

Mastery Check: Evidence, Plates and Rates

Learning target: I can recall the key evidence, structures and processes of plate tectonics, compute distances from plate rates, and explain how the evidence turned a hypothesis into a theory.

Retrieval and mastery check

About 40 min

Individual

MS-ESS2-3 · assesses

MS-ESS2-2 · supports

MS-ETS1-1 · practice

independent practice

writing

Standards connections

MS-ESS2-3 (assesses, interpreting fossil, rock, shape and seafloor evidence of past plate motion): Items ask students to identify which patterns in fossils, rocks, shapes and seafloor structures count as evidence of plate motion and to read those patterns correctly; the synthesis asks them to argue from several lines of evidence. No magnetic data are used.

MS-ESS2-2 (supports): Two items convert plate rates into distances over millions of years, the slow, large-scale end of the time-and-space scale this PE describes.

MS-ETS1-1 (practice): One item checks that students can tell a criterion from a constraint in the drill-ship design problem from this lesson.

Purpose: assess · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Part A: Retrieval (12 items)

1. In the 1920s most geologists set Wegener's continental drift hypothesis aside mainly because:

Answer: B: he could not explain what force could move a continent.

Why: Wegener's fossil, rock and shape evidence was real; the hypothesis was shelved for lack of a workable mechanism.

Also acceptable: None.

2. Which of the following was **not** available to Wegener as evidence in 1915?

Answer: C: Drill cores showing seafloor ages increasing away from the ridge.

Why: Seafloor age data came from the Glomar Challenger in 1968-69; the other three lines were part of Wegener's 1912-1915 case.

Also acceptable: None.

3. True or false: The mantle beneath the lithosphere is liquid magma, and the plates float on it. Explain your answer in one sentence.

Answer: False. The mantle beneath the lithosphere is solid rock that is hot enough to creep very slowly, a few centimeters a year; plates move over a solid that flows, not a liquid.

Why: Seismic waves that cannot pass through liquid travel through the mantle, which shows it is solid.

Also acceptable: Accept 'solid but flows like a glacier.'

- False
- Mantle is solid and creeps slowly

4. Name **two** seafloor structures that sonar mapping revealed, and for each say what it tells us about plate motion.

Answer: Any two: the mid-ocean ridge (a world-circling chain of volcanic mountains where plates move apart and new seafloor forms); trenches (deep valleys where one plate bends down beneath another and old seafloor is destroyed); fracture zones (cracks that offset the ridge, showing the seafloor moves sideways along the ridge); continental shelves (the true edges of continents, which fit together better than coastlines).

Why: Each structure must be paired with its meaning for plate motion, not just named.

Also acceptable: Accept 'rift valley along the ridge crest' as a structure if linked to plates pulling apart.

- Two structures named
- Each linked to what it shows about plate motion

5. Volcanic rocks at Pinnacles National Park in California formed about 23 million years ago and have since been carried about 315 km along the San Andreas Fault from rocks of the same age that stayed on the other side. Calculate the average rate of motion in kilometers per million years, then convert it to centimeters per year. Show every step.

Answer: Rate = $315 \text{ km} \div 23 \text{ million years} = 13.7 \text{ km per million years}$. Conversion: $13.7 \text{ km} \times 100,000 \text{ cm/km} = 1,370,000 \text{ cm per million years}$; $\div 1,000,000 \text{ years} = 1.37 \text{ cm per year}$, about 1.4 cm per year.

Why: The Pinnacles-Neenach offset of about 315 km over about 23 million years is a real California example; the average is lower than the present plate rate because the fault has not moved at a constant speed and other faults share the motion.

Also acceptable: Accept 13.7 km/Myr and 1.4 cm/yr; accept 14 km/Myr if rounded first (giving 1.4 cm/yr).

6. A drilling ship cores the seafloor at the crest of a mid-ocean ridge, 300 km from it, and 900 km from it. Which core holds the **youngest** volcanic rock?

Answer: C: The core from the crest, because new seafloor forms there.

Why: Seafloor ages increase with distance from the ridge; the crest is where the age is near zero.

Also acceptable: None.

7. The southern Red Sea is widening at about 15 mm per year. How much wider will it be in 2 million years? Give your answer in kilometers and show the conversion ($1 \text{ km} = 1,000,000 \text{ mm}$).

Answer: $15 \text{ mm/yr} \times 2,000,000 \text{ yr} = 30,000,000 \text{ mm}$. $30,000,000 \text{ mm} \div 1,000,000 \text{ mm/km} = 30 \text{ km}$. The Red Sea will be about 30 km wider.

Why: Distance equals rate times time; the millimeter-to-kilometer conversion must be shown.

Also acceptable: Accept 30 km, or 30,000 m with the conversion shown.

8. Fill in the three boundary types: where plates move apart, the boundary is ____; where they move toward each other, it is ____; where they slide past each other, it is ____.

Answer: divergent; convergent; transform.

Why: Boundaries are named by the relative motion of the plates.

Also acceptable: Accept 'spreading' for divergent only if the word divergent also appears somewhere in the answer; the item tests the names.

9. A team designing a seafloor drill ship writes two statements: (i) 'The ship must be able to pull up a core without breaking it or mixing its layers.' (ii) 'The ship must be built with the drilling technology that exists this year.' Label each one a **criterion** or a **constraint** and explain the difference in one sentence.

Answer: (i) is a criterion: it states something the design must achieve to succeed. (ii) is a constraint: it is a limit the design cannot escape. A criterion is a requirement for success; a constraint is a limit on the possible solutions.

Why: This mirrors the drill-ship engineering spread of the lesson and Worksheet 9.

