LESSON 11

SEEING IN THE DARK

A Sound Approach to Exploration

by W.H. Berger and E.N. Shor

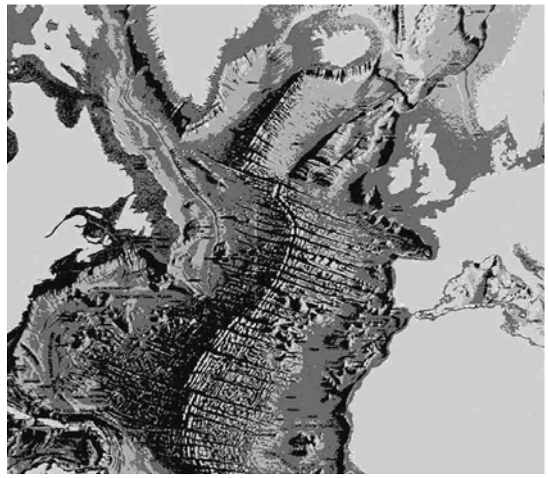


Fig. 11.01. Topography of the deep seafloor in the North Atlantic, as envisioned by Marie Tharp and Bruce Heezen, based on echo-sounder profiles.

Sensing sound in the sea is a strategy for survival that is geologically ancient, going back to the time when fish evolved a lateral-line system for detecting pressure waves, several hundred million years ago. The most ancient of marine mammals, the toothed whales, have lived by their skills as echo hunters for millions of years. Within the last 25 million years, they have perfected their echo system to an astonishing degree, including the growth of ever-larger brains, to process acoustic information.

The science of sound in the sea started with echo sounding for icebergs early in the 20th century. By the middle of the century, marine geologists were collecting information about the topography of the seafloor at a rapid rate, resulting in a new appreciation for the diversity of major subsea landforms, including enormous mountain chains, vast abyssal plains, and continent-size rolling-hill provinces (Fig. 11.01). In the process, they stumbled on the "deep scattering layer," acoustic evidence of daily migrations in a diverse fauna living below the surface waters, a phenomenon of fundamental interest in the biology of the ocean. After the 1950s, interest in biological sounds and their meaning greatly increased, in response both to the need of the Navy to become familiar with the acoustic environment in the sea and to the desire of marine biologists to understand the role of sound transmission in the life histories of a host of organisms, mainly mammals and fishes (Fig. 11.02).

Also in the 1950s, geophysicists were using powerful sound sources including dynamite explosions to gather echoes from sediments and rocks deep below the ocean bottom, to ascertain the nature of the oceanic crust that forms the ocean basins. As the exploration for new oil fields went farther offshore, into regions on the shelf and continental slope likely to hold hydrocarbons, this type of surveying became routine, using sudden release of compressed air for a sound source and listening for the echoes from the bottom and below with a towed array of microphones. Since the 1970s, concern has been expressed that this type of noise, or any other type of loud noise, may injure or otherwise harm marine deep-diving mammals. The U.S. Marine Mammal Protection Act (1972) makes it mandatory to consider such concerns. Thus, much research has been done since on the actual and possible impacts of human-generated sound in the sea on marine mammals. Such research has further expanded our understanding of the sound-filled ocean, in the last 30 years or so (1).

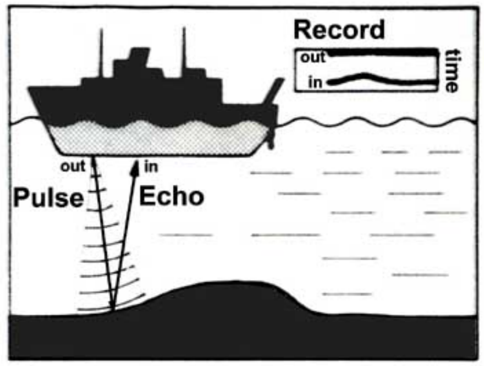
Fig. 11.02. Hearing aids: North Atlantic cod with their prominent lateral-line system.

