

The Unlabeled Box: Twelve Samples, Three Sites, No Names

Investigation question: Using only texture and setting clues on property cards, can we work out how each unlabeled rock sample formed, what energy made it, and which field site it came from?

Evidence-based mystery

Groups of 4

1 session

Setup 5 · Activity 38 · Cleanup 4 min

MS-ESS2-1 · practice

MS-ESS2-2 · practice

Scientific purpose

A box of twelve rock samples has come back from three field sites with the labels fallen off. Each sample is described on a property card: grain size and arrangement, special features, a simple test result and a note on how it was packed. Groups must assign every card to a rock family, name the process that formed it and the energy source behind that process, find the two parent-and-child pairs hidden in the set, and finally decide which of the three sites each sample most likely came from. The lab turns texture reading into a reasoned investigation with evidence, inference and uncertainty.

Why this helps students with this chapter

Students who can recite 'igneous, sedimentary, metamorphic' often cannot tell a sample's family from its texture, and they confuse layers with bands and crystals that grew in place with grains that were carried. Working from cards forces them to argue from specific observable features, to separate what the card says (observation) from what they conclude (inference), and to live with cases where two answers are defensible. The site puzzle adds a second layer: the same evidence that tells how a rock formed also tells where it is likely to be found.

Standards connections

MS-ESS2-1 (practice, linking each rock's evidence to the process and energy source in the model): Students connect texture evidence to melting and crystallization, weathering and sedimentation, and deformation and recrystallization, and name the energy that drives each. This builds the process-to-evidence link the model needs; no mineral identification is required, which respects the assessment boundary.

MS-ESS2-2 (practice, constructing an explanation for how a formation came to be where it is): Assigning samples to sites and explaining, for example, why an intrusive rock is found at the surface beside its own sand, is a small-scale version of explaining surface change from evidence. The time-scale comparison in the PE is not addressed here.

Roles (rotate each session)

- **Card reader:** Reads each card aloud in full, including the packing note, and keeps the cards in order on the sorting mat.

- **Texture judge:** Leads the first decision for each card: are the grains crystals that grew in place, pieces that were carried and stuck, or crystals that were flattened or regrown? Must point to the exact words on the card.
- **Process and energy tracker:** For each placed card, names the process that formed the rock and the Earth energy source, and checks that the family, process and energy agree.
- **Recorder and site detective:** Fills in the recording-sheet table, writes the group's confidence for each card, and leads the site-assignment discussion at the end.

Materials

Item	Quantity	Per	Note
Printed property card set (twelve cards, A to L), cut apart	1 set	group	Card text is given in the prep notes; print on card stock and laminate for reuse.
Sorting mat: a sheet with three family columns and a 'not sure yet' box	1	group	
Site briefing sheet describing Sites 1, 2 and 3	1	group	Site text is given in the prep notes.
Recording sheet	1	student	
Optional: real samples of granite, basalt, sandstone, limestone, marble and a banded metamorphic rock	1 set	class	If available, match them to cards A, B, C, D, G and F at the debrief. A school rock kit or samples from a landscaping yard work.
Optional: dropper bottle of white vinegar and a paper towel	1	class	For the teacher to show the fizz test on real limestone or marble. Goggles on.

Estimated cost: 1 to 3 per class for printing; 20 to 40 if a rock sample kit is bought (an estimate; Estimate. Card sets and mats cost only paper and card stock; a basic classroom rock kit from a science supplier runs about \$20 to \$40 and is optional.)

Safety

- No hazards from the cards. If real rock samples are used, handle them over the desk, not above the floor, and do not strike or break them; chips can fly.
- Only the teacher performs the vinegar test, wearing goggles, with one or two drops on a sample over a paper towel. Vinegar is a mild acid; rinse skin if splashed and keep it away from eyes.
- Never taste a rock sample, even though card K reports a salty taste; field geologists sometimes do this with known samples, and students never should.

