



Chapter 11: Scales of Change on Earth's Surface

Chapter 11 of 29 · Earth's Systems

Lesson 11: How does Earth's surface change, and how do we compare changes of every size and speed?

Angela's Wand · Bring Science Alive! 7th Grade Integrated

PHENOMENON

A century of nothing, then ten seconds of change

A granite cliff in Yosemite Valley matches photographs taken more than a hundred years ago. One afternoon a slab the size of a classroom peels off, falls for about ten seconds and leaves a pale scar. The valley around it, nearly a kilometer deep, was carved by glaciers that melted away about fifteen thousand years ago. Both changes are still going on.

- Notice: what changed in ten seconds? What stayed the same for a hundred years?
- Wonder: what was happening inside the cliff during the hundred quiet years?
- Predict: which change was bigger, and which was faster? Do big and fast go together?





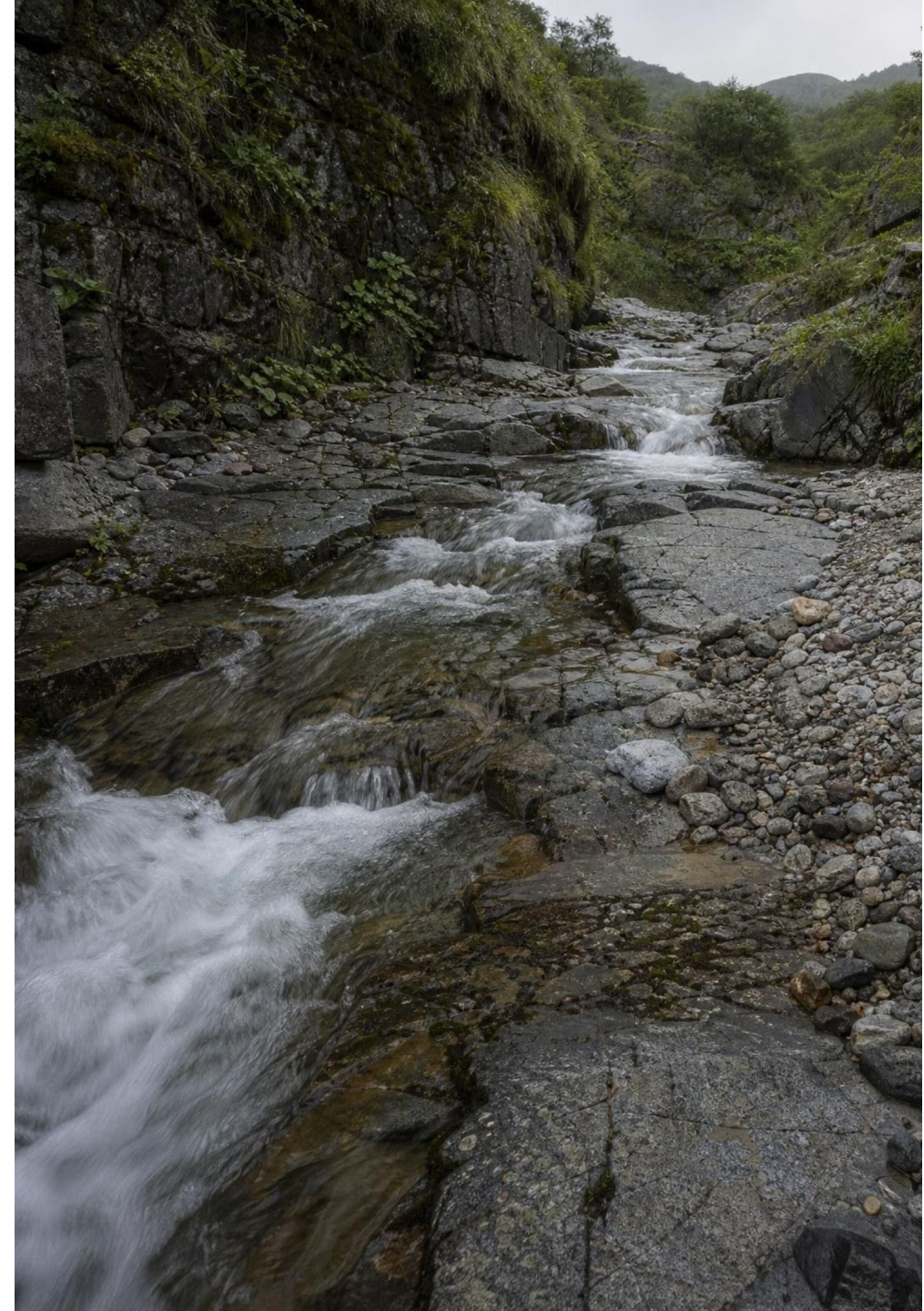
LEARNING TARGETS

What you will be able to do

- 1 Tell apart weathering, erosion, deposition and uplift, and name what drives each.
- 2 Place a change on a space scale and a time scale, and explain why both are needed.
- 3 Calculate a rate of change and use it to predict a big change or a long time.
- 4 Explain, with evidence, how slow processes and sudden events together reshape a landscape.
- 5 Use uniformitarianism to read the past, and say what it does and does not claim.

Earth's surface is a work in progress

- Rock looks permanent, but every surface you can touch is being broken down, moved and rebuilt.
- Weathering breaks rock apart where it sits. Erosion carries the pieces. Deposition drops them somewhere new.
- Uplift pushes large areas of crust upward from below, usually very slowly.
- The agents: water, ice, wind, gravity, living things and chemical reactions.



Three verbs for rock: break, carry, drop

weathering: Breaking rock down where it sits, by physical forces or by chemical reactions. *Frost splits a boulder; roots widen a sidewalk crack; acidic rain dissolves limestone.*