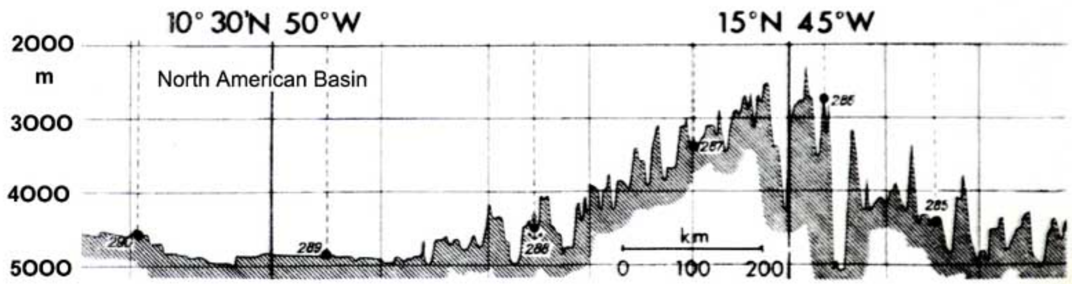
Notes and references

1. A recent survey of findings of acoustic research relevant to the Marine Mammal Protection Act is in W.J. Richardson, C.R. Greene, C.I. Malme, D.H. Thomson, 1995. *Marine mammals and noise,* Academic Press, San Diego, 576pp. The U.S. Office of Naval Research provided funds toward completion of this review.

Images

Fig. 11.03. Discovery of the ruggedness of the Mid-Atlantic Ridge, by the *Meteor* Expedition, 1925-1927.
Upper: Principle of echo sounding.
Lower: Topographic profile and stations reported.





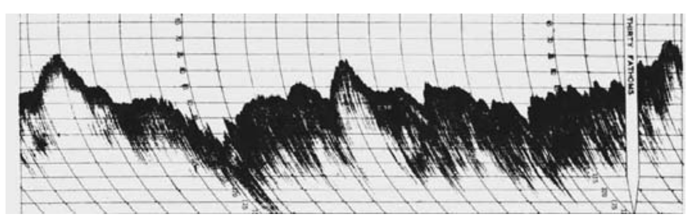


Fig. 11.04. An echo signal from the seafloor, obtained in the 1930s, by a U.S. vessel using an early type of echo recorder.

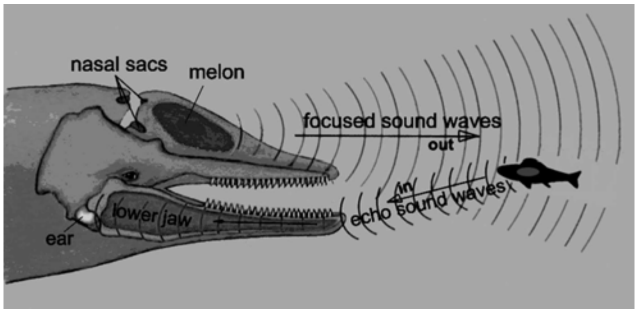


Fig. 11.05. Echo hunting in dolphins. The sound is made in the nose (nasal sacs), and is emitted through the melon, which acts as an acoustic searchlight. The echo returning from the target is guided to the ear through the lower jaw. Swim-bladders make a strong echo; thus a dolphin can readily distinguish schools of fish from aggregations of squid.

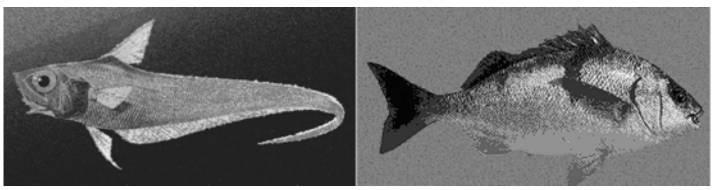


Fig. 11.06. Noisy fishes: a rattail “drummer” (*Macrurus*) and a “croaker” (*Sargo*).

