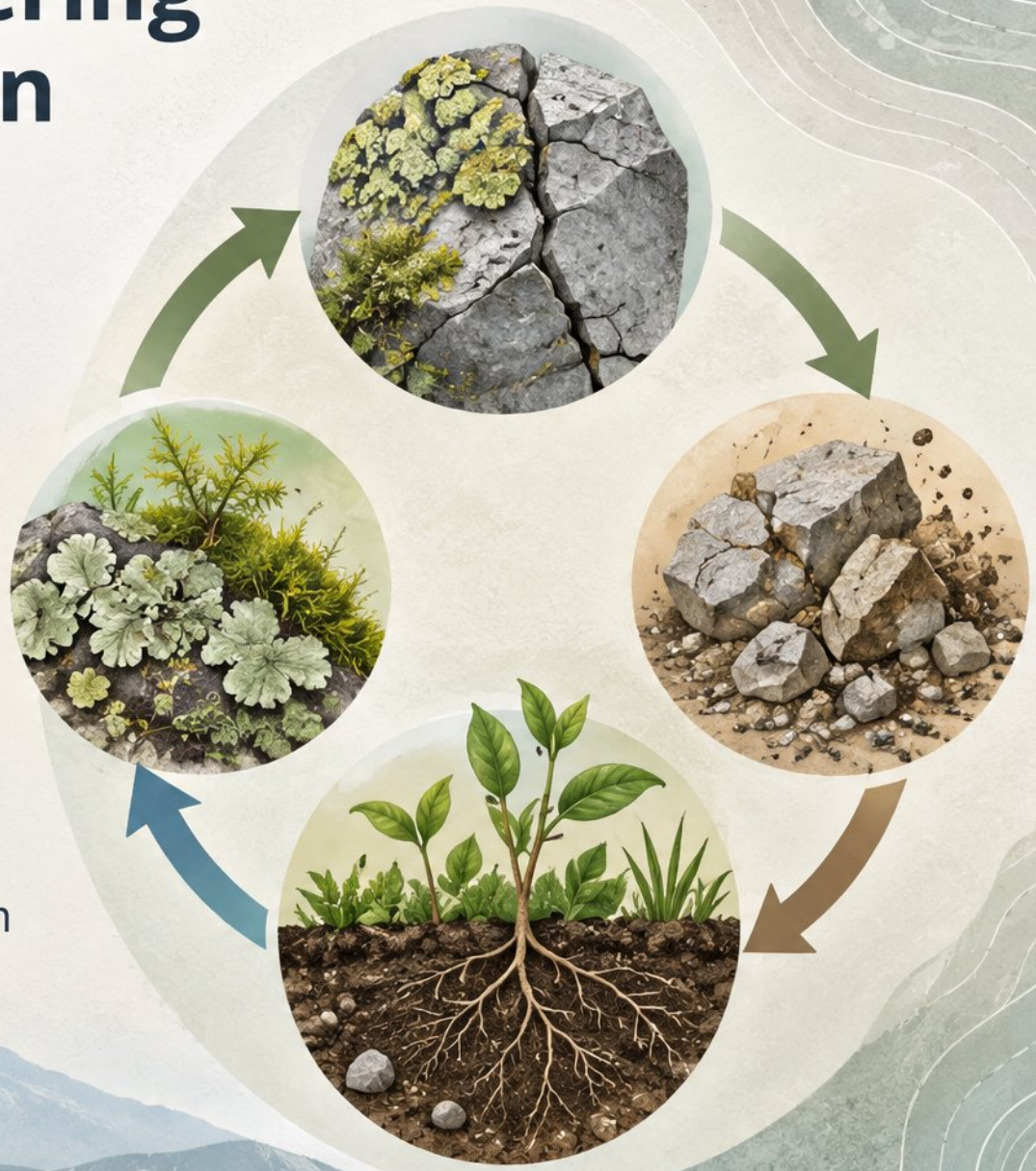
Chemical Weathering:
Rock Transformed by Water and Air

- **Hydrolysis:** water loosens mineral bonds; feldspar becomes kaolinite clay
- **Dissolution and carbonation:** carbonic acid dissolves limestone and gypsum, forming caves and karst
- **Oxidation:** iron-bearing minerals rust, reddening basalt and sandstone and weakening rock
- **Controls:** quartz resists; feldspar and olivine alter readily; moisture, heat, and acidity speed reactions
- **Weathering profiles:** fresh rock grades upward into saprolite and regolith, fastest in warm, humid climates



Biological Weathering and Soil Formation

- Roots pry open cracks; burrowers mix and break rock and soil
- Lichens, fungi, and microbes release acids that dissolve minerals
- Lichens and mosses colonize bare rock first, trapping windblown debris
- Positive feedback: life speeds weathering, weathering builds soil, soil supports life
- Soil formation bridges geology and ecosystems — key for restoration