Teacher preparation and setup

1. Write and print the twelve property cards. Suggested text (reword as needed): A: pink, white, black and gray crystals the size of rice grains, locked together with no gaps and no layers; heavy for its size; packed in a bag labeled 'base of dome.' B: dark gray, dull, crystals too small to see without a lens; a few small round holes; packed from 'edge of a black flow.' C: tan, feels sandy, rounded grains about 1 mm across in flat layers, grains rub off on your fingers; packed from 'canyon wall.' D: gray, fine-grained, in thin flat

layers, contains curved shell shapes; fizzes when vinegar is dropped on it; packed from 'low ridge.' E: shiny, flaky, flattened crystals all lined up in one direction; splits into sheets; packed from 'mountain core.' F: alternating light and dark wavy bands of coarse crystals; bands do not rub off; packed from 'mountain core.' G: white, sparkly, sugar-like interlocking crystals, no layers; fizzes with vinegar; packed from 'quarry near the mountain core.' H: pale, very light, floats in water, full of tiny holes, glassy between the holes, no visible crystals; packed from 'cone slope.' I: sharp-edged chunks of several different rocks, 1 to 5 cm, stuck in a finer sandy material; packed from 'base of a cliff.' J: black, smooth, glassy, breaks with curved shiny surfaces, no crystals, no holes; packed from 'cone slope.' K: clear to white cube-shaped crystals in a crust; a geologist's note says it tasted salty (do not taste); packed from 'dry lakebed.' L: looks like sandstone but very hard; grains fused so none rub off; breaks across the grains with glassy surfaces; packed from 'deep road cut.'

2. Write the site briefing: Site 1, a young volcanic cone and its lava flows in a dry region. Site 2, a desert basin with a dry lakebed, a canyon whose walls and cliffs are layered rock, and a low ridge of old sea-floor layers. Site 3, the core of a mountain range where two plates collided long ago, with a granite dome exposed at the top, a quarry on its flank and a deep road cut through buried layers.
3. Prepare the sorting mat with three columns headed 'Igneous: melt cooled,' 'Sedimentary: pieces or dissolved material settled,' 'Metamorphic: solid rock changed by heat and pressure,' plus a 'Not sure yet' box.
4. Decide whether you will show the vinegar fizz test live on a real limestone or marble sample. If so, have goggles, a dropper and a towel at the front; the fizz is carbon dioxide from the reaction of acid with the calcium carbonate in the rock.
5. Review the two parent-and-child pairs built into the set (C and L: sandstone and the metamorphic rock made from it; D and G: shell limestone and the marble made from it) so you can guide groups toward them without giving them away.

Investigation design

Independent variable	The set of texture and setting clues given on each card
Dependent variable	The family, formation process, energy source and site the group assigns, with a confidence rating
Controlled	Every group receives the same twelve cards and the same site briefing; Family decisions are made from texture clues only; packing notes are used only for the site step; The same three texture tests are applied to every card
Trials	One full sort per group, then a two-minute comparison with a neighboring group; the class tallies placements for the contested cards.
Comparison	Group placements versus the class consensus and the teacher's key, with attention to the cards where the evidence allows more than one answer.

Student procedure

1. Read the site briefing together and the three column headings on the sorting mat. Agree on the texture test for each family: crystals that grew in place and interlock (igneous), separate pieces or shells that

were carried and stuck together or crystals left by drying water (sedimentary), crystals flattened, lined up, banded or regrown while the rock stayed solid (metamorphic).

