

Drill Cores Across Ridge R: Age, Distance and a Spreading Rate

Learning target: I can graph seafloor age against distance from a ridge, compute a spreading rate with correct units, and use the pattern as evidence that new seafloor forms at the ridge and moves outward.

Data and graphing

About 45 min

Individual

MS-ESS2-3 · assesses

MS-ESS2-2 · supports

data analysis

independent practice

Standards connections

MS-ESS2-3 (assesses, analyzing seafloor data (rock ages by distance from a ridge) as evidence of past plate motion): Students analyze and interpret a seafloor age-distance dataset, graph it, compute a rate and argue from the pattern that the plates on each side have moved apart. This is the seafloor-structures half of the PE; no magnetic data are used, in line with the assessment boundary.

MS-ESS2-2 (supports): Converting centimeters per year into kilometers per million years gives students the time-and-space scale of the slowest, largest geoscience process; the full explanation of surface change at many scales belongs to other lessons.

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

Answers with reasoning

Part A: Ten drill sites across one ridge

A research ship drilled ten holes in a straight line across a mid-ocean ridge we will call Ridge R. At each site the crew measured the site's distance from the ridge crest and the age of the oldest sediment lying directly on the volcanic rock, which tells how long ago that piece of seafloor formed. Five sites were west of the ridge and five were east. 'Ma' means millions of years ago.

Seafloor age at ten drill sites across Ridge R (teaching dataset)

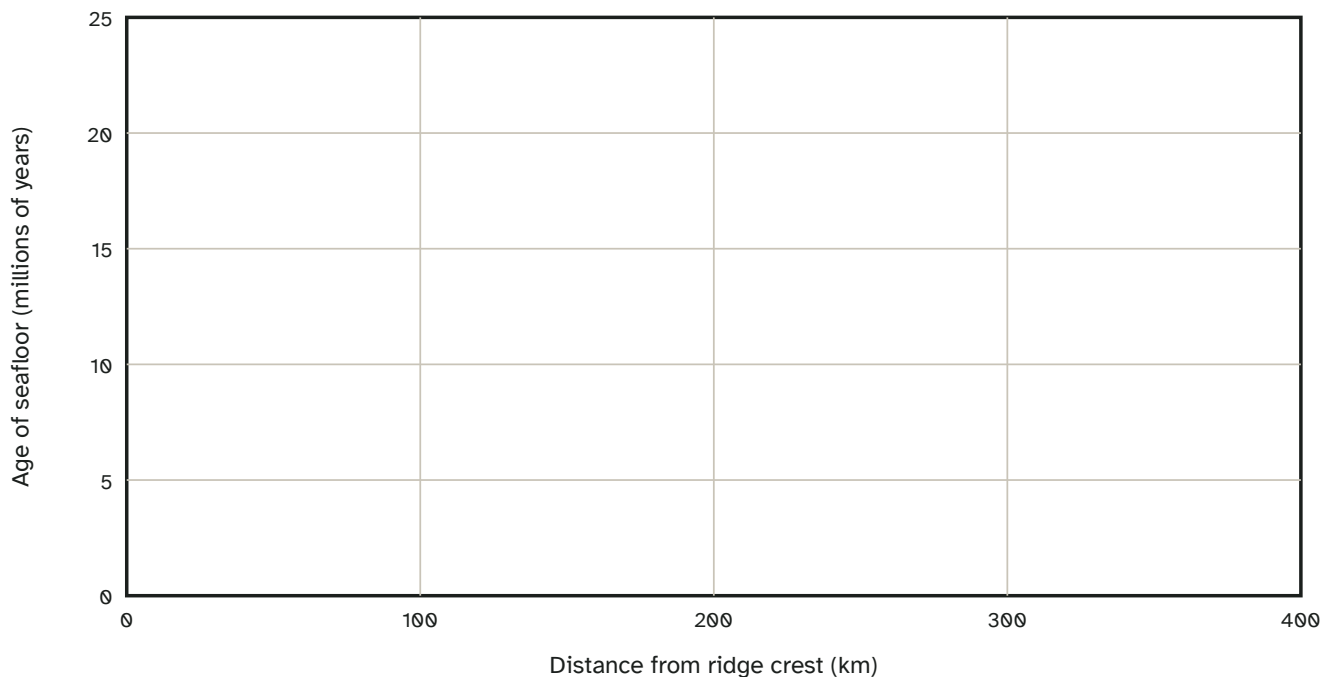
Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Site	Side of ridge	Distance from ridge crest (km)	Age of seafloor (Ma)
W5	west	400	19.9
W4	west	300	15.2
W3	west	200	9.8
W2	west	100	5.1
W1	west	40	2.0
E1	east	40	1.9