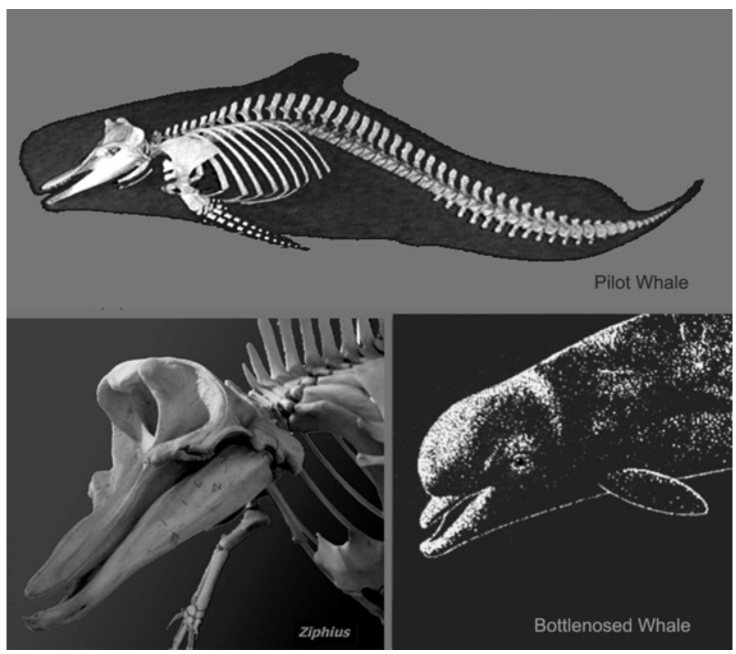


Fig. 11.07. The strongly modified skull of the pilot whale (upper panel) and of the bottlenose whale (lower panel) accommodates a large melon, for the focusing of sound in echo hunting.