erosion: Picking up loosened rock material and moving it, by water, wind, ice or gravity. *A muddy stream after a storm is erosion you can see; a glacier hauling boulders is erosion you cannot.*

deposition: Dropping carried material in a new place when the water, wind or ice slows or stops. *A gravel fan where a canyon opens onto a valley; a sand dune; mud on a flooded floor.*



One sand grain's long journey

Model

Model: From cliff to sandstone and (eventually) back again

1 Solid rock on a cliff →
(weathering) (frost, roots,
grinding, chemistry))

2 Loose grains → **(erosion)** (wind,
water, ice, gravity))

3 Grains on the move →
(deposition) (the carrier slows
down))

4 Grains settle in a dune or river
bed → **(compaction)** (weight of
layers above))

5 Buried and squeezed →
(cementation) (minerals from
groundwater))

6 Glued into sandstone

One of many paths. Uplift can raise the sandstone into a new cliff and the journey starts over; that full loop is the rock cycle in Lesson 17.

CHECK FOR UNDERSTANDING

Quick check: which process?

A stream drops gravel where it reaches a flat valley. Frost splits a boulder on a ridge. Which pair names these two events, in order?

A. Erosion, then weathering

B. Deposition, then weathering

C. Deposition, then erosion

D. Weathering, then deposition





Who does the breaking and the moving?

- Water dissolves some rock, pries cracks open when it freezes, and carries almost anything.
- Ice in glaciers scrapes bedrock and hauls boulders the size of houses.
- Wind sandblasts rock and lofts dust across whole oceans.
- Gravity pulls everything downhill, from one grain to an entire hillside.
- Living things split rock with roots, grind it underfoot and dissolve it with acids.
- Most of these are Earth's other systems, water, air, ice and life, acting on rock.

One process, many sizes: wind on sand

Model: The same wind doing the same thing, added up

A grain, about 1 mm: Bounces a few centimeters in a gust. Grinds against its neighbors and gets smaller.

A ripple, centimeters high: Forms in minutes as grains pile up on the sheltered side of a bump.

