

Did the Rock at Kettle Ridge Melt? A Claim-Evidence-Reasoning Case

Learning target: I can use observations and lab data from two rock samples to argue whether a rock was changed by heat and pressure while solid, or melted and re-formed, and explain the energy behind the change.

Claim, evidence, reasoning

About 45 min

Individual

MS-ESS2-1 · practice

writing

data analysis

Standards connections

MS-ESS2-1 (practice): Students distinguish deformation and recrystallization from melting and crystallization, the processes the PE names, and tie the change to heat from Earth's interior. Arguing from evidence about one route of the cycle builds toward the model without producing the whole model.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The scenario

Kettle Ridge is a long hill of dark gray, thinly layered rock. At its west end, a mass of pink crystalline rock (an old intrusion, now exposed by erosion) pushes into the gray rock. A geology student, Priya, collects two samples of the gray rock: **Sample F**, from 3 kilometers east of the pink rock, and **Sample N**, from 20 meters from the contact with it. Sample N looks different: harder, shinier, with a faint wavy banding. Priya's question is simple to ask and harder to answer: **did Sample N melt and then re-harden, or was it changed while it stayed solid?** Her field notes and lab results are below. The site and numbers are a teaching case built from patterns geologists see at real contacts.

Priya's observations and lab results for the two samples (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Feature	Sample F (3 km from the pink rock)	Sample N (20 m from the pink rock)
Layering	Thin, flat layers 2 to 5 mm thick	Layers still present, but bent into gentle waves and thinned to 1 to 3 mm
Fossils	Small shell outlines, common	Faint, stretched shell outlines, rare
Crystal size and arrangement	Too small to see (under 0.05 mm), no preferred direction	0.5 to 1 mm, flattened, nearly all lined up in the same direction
Silica content (lab)	61 percent	60 percent
Glass or gas bubbles	None	None
Boundary with the pink rock	Not in contact	Sharp line; no mixing of gray and pink rock across it
Highest temperature the sample ever reached (lab estimate)	About 100 °C	About 500 °C
Temperature at which this rock begins to melt (lab)	About 700 °C	About 700 °C

Simulated data for teaching. Peak temperatures were estimated in the lab from which minerals are present; the melting temperature is for this rock's composition.

Warm-up: organize the evidence

1. List every feature that Sample N **kept** from the original gray rock, even in changed form. Why would a rock that had melted completely be unlikely to keep those features?

Answer: Kept: the layering (now bent and thinned), the shell outlines (now faint and stretched), the silica content (60 percent, almost the same as 61 percent), and a sharp boundary with the pink rock. A fully melted rock becomes a liquid in which layers and fossil shapes are destroyed, and when it re-cools its new crystals grow in all directions with no memory of the old layers.

Why: Inherited features are the strongest evidence for a solid-state change. Students should connect 'melting destroys structure' to why the kept features matter.

Also acceptable: Accept 'no glass or bubbles' as a kept feature if the student explains that melt near the surface often leaves glass or bubbles.

- Lists at least three kept features
- Explains that melting would erase layers and fossils

2. Compare the highest temperature Sample N reached with the temperature at which this rock starts to melt. What does the comparison tell you?

Answer: Sample N reached about 500 °C, but this rock does not begin to melt until about 700 °C, so Sample N was about 200 °C short of melting. It got hot enough to change but never hot enough to become liquid.

Why: The temperature comparison is the most direct evidence against melting.

Also acceptable: Accept 'it was 200 degrees below melting.'

- Compares 500 °C with 700 °C
- Concludes it was never hot enough to melt

3. Sample N's crystals are larger than Sample F's and lined up in one direction. Name the two metamorphic processes these two observations point to, and say what caused each one.

Answer: Larger crystals point to recrystallization: heat from the nearby magma (conducted into the rock) let the atoms rearrange into bigger crystals while the rock stayed solid. Crystals lined up in one direction point to deformation: pressure that was stronger in one direction, from the push of the intruding magma, squeezed the rock so the growing crystals became flattened and aligned, and bent the layers into waves.

Why: Both textbook processes are present at once, which is typical; the point is matching each observation to its cause.

Also acceptable: Accept 'heat and pressure' for both if each is matched to the right observation.

- Larger crystals = recrystallization caused by heat
- Alignment = deformation caused by pressure

Your argument

Answer: Claim: Sample N formed by change in solid rock, not by melting; it is a metamorphic rock made from the same layered sedimentary rock as Sample F. Evidence: (1) Sample N reached only about 500 °C while the rock melts at about 700 °C, so it never became liquid; this rules out melting. (2) Its layers are still present (bent, 1 to 3 mm) and faint stretched shell outlines remain; a melt would have destroyed both, so this supports solid-state change. (3) Its silica content (60 percent) matches Sample F (61 percent), showing it is the same original rock with its chemistry essentially unchanged; melting and mixing with the pink magma would likely have changed it. (4) Its crystals grew from under 0.05 mm to 0.5 to 1 mm and are flattened and lined up, which is what heat and pressure do to crystals in solid rock, while crystals grown from a melt point in all directions. (5) There is a sharp boundary with no mixing, so the gray rock stayed solid at the contact instead of blending into the magma. (6) No glass or bubbles are present, which a quickly cooled melt often leaves. Reasoning: Metamorphic rock forms when heat and pressure change the texture or minerals of existing rock without melting it; igneous rock forms only from a melt. Every row of the table fits the first process and contradicts the second: the temperature stayed below melting, the original layers, fossils and chemistry survived, and the crystals regrew and lined up as they do under pressure. The energy came from Earth's interior: it melted the magma that became the pink rock, and when that magma intruded, heat flowed by conduction into the neighboring gray rock. Heat weakens with distance, so rock 20 m away was heated to about 500 °C and changed, while rock 3 km away reached only about 100 °C, the warmth of ordinary burial, and kept its original fine, unchanged texture.

