

Two Wells, One Oil Field: A Claim-Evidence-Reasoning Case

Learning target: I can construct a scientific explanation, based on rock-core evidence, for why petroleum is found at one site and not at another 200 kilometers away.

Claim, evidence, reasoning

About 45 min

Individual

MS-ESS3-1 · assesses

writing

data analysis

Standards connections

MS-ESS3-1 (assesses, the explanation of uneven distribution of an energy resource from past geoscience processes): Students write a scientific explanation, grounded in core-log evidence, for why an energy resource (petroleum) is unevenly distributed as the result of past geoscience processes (an ancient sea, burial and heating, migration and trapping). This is the PE as written, so the CER is scored against it.

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

Answers with reasoning

The scenario

An energy company drilled two exploration wells in the same state, about 200 kilometers apart. Site A is in the Harlow Basin, a region of low rolling hills. Site B is in the Kessler Highlands, a region of worn, rounded mountains. Both wells reached 3,000 meters, and the rock temperature at 2,500 meters was almost identical. Site A found oil; Site B found nothing. The company's board has asked for an explanation that a non-geologist can follow, and for a prediction about whether drilling deeper at Site B could ever succeed. The core logs below are simulated for this case, but every rock type and every clue in them is the kind geologists really use.

Core log, Site A (Harlow Basin), surface to 3,000 m (teaching data)

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

Depth (m)	Rock	What the geologist noted
0 - 300	Loose river sand and gravel	Recent; fresh groundwater
300 - 1,500	Limestone	Fossil shells of sea creatures throughout; layers tilt gently, forming a broad arch under the drill site
1,500 - 1,800	Dense gray shale	No pores a liquid could pass through; same arch shape
1,800 - 2,300	Sandstone, porous	Pores filled with oil in the upper 120 m; below that, pores filled with salty water
2,300 - 2,900	Black shale	Microscopic fossils of ocean plankton; about 5 percent of the rock's mass is organic carbon; smells faintly of oil
2,900 - 3,000	Older sandstone	Water-filled; no oil

Simulated core log written for this case; the rock types and clues are the kinds geologists really record.

Core log, Site B (Kessler Highlands), surface to 3,000 m (teaching data)

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

Depth (m)	Rock	What the geologist noted
0 - 40	Thin soil over weathered rock	Rocky, well drained
40 - 2,100	Granite	Crystallized from magma; no layers, no fossils, no pores a liquid could pass through except a few cracks
2,100 - 3,000	Gneiss (banded metamorphic rock)	Formed deep in the crust under great heat and pressure long before the granite; no fossils; organic carbon near zero

Simulated core log written for this case; the rock types and clues are the kinds geologists really record.

Measured at both sites — Rock temperature at 2,500 m: Site A, 82 °C; Site B, 80 °C. Age of the deepest rock: Site A, about 150 million years; Site B, more than 1 billion years. Rainfall today: Site A, 600 mm per year; Site B, 900 mm per year. Neither site has had a volcano or a sea in the last 100 million years.

Warm-up: organize the evidence

1. Which layer at Site A is the source rock (the rock in which the oil formed)? Give its depth and two clues from the log that identify it.

Answer: The black shale at 2,300 to 2,900 m. Clues: it contains microscopic fossils of ocean plankton; about 5 percent of its mass is organic carbon; it smells faintly of oil.

Why: Plankton fossils and high organic carbon are the two defining clues of a source rock; the oil smell confirms that oil has been generated there.

Also acceptable: Accept any two clues.

- Names the black shale with its depth
- Gives two of the three clues

2. Which layer at Site A is the reservoir, and which is the cap rock? Explain why the oil sits in the top 120 m of the reservoir and not at its bottom.

Answer: Reservoir: the porous sandstone at 1,800 to 2,300 m. Cap rock: the dense gray shale at 1,500 to 1,800 m, which liquids cannot pass through. Oil is less dense than the salty water in the pores, so it floats up to the top of the sandstone and collects under the cap rock; the water stays below.

Why: Reservoir plus seal, with the density explanation for the oil-over-water arrangement.

Also acceptable: Accept 'oil is lighter than water, so it rises until the shale stops it.'

