

Where Should the Drill Ship Go? Spend the Budget to Test Spreading

Investigation question: Six drill cores from a simulated ocean are already in hand. Which idea about the seafloor do they support, what ages do they predict elsewhere, and which four new drilling sites would test that prediction best within a fixed budget?

Data-driven decision

Groups of 4

1 session

Setup 5 · Activity 45 · Cleanup 3 min

MS-ESS2-3 · assesses

MS-ETS1-1 · practice

Scientific purpose

Students act as the science team planning the next leg of a seafloor drilling voyage. Using a simulated set of six core ages across a ridge, they compute spreading rates, graph age against distance, and decide whether the data fit seafloor spreading or an older idea that ocean floors are ancient and permanent. They then predict the ages at eight candidate sites under both ideas, and choose which sites to drill with a budget of 14 cost units, defending the choice with criteria (which sites separate the two ideas most sharply) and a constraint (cost rises with water depth). The lab moves the lesson's evidence from 'look at the pattern' to 'use the pattern to decide what to do next.'

Why this helps students with this chapter

The textbook presents the seafloor age map as a finished result. Scientists in 1968 did not have it; they had a few expensive holes and a choice about where to drill next. Putting students in that position makes them use the age pattern as a tool rather than a fact: a site is worth drilling only if the two ideas predict different ages there, and a cheap site on the continental shelf is worthless because it does not sample seafloor at all. Computing rates from both sides also gives students their own check on the symmetry that makes the pattern convincing.

Standards connections

MS-ESS2-3 (assesses, analyzing and interpreting seafloor age data as evidence of past plate motion):

Students analyze age-versus-distance data from both sides of a ridge, interpret the symmetric increase as evidence that seafloor has formed at the ridge and moved outward, and use the pattern to make and test predictions. This is the seafloor-structure half of the PE; the data are simulated and labeled as such, and paleomagnetic evidence is not used.

MS-ETS1-1 (practice, stating criteria and constraints for a plan): Choosing drilling sites under a budget requires students to state what a good site must do (criteria) and what limits the plan (constraints), the same reasoning the lesson's drill ship story describes. The problem is given rather than defined from scratch, so this practices rather than assesses the PE.

Roles (rotate each session)

- **Data analyst:** Computes the rate for every existing core (distance divided by age), checks the west and east rates against each other, and reports the average.
- **Grapher:** Plots age against distance for the six cores, draws the best-fit line through the ridge, and reads predicted ages for the candidate sites from the line.
- **Budget officer:** Tracks the cost of every proposed set of sites, enforces the 14-unit limit, and records the final plan's total.
- **Reporter:** Writes the group's hypothesis decision and the reason for each chosen site, and presents the plan to the class in one minute.

Materials

Item	Quantity	Per	Note
Recording sheet with the simulated core data and candidate site list	1	student	
Calculator	1	student	
Ruler	1	group	For the best-fit line.
Sticky notes or small paper flags	8	group	Optional: to place proposed sites on the class ocean strip.
Masking tape ocean strip on the board or floor, 240 cm long with the ridge marked 100 cm from the west end	1	class	Scale 1 cm = 10 km; optional but helps students see the basin.

Estimated cost: 1 to 2 per class (an estimate; Estimate. Photocopies of the recording sheet plus a few sticky notes; calculators and rulers are classroom stock.)

Safety

- This is a paper-and-calculator activity with no physical hazards. If the floor ocean strip is used, keep the tape line clear of walkways and remove it at the end of class.

Teacher preparation and setup

1. Print one recording sheet per student. Work the key yourself first: all six existing cores give rates close to 20 km per million years, and the budget-best plans are listed in the answer key.
2. Make the class ocean strip: a 240 cm line of masking tape on the board or floor, scale 1 cm = 10 km. Mark WEST SHORE at the west end, RIDGE at 100 cm from the west end, and TRENCH at the east end (the east continent lies just beyond). Mark the six existing cores and the eight candidate sites at their scaled positions so groups can post sticky-note flags on the sites they choose.
3. Write the two ideas on the board exactly as the recording sheet states them, and the budget: 14 cost units for the new leg.