2. The Card reader reads card A in full. The Texture judge points to the words that decide the family and places the card in a column or in the 'not sure yet' box. The Process and energy tracker names the process and the Earth energy source. The Recorder writes the row, including a confidence rating from 1 (guess) to 3 (sure).
3. Repeat for cards B through L. Do not skip the packing note; it is a setting clue, not a family clue, and the group should say which kind of clue it is each time.
4. Return to the 'not sure yet' box. For each card there, list the two families it could belong to and the single observation that would settle it. Place it where the evidence leans and keep the confidence rating low.
5. Find the pairs. Two cards describe a rock and the metamorphic rock made from it. Identify both pairs, write which card is the parent and which the child, and name the process that connects them.
6. Assign sites. Using the packing notes and the site briefing, decide which site each sample most likely came from and write it in the table. Some samples fit more than one site; write 'or' and your reasoning.
7. Draw the texture of one sample from each family in the drawing box, as you picture it from the card, and label the feature that gave the family away.
8. Compare your mat with a neighboring group's for two minutes. For any card placed differently, each group states its evidence; change your placement only if the other group's evidence is stronger, and note the change.
9. Answer the analysis questions individually.

Expected observations

- Most groups place A, B, C, E, F, H, I and J confidently; D, G, K and L draw debate.
- A common early error is putting G (marble) in igneous because of its interlocking crystals, and K (halite crust) in igneous because 'crystals grew'; the fizz note and the dry-lakebed note usually move them.
- L is often placed in sedimentary at first because it 'looks like sandstone'; the fused grains and breaking across the grains move it to metamorphic once the group applies the rub-off test.
- Most groups find the C and L pair quickly and the D and G pair only after the fizz clue is pointed out.
- Site assignments: Site 1 for B, H and J; Site 2 for C, D, I and K; Site 3 for A, E, F, G and L; some groups reasonably put I at Site 3 (base of a cliff) or C at Site 3 (the road cut's original rock).

Likely difficulties

- Groups sort by color or by how 'pretty' a rock sounds. Keep sending them back to the three texture tests on the mat and require the key-clue words to be copied from the card.
- The packing note is used as a family clue ('it came from a cone, so it is igneous'). Insist that the family comes from texture; the note is for the site step only, which is why the 'quarry' and 'road cut' notes do not say what the rock is.
- Students treat confidence ratings as a grade and mark everything 3. Model a 1 and a 2 with a worked example and praise honest doubt in the debrief.

- The parent-and-child step stalls because groups look for identical cards. Hint that the child has the same ingredients but a changed texture, and that one shared test result (the fizz) links one pair.
- Groups with real samples spend the time handling rocks instead of reading cards. Keep the samples at the front until the debrief.

Structured debrief

1. Tally the class placements for the four contested cards (D, G, K and L) on the board before revealing anything. Ask a group on each side to state its evidence in one sentence. Then give the key and emphasize that a placement backed by the right evidence and the right doubt is good science even when it lands in the wrong column.
2. Reveal the two pairs. Lay out C beside L and D beside G (real samples if you have them). The grains of C can still be rubbed off; the grains of L are fused and the rock breaks through them. D shows shell shapes and layers; G shows interlocking sugary crystals and no layers, yet both fizz because the material is the same. That is recrystallization: same ingredients, new texture, no melting.
3. Walk the four igneous cards from slowest to fastest: A (large crystals, deep intrusion), B (tiny crystals, lava flow), J (glass, very fast), H (frothy glass, almost instant, gas bubbles frozen in). Point out that H and J came from the same site and that gas content, not just speed, explains H's holes.
4. Return to the sites. Ask what Site 3 tells us: a granite dome at the top, metamorphic rocks around it, a quarry of marble and a road cut through fused sandstone all point to a place where magma intruded and plates collided, then uplift and erosion exposed the whole package. The samples are evidence for an event nobody watched.
5. Finish by asking which card could not be placed by texture alone and why the site clue helped: K's cube crystals could be read as 'crystals grew, so igneous' until the dry lakebed and the salty note point to evaporation, which the Sun drives.

Recording sheet: what students fill in

Lab 2 recording sheet: The unlabeled box

Fill in one row per card as your group places it. In 'key clue' copy the exact words from the card that decided the family. Confidence: 1 = guess, 2 = likely, 3 = sure.

