

Rock Detectives at Red Mesa: An Evidence Jigsaw

Learning target: I can work with a team to combine evidence cards from one site into an ordered history of its rocks, naming the rock-cycle process and energy source behind each event, and defend that history to another group.

Collaborative investigation

About 55 min

Jigsaw

MS-ESS2-1 · practice

MS-ESS2-2 · supports

collaboration

discussion

visual modeling

Name _____

Date _____

Period _____

Directions

Work in home groups of four. Step 1, expert round (12 minutes): each member takes one expert set of three cards (Set A: cards 1-3, Set B: cards 4-6, Set C: cards 7-9, Set D: cards 10-12), reads them, and meets with the students from other groups who hold the same set to agree on what each card is evidence for. Step 2, home round (20 minutes): return to your home group, teach your cards, and build the timeline in Part B. Step 3, defense (10 minutes): present your timeline to a neighboring group, who will challenge at least one placement. Step 4, individual (13 minutes): answer Part C alone. Red Mesa is a teaching site built from patterns geologists see in real places; the numbers are realistic but invented.

You will need: Twelve cards per group, cut from the card sheet, Timeline table (Part B), Pencils, Calculator (optional, for q7)

The site. Red Mesa is a flat-topped hill in a dry region. A river has cut a canyon into its side, exposing everything from the hill's dark cap down to the pink rock at the canyon floor. Your class visited, and the cards below are the field notes and lab results, split among four experts. Nobody has the whole story until the group puts the cards together.

Twelve evidence cards from Red Mesa

1 Card 1 (Set A): The river today

The river in the canyon carries sand after storms. The sand on its bars is pink, white, gray and black, and the grains are rounded. Upstream, the river flows across the pink rock at the canyon floor.

2 Card 2 (Set A): The pebbly layer

The lowest of the tilted layers is a rock made of rounded pebbles cemented together. Most pebbles are pink-and-gray with interlocking crystals about 5 mm across, exactly like the pink rock at the canyon floor. The pebbly layer rests directly on top of the pink rock.

3 Card 3 (Set A): The stack of layers

Above the pebbly layer come, in order: tan sandstone in layers with ripple marks on some surfaces; gray shale in very thin layers; and a pale limestone full of shell fossils. All of these layers are tilted 20 degrees toward the east.

4 Card 4 (Set B): The pink rock at the canyon floor

The pink rock has no layers. It is made of interlocking pink, white, black and gray crystals 4 to 8 mm across. It forms the floor and lowest walls of the canyon over a width of at least 2 km.

5 Card 5 (Set B): The banded rock beside the pink rock

At the east edge of the pink rock is a dark rock whose crystals are flattened and lined up in wavy bands. The pink rock cuts straight across the bands. Within about 30 m of the pink rock, the banded rock's crystals are noticeably larger than they are farther away. No fossils are found in it.

6 Card 6 (Set B): Lab report on the banded rock

The banded rock's chemical makeup matches a mud rock such as shale, not the pink rock. It contains no glass and no gas holes. The highest temperature it ever reached is estimated at about 550 °C, which is below the roughly 700 °C at which a rock of this makeup begins to melt.

7 Card 7 (Set C): The cap rock on top

The mesa's flat cap is a dark gray rock with crystals about 0.2 mm across, too small to see without a lens. Near its top surface it is full of small holes left by gas bubbles. The cap lies flat (horizontal) and is about 15 m thick.

8 Card 8 (Set C): The sandstone and limestone under a lens

The sandstone's grains are rounded sand, glued together by a mineral cement, with small gaps between grains. The limestone is built mostly of broken shells of sea animals, pressed together in layers.

9 Card 9 (Set C): Crystal sizes measured in the lab

Pink rock: 4 to 8 mm, interlocking, random directions.
Banded rock: 1 to 2 mm, flattened and lined up. Cap rock: about 0.2 mm, interlocking, random directions.
Sandstone: grains about 0.5 mm, rounded, not interlocking.