Site	Side of ridge	Distance from ridge crest (km)	Age of seafloor (Ma)
E2	east	100	4.9
E3	east	200	10.1
E4	east	300	14.9
E5	east	400	20.2

Simulated data for teaching. The pattern matches what real drilling across the South Atlantic ridge found in 1968-69; the numbers themselves are invented.

Seafloor age versus distance from Ridge R



- Describe the pattern in the table and on your graph in two sentences: one about how age changes with distance, and one comparing the west side with the east side.

Answer: Age increases steadily with distance from the ridge crest: the sites nearest the crest (W1, E1) are about 2 million years old and the farthest (W5, E5) about 20 million years old, and the points fall close to a straight line through the origin. The west and east sides match: at each distance the two ages differ by 0.3 million years or less, so the pattern is symmetric about the ridge.

Why: Students should name both the linear increase and the symmetry; the symmetry is the evidence used in q7.

Also acceptable: Accept 'the farther away, the older, by about 5 million years every 100 km.'

- Age increases with distance, roughly as a straight line
- The two sides give nearly the same ages at the same distances

2. Use site E5 to calculate how fast the seafloor on the east side has moved away from the ridge, in kilometers per million years. Show the division. Then check your answer with site W4 and say whether the two sides agree.

Answer: E5: $400 \text{ km} \div 20.2 \text{ million years} = 19.8 \text{ km per million years}$. W4: $300 \text{ km} \div 15.2 \text{ million years} = 19.7 \text{ km per million years}$. The two sides agree (both about 20 km per million years).

Why: Rate equals distance divided by age. Any site gives nearly the same value because the data were built on a 20 km per million year half-rate with small scatter.

Also acceptable: Accept 19.8 or 20 km per million years for E5 and 19.7 or 20 for W4; accept any other site used as the check if the division is shown and the agreement is stated.

3. Convert your rate from q2 (round it to the nearest whole number of km per million years) into **centimeters per year**. Show every step. (1 km = 100,000 cm; 1 million years = 1,000,000 years.)

Answer: 20 km per million years. $20 \text{ km} \times 100,000 \text{ cm/km} = 2,000,000 \text{ cm per million years}$. $2,000,000 \text{ cm} \div 1,000,000 \text{ years} = 2 \text{ cm per year}$.

Why: Converting the numerator and denominator separately keeps the unit logic visible. Two centimeters a year is about the rate found across the real South Atlantic ridge.

Also acceptable: Accept 1.98 cm per year if the student did not round first; accept 2 cm/yr written as 20 mm/yr with the conversion shown.

4. The ship could not reach a site 600 km east of the ridge. Use your rate to predict the age of the seafloor there. Show the calculation.

Answer: Age = distance $\div$ rate = $600 \text{ km} \div 20 \text{ km per million years} = 30 \text{ million years}$.

Why: Extending the straight line to 600 km. Students who use the line on their graph should get 29 to 31 million years.

Also acceptable: Accept 30 Ma, or 30.3 Ma if 19.8 km per million years was used.

5. The rate you found is for **one** side of the ridge. The whole ocean widens by the motion of both sides together. Calculate the full spreading rate in cm per year, then use it to find how much wider this ocean becomes in 50 million years. Give that answer in kilometers and show the conversion.

Answer: Full rate = $2 \text{ cm/yr} + 2 \text{ cm/yr} = 4 \text{ cm per year}$. In 50 million years: $4 \text{ cm/yr} \times 50,000,000 \text{ yr} = 200,000,000 \text{ cm}$. $200,000,000 \text{ cm} \div 100,000 \text{ cm/km} = 2,000 \text{ km}$. The ocean becomes about 2,000 km wider.