Sample sort

Card	Family	Key clue (words from the card)	Process that formed it	Energy source on Earth	Likely site	Confidence
A						
B						
C						
D						
E						

Card	Family	Key clue (words from the card)	Process that formed it	Energy source on Earth	Likely site	Confidence
F						
G						
H						
I						
J						
K						
L						

Parent and child pairs

Parent card	Child card	Process that connects them	Evidence that they are related

-  Draw the texture you picture for one card from each family (three sketches). Label each with the card letter and circle the feature that gave the family away.

Answer: Three sketches, one per family, each labeled with a card letter and the decisive feature circled.

Acceptable examples: A or B as a mass of interlocking crystals with no gaps (circle the interlocking crystals); C as rounded grains in flat layers or D as layers with shell shapes (circle the separate grains or shells); E or F as flattened crystals in sheets or wavy light-dark bands (circle the bands), or G as sugary interlocking crystals with a note that it fizzes.

Why: The sketch is a check that the student can translate card words into a texture image. The circled feature must be the one that decides the family, not color or size of the sample.

- One sketch per family, each labeled with a card letter
- Decisive texture feature circled and consistent with the family
- Sedimentary sketch shows separate pieces; metamorphic sketch shows flattening or banding; igneous sketch shows interlocking crystals or glass

1. Which card did your group place with the lowest confidence? What two families could it belong to, and what single extra observation would settle it?

Answer: Group-specific. The most common low-confidence cards are G (igneous or metamorphic: interlocking crystals, but the fizz matches limestone's ingredients; a settling observation would be finding shell traces or layering in nearby rock, or testing whether the crystals are the same material as D), K (igneous or sedimentary: crystals grew, but in water; settling observation: whether the crust sits on a dry lakebed with other evaporation layers, or whether the crystals dissolve in water), and L (sedimentary or metamorphic: sand grains, but fused; settling observation: whether grains can be rubbed off or whether the rock breaks across them).

Why: Credit is for naming two plausible families and a specific, observable test, not for picking the right card.

- Names a card and two candidate families
- Gives one specific observation that would decide between them

2. Pick one card and write one observation sentence (what the card says) and one inference sentence (what your group concluded from it).

Answer: Example for card C: observation, 'the card says the grains are rounded, about 1 mm, in flat layers, and rub off'; inference, 'the grains were carried by water a long way, dropped in layers and lightly cemented, so this is sedimentary rock.' Any card works if the observation repeats card wording and the inference states a conclusion the card does not say.

Why: Checks the observation-versus-inference skill from slide 25. The observation must be checkable on the card; the inference must go beyond it.

- Observation sentence quotes or closely paraphrases the card
- Inference sentence states a process or history not written on the card

Analysis questions: answer key

3. Cards C and D are both in flat layers, and cards E and F both have lined-up crystals. Explain why 'layers' is not enough to decide a family, and state the test your group used to tell sedimentary layers from metamorphic bands.

Answer: Flat layers in C and D are layers of separate pieces (sand grains, shell bits) that settled one on top of another; the lined-up crystals in E and F are crystals that were flattened and aligned while the rock was solid under pressure. Both can look striped, so 'layers' alone cannot decide. The test is whether the stripe is made of separate pieces that can rub off or be seen as individual grains and shells (sedimentary), or of flattened, interlocking crystals that do not rub off and often form wavy light-and-dark bands (metamorphic).

Why: This is the layers-versus-bands confusion the chapter targets. Full credit requires the test, not just the claim that they differ.

- Explains that both families can show stripes
- Sedimentary layers described as separate deposited pieces
- Metamorphic bands described as flattened, aligned crystals that do not rub off

4. Cards A, B, H and J are all igneous, yet they look completely different. Rank them from slowest-cooled to fastest-cooled and give the evidence for your ranking.

Answer: Slowest to fastest: A, B, J, H. A has crystals the size of rice grains, so the melt stayed liquid long enough underground for crystals to grow large (intrusive). B has crystals too small to see, so it cooled fast at the surface in a lava flow (extrusive), with a few gas holes. J is solid glass with no crystals, so it cooled too fast for any to grow. H is frothy glass full of gas holes, blasted out of the volcano and frozen almost instantly around its bubbles. Students may argue J and H are equally fast; either order for those two earns credit if the gas-bubble evidence is explained.