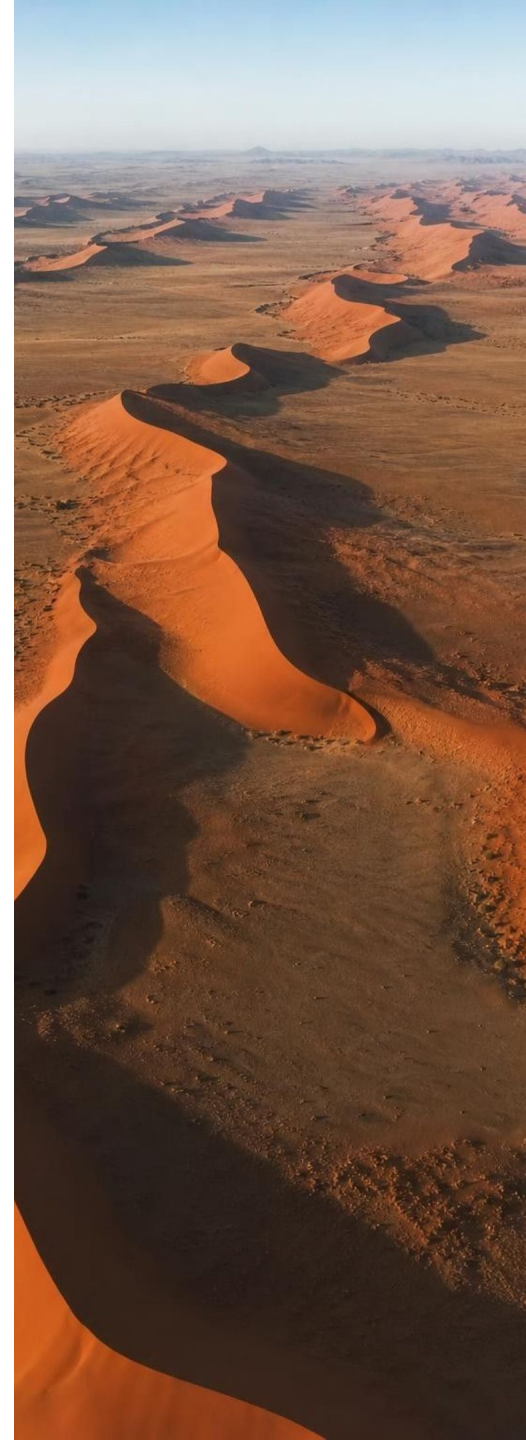
A dune, tens to hundreds of meters: Grains climb the windward slope and tumble down the steep side; the whole dune creeps downwind.

A dune field, kilometers across: Hundreds of dunes marching in the same direction.

A sand sea, tens of thousands of km²: Visible from orbit. The Namib sand sea in southwest Africa covers about 34,000 km².

Dust plumes, across an ocean: The finest grains, worn to dust, blow from Africa over the Atlantic.

Six sizes, one process. Each level is built from the one below it.





THINK, PAIR, SHARE

Discuss: can a change you cannot see build a 300 m dune?

- What is the smallest change you could measure on a dune in one day? In one year?
- How would you turn that measurement into a rate?
- What else, besides the rate, would you need to know to predict the dune's size?

A gust moves each sand grain only a few centimeters, and nobody has ever watched a dune grow. Could gusts alone build a dune 300 m tall? What would you need to measure to decide?

Slow changes: the ones you cannot feel

- Plates carrying continents creep a few centimeters a year, about as fast as fingernails grow.
- Uplift raises mountain ranges over millions to tens of millions of years.
- Buried sand becomes sandstone: compaction squeezes, cementation glues. Millions of years.
- Weakly acidic water dissolves limestone into caves over hundreds of thousands of years.
- A river cutting a fraction of a millimeter a year can carve a canyon in a few million years.





VOCABULARY IN CONTEXT

Words for slow change and for measuring it

uplift: The raising of a large area of crust by forces from deep inside Earth; usually very slow, but an earthquake can lift land several meters in minutes. *Sea-floor fossils found high in the Himalaya got there by uplift.*

chemical weathering: Weathering by a chemical reaction that dissolves or changes rock. *Weakly acidic groundwater dissolving limestone to open a cave.*

rate of change: Change divided by time, such as millimeters per year. Rate times time gives the total change. *0.3 mm per year of river cutting, times 5 million years, is 1,500 m of canyon.*

CHECK FOR UNDERSTANDING

Quick check: how far does slow go?

