Investigation 3B

Exploration in Action

Objectives

The ocean's average depth exceeds 3500 m (11,500 ft.), which is far deeper than the narrow 200 m (660 ft.) layer where light penetrates. Rather than flat and featureless as once supposed, the ocean floor is highly dynamic, boasting mountains, valleys, and jagged features such as cliffs, gullies, and trenches. Exploring the ocean, especially its deepest parts, is a challenging undertaking because of its complete darkness, immense pressure, and frigid temperatures.

In this investigation, we will:

- Describe the challenges of exploring the deep ocean
- Compare the capabilities and limitations of piloted submersibles, remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs)
- Identify appropriate underwater technologies for specific research scenarios

Exploring the Deep

More than 80% of the ocean remains unexplored, with the deep ocean being especially uncharted. In fact, direct human observation of the deep seafloor has occurred only through submersibles or video footage from remotely operated vehicles (ROVs). Collectively, these efforts are estimated to have visually surveyed less than 0.001% of the seafloor.

1. It is important to note that only a very small percentage of the seafloor has been visually surveyed using submersibles or ROVs because _____.

    a. visual surveys are outdated compared to sonar
    b. direct observation is unnecessary in deep-sea science
    c. there are limitations to current exploration technology
    d. ROVs and submersibles are no longer used for deep-sea research

Although seawater, sediments, and deep-sea organisms can be sampled from research vessels, retrieving them without contamination or alteration is challenging due to the extreme changes in pressure, temperature, and other conditions during ascent. These samples offer valuable insights into the deep ocean's conditions, including its chemistry, composition, and geological history, but some things must be seen firsthand to be fully understood.

2. While temperature decreases down to about 1000 m, _____ continues to increase with depth due to the increasing weight of water.

    a. salinity
    b. pressure
    c. photosynthesis

d. light transmission

The change in pressure with depth is one of the most challenging aspects of ocean exploration. **Pressure** is the weight of the molecules pushing down on a surface due to gravity. The pressure at sea level is approximately 1 atmosphere (atm) and decreases with altitude to approximately 0.2 atm at 1500 m, above which humans need supplementary oxygen. Comparatively, pressure increases by about 1 atm with every 10 m of water depth.

Scuba diving is one of the most accessible ways to gain a first-hand view of the upper ocean. However, due to the rapid rise in pressure, it becomes increasingly difficult with depth. Scuba divers are generally limited to about 50 m deep for extended dives, while brief excursions may reach depths of up to 90 m.

3. At the maximum depth for most extended scuba dives, 50 m. If pressure is 1 atm at the ocean's surface and increases by about 1 atm for every 10 m of water depth the pressure at 50 m is _____ atm.

   a. 2
   b. 5
   c. 10
   d. 100

This increased pressure can cause two dangerous syndromes, decompression sickness (commonly known as the bends) and nitrogen narcosis. Under high pressure, the gases in the air tank, particularly nitrogen, are forced into the diver's bloodstream and tissues. As the diver ascends, the pressure decreases and the gases expand into larger and larger bubbles, which can cause catastrophic damage. To avoid these syndromes, divers must ascend slowly and in stages, allowing the gases to be released more gradually and integrate back into body tissues.

As most of the seafloor lies far beyond the safe limits of scuba diving, alternative exploration methods are required.

4. At the ocean's average depth of 3500 m, the pressure is approximately _____ atm, which is about _____ the average pressure at 50 m deep.

   a. 1 ... one fifth of
   b. 11 ... twice
   c. 151 ... 30 times
   d. 351 ... 60 times

Piloted Submersibles

A piloted submersible, or sub, can be used to observe the ocean's greater depths in person. These subs are necessarily small, carrying no more than 2 or 3 people. Starting as early as 1620, the development of piloted submersibles was difficult and often disastrous. Early subs usually provided only windows and lights to observe the depths, with no way to collect samples or affix their position on the seafloor.