Why: Crystal size records cooling time; glass means no time at all. The holes in H are gas, not a cooling-speed clue by themselves, so J and H are a tie on texture.

Also acceptable: Accept A, B, H, J with the reasoning that H's froth means it was blown apart during eruption.

- A ranked slowest with large-crystal evidence
- B placed after A with tiny-crystal evidence
- J and H ranked fastest with glass evidence; holes in H explained as gas

5. Card A was packed at the 'base of dome' at Site 3, next to a slope of sand with the same colors. Write the story of how this rock formed and reached the surface, and what is happening to it now. Name the energy source for each part of the story.

Answer: Magma formed deep underground from Earth's interior heat and pushed up into the crust but never reached the surface. Wrapped in warm rock, it cooled over a very long time, so its crystals grew to rice-grain size: intrusive igneous rock (energy: Earth's interior). Later, plate collisions in this mountain range lifted the region (energy: Earth's interior driving plate motion). Rain, ice, wind and gravity, powered by the Sun, wore away the kilometers of rock on top until the granite was exposed as a dome (energy: Sun and gravity). Today the same surface forces are breaking the dome into grains, which is why sand with the same colors lies at its base; the sand will be carried downhill and could become sedimentary rock (energy: Sun and gravity). Observations: large interlocking crystals, exposed at the top, matching sand. Inferences: slow cooling at depth, uplift, erosion, present weathering.

Why: This is the chapter's phenomenon retold from evidence. Full credit requires the sequence (cooling at depth, uplift, erosion, weathering now), an energy source for each, and a separation of what was observed from what was inferred.

- Slow cooling at depth inferred from large crystals
- Uplift and erosion explain exposure at the surface
- Present-day weathering explains the matching sand
- Energy sources named: interior for melting and uplift, Sun and gravity for erosion and weathering

6. Cards D and G both fizz with vinegar, but one is sedimentary and one is metamorphic. What does the fizz tell you they share, and what texture evidence shows they formed by different processes?

Answer: The fizz tells you D and G are made of the same material, the calcium-carbonate mineral that reacts with acid, so G's ingredients came from a limestone like D. The texture shows different processes: D has thin flat layers and shell shapes, so its material settled as shells on a sea floor and was buried (sedimentary). G has interlocking, sugar-like crystals and no layers or shells, so heat and pressure regrew the crystals and erased the shells while the rock stayed solid (metamorphic recrystallization).

Why: Same composition, different texture, different process. Students need not name calcite; 'the same material that reacts with vinegar' is enough.

- States that the fizz shows shared ingredients
- Uses shells and layers as evidence for D's sedimentary origin
- Uses regrown interlocking crystals and the loss of shells as evidence for G's metamorphic origin

7. Card I has sharp-edged chunks; card C has rounded grains. What does the shape of the pieces suggest about how far each one's sediment traveled before it was deposited? Explain the reasoning.

Answer: Card I's sharp-edged chunks suggest the pieces traveled only a short way, such as falling from a cliff and being buried near its base, because travel in water knocks the corners off. Card C's rounded, evenly sized grains suggest long transport by a river or along a beach, where repeated tumbling rounded them and sorting by the water's energy left grains of similar size. Shape and sorting are clues to distance, not proof, but they fit the packing notes (base of a cliff; canyon wall).

Why: Angular equals short transport; rounded and sorted equals long transport. The energy-of-the-carrier idea from slide 15 supports the sorting part.

- Angular pieces linked to short travel
- Rounded, sorted grains linked to long travel by water
- States the reasoning (tumbling rounds; carrier energy sorts)

8. A classmate argues that card K cannot be a rock because its crystals grew from water, not from magma. Evaluate this argument using what you know about dissolved material and the energy that drives evaporation.