4. Decide whether to run the debrief as a 'funding panel': each group presents its plan and the class votes on which plan tests spreading most sharply for the money.

Investigation design

Independent variable	Distance of each core or candidate site from the ridge (km, west or east)
Dependent variable	Age of the oldest sediment resting on the lava at each site (millions of years), measured for existing cores and predicted for candidate sites
Controlled	The same dating method for every core: age of the first sediment deposited on the lava, which settled soon after the seafloor formed; Distances measured from the ridge crest along the same line across the basin; The same two hypotheses applied to every site; A fixed budget of 14 cost units for the new sites
Trials	Six existing cores analyzed by every group; each group proposes one plan, and the class compares plans in the funding panel.
Comparison	Seafloor spreading (age rises with distance from the ridge, symmetric on both sides) versus the ancient-ocean idea (ages old everywhere, no relation to distance).

Student procedure

1. Read the scenario and the two ideas on the recording sheet. In one sentence each, write what age pattern each idea predicts for cores at different distances from the ridge.
2. Data analyst: for each of the six existing cores, divide the distance from the ridge by the age to get a rate in kilometers per million years. Record the six rates and the average of the west rates and of the east rates.
3. Grapher: plot the six cores on the graph (west distances to the left of zero, east to the right). Draw a best-fit straight line for each side passing through the ridge at age 0.
4. Decide as a group which idea the six cores support. Write the decision in question 1 with two numbers from your table as evidence.
5. Predict: for each of the eight candidate sites, write the age that seafloor spreading predicts (distance divided by 20, or read from your line) and the age the ancient-ocean idea predicts. Note any site where the two ideas predict nearly the same thing, or where the site would not sample seafloor at all.
6. Choose: pick the set of sites you would drill with 14 cost units. Budget officer checks the total. A good set gives the sharpest test of the prediction for the money: sites where the two ideas disagree most, on both sides of the ridge if possible, with at least one site near the ridge and one far from it.
7. Post your chosen sites on the class ocean strip with sticky notes, and have the Reporter write a one-sentence reason for each site in the selection table.
8. Answer the analysis questions individually, then compare within the group before the funding panel.

Expected observations

- Rates: H1 20.0, H2 19.6, H3 21.4, H4 20.0, H5 20.7, H6 19.6 km per million years; west average about 20.3, east average about 20.1. The graph is a V with its point at the ridge and straight arms of nearly

equal slope.

- Predictions under spreading at 20 km per million years: S1 about 0, S2 47.5, S3 15, S4 67.5, S5 45, S6 2.5, S7 not seafloor (continental rock, far older), S8 35. Under the ancient-ocean idea every site over 500 million years with no pattern, so the ideas disagree at every seafloor site.
- Most groups choose S1 or S6 plus S4 plus one of S2, S3 or S5 for 13 or 14 units; a few are tempted by S7's low cost until they read the note.

Likely difficulties

- Students divide age by distance instead of distance by age and get 0.05; ask them what units a spreading rate should have (km per million years).
- Students plot west cores on the positive side of the axis; the graph's negative ticks and the 'V' shape in the expected observations help the Grapher check.
- Groups spend the budget on the cheapest sites and miss the far site; the criterion 'where do the ideas disagree most' and the requirement of one near and one far site steer them.
- Students treat S8 as valuable because the ideas disagree there; ask what H5, only 100 km away, already told them.

Structured debrief

1. Collect rates on the board. All six cores give 19.6 to 21.4 km per million years, west and east alike. Ask what it would take to get this by accident under the ancient-ocean idea: six random old ages that happen to fall on one straight line through the ridge on both sides. The symmetry is the point; a pattern on one side could be a coincidence, the same pattern on both sides is a prediction coming true.
2. Run the funding panel. Each Reporter presents the plan in one minute. Push on the trade-offs: S4 is the most expensive site and the most informative, because it tests the oldest predicted seafloor right before the trench; S1 or S6 is cheap and tests the youngest; S7 is cheap and useless because it samples the continent; S8 mostly repeats H5. Plans that spend all 14 units on near-ridge sites test only one end of the prediction.
3. Tell the real story briefly: in late 1968 and early 1969 the Glomar Challenger's third voyage drilled 17 holes at 10 sites across the South Atlantic ridge and found ages rising with distance at close to 2 cm per year on each side, the first direct test of spreading by drilling. The ship could hold position without an anchor using thrusters, which is why deep sites like S4 were possible at all.
4. Close on q8: the basin's oldest floor is young compared with the continents because seafloor is removed at the trench; nothing on Earth's ocean floors is older than about 200 million years, while continental rocks reach past 4 billion. Note the textbook's 'oldest rocks at the trenches' holds in this basin because it has a trench; in the Atlantic, with almost no trenches, the oldest seafloor lies against the continental shelves.