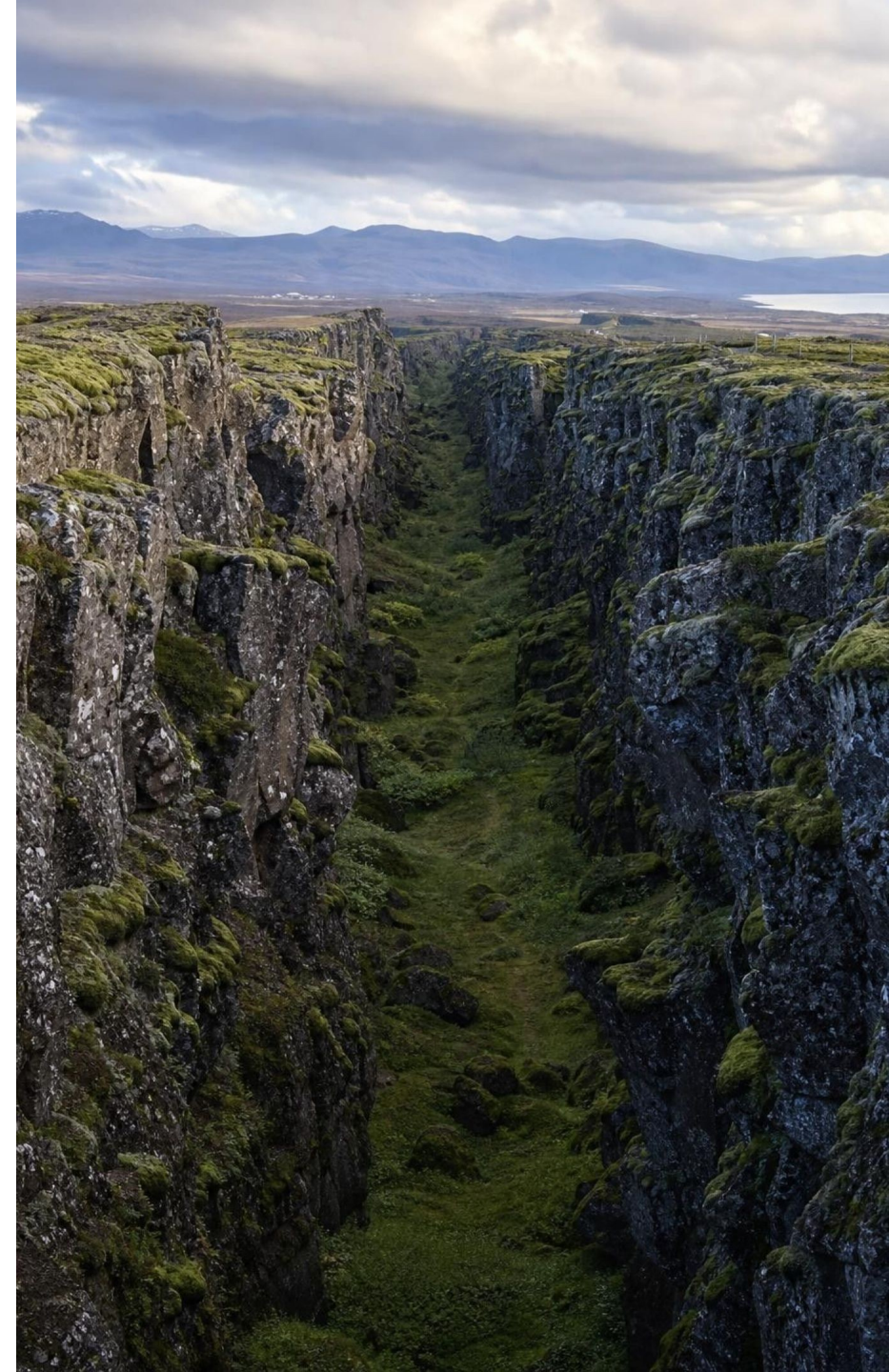
A plate moves 2.5 cm every year. If it keeps that pace, how far does it travel in one million years?

