Investigation 2B

Bathymetry in Action

Objectives

Oceanographers apply a variety of methods to investigate the ocean floor's architecture and composition. Some methods are direct, such as casting a line to measure depth or using a crane that excavates and retrieves samples from the ocean floor. Others, such as acoustic instruments, measure water depth by bouncing sound signals off the floor. Radar altimeters mounted on satellites provide vertical measurements essentially everywhere on Earth, enabling scientists to produce a detailed global view of ocean floor features.

In this investigation, we will:

- Describe why mapping bathymetry is important
- Explore the history of measuring bathymetry
- Explain the benefits and drawbacks of each mapping method

Bathymetry

The average depth of the ocean exceeds 3500 m (11,500 ft), which is far deeper than the narrow 200 m (660 ft.) layer that light penetrates. Rather than flat and featureless, as once assumed, the ocean floor is highly dynamic, boasting mountains, valleys, and jagged features such as cliffs, gullies, and trenches.

Bathymetry is the measure of the depth of the ocean floor from mean sea level; the ocean's equivalent of topography. In addition to the curiosity sparked by the invisible ocean realm, understanding bathymetry is crucial for nearly all ocean-related activities, including fishing and navigation. Bathymetry maps are used in disaster risk planning for tropical cyclones, tsunamis, and coastal erosion, and to understand tides and ocean circulation. Accordingly, there is a long history of mapping the seafloor using increasingly sophisticated methods.

Soundings

The first recorded measurements of bathymetry were taken in 1840, soon followed by a U.S. coastal survey to study the Gulf Stream current. These measurements were conducted by dropping a hemp or flax rope with a weight attached over the side of a drifting ship. The length of the rope was recorded when the weight hit the bottom, and the rope was then pulled aboard for the next measurement. These measurements, known as **soundings**, revealed the contours of the U.S. East Coast and sections of the North Atlantic. The HMS *Challenger* expedition used this method to reveal the Mid-Atlantic Ridge and the first hint of the Mariana Trench off the coast of Guam in 1875. This method of measuring depth had significant drawbacks and was often very inaccurate because ocean currents could pull the weight sideways, away from the ship's actual position.

1. Drifting of the weight sideways would lead to depth measurements that appeared _____ than the actual depth.

a. deeper
b. shallower

To reduce the inaccuracies of this method and the time required to collect a single measurement, the piano-wire sounding (or Thomson sounding system), which used the same line and sinker method but a much thinner and more rigid line made the soundings more accurate as they prevented as much drifting and gave a better indication of when the weight hit the bottom. This method also took significantly less time to conduct a single sounding, enabling a much larger number of soundings to be collected.

2. A piano-wire sounding was more effective than the rope and weight sounding because it _____.

   a. used a heavier weight
   b. allowed measurements in deeper water
   c. used a thinner and more rigid line to reduce drifting
   d. was powered by steam engines

3. Overall, piano-wire soundings would most often record _____ distances than a rope and weight sounding. This means that the two types of soundings could not be used together to make an accurate map.

   a. longer
   b. shorter

In the early 1900s, nearly 20,000 soundings had been collected, allowing for a surprisingly accurate, even by today's standards, General Bathymetric Chart of the Oceans (GEBCO) to be published in 1903. **Figure 2B-1** shows the bathymetric map of the North Atlantic with deeper water shown in darker blue and shallower water in lighter blue. The GEBCO program persists to this day, providing the most accurate publicly available bathymetric maps.

Figure 2B-1. The first edition of the GEBCO map of the North Atlantic Ocean, published in 1903, features lines indicating the locations of soundings and shading representing depth. [GEBCO]

4. The lighter blue shading in Figure 2B-1 suggests an area of shallower water oriented from _____ through the North Atlantic.

    a. north to south
    b. east to west

Following the Titanic disaster in 1912, the U.S. Navy invented and deployed an acoustic transducer system that was able to both transmit and receive sound. This enabled ship-to-ship communication and the detection of objects, including the seafloor, underwater. This method, known as echo sounding, was further developed and utilized in submarine warfare during the First World War. Echo sounding was much faster and more accurate, which soon made piano-wire soundings obsolete.