Recording sheet: what students fill in

Lab 3 recording sheet: Where should the drill ship go?

Scenario. You are the science team on a drilling ship working in a simulated ocean basin 2,400 km wide. A ridge runs north to south 1,000 km from the west shore; a deep trench lies along the east edge, 1,400 km east of the ridge. The ship drills through the sediment into the lava rock beneath and brings up a core. The age you get is the age of the oldest sediment sitting directly on the lava, which settled soon after that seafloor formed. Six cores from the last leg are in hand. You have 14 cost units left for the next leg. This is a teaching dataset: the ocean, the sites, the ages and the costs are invented to behave like real ones.

The two ideas on trial — Idea 1, seafloor spreading: new seafloor forms at the ridge and moves outward, so age rises steadily with distance from the ridge and the two sides match. **Idea 2, the ancient ocean:** ocean basins are permanent and their floors are among the oldest rock on Earth, so every core should be very old (over 500 million years) with no relation to distance from the ridge.

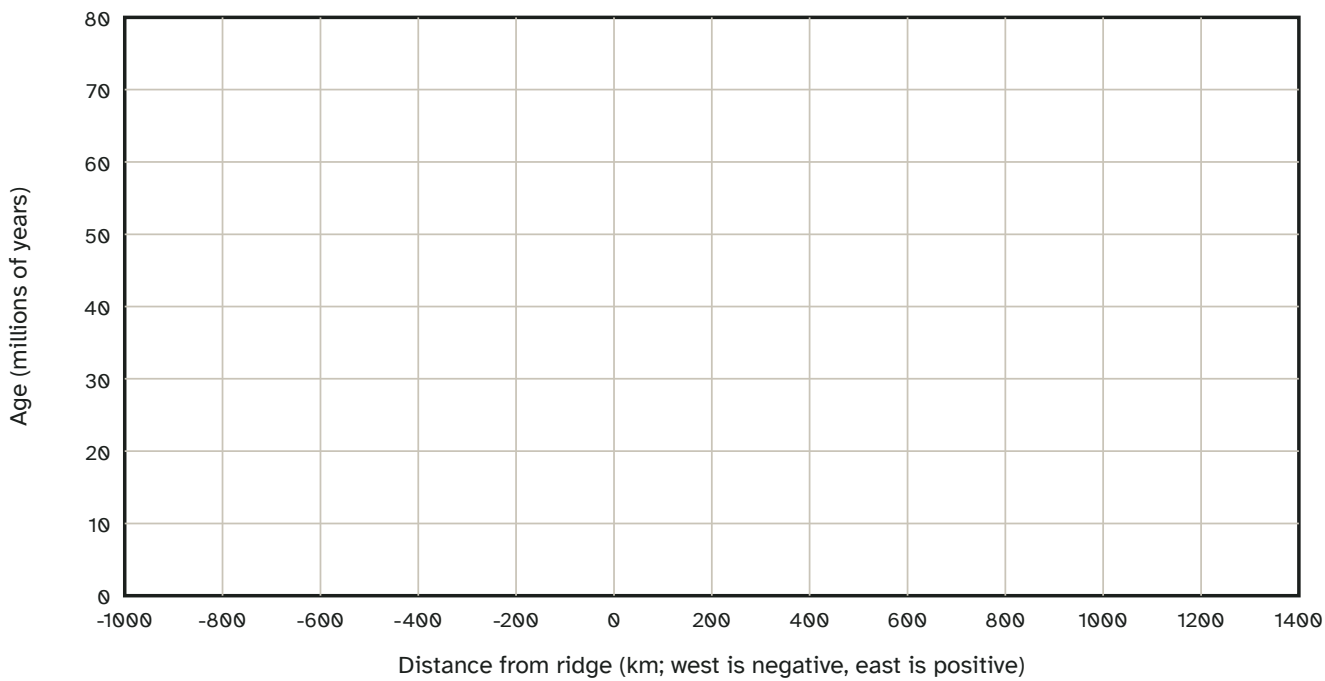
Existing cores from the last leg (simulated teaching data)