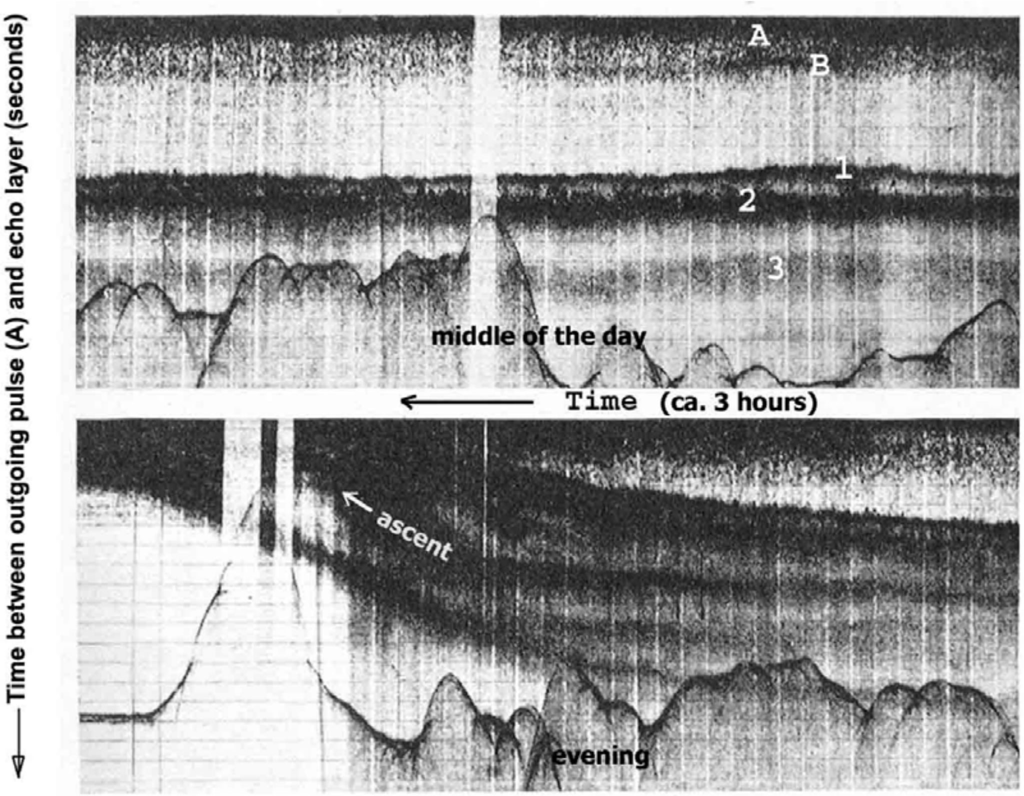


Fig. 11.08. Output from the echo recorder on an SIO vessel, as reported by Robert Dietz, in 1962. The fuzzy heavy traces are echoes from the deep scattering layer. The sharp record at the bottom is the echo trace from the seafloor. This deeper record is on a different listening cycle, for which the instrument waits several seconds before recording. A, outgoing pulse; B, scattering organisms near the bottom of the warm-water layer; 1-3, different groups of deep scattering organisms. The depth is roughly 1000 feet for Echo 2.

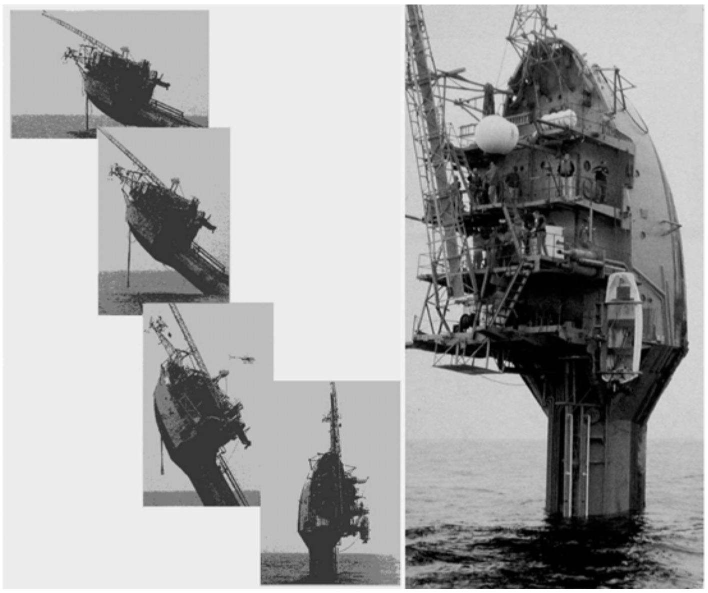


Fig. 11.09. The towed instrument platform FLIP in upright position, and ready to work.

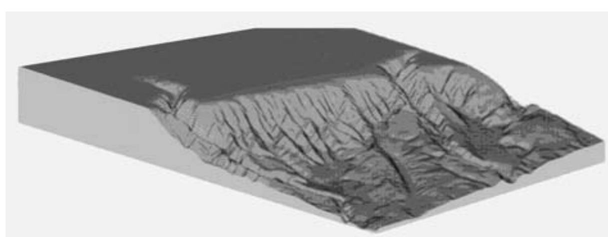


Fig. 11.10. Submarine canyons off the East Coast (Virginia), in a 3-dimensional NOAA map based on echo soundings.

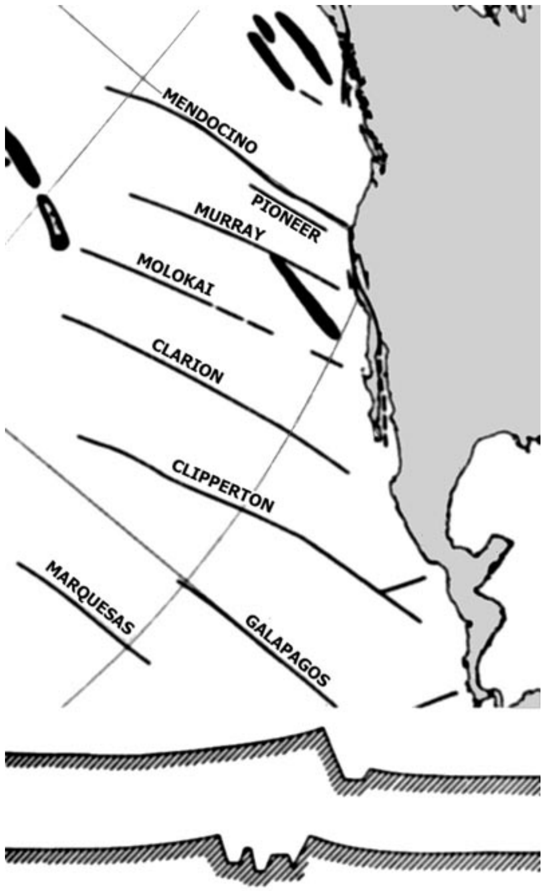


Fig. 11.11. Menard's great "fracture zones" of the northeastern Pacific, as published in 1964. The features were discovered by echo sounding. Their explanation (in 1967) marks the beginning of "plate tectonics."