Sonar

A system that uses echo sounding is called a **sonar**, which emits a sound then "listens" for the first echo to return, as shown in **Figure 2B-2**, and calculates the distance time between them. SONAR is short for SOund NAvigation and Ranging.

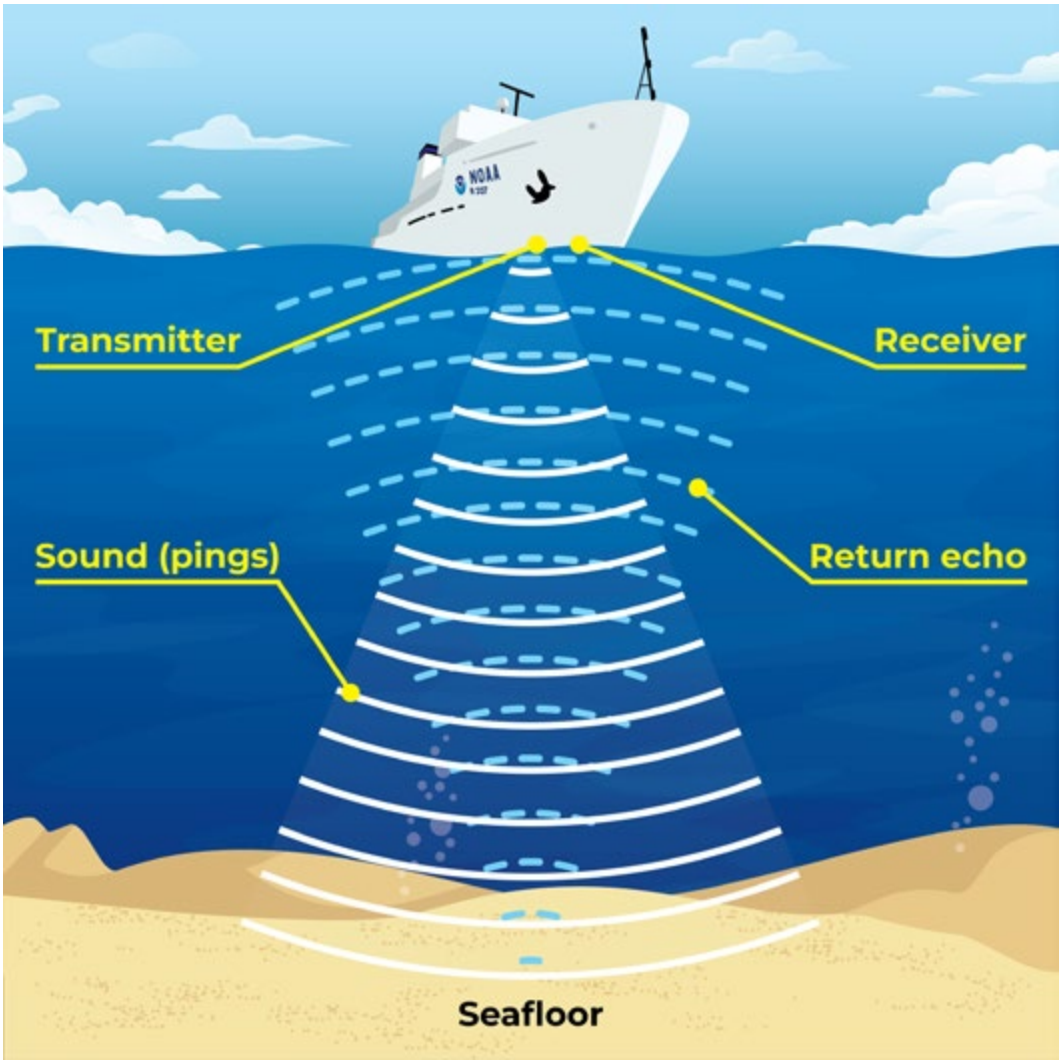

Figure 2B-2. Diagram of a sonar system mapping the seafloor. The transmitter emits sound pulses (pings), which bounce off the seafloor and return as echoes to the receiver allowing for the measurement of the distance to the object. [NOAA]

The system divides the time between transmission and detection in half, as half the time was spent traveling to the object and half on the way back, and multiplies the time by the nearly constant speed of sound in water, approximately 1500 m/s, to calculate the distance to the seafloor.