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

Core	Distance from ridge (km)	Side	Age of oldest sediment on the lava (millions of years)	Rate = distance ÷ age (km per million years)
H1	800	west	40	
H2	450	west	23	
H3	150	west	7	
H4	200	east	10	
H5	600	east	29	
H6	1100	east	56	

Fill in the rate column. Average of west rates: _____ Average of east rates: _____

Age of the seafloor against distance from the ridge



Candidate sites for the next leg (cost rises with water depth)

Site	Position	Water depth (m)	Cost (units)	Notes
S1	On the ridge crest, 0 km	2600	3	Thin sediment; quick to drill
S2	950 km west, near the west edge of the basin	4800	5	Thick sediment
S3	300 km west	3600	4	
S4	1,350 km east, just before the trench	5500	6	Deepest water on the list
S5	900 km east	4700	5	
S6	50 km east of the ridge	2800	3	Thin sediment
S7	On the west continental shelf, 980 km west (20 km off the west shore)	120	2	Shallow; the drill would enter continental rock, not seafloor lava
S8	700 km east	4300	4	100 km from existing core H5

Predictions and your selection

Site	Age if spreading (Myr)	Age if ancient ocean	Do the ideas disagree here? (yes/no)	Chosen? (yes/no)	Reason
S1					
S2					
S3					
S4					
S5					
S6					
S7					
S8					
TOTAL COST of chosen sites (must be 14 or less)					

- Which idea do the six existing cores support? Give two numbers from your rate column and one feature of your graph as evidence.

Answer: Idea 1, seafloor spreading. Rates such as $H1 = 800 \div 40 = 20.0$ and $H6 = 1,100 \div 56 = 19.6$ km per million years are the same on both sides, and the graph is a V with its point at the ridge: age rises in a straight line with distance on each side. The ancient-ocean idea predicts ages over 500 million years everywhere with no pattern, and no core is anywhere near that old.

Why: Full credit needs two rates and one graph feature (straight arms, V at the ridge, or both sides matching). Any two of the six rates are acceptable.

- Names seafloor spreading
- Quotes two rates from the table
- Cites the straight-line or symmetric pattern on the graph

- List the sites you chose, their total cost, and the single most important reason for your set as a whole.

Answer: Group-specific. Strong sets within 14 units include S1 + S2 + S4 ($3 + 5 + 6 = 14$), S6 + S2 + S4 (14), S1 + S3 + S4 (13) or S1 + S4 + S5 (14). The best single reason is that the set tests the prediction where the ideas differ most and where nothing is known yet: at the ridge and at the far ends of the basin.

Why: Any set within budget that includes a far site and a near-ridge site, excludes S7, and gives a coherent reason earns full credit. Sets of two sites that save money without using it are acceptable if justified, but sets that include S7 or that cluster near existing cores should be marked down.

Also acceptable: Accept S1 + S4 + S8 (13) with a reason that S8 checks H5, though it adds less than S2 or S5.

Analysis questions: answer key

3. Compute the spreading rate from core H1 and from core H6 in kilometers per million years, then convert the average of the two to centimeters per year. Show your work.

Answer: H1: $800 \text{ km} \div 40 \text{ million years} = 20 \text{ km per million years}$. H6: $1,100 \text{ km} \div 56 \text{ million years} = 19.6 \text{ km per million years}$. Average = $19.8 \text{ km per million years}$. Conversion: $19.8 \text{ km} = 1,980,000 \text{ cm}$; divided by $1,000,000 \text{ years} = \text{about } 2 \text{ cm per year}$.