A. 25 meters

B. 2.5 kilometers

C. 25 kilometers

D. 250 kilometers





Fast changes: seconds to weeks

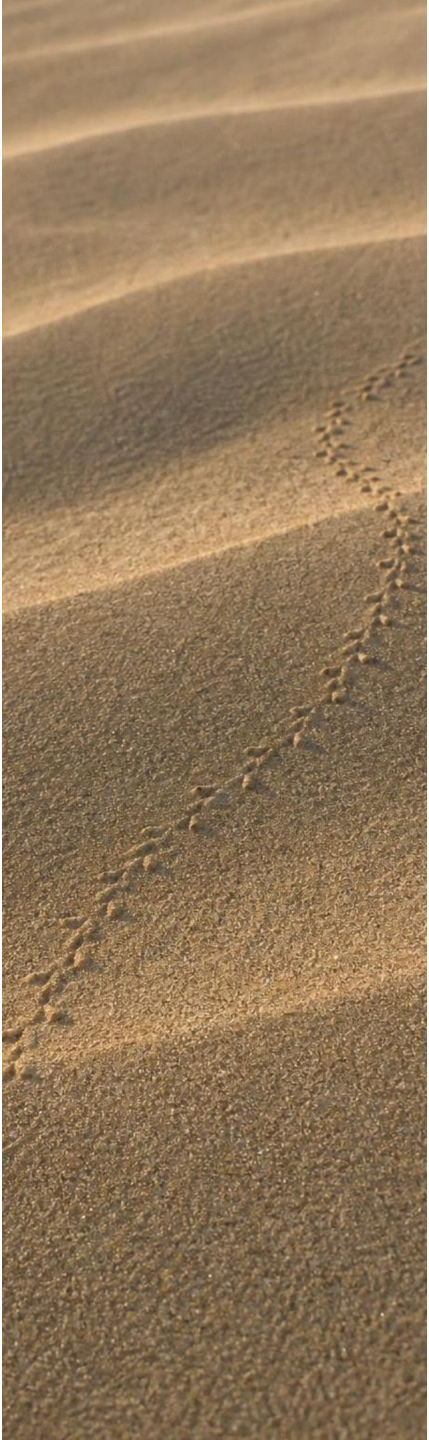
- Landslide: minutes. A slope soaked by rain or shaken by an earthquake lets go.
- Flash flood: hours. Heavy rain in a short time, or a dam, levee or ice jam giving way.
- Volcanic eruption: often weeks, though some run for years.
- Asteroid impact: seconds to blast a crater; dust can cool the whole planet for years.
- 'Sudden' describes the event. The conditions behind it usually build slowly.

Two rulers for every change

Model: Space ruler and time ruler, read separately

Beetle tracks in sand:	Space: millimeters.	Time: seconds.
A landslide:	Space: hundreds of meters.	Time: minutes.
Impact dust cools Earth:	Space: global.	Time: days to years.
A cave formation grows:	Space: tens of centimeters.	Time: thousands of years.
Ice sheets of an ice age:	Space: continents, millions of km ² .	Time: tens of thousands of years.
The Grand Canyon is carved:	Space: regional, hundreds of km long.	Time: about 5 million years (estimated; debated).
Rocky Mountains rise by uplift:	Space: continental.	Time: tens of millions of years.

Size and speed are separate rulers. Big is not always slow; small is not always fast.





CHECK FOR UNDERSTANDING

Quick check: big and fast, or small and slow?

Which example is both fast (days or less) and global (affects the whole planet)?