5. If a sonar emits a ping and receives the echo from the seafloor 2 s later, the seafloor is _____ m away.

    a. 750
    b. 1500
    c. 2500
    d. 5000

6. Single-beam sonar replaced piano-wire soundings because it _____.

    a. didn't require electricity
    b. was faster and more accurate
    c. worked better with ocean currents
    d. was cheaper to operate

Technological advances led to a rapid advance in the knowledge of the seafloor during the 1920s and 1930s, including the U.S.'s continental shelf, the Mid-Atlantic Ridge, trenches, and seamounts. These discoveries were essential for submarine warfare during the Second World War and the following Cold War. Many countries mapped the seafloor during the 1940s and 1950s; however, many of these surveys were classified for national security purposes, and some remain unavailable to the public today. Private oceanographic institutions, including Columbia University's Lamont Geological Observatory, the Woods Hole Oceanographic Institution, and the Scripps Institution of Oceanography, collected bathymetric and other oceanographic information from around the world, providing the basis of the science of oceanography.

Single-beam sonar is an incredibly accurate method for measuring the distance to an object, but it is a very slow way to map the seafloor, as it can only collect one line of data as a ship travels. Also, even if a ship collects data in a tight grid, there are still gaps in the data. Other sonar systems, including multibeam and side scan, were developed during the 1960s and 1970s. Each of these systems had different applications, but both allowed the mapping of a wider swath of the seafloor as shown in **Figure 2B-3**.

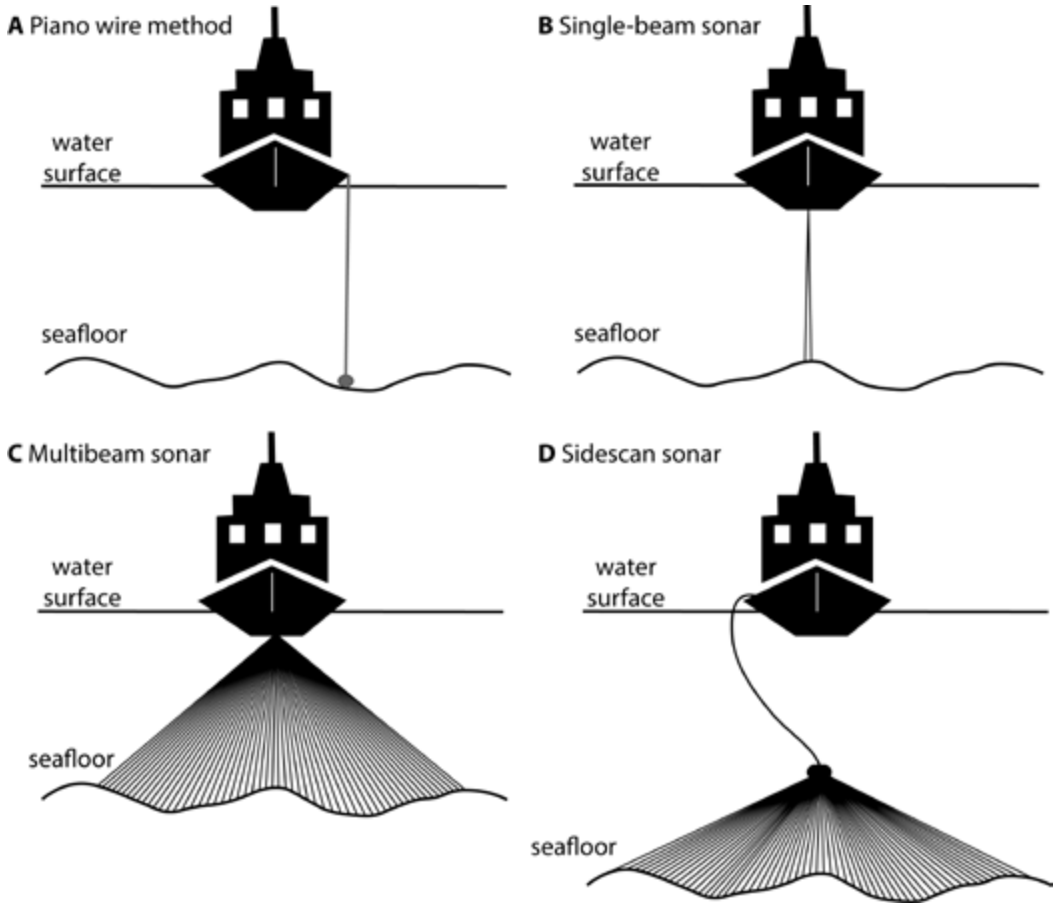

Figure 2B-3. BDiagram of (A) the piano wire method, (B) a single-beam sonar, (C) a multibeam sonar, and (D) a side-scan sonar mapping the seafloor.

