Sounding the Pacific Ocean
An echo sounder traverse of the eastern Pacific

The harbour at Callao, Lima, Peru in 2005.

A research ship sets out from the coast of Peru, near Lima, and travels due west for 3600km. As the ship moves, its echo sounder is continuously recording the depth of the ocean floor below sea level. Some of the echo sounder readings are shown in the Table. The Table shows the distance from Lima in kilometres and the time taken for the echo sounder's 'ping' to travel from the transmitter in the ship's hull and back up again to the receiver. We know that the speed of sound in sea water is around 1500 metres per second, so the depth of water beneath the ship can be calculated. Most of the depths have already been calculated for the class, but we have left some of the more significant ones for them to calculate. (If appropriate, the activity may be carried out using a spreadsheet to calculate the depths and to plot the graph).

$$\text{Speed } (v) = \frac{\text{Distance } (d)}{\text{Time } (t)}$$

So Distance (i.e. Depth) = vt

But remember that t is the time taken for the sound wave to travel down to the seabed and back again, so we must halve the value.

$$\text{i.e. Depth of sea } (d) = \frac{vt}{2}$$

- Ask pupils to calculate the missing depths and enter them on the Table.
- Then ask them to plot a graph of all the depths from the coast of Peru westward across this part of the Pacific Ocean.
- Ask them to describe out loud the main changes in depth to their partner in the class, and to discuss if they found any of these surprising, and if so, why. (*Answers will vary, but the rapid descent into the Peru/Chile Trench may be a surprise: also the monotonously flat section and the sudden rise to the seamount*).
- Ask them to label the following on their graphs:
  Continental shelf – depth less than 150m
  Continental slope – depths from 150m to 2000m
  Peru/Chile Trench – depth of 8000m
  Abyssal plain – very level sea bed at around 5000m depth
  Seamount – isolated underwater peak rising to 2000m or less below sea level
  East Pacific Rise –an underwater mountain range at around 2000m depth
  Rift valley of the East Pacific Rise – around 3500m depth.
- Ask what they would expect to happen to the water depth as the ship sails a few hundred kilometres further west. (*The East Pacific Rise is a symmetrical feature, so the water depth will gradually deepen to the west*).
- Ask them to apply the theory of plate tectonics to explain the origin of: a) the Peru/Chile Trench, b) the East Pacific Rise, c) the rift valley along the middle of the East Pacific Rise, d) the seamount. (*a)The Peru/Chile Trench lies above a convergent plate margin where the rocks of the Nazca Plate are pulled down beneath the South American Plate in a subduction zone; b) The East Pacific Rise marks a divergent plate margin, where new plate material is being formed; since this is warmer and so less dense than the surrounding plate, it is at a higher level, due to isostasy; c) The rift valley is caused by tensional forces as the Nazca Plate is pulled away from the Pacific Plate, and the rocks in between are faulted down; d) Seamounts are produced by localised melting of rocks of the oceanic lithosphere above hot spots in the mantle, giving rise to undersea volcanoes (which may sometimes break the surface to appear as islands)].*

Distance/km from Lima	Two-way travel time/sec	Depth/m
0 (in harbour)	0.02	15
100	0.27	
200	1.60	1197
300	10.69	
400	7.06	5299
500	6.66	4998
600	6.64	4977
700	6.60	4949
800	6.54	4907
900	6.52	4900
1000	6.50	
1100	6.49	
1200	6.43	4823
1300	6.43	4823
1400	6.40	4802
1500	6.34	4753
1600	6.29	4718
1700	6.26	
1800	2.67	
1900	6.20	
2000	6.16	4620
2100	6.13	4599
2200	6.07	4550
2300	5.94	4452
2400	5.87	4403
2500	5.60	4200
2600	5.07	3801
2700	4.80	3598
2800	4.27	3199
2900	4.00	3003
3000	3.73	
3100	3.42	2562
3200	2.80	2100
3300	2.67	
3400	4.67	
3500	2.67	
3600	3.33	2499

Distance/time data – pupils should calculate the missing depths.

……

The back up

Title: Sounding the Pacific Ocean.

Subtitle: An echo-sounder traverse across the eastern Pacific.