Erosion and Transport: Moving Weathered Material

- Four agents move sediment: water, wind, ice, and gravity
- Water is the dominant agent globally, shaping most landscapes
- Erosion, transport, and deposition form a continuous chain of removal and drop-off
- Grain size, rounding, and sorting reveal transport distance and agent
- Sorted, layered deposits mean water or wind; unsorted jumbles mean ice or mass movement
- River load moves as suspended, bedload (saltation), and dissolved material



Controls on Weathering and Erosion Rates

- Climate sets the pace: temperature, rainfall intensity, and freeze–thaw cycles
- Rock type and mineral composition resist or yield; joints and faults localize attack
- Land use often outweighs climate at broad scales: farmland erodes fastest
- Rates span orders of magnitude — from about 0.01 mm/yr to meters per year
- Measure with erosion pins, sediment loads, cosmogenic nuclides, and landscape models

EROSION RATES ACROSS LANDSCAPES



Stable cratons
0.01 mm/yr

Badlands
meters per year

KEY CONTROLS



PROCESSES SHAPE OUR PLANET

Landscapes and Landforms: Reading the Evidence

PROCESSES SHAPE PLACES

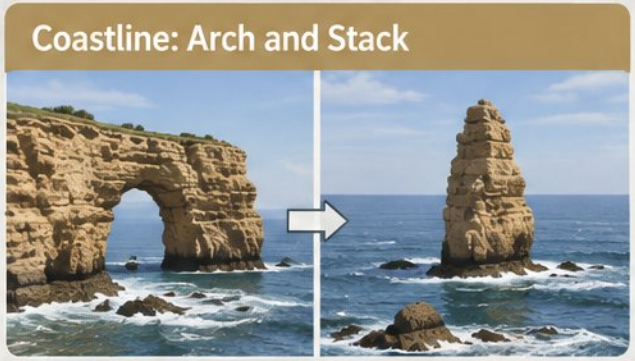
- Weathering landforms: tors, flared slopes, karst towers, and sinkholes
- Rivers carve V-shaped valleys, gorges, meanders, and oxbow lakes
- Glaciers leave U-shaped valleys, cirques, hanging valleys, fjords, striations
- Coastline sequence: crack → cave → arch → stack → stump; wave-cut platforms
- Wind and gravity: yardangs, desert pavement, ventifacts, landslide scarps, talus fans
- Landform shapes reveal which process and agent did the work

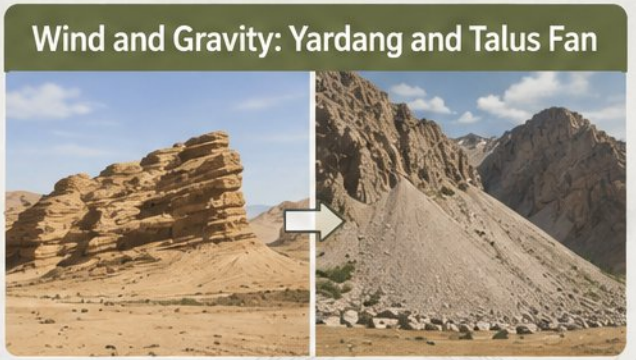












SHAPED BY EARTH'S PROCESSES
A MORE COMPLEX TOMORROW

Human Dimensions: Soil Loss, Hazards, and Management

- About 1.7 billion people live where land degradation cuts yields 10% (FAO, 2025)
- Roughly 36 Pg of soil erodes yearly; Africa, South America, and Asia hit hardest
- Sediment silts reservoirs, damages roads, and clogs channels; mass wasting threatens communities
- Deforestation and overgrazing accelerate erosion; conservation agriculture slows it
- Cover crops cut soil loss about 72%; no-till about 66–83%, with trade-offs
- Reversing just 10% of cropland degradation could feed 154 million more people