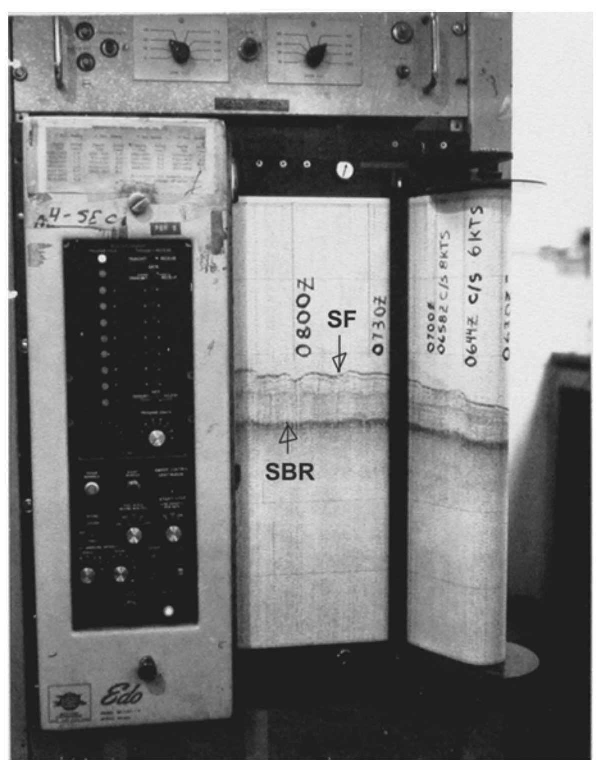


Fig. 11.12. Looking below the seafloor (SF), with an echo sounding system in use on a Scripps ship in the 1970s. The scientist standing watch has marked the times on the record ("Z" stands for "Zulu" or Greenwich time), along with the speed in places (c/s, change speed). The record is burnt onto special paper. Depth of penetration to the strong sub-bottom reflector (SBR) is about 500 m below SF.