A. A hoodoo toppling over

B. Dust from a large asteroid impact cooling the planet

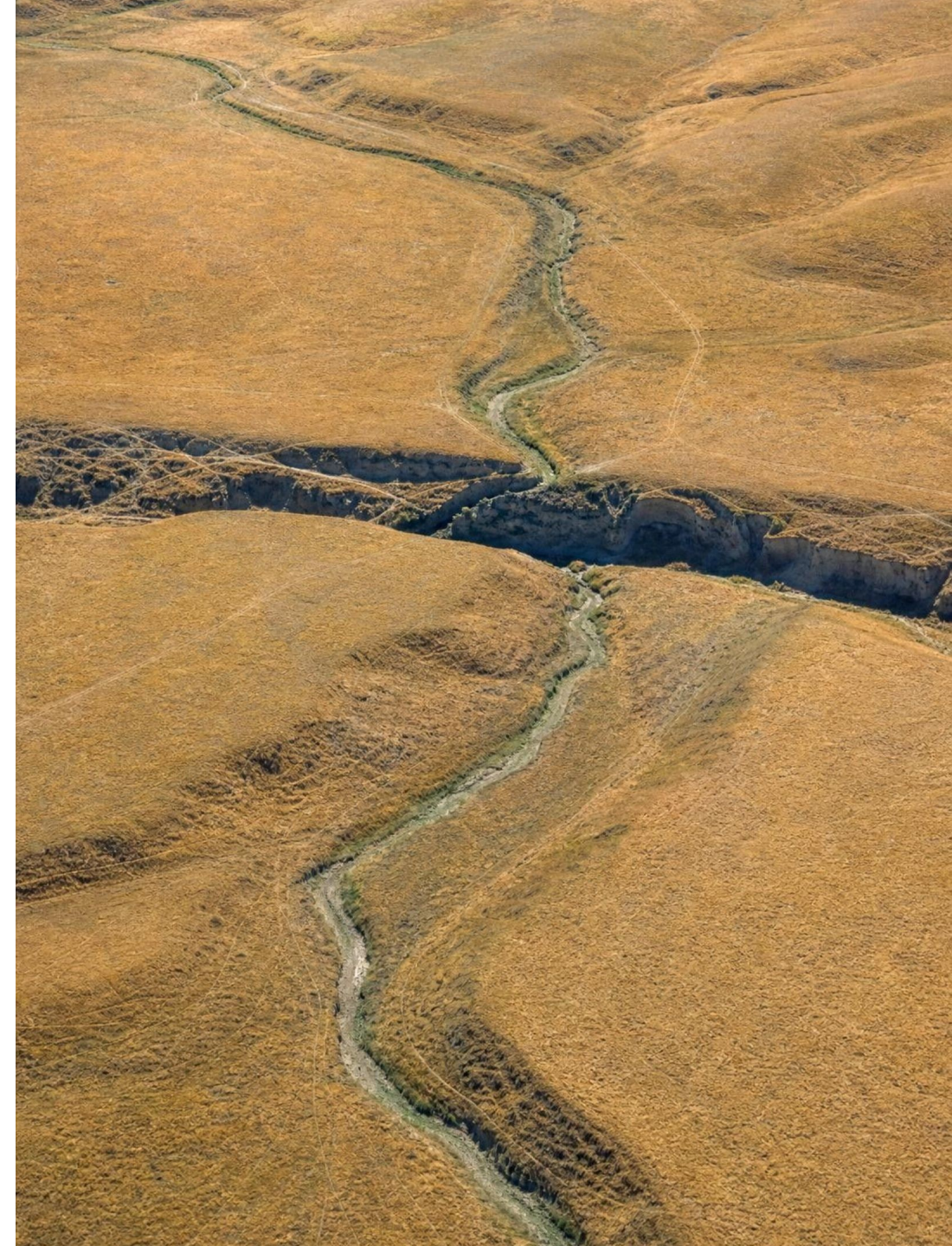
C. A cave formation growing from drips

D. Two continents drifting apart

REAL-WORLD CONNECTION

California connection: Wallace Creek on the San Andreas Fault

On the Carrizo Plain in San Luis Obispo County, a dry stream called Wallace Creek crosses the San Andreas Fault and bends sharply: its channel is offset by about 130 m. Averaged over a few thousand years the fault slips about 3.4 cm a year, but it does not creep smoothly here. In the great 1857 earthquake the ground jumped about 9 m in minutes. A slow sum, released in sudden jolts.