Topic: A pupil exercise in plotting echo sounder data from a ship's traverse in the eastern Pacific Ocean, followed by relating oceanic depths to plate tectonic theory.

Age range of pupils: 11 -16 years

Time needed to complete activity: 20 minutes or more, depending on the number of calculations pupils are asked to make.

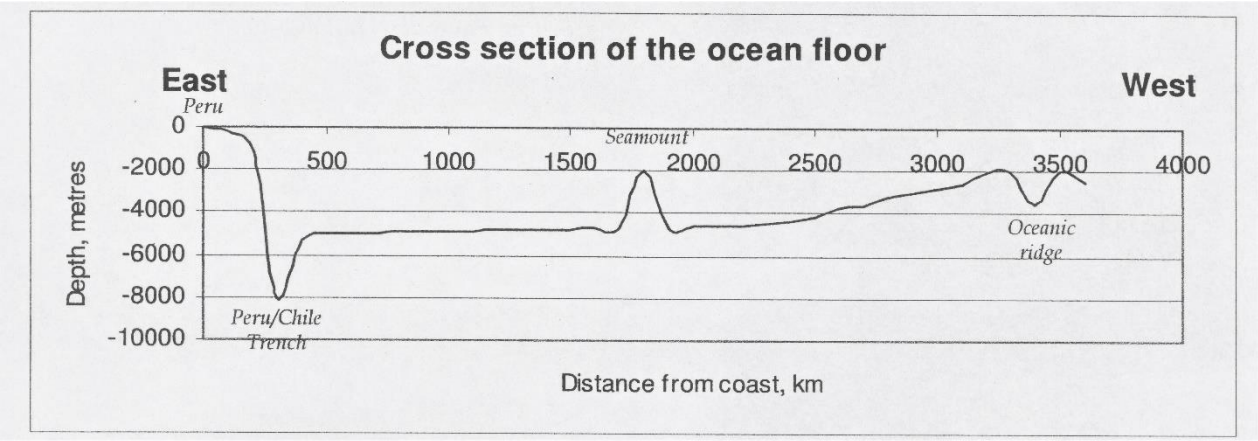
Pupil learning outcomes: Pupils can:

- calculate an oceanic depth from the two-way travel time of an echo sounder beam;
- draw a graph along a depth sounding traverse in the Pacific Ocean;
- describe the characteristics of their depth profile to another pupil verbally;
- relate the depth profile to plate tectonic theory.

Context: This is one of a series of activities involving sounding of ocean floors, and leads on to the relationship between the topographic features and plate tectonic theory. The other activities are shown in the table on page 4.

The Table with all depths calculated is shown below, together with the graph derived from it, i.e. the shape of the ocean floor along the line of the traverse.

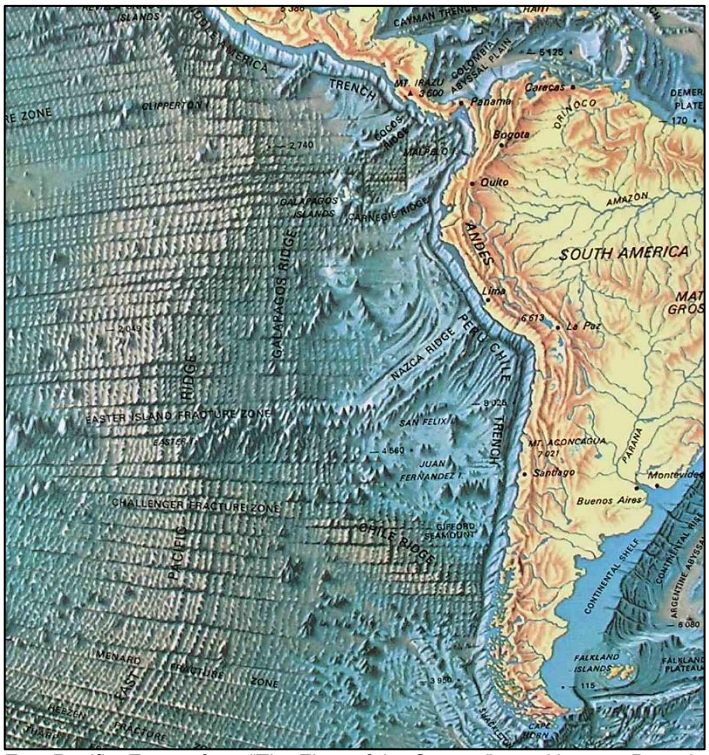
Distance/km from Lima	Two-way travel time/sec	Depth/m
0	0.02	15
100	0.27	203
200	1.60	1197
300	10.69	8001
400	7.06	5299
500	6.66	4998
600	6.64	4977
700	6.60	4949
800	6.54	4907
900	6.52	4900
1000	6.50	4872
1100	6.49	4851
1200	6.43	4823
1300	6.43	4823
1400	6.40	4802
1500	6.34	4753
1600	6.29	4718
1700	6.26	4697
1800	2.67	2002
1900	6.20	4648
2000	6.16	4620
2100	6.13	4599
2200	6.07	4550
2300	5.94	4452
2400	5.87	4403
2500	5.60	4200
2600	5.07	3801
2700	4.80	3598
2800	4.27	3199
2900	4.00	3003
3000	3.73	2800
3100	3.42	2562
3200	2.80	2100
3300	2.67	2002
3400	4.67	3500
3500	2.67	2002
3600	3.33	2499



