

Where the Oil Is: Four Things That Must Happen Before There Is an Oil Field

Learning target: I can explain, with evidence from a passage, why petroleum is found in some regions and not others, and why its distribution keeps changing.

Reading with evidence

About 35 min

Individual

MS-ESS3-1 · practice

reading

writing

Standards connections

MS-ESS3-1 (practice): The passage lays out the chain of past geoscience processes (ancient sea, burial and heating, migration, trap) that explains the uneven distribution of petroleum, and the final questions ask students to use that chain as evidence in a written explanation.

Purpose: build · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Where the Oil Is

[1] In 1948 a drilling crew in the Saudi Arabian desert struck oil, and the Ghawar field turned out to be one of the largest ever found. The oil they tapped did not begin in a desert. It began as countless microscopic organisms drifting in a warm, shallow sea well over 100 million years ago. Understanding how those organisms became oil explains something a world map makes obvious: a few regions hold enormous amounts of petroleum, and most regions hold none at all.

[2] The first requirement is a sea full of tiny life and a seafloor that preserves it. Plankton and algae live, die and sink in every ocean. On most seafloors their remains are eaten by scavengers or broken down by bacteria that use oxygen, and nothing is left. But in some sheltered basins the bottom water is still and nearly free of oxygen. There the remains pile up with fine mud faster than they can be destroyed. Over thousands of years, this organic-rich mud becomes a dark rock called source rock.

[3] The second requirement is burial and heat. New layers of sediment keep arriving, and the source rock is pushed deeper. Earth grows warmer with depth, about 25 degrees Celsius for every kilometer on average, because heat flows up from the hot interior. At roughly 2 to 4 kilometers down, where the rock reaches about 60 to 120 degrees Celsius, the buried organic matter slowly breaks apart into the molecules of crude oil. Pressure also rises with depth, but it is the heat, acting over millions of years, that does the chemical work. Bury the source rock too deep and too hot, and the oil breaks down further into natural gas, or is destroyed.

[4] The third requirement is a place for the oil to collect. Oil is less dense than the water that fills the pores of most rock, so once it forms it moves upward through any rock with connected openings, such as sandstone or cracked limestone. These porous rocks are called reservoir rocks. The oil keeps rising until it meets a layer it cannot pass through, such as a thick shale or a bed of salt, called a cap rock. Where the cap rock has been folded into an arch, oil gathers beneath the crest like air trapped under an upturned bowl. That arrangement is a trap, and it is what drillers aim for. Without a trap, oil keeps rising

and leaks out at the surface. The sticky asphalt that still oozes up at the La Brea tar pits in Los Angeles is petroleum that reached the surface because nothing held it underground.

[5] Put the requirements together and the uneven map explains itself. An oil field needs a source rock that formed in an ancient oxygen-poor sea, burial to the right depth and temperature, a porous reservoir above it, and a cap rock folded into a trap. Regions that were once covered by warm shallow seas and were later gently folded, such as the land around the Persian Gulf, the Gulf of Mexico and the North Sea, have all four. Regions made of ancient granite, which never collected organic mud, are missing the first requirement and can never have the rest. Geologists do not drill at random: the whole chain tells them where oil cannot be as clearly as where it can.

[6] The map is also changing, and this time people are the process. Oil that took millions of years to form is pumped out in decades, and nothing replaces it on a human timescale. As the easiest fields are drained, companies drill deeper, farther offshore and in colder places. Today's distribution of petroleum is therefore the product of two histories: the geologic one that put the oil in a few places, and the human one that has been removing it for more than 160 years. Most of what is pumped fuels transportation and is made into plastics and other materials; only a small share is burned to make electricity. Every barrel burned also releases carbon dioxide, which is one more reason that the ancient sea's gift is treated as a limited, nonrenewable resource.

Questions: cite the passage

1. According to paragraph 1, what did the Ghawar oil begin as, and roughly how long ago? What question does the paragraph say the formation story answers?