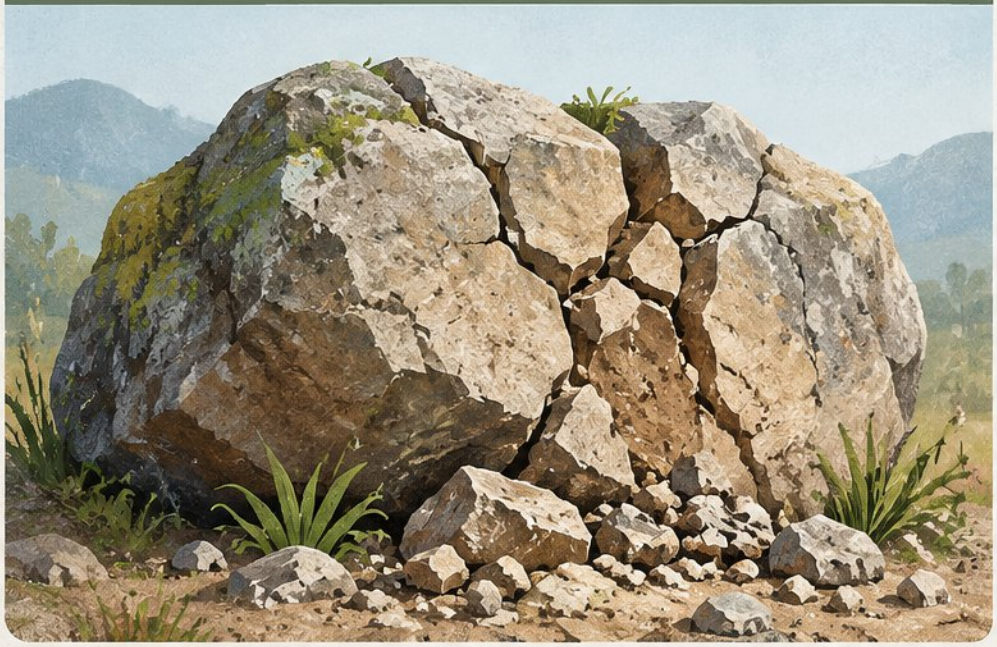
Teaching and Applying the Concepts

- Demonstrations: freeze–thaw plaster, acid on chalk, erosion trays, stream tables
- Field investigations and citizen science: observe weathering and erosion locally
- Interpret landscape change from images and maps, linking landforms to processes
- Assessment probes: “Is It Erosion?” and “Can a Plant Break Rocks?”
- Discussion prompts connect processes to local environments and everyday decisions



Weathering vs. Erosion: The In-Place vs. Transport Distinction

Weathering: In Place



Erosion: Transported Away



- **Common confusion:** everyday language blurs wearing away and breaking off
- **Precise test:** stays put, even if chemically changed, it is weathering
- If a loosened particle moves by gravity, water, wind, or ice, that is erosion
- Weathering includes physical breakup and chemical breakdown, even dissolution
- **Learner model:** "break it where it stands" versus "pick it up and take it away"

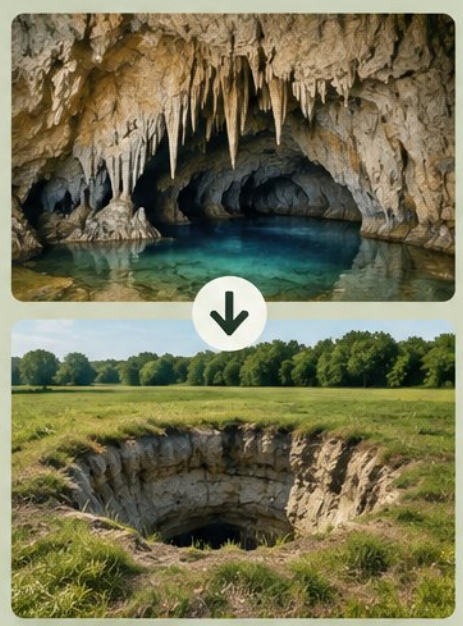
Case Study: The Wearing-Down Machine in Action

SAME PROCESSES. DIFFERENT PLACES. REAL IMPACTS.

Badlands and talus: frost wedging plus water erosion in dry or cold climates



Karst and caves: carbonic and sulfuric acid dissolution, with sinkhole hazard



Coastal cliffs: wave attack plus mass wasting; defend or retreat?



Farm fields: land-use change can multiply erosion more than climate alone



One lens for every case:
process → agent → rate controls → landform → human consequence

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Designing a Lesson Sequence: From Phenomena to Assessment

EXPLORE
INVESTIGATE
CONNECT
APPLY



- Launch with a local phenomenon: rock face, muddy river, sea arch
- Sequence: definitions → process families → rates → landforms → human use
- Hands-on: freeze–thaw stations, stream tables, image and map interpretation
- Probe misconceptions with "Is It Erosion?" and "Can a Plant Break Rocks?"
- Adapt vocabulary and depth for students, adult learners, or teacher PD

SAME PROCESSES
A BRIGHTER TOMORROW



Key Takeaways and Next Steps

- Weathering breaks rock in place; erosion moves the products
- Physical, chemical, and biological weathering work together — water is the common thread
- Water, wind, ice, and gravity each leave distinctive landforms and sediment clues
- Rates vary with climate, rock type, structure, vegetation, and land use
- Try it: observe one local feature, run one demo, connect it to a local decision

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