Following up the activity: The activity may be preceded by the Earthlearningidea activities listed in the table below and followed by https://www.earthlearningidea.com/PDF/334_Top_bottom_plates.pdf

Underlying principles:

- The speed of sound in sea water varies from around 1450 ms^{-1} to around 1570 ms^{-1} depending on salinity, temperature and pressure, but we are using 1500 ms^{-1} for the calculations.
- The features of the sea floor to the west of South America comprise: a very narrow continental shelf; a short steep continental slope and continental rise; a narrow trench (Peru/Chile Trench) with a maximum depth of 8065m; a relatively small abyssal plain; "foothills" leading up to the ridge of the East Pacific Rise, which has a linear rift valley at its centre. Irregular seamounts rise from the deeper water in many places. See the "*answers*" in italics on the pupil sheet.
Note that the East Pacific Rise is called the East pacific Ridge on the map. The distance from South America to the Rose is only about one quarter of the width of the Pacific at this latitude.



The floor of the East Pacific. Extract from "The Floor of the Oceans" map Heezan, B. and Tharp, M. 1980.
(Copyright permission for the use of this map given in a handwritten letter by Marie Tharp)

Thinking skill development: Looking for patterns in the depth data is a construction activity, with possible cognitive conflict arising when unexpected values are calculated. Discussion among the class involves metacognition and relating the data and graph to the Pacific Ocean uses bridging skills.

Resource list:

- personal calculators and graph paper **or**
- access to a computer with spreadsheet function
- a map showing the relief of the ocean floors (e.g. National Geographic, '*The Floor of the Oceans*' map Heezan, B and Tharp, M. 1980; a good modern Atlas)

Source: Adapted by Peter Kennett from "Teaching Science in an Earth Context – Through the lab window to the world: teaching KS3 Physics". Earth Science Education Unit, Keele University, 2005.

Image of The harbour at Callao, Lima, Peru in 2005 (https://commons.wikimedia.org/wiki/File:Callao.jpg The original uploader was Jimohagan at English Wikipedia. - Transferred from en.wikipedia to Commons by Vinhtantran)

The Earthlearningidea ocean floor mapping activities	
Measuring the depths of seas and oceans: How is it done? A simple demonstration of how we measure sea floor depths and relief	https://www.earthlearningidea.com/PDF/350_Sea_floor_mapping1.pdf
Modelling seafloor mapping: How to simulate an echo sounder study of seafloor topography	https://www.earthlearningidea.com/PDF/351_Sea_floor_mapping2.pdf
Sounding the Pacific Ocean: An echo sounder traverse of the eastern Pacific	https://www.earthlearningidea.com/PDF/352_Sea_floor_mapping3.pdf

Marie Tharp: 'The valley will be coming up soon'. Bruce Heezen: 'What valley?' A woman scientist in a man's world – what was it like?	https://www.earthlearningidea.com/PDF/353_Sea_floor_mapping4.pdf