Why: Both divisions and the unit chain must be shown. Accept 19.6 to 20.0 for the average depending on rounding, and 1.96 to 2.0 cm per year.

Also acceptable: Accept the answer carried through from the student's own rounded rates if the chain is correct.

4. Using a rate of 20 km per million years, what age does seafloor spreading predict at S4 (1,350 km east) and at S2 (950 km west)? What does the ancient-ocean idea predict at the same two sites?

Answer: Spreading: $S4 = 1,350 \div 20 = 67.5 \text{ million years}$; $S2 = 950 \div 20 = 47.5 \text{ million years}$. Ancient ocean: both over 500 million years, with no particular values and no reason for S4 to be older than S2.

Why: The contrast between a specific predicted number and 'old everywhere' is what makes these sites good tests.

Also acceptable: Accept 65 to 70 and 45 to 50 if read from a best-fit line instead of computed.

5. S7 is the cheapest site on the list. Explain why drilling it would tell you nothing about seafloor spreading, and what the shelf's position says about where the seafloor ends and the continent begins.

Answer: S7 sits on the continental shelf, which is the submerged edge of the continent. The drill would go into continental rock, which was never made at the ridge and is far older than any seafloor, so its age says nothing about whether seafloor spreads. The shelf's position shows that the true edge of the continent is not the shoreline but the shelf edge; the seafloor made at the ridge ends where the shelf begins. The low cost is a trap: a cheap site that cannot test the idea is worth nothing.

Why: This connects the lesson's continental-shelf idea to decision-making. Full credit requires both the 'not seafloor' point and the 'shelf is the continent's edge' point.

- States that S7 samples continental rock, not seafloor
- States that the shelf edge, not the coast, is the edge of the continent
- Concludes that cost alone does not make a site worth drilling

6. Which one of your chosen sites separates the two ideas most sharply, and why? Which candidate site would add the least new information even though the ideas disagree there?

Answer: S4 separates the ideas most sharply: spreading predicts about 67 million years, the oldest in the basin and a specific number, while the ancient-ocean idea predicts over 500 million years. It also tests the far end of the pattern, where no core exists yet, right before the trench. S8 adds the least: the ideas disagree there, but H5 is only 100 km away and already gave 29 million years, so S8 would nearly repeat a measurement already made.

Why: Students must weigh both 'do the ideas disagree' and 'is it already known.' Accept S2 as the sharpest if the student argues for the untested west end; the reasoning matters.

- Names a far site with the size of the predicted difference
- Names S8 (or another site next to an existing core) as low-information with the reason

7. A skeptic says: 'Ages rise away from the ridge only because the sediment is thicker out there, not because the rock is older.' Using how the ages were measured, explain why this objection fails, and why thicker sediment far from the ridge is actually what spreading predicts.

Answer: The age is not the thickness of the sediment; it is the age of the oldest layer sitting directly on the lava, dated from the fossils in it. That first layer settled soon after the lava hardened, so it dates the seafloor itself no matter how much sediment piled on later. Thicker sediment far from the ridge is exactly what spreading predicts: seafloor that has existed longer has had more time to collect sediment, so thickness rising with distance is more evidence for spreading, not against it.

Why: This checks that students understand what was measured and can turn the objection into a confirming prediction.

- Explains that the dated layer is the first sediment on the lava
- Explains that this dates the seafloor regardless of total thickness
- Notes that thickness increasing outward is itself predicted by spreading

8. The oldest seafloor in this basin, near the trench, is only about 67 million years old, while the continents on both sides contain rocks over a billion years old. What happened to seafloor older than 67 million years, and how does the trench's position support your answer?

Answer: Seafloor older than about 67 million years has been removed: carried into the trench at the east edge, where it bent down beneath the neighboring plate and sank into the mantle (subduction). The trench sits exactly where the oldest seafloor on the east side ends, which is what you would expect if the trench is where old seafloor goes. On the west side there is no trench, so the oldest seafloor there is still present against the continental shelf. Continents are not recycled this way because continental rock is less dense and does not sink, which is why they keep rocks billions of years old.