Why: Both sides move away from the ridge, so the ocean widens at twice the one-side rate. The conversion to kilometers must be shown.

Also acceptable: Accept 2,000 km, or $2 \times 10^3 \text{ km}$. A student who computes 1,000 km has forgotten to double the rate; give partial credit if the conversion is correct.

6. Suppose seafloor spreading were **not** happening and the whole ocean floor had formed at one time long ago. Describe what the table and graph would look like in that case. Then explain why the actual data rule that idea out.

Answer: If the whole floor had formed at once, every site would have about the same age no matter how far it was from the ridge: the table would show one age repeated, and the graph would be a flat horizontal line. The actual data show ages rising steadily from about 2 to 20 million years with distance, which is impossible if the floor formed all at once; the floor must have formed bit by bit at the ridge over at least 20 million years.

Why: Stating what the data would look like if the hypothesis were false is the core of using data as evidence. A flat line is the expected 'no spreading' signature; random scatter is also acceptable.

Also acceptable: Accept 'the ages would be random with no pattern' as the alternative picture.

- Describes the same age everywhere (flat line) or random ages
- Says the rising pattern contradicts that
- Concludes the floor formed over time at the ridge

7. Explain why the **matching** ages on the two sides (for example W3 and E3) are important evidence that new seafloor forms at the ridge crest and moves outward in both directions. What would it mean if the east side were consistently twice as old as the west side at the same distance?

Answer: Matching ages at matching distances mean both sides have been moving away from the crest at the same speed, which is exactly what you expect if new seafloor forms in the crack at the crest and each new strip is split in two, half going west and half going east. The crest is the only place where the age is zero, so it must be where the seafloor is made. If the east side were consistently twice as old at the same distance, the east side would be moving away at half the speed of the west side, or the seafloor would not be forming at the crest; either way the simple picture of a crest that splits new seafloor evenly would have to change.

Why: Full credit explains that symmetry implies equal outward motion from a single source at the crest. The second part checks that students can reason about what a different pattern would imply rather than just memorizing 'symmetric'.

Also acceptable: A student who says the 'twice as old' case would mean the ridge had shifted its position over time is reasoning well.

- Links matching ages to equal motion on both sides
- Identifies the crest (age near zero) as the source
- Interprets the 'twice as old' case as unequal rates or a different source

Part B: Comparing with real ridges

Real ridges spread at different speeds. The table gives rounded, approximate full spreading rates (both sides together) for four real ridges. Use it with your results from Part A.

Approximate full spreading rates of real mid-ocean ridges (rounded reference values)

Ridge	Ocean	Full spreading rate, both sides together (cm per year)
Gakkel Ridge	Arctic	about 1
Mid-Atlantic Ridge	Atlantic	about 2.5 to 4
Juan de Fuca Ridge	Pacific, off Oregon and Washington	about 6
East Pacific Rise	Pacific	about 6 to 15, fastest in the south

8. Which real ridge in the table spreads at a rate closest to Ridge R's full rate from q5? Explain how you decided.

Answer: The Mid-Atlantic Ridge: Ridge R's full rate is 4 cm per year, which falls in the Mid-Atlantic Ridge's range of about 2.5 to 4 cm per year. The Gakkel Ridge (about 1) is too slow and the Juan de Fuca Ridge (about 6) and East Pacific Rise (6 to 15) are faster.

Why: The simulated data were built to match the South Atlantic, where the 1968-69 drilling found about 2 cm per year on each side.

Also acceptable: None.

- Chooses the Mid-Atlantic Ridge
- Compares the 4 cm/yr full rate to the table

9. The fastest part of the East Pacific Rise spreads at about 15 cm per year (full rate). If a drilling ship surveyed that ridge the way it surveyed Ridge R, what age would it find at a site 400 km from the crest? Show your work, and compare the answer with site E5. (Hint: first find the one-side rate.)