APPLY IT

Task: rate detectives

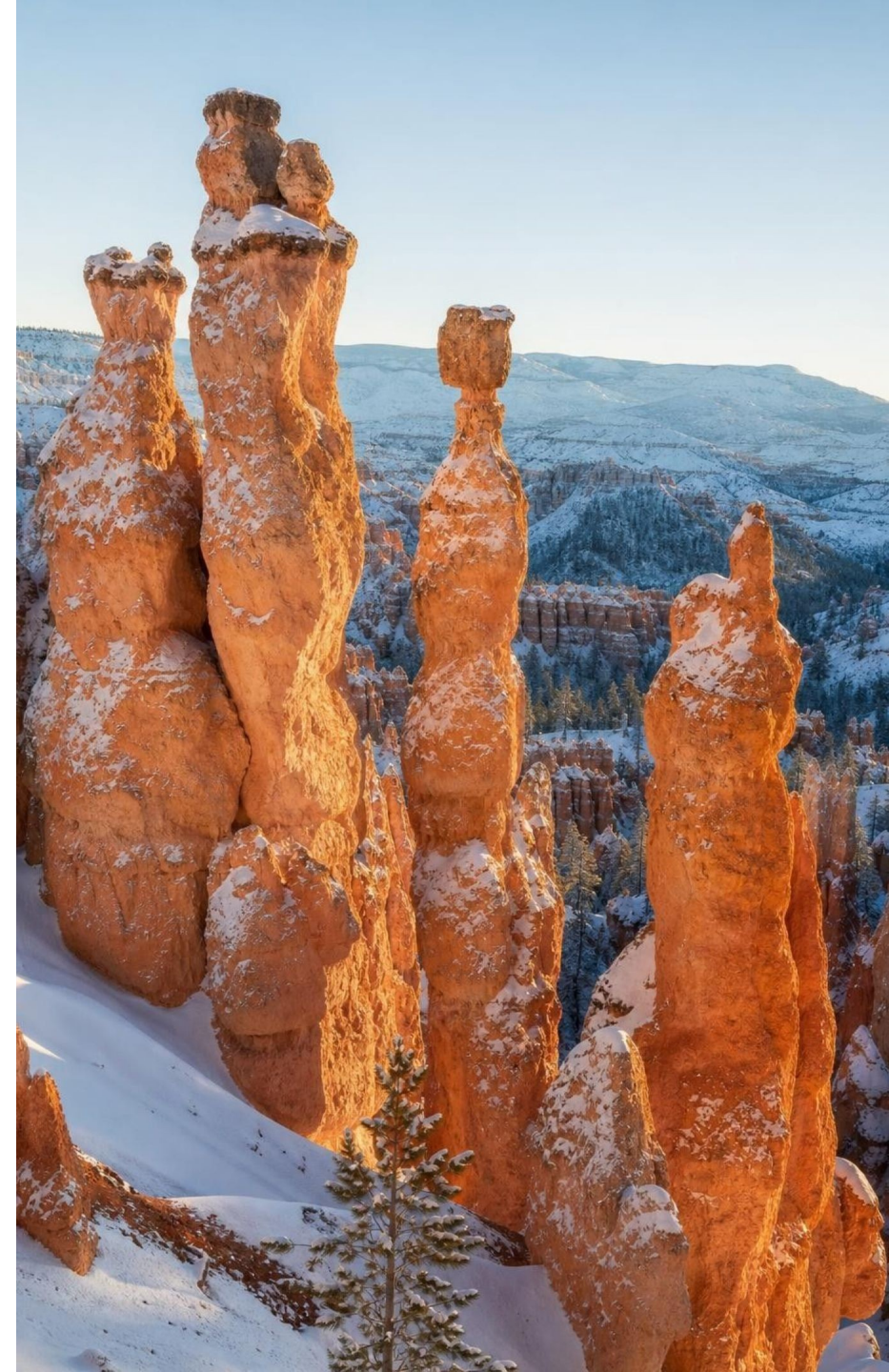
Simulated data for practice.