Why: Full credit requires subduction at the trench, the trench's position as evidence, and the contrast with continents.

- Names removal at the trench (subduction)
- Uses the trench's position at the end of the oldest seafloor as evidence
- Explains why continents keep older rock

9. Write one criterion and one constraint from your drilling plan, and label which is which.

Answer: Criterion (what a good plan must do): for example, 'include at least one site where spreading predicts an age over 60 million years' or 'test both sides of the ridge.' Constraint (a limit the plan must respect): 'total cost 14 units or less' or 'sites in water deeper than 5,000 m cost 6 units.'

Why: Any accurate pair correctly labeled earns credit; the test is success versus limit.

Also acceptable: Accept 'the ship cannot drill into continental rock and learn about seafloor' as a constraint, and 'ages must be measured the same way at every site' as a criterion.

Individual evidence of learning

Each student submits their own completed rate column, graph with best-fit lines, prediction and selection table, and written answers to q1 through q9. The rate column, graph and q1 are the primary evidence toward MS-ESS2-3; the selection table, q6 and q9 are the evidence for the criteria-and-constraints practice.

Assessment criteria

Criterion	Proficient looks like
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Data analysis	All six rates computed correctly to within rounding, west and east averages reported, points plotted on the correct sides and a V-shaped best fit drawn through the ridge.
Interpretation	States that the cores support spreading because age rises steadily with distance at the same rate on both sides, and that the ancient-ocean idea predicts old ages with no pattern, which the data do not show.
Site decision	Chooses a set within 14 units that includes a far site (S2, S4 or S5) and a near-ridge site (S1 or S6), excludes S7 with a stated reason, and justifies each site by where the ideas disagree and what is not already known.
Criteria and constraints	Correctly labels at least one criterion (what a good site must do) and one constraint (the budget or water depth) in q9.

Accessibility adaptations

- Provide the rate column with the first two rows worked and a graph with the axes already scaled and the ridge marked, for students who need more support.
- Allow the Data analyst and Grapher roles to be shared by a pair who talk through each calculation, and accept q5 through q8 as recorded spoken answers.
- Offer the recording sheet in large print and allow rates for three cores instead of six for students who need a reduced load; the pattern is still visible.
- Use the floor ocean strip so students who need movement can walk from the ridge to each site, placing flags; a multilingual glossary card for ridge, trench, core, sediment and budget supports multilingual learners.

Low-cost alternative

No special materials are needed. If photocopies are limited, project the data and site tables and have students draw their own rate table and graph on notebook paper; the masking-tape ocean strip can be a chalk line on the board.

Model limitations

The ocean, the cores, the site costs and the ages are invented to behave like a real spreading ocean; they are not measurements, and the basin's geometry (a ridge 1,000 km from one shore, a trench on the other side) is a simplified case chosen so that both sides and a trench can be tested. One consequence students may notice: with steady, equal spreading, seafloor against the west shelf (about 50 million years old) could not be younger than seafloor at the east trench (about 70 million years old); real basins of this shape have a more complicated history, which the lab leaves out. Real core ages carry uncertainty of a few million years, real spreading rates change over time and vary along a ridge, real drilling costs depend on far more than water depth, and real planning considers weather, ship time and many other objectives. The lab also stops short of mechanism: it shows that seafloor has formed at the ridge and moved outward, not why. This activity has not been physically tested by the authors; the data were constructed and the key computed on paper, so check the arithmetic against your own run before class.

Teacher notes

All numbers in this lab are simulated and must be presented as a teaching dataset. The rate of 20 km per million years (2 cm per year) was chosen to resemble the half-spreading rate the Glomar Challenger measured across the South Atlantic in 1968-69. The basin's asymmetry is deliberate: it lets the east side show a trench and the west side show seafloor ending at a shelf, which previews the difference between a Pacific-style and an Atlantic-style ocean. Do not let the lab drift into mechanism; MS-ESS2-3 assesses the interpretation of the pattern, not what moves the plates. If groups finish early, ask them to predict the age at the trench itself (about 70 million years) and what the ship would find 10 km beyond it (the continental slope of the east continent, not seafloor).