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The

USE OF BOTTOM SEDIMENT CHARTS

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WATER

DEEP

WATER

SHALLOW

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Introduction

Over the continental shelf the acoustical qualities of the bottom frequently play an important part in underwater sound transmission. This is especially true when downward refraction prevails, as when the temperature decreases with depth. Under such conditions a sound beam is bent down to the bottom a short distance from the source, and if no reflection of sound from the bottom were possible the maximum range of detection would be small. If the bottom is an efficient reflector, as is the case with a smooth, SAND, bottom, and if also the bottom is not too deep (roughly 100 fathoms or less) the range at which a signal can be detected may be greatly increased. A soft, MUD, bottom absorbs sound, and over such a bottom the range will not be increased by bottom-reflected sound. With very rough and especially ROCK bottoms, strong reverberation may sometimes make echo-ranging very difficult. A brief summary of the probable acoustical effects of various types of bottom is given in the Key below

THE EFFECT WHICH DIFFERENT TYPES OF BOTTOM HAVE ON ECHO RANGING AND LISTENING

I. With Downward Refraction

Type of Bottom	Probable Acoustic Effects of Bottom
SAND Firm, relatively smooth bottom, shells and washed gravel included.	Long extension of range commonly obtained.
MUD AND SAND Relatively firm, smooth bottom.	Moderate to poor extension of range.
MUD Soft, smooth bottom.	Sound commonly absorbed and little extension possible.
ROCK Rough broken bottom, includes bedrock outcrops and areas covered by boulders.	Strong reverberation tends to mask echoes. Extension of range unlikely with either echo ranging or listening.
STONY Hard bottom, commonly rough. Predominantly cobbles and pebbles. Varying amounts of sand and mud commonly present.	Extension variable depending on local conditions. Reverberations may be strong.
CORAL Hard bottom with sandy patches irregular to smooth. Includes various marine forms which secrete masses of lime covering the bottom.	Extension variable depending on local conditions. Reverberations may be strong. Noise level may be high due to presence of noise making animals living on the coral.

II. With Upward Refraction

Under these conditions, maximum ranges are usually long, and not dependent on the type of bottom. Over ROCK bottoms, however, strong reverberations may be encountered.

Refraction of Sound

Maximum ranges are usually limited by the refraction of sound produced by variations of temperature and pressure with depth. In an isothermal wind-stirred layer the sound rays curve gradually upwards. Where the temperature decreases with depth the rays curve downward.

The accompanying diagrams indicate the refraction pattern under varying temperature conditions for a sound source at a depth of 15 feet. The sound source can be either the projector of echo-ranging equipment or the high frequency component of ship noises as in listening. The temperature decrease between the surface and 300 feet is assumed to be 10°F and the change of temperature with depth is indicated to the left of each diagram. The depth scale is greatly amplified but the angle at which each ray leaves the source is indicated. The spread of the sound beam is taken to be 12°; the wider angle rays do not achieve a significant horizontal distance. Since each ray is reversible, the echo from a target in the sound beam returns to the projector along the same path by which the sound reaches the target.

Figures 1, 2, 3 and 4, which are for deep water, show the change of the sound beam when the depth of the isothermal layer is continually decreased and demonstrate the transition between GOOD and VERY BAD echo-ranging or listening conditions. The shading denotes the zone from which no echoes can be returned unless the sound is reflected from the sea surface. Note that in no case will the shadow zone be extended or diminished by the roll of the ship.

Reflection of Sound

When a sound beam hits a large area of the bottom, the sound is partly absorbed, partly reflected, and partly scattered. The scattered sound goes out in all directions; some of it goes back to the echo-ranging gear and produces reverberation. The reflected sound behaves like light reflected from a mirror; it is this reflected sound which makes extended ranges possible when the refraction is downward.

Figures 5, 6, 7 and 8 show the reflection of sound from a flat bottom. The paths of the reflected rays are shown by dotted lines. The shading indicates the region into which the sound reflected only once from the bottom cannot usually penetrate. It is evident from these figures that when the bottom is an efficient reflector, echo ranges can be at least doubled, and listening conditions may also be improved accordingly. In fact, under many conditions bottom reflected sound may improve listening ranges even more than echo ranges.