The Mariana Trench, the deepest part of the ocean, was discovered in 1875 by the *HMS Challenger*, a survey ship, when collecting soundings. This discovery was followed in 1951 when the crew of the *HMS Challenger II*, using both soundings and sonar, discovered the Challenger Deep, the deepest part of the Mariana Trench.

In 1960, the *Trieste*, a piloted submersible, reached the bottom of the Challenger Deep, nearly 11,000 m below the surface. **Figure 3B-1** shows a cross-section of the Mariana Trench with the depth in meters, ocean zones, and deep-diving piloted submersibles that are currently active or have reached Challenger Deep.

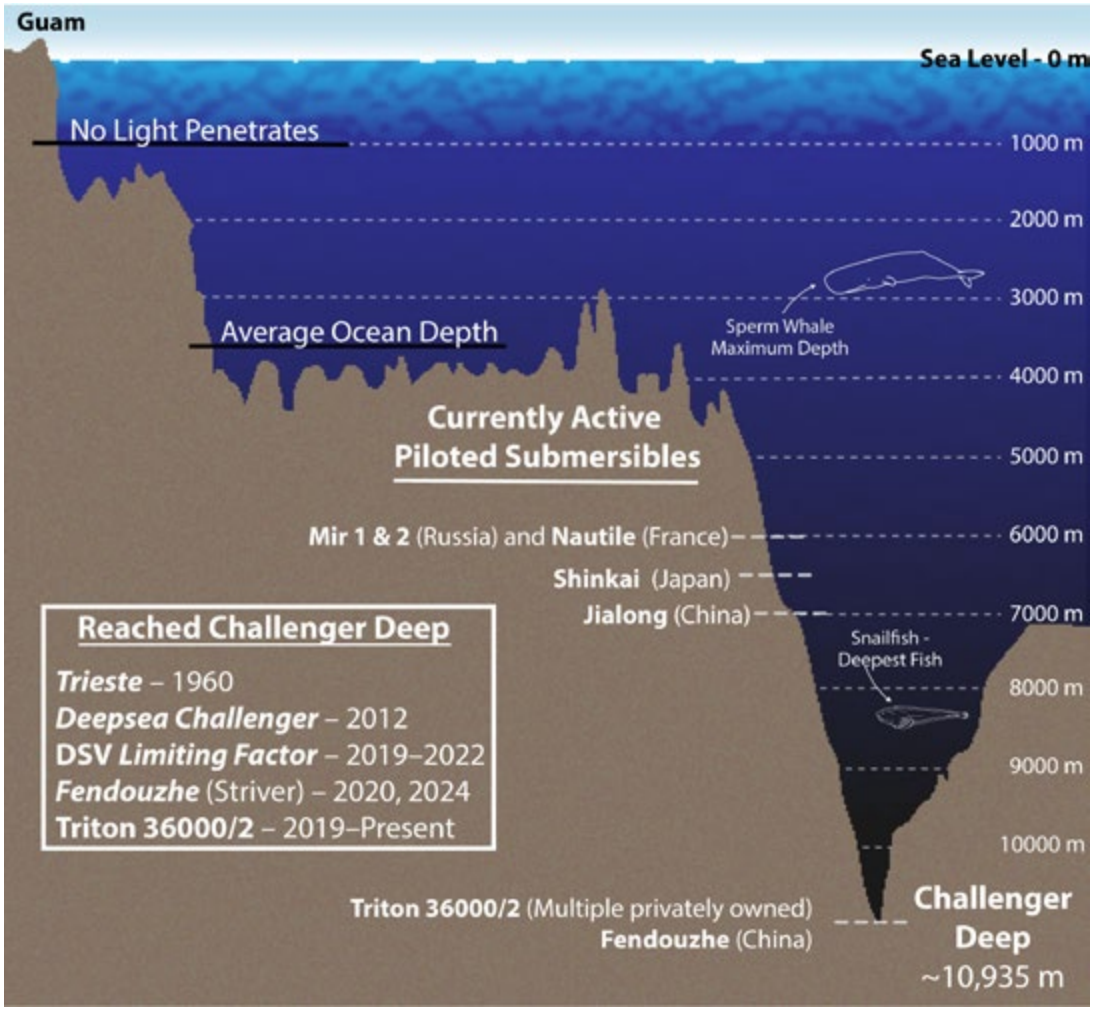

Figure 3B-1. Diagram of the Mariana Trench with depth in meters. The piloted submersibles that have reached Challenger Deep are listed, and the currently active submersibles are listed along the trench at their maximum depth.