For each row, calculate the rate with units. Decide whether it is a slow process or a sudden event. Then use row C to predict how long a river at that rate would take to cut a canyon 1,600 m deep.

Row	Change measured	Amount	Time	Rate (you compute)
A	Cave formation lengthened	12 cm	1,000 years	
B	Dune crest moved downwind	15 m	1 year	
C	River cut its bed deeper	30 cm	1,000 years	
D	Plate carried a continent	35 m	1,000 years	
E	Landslide moved a hillside	400 m	2 minutes	
F	Hoodoo pillar narrowed	5 cm	100 years	

Patterns: the same recipe, all over the world

- Hoodoos stand in Utah, Alberta, Italy, Serbia and New Zealand, and all share one shape.
- A tougher cap shields a softer pillar; rain, frost and wind strip the rock around it.
- Details differ by site: at Bryce Canyon, about 200 freeze-thaw cycles a year do most of the work.
- The same shape in many places is evidence that the same processes act everywhere.
- A hoodoo looks unchanged from year to year, then topples when its pillar gets too thin.





MODEL

The life of a hoodoo: slow, slow, slow, sudden

Model: Stages from layered rock to toppled cap

1. Layered rock is uplifted and cracks → (millions of years)
2. Frost and rain widen cracks into gaps → (thousands of years)
3. Softer layers wear away; a tougher cap shields the pillar → (thousands of years)
4. Pillar thins a fraction of a millimeter a year → (centuries)
5. Cap topples in seconds → (seconds, then on and on)
6. Debris is weathered and carried off

Five slow stages and one sudden one. The sudden stage is caused by all the slow ones.

THINK, PAIR, SHARE

Discuss: the present is the key to the past

A geologist finds ancient sandstone with ripple marks just like the ones forming in a shallow stream today. What can she safely conclude about the past? What can she not conclude?





Uniformitarianism: what it claims and what it does not

Claims: the processes we watch today (weathering, erosion, deposition, uplift) also worked in the past.

Claims: the same natural laws, such as gravity, applied then and will apply tomorrow.

Does not claim: every process always ran at today's speed. Ice ages and changing climates change rates.

Does not claim: nothing sudden ever happened. Impacts, giant floods and eruptions are part of the record.

Short version, the geologists' old motto: the present is the key to the past.

CHECK FOR UNDERSTANDING

Quick check: which statement fits uniformitarianism?

Which statement matches the modern meaning of uniformitarianism?

- A. Canyons formed only during ancient catastrophes that no longer happen.
- B. Rivers today cut rock the way rivers did millions of years ago, though some cut faster or slower.
- C. Every process on Earth has always run at exactly the same speed.
- D. The past cannot be understood because nobody was there to see it.





MISCONCEPTION CHECK

True or false? The unchanging cliff

"The cliff looks exactly the way it did in a photograph from 1900, so nothing has happened to it since then."

True or false? Explain your reasoning.

PUTTING IT TOGETHER

Putting it together

- Weathering breaks, erosion carries, deposition drops, uplift raises; water, ice, wind, gravity, life do it.
- Every change gets two rulers, space and time, and the rulers are independent.
- Rate times time is the key: a few millimeters a year becomes a canyon over millions of years.
- Slow build-ups end in sudden releases: rockfalls, toppling hoodoos, earthquakes.
- The same kinds of processes, following the same laws, explain the past and predict the future.





EXIT TICKET

Exit ticket

- 1 Give one example each of weathering and erosion from this lesson, and say how you told them apart.
- 2 Name one change that is fast and global, and one that is slow and small.
- 3 A cliff retreats 2 mm a year. How far does it retreat in 10,000 years? Show the units.
- 4 In one sentence, say what uniformitarianism does NOT claim.