7. _____ covers the smallest area of seafloor per measurement.

   a. Single-beam sonar
   b. Multibeam sonar
   c. Side-scan sonar

8. Each sonar system only captures one swath at a time, so vessels must sweep the area in parallel lines. A _____ would require the fewest passes to cover the same amount of seafloor.

   a. piano-wire sounding
   b. single-beam sonar
   c. multibeam sonar

9. *Sidescan sonars* record the strength of the sound that returns to the towed device rather than the time that the sound takes to return, creating a detailed image of the texture of the seafloor. This image can differentiate whether the bottom is solid rock, sediment, reef, or something like metal. This would be most useful when _____.

   a. measuring the exact depth of the seafloor
   b. searching for shipwrecks

c. calculating the speed of ocean currents
d. measuring the salinity of the water

Satellite Radar Altimeters

Despite this improved technology, only 15–20% of ocean basins have been mapped using multibeam sonar, as collecting the data from ships is expensive and time-consuming. However, much of the ocean has been mapped by radar altimeters onboard Earth-orbiting satellites. *Radar altimeters* determine the distance from their orbit to the ocean surface, which mimics the large features of the ocean floor with permanent high and low bulges. Satellite measurements of sea-surface slope are used to compute gravity anomalies, which in turn are used to estimate ocean depths. **Figure 2B-4** shows topography and bathymetry from satellite radar altimetry in the North Atlantic.

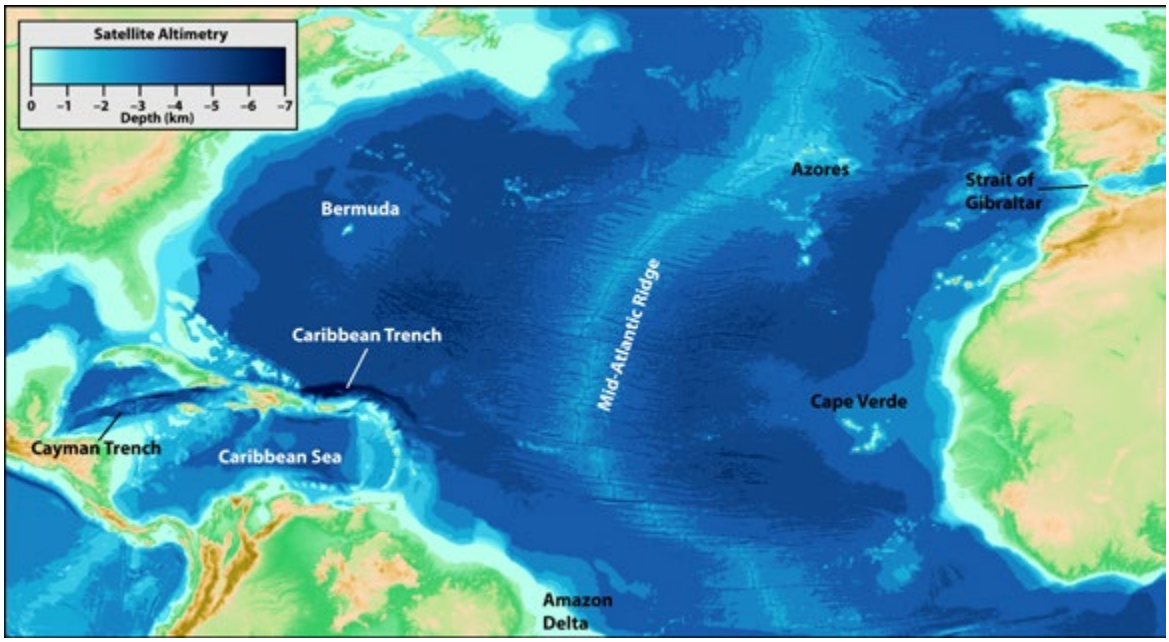

Figure 2B-4. The bathymetry of Earth from satellite measurements. [GEBCO, 2025]