5. The main advantage of human-piloted submersibles is the first-hand experience passengers gain, which gives them greater context while collecting data _____.

   a. in situ
   b. remotely

6. After the *Trieste* reached Challenger Deep in 1960, it took _____ years for another piloted submersible to reach the same depth.

   a. 32
   b. 52
   c. 59
   d. 62

The *Trieste* technically had an unlimited diving depth, but it was large and very fragile, transported by towing slowly through the water rather than aboard the ship. Synthetic foam for buoyancy allows modern submersibles to be smaller, lighter, and more durable than earlier designs. However, piloted submersibles are still large and heavy, typically weighing over 11,000 kg (24,000 lbs), primarily because of their life support systems. They are also equipped with high-powered lights, video cameras, robotic arms, and specialized sampling instruments. Due to their significant weight and irregular shapes, these subs must be launched and retrieved using dedicated research vessels with large crews. This makes each dive a major logistical effort and much more expensive than other methods of collecting oceanic samples. In addition to the high cost, piloted subs have a limited crew and a maximum dive time that includes the long descent and ascent.

7. Which advancement has reduced the logistical challenges and high costs of piloted submersible excursions?

    a. Replacing traditional lights with brighter LED systems
    b. Developing lighter materials and more compact life support systems
    c. Increasing the number of people on each dive
    d. Designing larger research vessels to transport submersibles more easily

Human-operated submersibles were once built with one of each model by national oceanographic programs, but in 2019, Triton Submarines began manufacturing standardized models with titanium hulls available for private purchase. Though they often work with national programs, these private owners have explored larger areas of the deep ocean than ever before. These submersibles have been featured on multiple programs, including OceanXplorers and Blue Planet II.

In addition to piloted missions, remotely operated vehicles, controlled by operators at the surface and often tethered to a ship, and autonomous underwater vehicles, with pre-programmed routes, explore the ocean depths.

Underwater Vehicles

Remotely operated vehicles (ROVs) are typically equipped with sampling mechanisms, cameras, and lights, all of which are attached to a frame or sled that is tethered to a ship by a cable. They may be towed by the ship or can move around, propelled by motors on the sled. ROVs are significantly lighter than piloted subs because they do not need to maintain a specific pressure or carry life support systems, allowing them to be deployed from smaller ships. They can also spend a significantly longer time underwater while transmitting high-quality, live video back to the ship through a fiber optic cable. This enables scientists to see the location and make informed, real-time decisions about what to sample and in which direction to move. **Figure 3B-2** shows 2 NOAA ROVs: the *Deep Discoverer* and *Little Hercules*.