Also acceptable: Accept 'criteria are goals, constraints are limits.'

- (i) criterion, (ii) constraint
- One sentence contrasting requirement with limit

10. Sketch a cross-section from a mid-ocean ridge on the left to a trench on the right. Label the ridge, the trench, the youngest seafloor, the oldest seafloor, and draw arrows showing the direction the seafloor moves on each side of the ridge.

Answer: A sketch with a ridge bump on the left, seafloor sloping gently down to the right and bending sharply down at a trench on the right; 'youngest' labeled at the ridge crest and 'oldest' near the trench; arrows pointing away from the ridge on both sides (left arrow pointing left, right arrow pointing right).

Why: Grade the four labels and the arrow directions. The most common errors are arrows pointing toward the ridge and 'oldest' placed at the ridge.

Also acceptable: A sketch that also shows the sinking plate or volcanoes on the overriding plate is correct and earns full credit.

- Ridge and trench labeled in the correct positions
- Youngest at the ridge, oldest near the trench
- Arrows away from the ridge on both sides

11. Which statement best describes the difference between continental drift and plate tectonics?

Answer: B: Continental drift says the continents moved; plate tectonics also explains how, through plates that form at ridges and sink at trenches.

Why: Drift was a hypothesis without a mechanism; plate tectonics supplies one and is a theory supported by many independent lines of evidence. Option A reverses the labels.

Also acceptable: None.

12. New seafloor forms at mid-ocean ridges all the time. Explain in two sentences why Earth is not getting bigger, naming the structure and the process involved.

Answer: Old, cold, dense seafloor bends down and sinks into the mantle at trenches, a process called subduction. Seafloor is destroyed at trenches at about the same rate it is made at ridges, so the surface stays the same size.

Why: Both the structure (trench) and the process (subduction) must be named, with the balance stated.

Also acceptable: Accept 'recycled into the mantle' for subduction if the trench is named.

- Names trenches and subduction
- States that destruction balances creation

Part B: Synthesis

13. In four to six sentences, explain how the idea that continents move went from a hypothesis to a theory. Your paragraph must name at least **three** different lines of evidence (choose from fossils, rock belts, continental shapes, earthquake belts, seafloor structures and seafloor ages), state what each one shows, and explain what the seafloor evidence added that Wegener did not have.

Answer: Model paragraph: In 1912 Alfred Wegener proposed that the continents were once joined and had drifted apart, and he backed it with fossils such as Mesosaurus and Glossopteris found on continents now separated by oceans, old rock belts that match across the Atlantic in type, age and order, and the fit of the continents' shapes. Geologists set the idea aside because he could not explain what moved the continents. From the 1950s, sonar revealed a mid-ocean ridge running down the middle of the Atlantic with a valley along its crest, and earthquakes were found to cluster in narrow belts along the ridges and trenches, outlining rigid plates. In 1968-69 drill cores showed that the seafloor is youngest at the ridge and grows older with distance on both sides, which confirmed that new seafloor forms at the ridge and spreads outward. The seafloor evidence added the mechanism Wegener lacked, moving plates made at ridges and destroyed at trenches, and a prediction that was tested and came true, so continental drift became part of the theory of plate tectonics.

Why: Full credit requires at least three lines of evidence with what each shows, the missing-mechanism reason for the rejection, and a clear statement that the seafloor evidence supplied a mechanism and a tested prediction.

Also acceptable: A student who uses satellite measurements of present-day motion as a line of evidence is correct. A paragraph that names three lines but does not say what the seafloor added earns partial credit.

- At least three lines of evidence named
- What each line shows
- Why drift was set aside (no mechanism)
- What the seafloor evidence added (mechanism and tested prediction)
- Four to six sentences

Teacher notes

Suggested scoring: items q1-q4, q6-q9, q11 and q12 at 2 points each (20), q5 and q7 at 3 points each for calculation with units (6), q10 at 4 points, q13 at 10 points, for 40 total. Facts checked: Pinnacles National Park's volcanic rocks formed about 23 million years ago and have been offset about 315 km from the Neenach volcanic rocks along the San Andreas Fault (National Park Service); the southern Red Sea opens at about 15 mm per year from GPS studies; seafloor age data came from the Glomar Challenger's South Atlantic drilling in December 1968 to January 1969. The Pinnacles average of about 1.4 cm per year is lower

than the present Pacific-North American plate rate of about 5 cm per year because slip along this part of the fault began later than 23 million years ago and other faults share the motion; the extension asks students to reason about exactly this. The textbook's 5 mm per year for the San Andreas appears to be a unit slip; the extension treats it as a check rather than a fact to memorize. Magnetic stripes are not assessed, in line with the MS-ESS2-3 assessment boundary.

Scaffold offered to students: Rate problems in one pattern

Every rate problem on this sheet is the same pattern: $\text{distance} = \text{rate} \times \text{time}$, or $\text{rate} = \text{distance} \div \text{time}$. Write the three quantities with their units before you calculate, decide which one is missing, and do the unit conversion as a separate line. For q5 you have distance (315 km) and time (23 million years) and want the rate. For q7 you have the rate (15 mm per year) and the time (2 million years) and want the distance.

Extension: Check the textbook

Our textbook gives the rate of motion along the San Andreas Fault as about 5 millimeters per year, while the U.S. Geological Survey gives about 5 centimeters per year for the Pacific and North American plates moving past each other. Using your Pinnacles answer from q5, decide which figure is more believable, and explain your reasoning. Then explain why the Pinnacles rate (an average over 23 million years along one fault) could still be lower than the USGS plate rate even if both numbers are correct.