10. Compare the maps in Figure 2B-1 and Figure 2B-4. The map made in 1903 using piano-wire sounding was more accurate _____.

    a. in shallow water near coastlines
    b. in deep water in the northwestern Atlantic

11. The first GEBCO survey and the satellite measurements show that the deepest part of the North Atlantic is _____.

    a. near the Azores
    b. west of the Strait of Gibraltar
    c. in the Amazon Delta
    d. north of the Caribbean Sea

To compare the resolution of satellite altimetry and multibeam sonar, **Figure 2B-5** shows a map of bathymetry directly south of the Cayman Islands in the Caribbean Sea. (For reference, the Cayman

Islands are southwest of Cuba.)

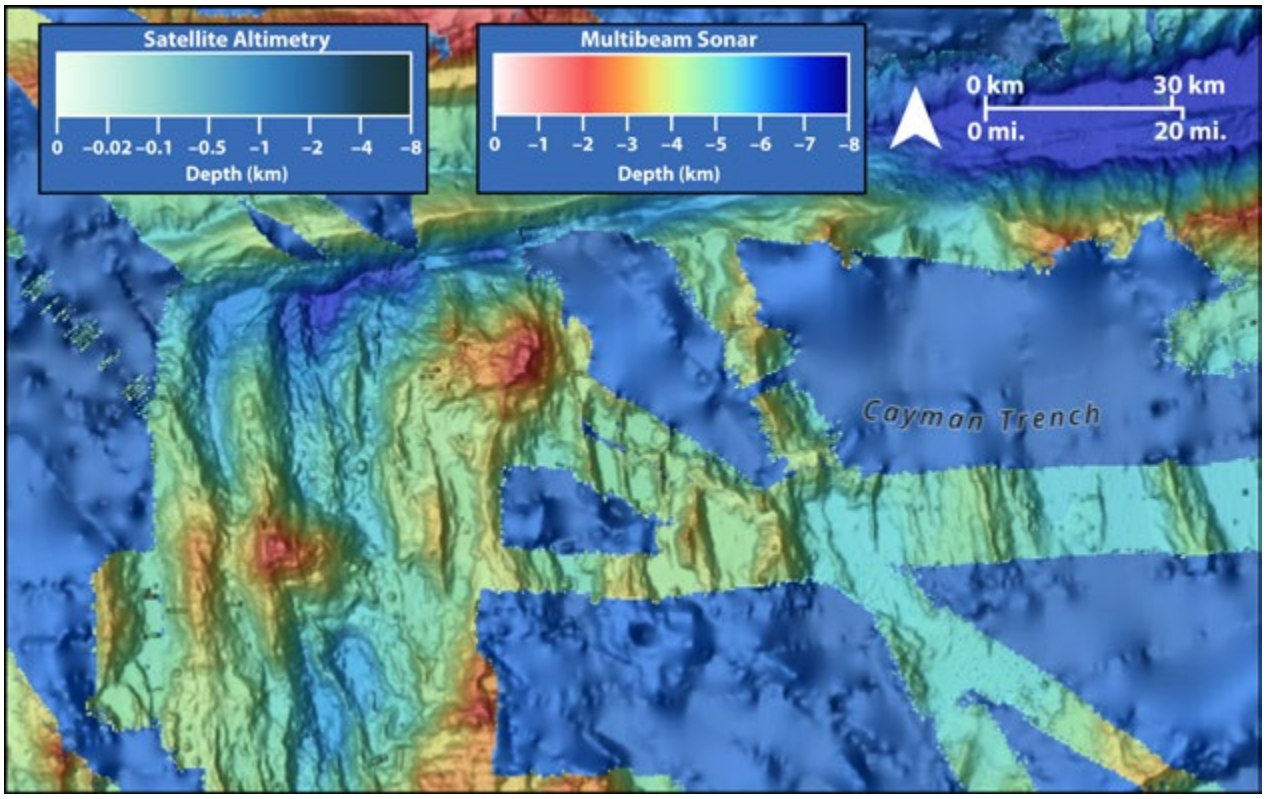

Figure 2B-5. Seafloor bathymetry south of the Cayman Islands with multibeam and GEBCO 2025 radar altimetry data mapped. [NOAA NCEI]

Multibeam data is color-coded from red to green, with red representing the shallowest areas (including peaks of underwater mountains) and green indicating deeper terrain. Bathymetry calculated from satellite data is shown in shades of blue, with lighter blue indicating higher elevation and darker blue indicating lower elevations.