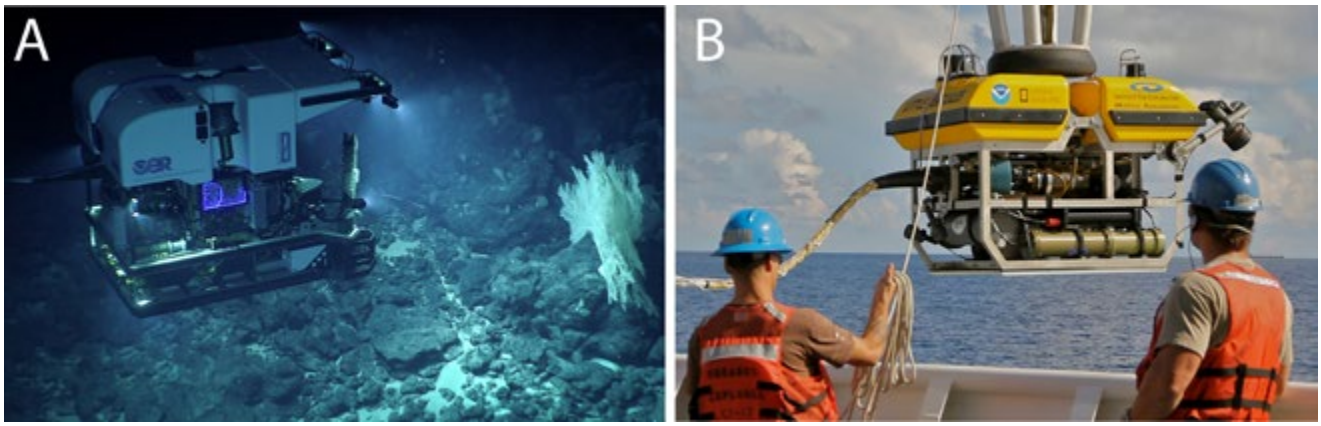

Figure 3B-2. NOAA's AUVs include (A) the *Deep Discoverer*, which views and samples the seafloor and its benthic communities, and (B) the *Little Hercules*, which explored the depths off Hawaii. [NOAA/OER]

8. ROVs may be deployed from smaller ships compared to piloted submersibles because they _____.

    a. do not require any surface crew
    b. are designed for shallow water use only
    c. don't need to support human life
    d. are autonomous and require no equipment on board

Autonomous underwater vehicles (AUVs), like the Argo floats in *Investigation 3A*, follow pre-programmed routes and can access remote or hazardous locations that piloted submersibles and ROVs cannot, such as under ice shelves or deep oceanic trenches. They are efficient for long-term missions and wide-area surveys that follow a pre-determined route.

9. An AUV is most similar to a _____.

    a. car with someone inside driving it
    b. remote-controlled toy car
    c. self-driving vacuum cleaner following a programmed path
    d. drone flown manually using a joystick and a real-time camera

AUVs, such as those shown in **Figure 3B-3**, typically carry an echo sounder, thermometer, conductivity sensor, and cameras, enabling them to collect high-resolution bathymetric data or monitor environmental conditions in the water column. Their small size and quiet operation also reduce disturbance to marine life, making them ideal for ecological research.

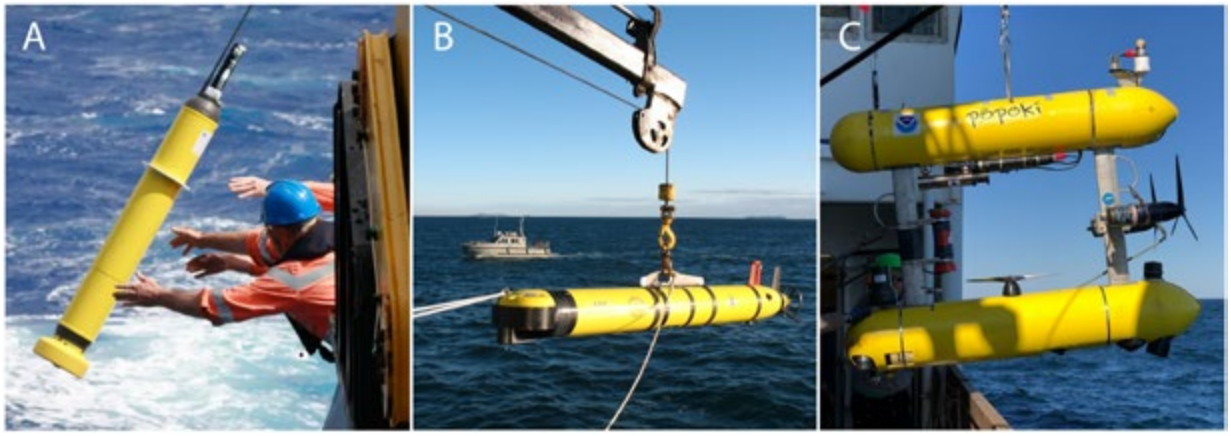

Figure 3B-3. AUVs like (A) ARGO core floats [Alicia Navidad/CSIRO], (B) *ATLAS* [NOAA-OER], and (C) *SeaBED* [NOAA Fisheries] are used to explore and collect continuous data in the water column or on the seabed.