10 Card 10 (Set D): The surface under the cap

The tilted layers do not continue up into the cap. Their tops are cut off along an uneven surface, and a thin layer of old soil with plant roots lies on that surface, directly under the flat cap rock.

11 Card 11 (Set D): Drill-hole temperature log

A drill hole near the mesa measured rock temperatures: 15 °C at the surface, 40 °C at a depth of 1 km, and 65 °C at 2 km. The deeper the hole went, the hotter the rock.

12 Card 12 (Set D): Weather and the canyon edge

The mesa receives about 300 mm of rain a year, mostly in storms. In winter, water freezes in cracks along the cap rock's edge, and blocks of cap rock break off and fall to the canyon floor, where the river gradually rounds and moves them.

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, write one sentence: what the card is evidence **for** (which rock-cycle process or event), and whether the energy behind it is the Sun (with gravity) or Earth's interior.

Part B: Home group task

1. Lay all twelve cards on the desk. Each expert teaches their three cards in two minutes or less.
 2. Decide which rock is the oldest. Use the rules: a rock that cuts across another is younger than it; a layer on top of another is younger than it; pebbles of a rock are younger than the rock they came from.
 3. Arrange the events in order from oldest to today. There are eight events. Write them in the timeline table, with the card numbers that are your evidence for each.
 4. For each event, write the rock-cycle process (melting, cooling and crystallization, weathering, erosion, deposition, compaction and cementation, deformation, recrystallization, uplift, tilting) and the energy source.
 5. Prepare a one-minute defense of the two placements your group found hardest. Every member must be able to give it.
2. Group timeline: complete all eight rows.

Event (what happened)	Card(s) used as evidence	Rock-cycle process	Energy source (Sun and gravity, or Earth's interior)
1 (oldest)			
2			
3			
4			
5			
6			
7			
8 (today)			

3. Group answer: Which placement did the neighboring group challenge, and which card(s) did you use to answer the challenge?

Part C: Individual accountability (complete alone)

4. Explain how cards 2 and 4 together prove that the pink rock is older than the tilted layers, and what must have happened to the pink rock between its formation and the deposition of the pebbly layer.

5. Using card 9, explain why the cap rock and the pink rock have such different crystal sizes even though both have interlocking crystals in random directions. Where did each one cool?

6. Card 10 shows an uneven surface with old soil between the tilted layers and the flat cap. List the events that must have happened, in order, between the limestone forming and the cap forming. Name the energy source for each.

7. From card 11, calculate how many degrees Celsius the temperature rises for each kilometer of depth. Then estimate the rock temperature at 20 km depth. Using card 6's figures, decide whether a shale at 20 km would more likely be melting or changing while solid, and explain.

8. Card 5 says the banded rock's crystals are larger within 30 m of the pink rock. Explain what caused this and why the effect stops at about 30 m. Does card 6 support or contradict your explanation?

9. Trace the material in **one** of the pink-and-gray pebbles in card 2 from its earliest stage in the cards to where it is now, naming each rock type or material it was part of, the process that moved it to the next stage, and the energy source. Then say what could happen to it next, and why the rock cycle has no end point.

Three age rules and two energy rules

Age rules: (1) a rock that cuts across another rock is younger than the rock it cuts; (2) in an undisturbed stack, each layer is younger than the one below it; (3) a pebble inside a layer is older than the layer, and the rock the pebble came from must have been at the surface before the layer formed. Energy rules: anything done by rain, rivers, wind, ice or living things at the surface runs on the Sun (with gravity pulling material downhill); anything that needs heat or squeezing underground, or that lifts or tilts whole regions, runs on Earth's interior. Start by finding the oldest rock with rule 1 (what does the pink rock cut?).

Thirteenth card

Write a thirteenth evidence card that would **change** your group's timeline if it were true: for example, a fossil found inside the banded rock, or a pebble of cap rock found inside the pebbly layer. Explain which placement it would force you to move and why. Then explain why a geologist would treat a single surprising card with caution and what further evidence they would look for before rewriting the history.