12. In Figure 2B-5, the Caribbean Sea is _____ with a depth range of approximately _____ km.

    a. mountainous ... 4
    b. hilly ... 2
    c. nearly flat ... 1
    c. completely flat ... 0

A map of bathymetry with measurements collected at a higher resolution provides sharper, more accurate depth measurements, allowing you to distinguish between closely spaced objects or features on the seafloor.

13. In Figure 2B-5 multibeam data is shaded from red to green, and satellite radar altimeter data are in shades of blue. The _____ data has a higher resolution, enabling you to see more detail.

    a. multibeam sonar
    b. satellite radar altimetry

Using estimated depths from radar altimetry and more accurate shipboard measurements, NOAA main-

tains a map of ocean bathymetry with a minimum resolution of 1 nautical mile (NM) or 1.852 km.

NOAA is a member of the International Hydrographic Organization (IHO), which promotes the exchange of bathymetric data among nations to fill in the gaps in our knowledge of the seafloor. This project is in accordance with the United Nations Decade of Ocean Science 2030 Agenda and other international initiatives. To supplement official surveys, the IHO is collecting crowdsourced data from all mariners. This data is used to help identify uncharted features and confirm depths in previously charted areas that may have changed since their original surveys in the 1950s. This crowdsourced approach will help fill in the gaps in our knowledge of the seafloor and identify areas that require further study. However, some of this data may not be entirely reliable because it was collected by individuals rather than professional surveyors.

Summary

Ocean bathymetry includes mountain ranges, plains, and trenches. Mapping the seafloor is essential for nearly all ocean-based activities, from navigation to natural disaster forecasting. People have been measuring the depth of the ocean since the late 1800s, when measurements were collected with a rope with a weight on the end. Since then, numerous innovations have been developed to map the seafloor more efficiently and with higher resolution. Even with this technology, only a small fraction of the ocean has been surveyed. Measurements taken from satellites estimate the shape of the seafloor, but this method does not provide the same amount of detail. The international community is sharing information and encouraging all mariners to report bathymetric measurements to map a greater portion of the ocean floor.

References

Figure 2B-1 – GEBCO, 1903: First Edition Sheet A I (N). Accessed 13 August 2025, https://portal.iho.int/iho-wms/gebco/edition_1.html.

Figure 2B-2 – NOAA Ocean Exploration, 2022: Sonar: Seeing with sound. Accessed 23 May 2025, https://oceanexplorer.noaa.gov/edu/materials/sonar-fact-sheet.pdf.

Figure 2B-4 – ESRI, 2025: TopoBathy. Accessed 21 July 2025, https://www.arcgis.com/home/item.html?id=c753e5bfadb54d46b69c3e68922483bc.

Figure 2B-5 – NOAA NCEI, 2025: Bathymetric Data Viewer. Accessed 23 May 2025, https://www.ncei.noaa.gov/maps/bathymetry/.

Dierssen, H. M., and A. Theberge, 2014: Bathymetry: History of Seafloor Mapping. Encyclopedia of Natural Resources. Volume II -- Water and Air. Y. Wang, Ed., CRC Press, 40–48, https://doi.org/10.1201/9780203757611, https://www.researchgate.net/publication/281410339_Bathymetry_History_of_Seafloor_Mapping.

NOAA NCEI, 2022: The power of the crowd. Accessed 23 May 2025, https://www.ncei.noaa.gov/news/power-crowd.

NOAA Ocean Exploration, 2022: Multibeam sonar. Accessed 23 May 2025, https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf.

NOAA Ocean Exploration, 2022: Sonar. Accessed 23 May 2025, https://oceanexplorer.noaa.gov/technology/sonar/sonar.html.

NOAA Ocean Exploration, 2022: Sonar: Seeing with sound. Accessed 23 May 2025, https://oceanexplorer.noaa.gov/edu/materials/sonar-fact-sheet.pdf.