AUVs are designed for specific tasks, with distinct designs tailored to their respective missions. For example, ARGO floats are vertically oriented because they are meant to drift with ocean currents while actively moving up and down in the water column.

10. Torpedo-shaped AUVs like the *ATLAS* are designed to maintain a constant depth using buoyancy control and move _____ in a grid pattern to map the seafloor using sonar.

    a. vertically
    b. horizontally
    c. as directed from a ship

The *SeaBED* AUV has a specialized design for photographing benthic habitats and the seafloor at regular intervals. To ensure it stays upright while capturing images, it features a bottom hull that sinks and a top hull that floats, creating a stable platform for the camera.

Despite these benefits, AUVs have several limitations. Once deployed, they cannot be guided in real time, which makes it difficult to use them to respond to unexpected discoveries or adjust their path without retrieval and reprogramming. Navigation is another challenge, as they cannot use GPS underwater, which can lead to positional drift. Underwater communication is limited, so data is typically only accessible after recovery or when they surface and can transmit data to satellites. Additionally, AUVs are constrained by battery life, which limits their operating time and the number of sensors and additional equipment.

11. A large group of geologists and chemists is investigating the mineral composition and microbial life around deep-sea hydrothermal vents and needs to collect precise samples of water and rock while observing the scene live. They would most likely use a(n) _____.

    a. piloted submersible
    b. ROV
    c. AUV

12. A government agency is conducting a large-scale survey of an oceanic trench to classify benthic habitats and create a high-resolution bathymetric map. They would most likely use a(n) _____.

a. piloted submersible
b. ROV
c. AUV

13. A small team of marine biologists wants to directly observe how reef organisms living at depths of 1000 m interact with their environment in real time. They want to observe the nuances of behaviors and relationships and select their samples based on their observations. They would most likely use a(n) _____.

a. piloted submersible
b. ROV
c. AUV

Unmanned underwater vehicles, such as ROVs and AUVs, have become essential tools for exploring and understanding the ocean, providing access to areas that are too deep, hazardous, or remote for humans. By expanding our ability to collect data efficiently and safely, these technologies continue to transform marine science and ocean engineering.

Summary

Exploring the deep ocean requires advanced technology to overcome extreme conditions, including darkness, high pressure, and freezing temperatures. Three types of vehicles are available to explore the ocean's depths, each offering unique advantages and disadvantages. Piloted submersibles enable direct observation, while ROVs facilitate precise sampling with real-time control, and AUVs are best suited for large-scale, autonomous surveys. Each of these technologies has expanded our ability to study deep-sea habitats, map the seafloor, and gather environmental data.

References

Figure 3B-2A – NOAA Ocean Exploration, 2017: Remotely operated vehicle Deep Discoverer. Accessed 30 July 2025, https://oceanexplorer.noaa.gov/technology/subs/deep-discoverer/deep-discoverer.html.

Figure 3B-2B – Lovalvo, D, 2011: Little Hercules remotely operated vehicle. NOAA Ocean Exploration, accessed 30 July 2025, https://oceanexplorer.noaa.gov/wp-content/uploads/2025/04/exploration-vehicle-summary-sheets.

Figure 3B-3A – Mkitarian, J., 2024: Celebrating 25 years of Argo, the 'crown jewel' of ocean observing systems. NOAA, accessed 30 July 2025, https://globalocean.noaa.gov/celebrating-25-years-of-argo-the-crown-jewel-of-ocean-observing-systems/.

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Figure 3B-3C – NOAA Fisheries, 2022: Using an autonomous underwater vehicle to survey West Coast habitat and fish. Accessed 30 July 2025, https://www.fisheries.noaa.gov/west-coast/science-data/using-autonomous-underwater-vehicle-survey-west-coast-habitat-and-fish.