Answer: It began as microscopic organisms (plankton) drifting in a warm, shallow sea well over 100 million years ago. The formation story answers why a few regions hold huge amounts of petroleum and most regions hold none.

Why: Both facts are stated directly in paragraph 1; the question checks that students read the hook as the frame for the whole passage.

Also acceptable: Accept 'tiny sea life' for plankton.

- Names tiny sea organisms (plankton)
- Gives the time scale of over 100 million years
- States the uneven-distribution question

2. Paragraph 2 says most seafloors leave nothing behind. Give the two things that destroy the remains on an ordinary seafloor, and the one condition in a sheltered basin that lets them pile up instead. Cite the paragraph.

Answer: Destroyers: scavengers that eat the remains, and bacteria that break them down using oxygen (paragraph 2). The condition that preserves them: still bottom water that is nearly free of oxygen, so the remains pile up with mud faster than they can be destroyed.

Why: The low-oxygen basin is the first 'must-happen' and explains why source rock is rare.

Also acceptable: Accept 'no oxygen' for 'nearly free of oxygen.'

- Names scavengers and oxygen-using bacteria
- Names low oxygen (or still water) as the preserving condition
- Cites paragraph 2

3. Paragraph 3 says temperature rises about 25 °C per kilometer. If the surface is 15 °C, calculate the temperature 3 kilometers down. Then state whether that depth is inside the oil-forming range the paragraph gives. Show your work.

Answer: $15\text{ °C} + (3\text{ km} \times 25\text{ °C/km}) = 15\text{ °C} + 75\text{ °C} = 90\text{ °C}$. Yes: 90 °C is inside the 60 to 120 °C range, and 3 km is inside the 2 to 4 km range the paragraph gives.

Why: A one-step rate calculation using the gradient in the passage. The 25 °C per km value is a widely used average geothermal gradient.

Also acceptable: Accept 75 °C if the student forgot to add the surface temperature but clearly shows 3×25 , with a note to add the surface value; the range conclusion is then still 'yes.'

4. Some students think that pressure turns buried remains into oil. Find the sentence in paragraph 3 that corrects this and write it down. Then explain what the passage says actually does the 'chemical work.'

Answer: The sentence: 'Pressure also rises with depth, but it is the heat, acting over millions of years, that does the chemical work.' Heat, which increases with depth because heat flows up from Earth's interior, breaks the buried organic matter apart into oil molecules over millions of years.

Why: This corrects the textbook's wording, which can be read as pressure causing the heating. Students should connect the heat to depth and to time.

Also acceptable: Accept 'heat and time' as the chemical workers.

- Quotes or closely paraphrases the pressure sentence
- States that heat over millions of years converts the organic matter

5. Explain what a trap is, using the words **reservoir rock** and **cap rock** from paragraph 4. What real example does the passage give of oil that had no trap?

Answer: A trap is a place where oil that has risen through porous reservoir rock (such as sandstone) is stopped by a cap rock it cannot pass through (such as shale or salt), usually where the cap rock is folded into an arch, so the oil collects beneath the crest. The example of oil with no trap is the La Brea tar pits in Los Angeles, where petroleum reached the surface as asphalt.

Why: Full credit uses both terms correctly and names the California example.

Also acceptable: Accept 'the tar pits in Los Angeles' without 'La Brea.'

- Reservoir rock described as porous rock the oil moves through
- Cap rock described as the layer oil cannot pass
- Mentions the arch or fold
- Names La Brea

6. Paragraph 5 lists four requirements for an oil field. List all four in your own words. Then explain why a region 'made of ancient granite' can never have an oil field, no matter how deep anyone drills.

Answer: The four requirements: (1) a source rock made from the remains of tiny sea life that piled up in an oxygen-poor sea; (2) burial deep enough, about 2 to 4 km, to reach the 60 to 120 °C range for millions of years; (3) a porous reservoir rock above the source rock for the oil to move into; (4) a cap rock folded into a trap so the oil cannot escape. Ancient granite was never a seafloor and contains no remains of sea organisms, so there is no source rock; without the first requirement there can be no oil to bury, move or trap, so drilling deeper cannot help.

