

Propagation of Sound in the Ocean

J. Lamar Worzel, C. L. Pekeris and Maurice Ewing
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This is the Acoustical Society of America's reprinting, in 2000, of "The Geological Society of America Memoir 27" which was originally published by that society in 1948 and then reprinted in 1963. The original publication is a collection of three papers considered to be classic in the understanding of underwater acoustics. ASA's reprinting appends six additional articles.

The many oscillograph and journal article reproductions throughout the book are very difficult to read, chiefly due to scanning at too low resolution and the reduction of the appended journal articles to fit the 5×7 print format. For researchers needing more detail, the 1963 reprinting can still be found, with its collotype plate printing allowing one to clearly read the oscillographs right down to the operator's scribbled notes.

1 THE ORIGINAL THREE PAPERS

The original three papers are summary reports of previously secret classified collaborative work between Woods Hole Oceanographic Institute geophysics professor Maurice Ewing, his former student Joe Worzel and Columbia University professor Chaim Pekeris.

2 EXPLOSION SOUNDS IN SHALLOW WATER — WORZEL AND EWING

A particularly effective weapon used during WWII was the acoustic mine. These mines typically were laid on the bottom in shallow water to intercept convoy routes. Each mine was equipped with a hydrophone and circuitry which measured the broadband noise level. The mine was set to explode when the noise level reached a level which corresponded to that of a large ship. Many ships along the US eastern seaboard were being damaged or sunk by this type of mine, so in the winter of 1943, Worzel and Ewing's team were directed to collect the shallow water acoustic transmission data needed to design effective countermeasures.

Anyone who has participated in collecting acoustic data at sea will immediately appreciate the Spartan conditions of this first shallow water expedition: most of the recordings were made on an 8 pen oscillograph; their vessel was the USS Saluda IX 87 (an 88 ft. sailing yacht); and their 125 ft. target ship USCGC Rush II also served as their anti-sub escort. I was pleased to find that the Saluda is still sailing as the Sea Scout's SSS Odyssey (visit the ship on their website www.sssodyssey.org).

The field tests comprised dropping explosive charges from the Rush as it moved away from the Saluda. Saluda

recorded the received signals through two different hydrophones and a geophone placed on the bottom. Tests were performed at various locations to determine the effect of different sea beds. As with any test, problems came up and solutions had to be pieced together from what was readily available. The resulting graphs and charts are honestly documented with notes such as "wrong gain" and it is amusing to read between the lines of their description of having to kludge together a hydrophone calibrator from a variable air capacitor which was "varied approximately sinusoidally".

Worzel and Ewing's work was important in showing that low frequency propagation in shallow water is conducted through the ocean floor layers and for discovering the "Ewing effect" which causes frequency dispersion of sound in shallow water.

3 THEORY OF PROPAGATION OF EXPLOSIVE SOUNDS IN SHALLOW WATER — PEKERIS

Worzel and Ewing collaborated extensively with Pekeris to work out empirical equations to fit their data which could then be quickly used in countermeasure operations to determine maximum acoustic ranges. They converted all of their data to apply to standard 25 pound TNT charges then used by sub-chasers. The resulting equations were able to predict ranges in most, but not all, of the shallow water conditions they had recorded.

Shallow water acoustics was (and still is) a complicated system to mathematically model. It was even more difficult in the 1940's when solutions needed to be closed form and highly simplified for slide rule calculations. Pekeris' paper reviews Worzel and Ewing's data (actually doing a much better job of it than in the first paper) and develops a normal mode theory of shallow water sound propagation which accurately predicts the "Ewing effect". I found it an interesting sign of the times that Pekeris invokes quantum theory as a possible solution to a particular acoustic phenomenon.

Collaboration worked both directions. Checking his resulting model with the data, Pekeris discovered one outlier and called Ewing to see if it had been written down wrong. Both decided that the water depth in that dataset should have been 53 ft. instead of 25 ft. and this change made the outlier fall in line with the theory.

4 LONG RANGE SOUND TRANSMISSION — EWING AND WORZEL

The last of the original three papers is an investigation to confirm the existence of the deep sound channel. This is a low loss channel located at the depth of minimum sound velocity in which sound may travel very long distances with little loss in energy. Once established, this

phenomenon was exploited during the war as the SOFAR method of locating and rescuing downed pilots. The pilot would release a small explosive which would explode at depth. The distinctive sound would travel thousands of miles to several shore stations which could then triangulate the pilot's position and direct rescuers to the crash site.

Although they did not identify it at the time, the hand drawn ray diagram (Figure 5) included in this paper shows a convergence zone, the effect which causes long range sound rays to converge at or near the surface approximately every 30 miles from the source.

5 THE SIX APPENDED PAPERS

The six papers appended to this edition include an analysis of shadow zone formation, a quick derivation of acoustic scattering equations, the discovery of SOFAR transmitted sound from earthquakes showing up on seis-

mograms and its possible association with tsunamis, and the extension of both normal mode, and ray theories of shallow water acoustic propagation to multiple layers to allow for more realistic modeling of the surface, bottom and water column.

Although the printing lacks great detail and there is no editor's comment on the selection process and significance of the appended papers, future progress in any technical field stands on the shoulders of giants in the past and, on that basis alone, I recommend this republished collection.

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