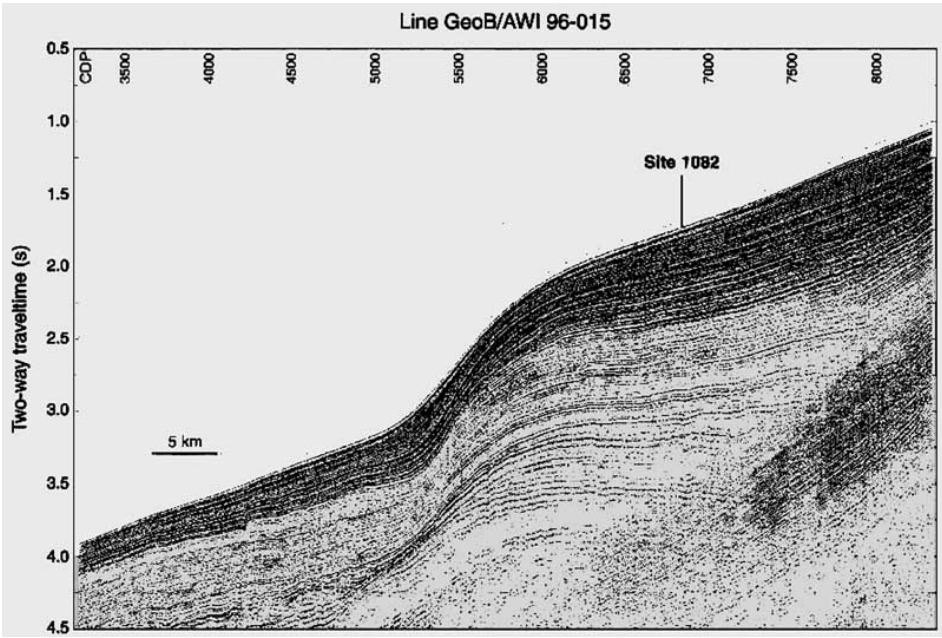


Fig. 11.13. Sediment layers on the continental slope off southwestern Africa, obtained in preparation for drilling Site 1082 of the Ocean Drilling Program, using a sound source of intermediate strength and frequency. (GeoB, Geo Bremen; AWI, Alfred-Wegener-Institut.)

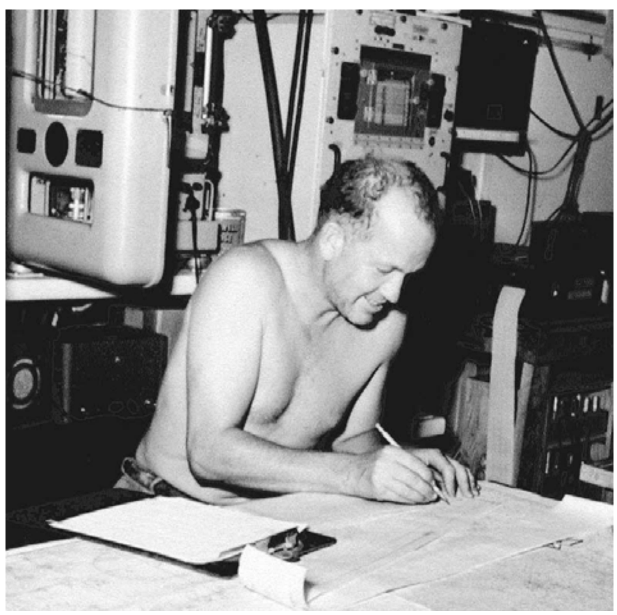


Fig. 11.14. Geophysicist Russ Raitt at sea, collecting data on the nature of the ocean bottom in the central Pacific. Capricorn Expedition, 1952-1953.

Fig. 11.15. Gathering data on temperature and thermocline depth, using a bathythermograph. MidPac Expedition, 1950.

Figure sources (where based on sources in the literature, on the web or in museum exhibits: figures are considerably modified and adapted for present purposes, using Adobe Photoshop; drawings and photographs by the author are marked "orig."):
1, Heezen and Tharp 1956; 2, Bergen Aquarium (orig.); 3, Seibold and Berger 1996; 4, NOAA Historical Collections; 5, Aquarium of the Pacific, Long Beach (orig.); 6, Russell and Yonge 1936 (see Ch. 6 for reference), and California Department of Fish and Game; 7, Zoological Institute and Museum Hamburg (orig.), San Diego Nat. Hist. Museum (orig.), and R. Ellis 1997 (bottlenose whale, lower right); 8, Dietz 1962; 9, SIO archives; 10, NOAA; 11, Menard 1964; 12, orig.; 13, Spiess 1996; 14, SIO archives; 15, SIO archives. **References:** Painting by H.C. Berann (Nat. Geogr. Soc.) based on studies of B.C. Heezen and M. Tharp, cited in E. Seibold and W.H. Berger, 1996. *The Sea Floor, An Introduction to Marine Geology*, 3rd Edition. Springer Verlag, Heidelberg; National Oceanic and Atmospheric Administration, U.S. Department of Commerce; R. Ellis, 1997, see Ch. 10 for reference; R.S. Dietz ,1962, *The sea's deep scattering layers*, Scientific American 207 (2) 44-50; H.W. Menard, 1964. *Marine Geology of the Pacific*. McGraw-Hill, New York, 271pp., V. Spiess, *Meteor* Expedition in prepration of ODP Leg 175 (G. Wefer, W.H. Berger, C. Richter, and Scientific Shipboard Party, 1998. Proceedings of the Ocean Drilling Program, Init. Rpts., Vol. 175, College Station, Texas).