Why: Students must see the chain as a chain: each later requirement is meaningless without the first.

Also acceptable: A student who adds that granite also lacks pore space for a reservoir is giving a correct extra reason.

- All four requirements in the student's own words
- Explains that granite lacks source rock
- Explains that without a source, the other requirements cannot produce oil

7. Paragraph 6 says 'this time people are the process.' What does the author mean? Give one piece of evidence from the paragraph that the distribution of petroleum is changing because of human activity.

Answer: The author means that, just as geologic processes once decided where oil is, human pumping is now changing where oil remains. Evidence (any one): oil that took millions of years to form is pumped out in decades and nothing replaces it; as the easiest fields are drained, companies drill deeper, farther offshore and in colder places; today's distribution is the product of a geologic history and a human history of more than 160 years of removal.

Why: This is the 'current processes' half of the PE: removal by humans is changing the distribution.

Also acceptable: Accept the carbon dioxide sentence only if the student links it to why oil is treated as limited, not as evidence of changing distribution.

- Interprets 'people are the process' as human removal changing the distribution
- Cites one piece of evidence from paragraph 6

8. A classmate claims, 'Oil is found under the ocean, so it must form wherever sea animals live today.' Using evidence from at least two different paragraphs, explain what is right and what is wrong about this claim.

Answer: Right: petroleum does come from sea organisms, and some fields are under today's oceans (paragraph 1 and paragraph 6's mention of drilling offshore). Wrong: the organisms were plankton that lived well over 100 million years ago in a warm shallow sea (paragraph 1), not the animals living there now, and the remains only become oil if they piled up in a low-oxygen basin (paragraph 2), were buried 2 to 4 km and heated for millions of years (paragraph 3), and were trapped (paragraph 4). Where sea animals live today tells you nothing about whether that chain happened; the Ghawar field is under a desert, and the Persian Gulf region is oil-rich because of an ancient sea, not the present one.

Why: This targets the misconception that resources form where the matching environment exists today. Full credit separates what is right (marine origin) from what is wrong (present-day location and the missing requirements) with evidence from two or more paragraphs.

Also acceptable: A student who argues entirely from the Ghawar-under-a-desert example and the time scale, citing paragraphs 1 and 5, has given a complete answer.

- Identifies the marine origin as the correct part
- Explains that the sea was ancient and the process takes millions of years
- Uses evidence from at least two different paragraphs
- Mentions at least one further requirement beyond the organisms

Teacher notes

The passage is about 690 words and is accurate where the textbook simplifies. The Ghawar discovery well was drilled in 1948; its main reservoir rocks are Jurassic, so 'well over 100 million years' is a safe statement. The 25 °C per km gradient and the 60 to 120 °C oil window are standard petroleum-geology values. Heat, not pressure, drives the conversion, and petroleum supplies only a small share of electricity (under 1 percent of U.S. generation), which is why paragraph 6 says 'only a small share.' La Brea is a genuine example of petroleum seeping to the surface where no trap held it. Commercial petroleum drilling began in 1859, which is the basis for 'more than 160 years'.

Scaffold offered to students: Star the must-happens

The passage is organized around four requirements, and paragraphs 2, 3 and 4 each introduce one or two of them. As you read, write 'R1', 'R2', 'R3', 'R4' in the margin where each requirement first appears (source rock, burial and heat, reservoir, cap rock and trap). Questions 2 through 6 can each be answered by going back to the matching R-number. Question 8 is answered by R1 plus the time words in paragraph 1.

Extension: Find the missing link

Choose one region the passage does not name (for example, Alaska's North Slope, Nigeria, or California's San Joaquin Valley, which has produced oil for more than a century). Find out which ancient sea or basin supplied its source rock and roughly when the rock was deposited. Then write a short paragraph that walks through the four requirements for that region, saying which ones are well documented and which you could not find. End with one sentence on what you would want a geologist to show you before believing a new field exists there.