- Correct reservoir and cap rock with depths
- Explains the oil-on-top arrangement by density

3. The temperatures at 2,500 m are nearly the same at both sites (82 °C and 80 °C). Explain why the heat at Site B could not make oil anyway. Which requirement is missing?

Answer: Heat only makes oil if there is organic matter to change. Site B's rock is granite (crystallized from magma) and gneiss (formed deep in the crust under heat and pressure); neither contains the remains of living things, and the log says organic carbon is near zero. The missing requirement is the source rock. Heating rock with nothing organic in it produces no oil.

Why: This separates the necessary condition (heat) from the sufficient chain (source plus heat plus reservoir plus trap).

Also acceptable: Accept 'nothing to cook' as a plain-language version if the source rock idea is clear.

- States that there is no organic matter or source rock at Site B
- Connects granite and gneiss to their igneous and metamorphic origin, or to 'no fossils'

4. Site B gets more rain than Site A. Is rainfall today relevant to whether oil exists at either site? Explain in one or two sentences.

Answer: No. Today's rainfall affects groundwater and soil, not petroleum. The oil at Site A formed from an ancient sea about 150 million years ago and from burial and heat since then; the present climate did not exist when the oil formed and cannot create a source rock now.

Why: Checks that students separate present surface conditions from the past processes that made the resource.

Also acceptable: A student who adds that rainfall would matter for the groundwater resource at either site is making a correct distinction.

- Says rainfall is not relevant to petroleum
- Gives the reason: oil formed from past processes, not today's climate

Your explanation

Answer: Claim: Petroleum is found at Site A because the Harlow Basin was once a sea whose buried plankton remains were heated into oil, which rose into porous sandstone and was trapped under an arched shale cap; Site B has none and never can, because its granite and gneiss never contained the remains of living things. Drilling deeper at Site B will not help. Evidence: (1) Site A's black shale at 2,300 to 2,900 m holds plankton fossils and about 5 percent organic carbon, the sign of a source rock made from sea life; Site B's rock has organic carbon near zero and no fossils. (2) Site A's temperature of 82 °C at 2,500 m is in the range where buried organic matter becomes oil; Site B's 80 °C is similar, so heat is not what separates the sites. (3) Site A's porous sandstone at 1,800 to 2,300 m holds oil in its upper 120 m above salty water, showing oil rose into a reservoir; Site B's granite has no pores except a few cracks. (4) Site A's dense gray shale at 1,500 to 1,800 m, arched over the drill site, is a cap rock and trap; Site B has no sealing layer and no arch. (5) Site A's rocks are marine sedimentary layers (the black shale with plankton and the limestone with shells) whose deepest layer is about 150 million years old; Site B's deepest rock is more than a billion years old and formed deep in the crust, under granite that crystallized from magma. Reasoning: About 150 million years ago the Harlow Basin lay under a warm sea. Plankton died and sank into still, oxygen-poor mud, where their remains were not destroyed, and the mud became the black shale. More layers piled on, including the limestone with shells, burying the shale thousands of meters down. Because rock gets hotter with depth, the organic matter reached about 80 °C or more and, over millions of years, broke down into oil. Oil is less dense than water, so it moved upward out of the shale into the porous sandstone and kept rising until the dense gray shale stopped it; the arch in the layers held the oil in one place, which is why the well found it in the top of the sandstone. At Site B the chain could never start: granite crystallized from magma and gneiss formed deep in the hot crust, so neither ever held sea life or any organic carbon; with no source rock there is nothing for heat to turn into oil, and there is no porous reservoir or cap rock either. The explanation predicts that other regions made of ancient granite and gneiss will have no oil fields no matter how deep anyone drills, while regions that were once shallow seas and were later buried and gently folded are the places to look.

Why: Solved model response. Full credit: a claim that explains both sites and answers the deeper-drilling question; four or more evidence items with depths, rock names or numbers, each tied to a formation step; reasoning that narrates the past processes in order and explains the absence at Site B from the nature of the rock; a prediction at the end.

Also acceptable: A student may organize the evidence by site rather than by step; that is acceptable if each item is still linked to a formation step. A claim that says 'Site B might have oil deeper down' contradicts evidence item 5 and the log, and should be scored at level 2 for the claim.