Answer: One-side rate = $15 \text{ cm/yr} \div 2 = 7.5 \text{ cm per year}$. In km per million years: $7.5 \text{ cm} \times 1,000,000 = 7,500,000 \text{ cm per million years} = 75 \text{ km per million years}$. Age at 400 km = $400 \text{ km} \div 75 \text{ km per million years} = 5.3 \text{ million years}$. That is about one quarter of E5's 20.2 million years, because the East Pacific Rise spreads nearly four times faster than Ridge R.

Why: The hint matters: students who use the full rate get 2.7 million years. The comparison shows that a faster ridge puts the same age farther from the crest.

Also acceptable: Accept 5.3 Ma; accept 5.2-5.4 with rounding. If the student uses 15 cm/yr as the one-side rate, give partial credit for the correct method and note the factor-of-two error.

10. The oldest seafloor anywhere in the open oceans is less than about 200 million years old, while some continental rocks are about 4,000 million years old. Using what the Ridge R data show about how seafloor forms and moves, explain why the ocean floor is so much younger than the continents, and name the process and the structure that make seafloor disappear.

Answer: The Ridge R data show that seafloor is made continuously at the ridge and carried away, so the ocean floor is like a conveyor belt: every piece is new when it forms and gets older as it moves. If nothing removed it, the oldest seafloor would be as old as the oceans themselves, but it is not. Old, cold, dense seafloor sinks back into the mantle at trenches by subduction, so no piece of ocean floor survives much beyond about 200 million years. Continents are too thick and too low in density to sink, so their rocks can last billions of years.

Why: This item connects the dataset to the destruction half of the cycle. Full credit names subduction (process) and trenches (structure) and gives the buoyancy reason for continents.

Also acceptable: Accept 'continents are lighter and float higher' for the buoyancy point.

- Seafloor forms continuously and ages outward
- Old seafloor is removed by subduction at trenches
- Continents do not sink, so they keep older rock

Teacher notes

The Part A dataset is simulated on a half-rate of 20 km per million years (2 cm per year) with small scatter, so any site gives about the same rate; the symmetric pair design (W1/E1 through W5/E5) is deliberate so that students can test symmetry. The real South Atlantic drilling (Glomar Challenger, Leg 3, 1968-69) found about 2 cm per year on each side, which is why the Mid-Atlantic Ridge is the right match in q8. Part B's reference values are rounded from published rates: the Gakkel Ridge is the slowest known (about 1 cm/yr), the Mid-Atlantic Ridge spreads at about 2.5 cm/yr in the north and 3 to 4 cm/yr in the south, the Juan de Fuca Ridge at about 6 cm/yr, and the East Pacific Rise from about 6 cm/yr to about 15 cm/yr in its fastest southern section. Age is measured here as the age of the oldest sediment resting on the volcanic rock, which is how the 1968-69 cores were dated; say so if students ask how a core gives an age. The oldest open-ocean seafloor is about 180 million years old in the western Pacific; the sheet says 'less than about 200 million years' to stay safely rounded. The extension gives roughly $1,500 \text{ km} \div 20 \text{ km per million years} = 75 \text{ million years}$; the South Atlantic actually began opening about 130 million years ago, and the difference is a good discussion of changing rates and of where the oldest Atlantic seafloor lies.

Scaffold offered to students: Rate in three lines

A rate is a distance divided by a time. Line 1: write the distance with its unit (for example, 400 km). Line 2: write the time with its unit (for example, 20.2 million years). Line 3: divide and write the unit as 'km per million years.' To change km per million years into cm per year, change the top and the bottom separately: multiply the kilometers by 100,000 to get centimeters, then divide by 1,000,000 years. Write each step on its own line so you can find a slip.

Extension: When did Ridge R's ocean open?

Suppose the ocean that contains Ridge R is 3,000 km wide from one continental shelf to the other, with the ridge in the middle. Use the one-side rate from Part A to estimate how long ago the ocean began to open, and show your reasoning. Then explain two reasons your estimate could be wrong: one about the assumption that the rate never changed, and one about where the oldest seafloor in an Atlantic-type ocean actually lies. Finally, look up the age when the South Atlantic began to open and compare it with your estimate.