Why: This is the solved model response. Full credit requires a clear claim (solid-state change, metamorphic), four or more table-based evidence items each tied to what it rules out or supports, and reasoning that invokes the definitions of the two rock types, names Earth's interior (through the magma) as the energy source, and uses distance from the heat source to explain the 20 m versus 3 km contrast.

Also acceptable: A student who claims 'it melted a little' must be pushed on the 500 °C vs 700 °C row; partial melting is not supported by the data here. A student who calls Sample N 'contact metamorphic rock' or names a specific rock type is going beyond what is required and should be credited if the reasoning is sound.

- Claim says solid-state change / metamorphic and identifies the original rock
- At least four evidence items with numbers or observations from the table
- Each evidence item states what it supports or rules out
- Reasoning uses the definitions: metamorphic = changed without melting; igneous = from a melt
- Reasoning names Earth's interior (via the magma) as the energy source
- Reasoning explains the distance effect

4. Suppose a third sample from 300 meters away reached a peak temperature of about 250 °C. Predict what its layers, fossils and crystals would look like, and explain your prediction.

Answer: At 300 m and about 250 °C, the sample should be in between: layers flat or only slightly bent, shell outlines clearer than in N but perhaps a little blurred, crystals slightly larger than F's (still very small) with weak or no alignment. The amount of change depends on how much heat reached the rock, and heat decreases with distance from the magma, so a rock halfway in temperature should be partway in change.

Why: This tests the distance-from-heat-source relationship as a prediction.

Also acceptable: Accept any intermediate description that keeps layers and fossils mostly intact.

- Predicts an in-between appearance
- Links the prediction to less heat at greater distance

5. What single new result would **force you to change** your claim? Describe it and say what it would mean.

Answer: A new lab result showing that Sample N had reached a temperature above about 700 °C, or the discovery of glass, gas bubbles, or crystals growing in random directions with no trace of the old layers, would mean the rock had actually melted; the claim would then have to change to an igneous origin. Alternatively, finding that the pink and gray rock blend into each other across the boundary would suggest mixing of melts.

Why: Students should name a result that contradicts the solid-state explanation, showing the claim is revisable.

Also acceptable: Accept 'a much higher peak temperature' alone if tied to melting.

- Names a specific result that contradicts the claim
- States what the new result would mean

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States clearly that Sample N changed while solid (metamorphic) and identifies it as the altered version of the original layered rock.	States that Sample N is metamorphic but does not connect it to the original rock, or wording is slightly vague.	Claim is hedged between melting and solid-state change, or says 'metamorphic' with statements that contradict it.	No claim, or claims an igneous origin without engaging the evidence.
Evidence	Four or more specific items from the table, with numbers where available, each labeled as supporting solid-state change or ruling out melting.	Four items, but one lacks a number or does not say what it rules out; or three strong items.	One or two items, or items copied from the table without connecting them to either explanation.	Evidence missing, invented, or contradicts the table.
Reasoning	Uses the definitions of metamorphic and igneous rock, names Earth's interior (through the magma) as the energy source, and explains the distance effect between 20 m and 3 km.	Uses the definitions and the energy source but does not explain the distance effect, or explains distance without naming the energy source.	Restates the evidence without definitions, or states a rule without linking it to the claim.	No reasoning, or reasoning that treats metamorphism as melting.
Scientific accuracy and language	Uses recrystallization, deformation, conduction, magma and metamorphic correctly; no scientific errors.	Terms mostly correct; one minor slip (for example, 'lava' for magma underground).	Several terms used loosely (heat and pressure described as melting; igneous and metamorphic interchanged).	Scientific language absent or consistently wrong.

Teacher notes

The case models contact metamorphism of a shale next to a granite intrusion: real contact zones show this pattern of increasing recrystallization and loss of fossils toward the contact, with chemistry nearly unchanged and a sharp boundary. Many real contact rocks are unbanded (hornfels), because heat does most of the work; here the alignment records the magma shouldering its way in, since the even weight of overlying rock presses from all sides and cannot line crystals up by itself. The numbers are teaching values: a 700 °C onset of melting is reasonable for water-bearing shale, and 500 °C is typical of an inner contact zone, but both

vary with pressure and composition. Peak temperatures are estimated in real labs from which minerals have formed; students need only accept the estimate. Do not require students to name the rocks (shale, hornfels, slate or schist); the PE's assessment boundary excludes mineral identification, and the argument works on process alone. The most common weak response claims 'partial melting'; redirect to the temperature rows. Use the two-column scaffold with the whole class if CER writing is new.

Scaffold offered to students: Two-column test

On scrap paper, make two columns headed 'If it melted, I would expect...' and 'If it changed while solid, I would expect...'. Under the first, write: no layers, no fossils, brand-new crystals growing in all directions, maybe glass or bubbles, temperature above the melting point. Under the second, write: layers and fossils kept but squashed, crystals regrown and lined up by pressure, temperature below the melting point, sharp boundary with the heat source. Then go down the table row by row and put a check in the column each row matches. Your evidence section is the list of checks.

Extension: Reading the pink rock

The pink rock has interlocking crystals 6 to 10 mm across and no layers. Write a second, shorter CER for the pink rock: what it is, how you know, and what its crystal size tells you about where and how slowly it cooled. Then explain how the pink rock and Sample N together show two different routes of the rock cycle driven by the same energy source, and describe what must have happened to the land for both to be at the surface today.