Answer: The argument is wrong because rock does not have to come from magma. Card K is sedimentary rock formed from dissolved material: chemical weathering dissolved minerals from older rock, streams carried the dissolved material into a lake with no outlet, and when the Sun evaporated the water the minerals became too concentrated to stay dissolved and crystallized into a crust. Crystals can grow from water as well as from melt. The energy was the Sun, which drove both the weathering upstream and the evaporation; this is the surface budget, not the interior. If the crust is later buried, it is part of the rock cycle like any other sedimentary rock.

Why: Tests the dissolved route and the energy source. Full credit requires rejecting 'rock must come from magma,' describing crystallization from evaporating water and naming the Sun.

- Rejects the claim that rock must come from magma
- Describes dissolved material crystallizing as water evaporates
- Names the Sun as the energy source

Individual evidence of learning

Each student submits the completed sort table with key-clue words, process, energy source, site and confidence for all twelve cards, the pairs table, the three labeled sketches and written answers to q1 through q8. The sort table's process and energy columns are the evidence for the model's process-to-energy link; q5 is the evidence for constructing an explanation from texture and setting.

Assessment criteria

Criterion	Proficient looks like
Family from texture	At least ten of twelve cards placed in the key's family with a key clue quoted from the card; the two most contested placements are accompanied by a stated doubt and the observation that would settle it.
Process and energy	Every placed card has a process (cooling slowly or quickly from melt; weathering, transport, deposition and cementation; shell build-up or evaporation; deformation or recrystallization) and the correct energy budget (Sun and gravity, or Earth's interior).
Evidence-based explanation	q5 tells the dome's story in order (slow cooling at depth, uplift and erosion of the cover, present-day weathering into matching sand) with the energy source named for each stage, and keeps observations separate from inferences.
Pairs and relationships	Both parent-and-child pairs identified with the connecting process named and the shared-ingredient evidence (fizz, or same grains fused) stated.

Accessibility adaptations

- Print cards in large type with a small icon strip for the three texture tests (interlocking, layered pieces, flattened bands) so multilingual learners and students with low vision can match patterns before reading every word.

- Provide a word bank for the process and energy columns and allow the table to be completed as a shared group document with one row per student read aloud.
- Allow the sketches to be replaced by matching each card to one of three printed texture images, or by a spoken description recorded on a device.
- Let students who need movement run the sort as a wall activity: cards taped under three column headings, with the group walking to re-place contested cards during the neighbor comparison.

Low-cost alternative

The lab needs only printed cards and a sheet for the mat; if printing is limited, write the twelve descriptions on the board and have groups sort letter tiles or sticky notes. No rock samples or vinegar are required.

Model limitations

Property cards are a model of the geologist's first look: they give pre-selected clues in plain words, while a real sample offers unlabeled evidence and sometimes misleading surfaces. The cards simplify real rocks (for example, real pumice often carries a few crystals, and limestone can form from shells, from lime mud or from crystallization), and the three sites are invented so that each sample has at least one defensible home.

Packing notes stand in for the field relationships a geologist would map. This activity has not been physically tested with students; the contested-card pattern and timing are the authors' estimates.

Teacher notes

Key placements: igneous A (intrusive), B (extrusive lava), H (extrusive, frothy glass), J (extrusive, glass); sedimentary C (sandstone, physical), D (shell limestone), I (breccia, short transport), K (halite crust, evaporation); metamorphic E (schist-like, deformation), F (gneiss-like, deformation at high temperature), G (marble, recrystallization of D), L (quartzite-like, recrystallization of C). Energy: interior for A, B, H, J (melt), E, F, G, L (heat and pressure); Sun and gravity for C, D, I, K. Sites: 1 for B, H, J; 2 for C, D, I, K; 3 for A, E, F, G, L, with I and C acceptable at Site 3 if argued. Grade placements on evidence: a student who places L in sedimentary but writes 'fused grains make me unsure, I would test whether grains rub off' has done the thinking the lab is for. Do not require rock names anywhere; they appear here only for your reference.