- Claim explains both the presence at A and the absence at B, and rules out deeper drilling at B
- At least four evidence items with specific depths, rock names or numbers
- Each evidence item is linked to a step (source, heat, reservoir, trap)
- Reasoning narrates the past processes in order for Site A
- Reasoning explains Site B's absence from what granite and gneiss are
- Ends with a prediction about similar regions

5. A third well, Site C, is drilled in the Harlow Basin 30 km from Site A. Its log shows the same black shale and the same porous sandstone, but the layers above are flat instead of arched, and the gray shale is missing. Predict what Site C found and justify your prediction with the formation steps.

Answer: Site C most likely found little or no oil in the sandstone, perhaps only traces or water. The source rock is there and was heated, so oil formed and rose into the porous sandstone, but with no cap rock above the sandstone and no arch to hold it, the oil kept rising and escaped toward the surface over millions of years, or spread out instead of collecting in one place. Having three steps without the fourth is not enough.

Why: Applies the chain to a missing-trap case, the same idea as the La Brea seeps in W3.

Also acceptable: Accept a prediction of 'oil-stained sandstone but no pool' as a sophisticated answer.

- Predicts no commercial oil (or only traces)
- Explains that the missing cap rock and arch let the oil escape or spread out

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States clearly why Site A has oil and Site B does not, and answers whether deeper drilling at B could succeed.	States why A has oil and B does not; the deeper-drilling question is missing or vague.	Claim covers only one site, or says B might have oil deeper down.	No claim, or a claim unrelated to the evidence.
Evidence	Four or more specific items with depths, rock names or numbers, each linked to a formation step, including at least one contrast with Site B.	Four items with specifics, but one is not linked to a step or there is no Site B contrast.	Two or three items, or items given without depths, names or numbers.	Evidence missing, invented, or contradicting the logs.
Reasoning	Narrates the past processes in order (ancient sea, low-oxygen burial, heat with depth over millions of years, upward migration, cap rock and arch), explains B's absence from the origin of granite and gneiss, and ends with a prediction.	Narrates the processes in order and explains B, but the prediction is missing or the order has one gap.	Restates evidence without the process story, or tells the story without connecting it to the two sites.	No reasoning, or reasoning with a major error (for example, pressure makes the oil, or rain makes oil).
Scientific accuracy and language	Uses source rock, reservoir, cap rock, trap, porous and organic correctly; attributes the oil to heat over time; no errors.	Terms mostly correct; one minor slip (for example, 'oil is lighter' without saying less dense).	Several terms misused or missing; one scientific error.	Scientific language absent or consistently wrong.

Teacher notes

The logs are simulated but typical: a Jurassic-age marine source shale with about 5 percent organic carbon, a sandstone reservoir with an oil column above a water leg, and a shale seal over an anticline are a classic trap, while granite over billion-year-old gneiss describes a continental shield with no petroleum potential at any depth. Temperatures of 80 to 82 °C at 2,500 m correspond to an ordinary geothermal gradient and are deliberately matched so that heat cannot be the explanation. The rainfall values are a distractor that q4 defuses. Site C (q5) has source and reservoir but no seal or closure. If students ask whether Site B's cracks

could hold oil, say that cracks can hold small amounts in some places, but without a source rock nearby there is no oil to fill them.

Scaffold offered to students: Match each layer to a step

Before writing, copy this list on scrap paper and fill in the depth from Site A's log next to each step: (1) ancient sea with plankton, buried in low-oxygen mud, becomes source rock: _____ m; (2) buried deep and heated so the organic matter turns to oil: temperature _____ °C at 2,500 m; (3) oil rises into porous reservoir rock: _____ m; (4) cap rock stops it and the arch traps it: _____ m. Now do the same for Site B and write 'none' wherever a step has no matching layer. Every blank you fill for Site A and every 'none' you write for Site B is a piece of evidence.

Extension: What the board should ask next

Oil companies use the four-step chain not only to explain but to search. Write three questions the company's board should ask before drilling a fourth well anywhere in the Harlow Basin, each tied to one step of the chain, and say what evidence (a rock type, a fossil, a temperature, a shape of the layers) would answer it. Then explain, in two sentences, why no amount of money could turn the Kessler Highlands into an oil field, and what that tells you about the difference between where a resource is *wanted* and where it *is*.