It is fairly certain that SAND bottoms do not absorb very much sound, and either reflect or scatter a considerable fraction of the sound which falls upon them. The ratio of scattering to reflection is not known, and may vary widely for dif-

ferent types of SAND bottom. SAND bottoms are the best reflectors known, however, and over such bottoms extended ranges may frequently be expected.

MUD bottoms are known to reflect less sound than SAND bottoms. When the mud is very soft, as near the mouth of a river, very little sound is reflected and no extension of range may be expected. Firmer muds may in some circumstances reflect enough sound to extend maximum listening or echo ranges somewhat; such extension of range is thought to be much less frequent over MUD bottoms, however than over SAND bottoms. Similarly, the reverberation found over a MUD bottom will usually be less intense and, when the refraction is downward, also of shorter duration, than over a SAND bottom.

The properties of MUD AND SAND bottoms should be intermediate between SAND and MUD bottoms although the information is lacking in this respect.

Although STONY, CORAL, and ROCK bottoms do not absorb much sound, they are likely to show such irregularities that most of the sound is scattered, producing strong reverberation with little extension of range. Of these three types STONY is likely to be the most regular and the best reflector. Occasional CORAL reefs will produce high reverberation, although the CORAL sand in between the reefs is a good reflector, as evidenced in the extended ranges obtained in the Key West area. ROCK bottoms give probably the highest reverberations, and in some cases the numerous false echoes obtained over a ROCK area may make submarine detection very difficult.

Research on these problems is now in progress. When further information becomes available, it should be possible to specify more exactly the probable acoustic effects to be expected in different areas.

Background Noises

Crackling background noises resulting from the activities of snapping shrimps have been shown to be prevalent over rocky, coral or shell bottoms which offer suitable habitats for these animals in tropical and subtropical waters of less than 30-40 fathoms in depth.

Intensity

The intensity of the sound in all parts of the direct beam is by no means the same. In the absence of refraction it would diminish in proportion to the inverse square of the distance from the source. But because of refraction the energy in some parts of the direct beam has all come from a very small angle at the source. Compare, for example, the spacing of the sound rays in Figures 1 and 4. In Figure 1 at ranges between 2000 and 3000 yards and at depths below 120 feet all the energy has come from an angle of $.4^{\circ}$ at the source. In echo ranging, unless a very carefully tuned receiver is used and the background noise level is low, an echo from a target in this zone might not be detected. Certainly the bottom reflected energy from the outer part of this interval would be too weak to return an echo. However, in listening this weak part of the beam might be used.

In a general way, the spreading of the sound rays in the diagrams provides a rough measure of intensity. It will be noticed that under conditions of strong downward refraction (as in Figure 8) most of the energy from the source is concentrated over a relatively short distance on the bottom. It is believed that under such circumstances the effectiveness of bottom reflections in increasing the range is usually considerably increased; in such a case even a MUD AND SAND bottom may be likely to produce at least one "bounce."

Low Frequency Sound

Sound in the audible frequencies is refracted and reflected in the same way as supersonic sound, although the reflecting power of different sediments at low frequencies has not been accurately determined. With low frequency sound, however, the boundaries of the shadow zones will be much less sharp owing to diffraction. It is not known how effective diffracted sound is in increasing listening ranges.

Although for audible frequencies, the data are even less complete than for supersonic frequencies, it may be assumed that over a SAND bottom the listening conditions may possibly be good even when several surface and bottom reflections are required.

The Bathythermograph

This is an instrument for measuring the vertical temperature gradients from a vessel proceeding at speeds up to 15 or 20 knots. From such an observation the refraction pattern and the "Assured Range" of echo-ranging equipment can be determined. Obviously the usefulness of sedimentary charts in sub-

marine detection is greatly increased when the refraction pattern is known. Near the coast during the summer months downward refraction generally prevails; in such regions, sediment charts indicate in which areas echo ranging and listening may possibly be improved by bottom reflections. Whenever possible, however, the sediment charts should be used in conjunction with a bathythermograph.

Other Uses of Sediment Charts

As has been briefly explained, sediment charts, especially when used in conjunction with a bathythermograph, allow a qualitative prediction of the range at which a submarine can be detected in shallow water. In addition the charts may be useful in the following ways:

1. ROCK areas are shown in which one may expect strong reverberations, which at times can be mistaken for echoes from a submarine.
2. In so far as mine laying operations are concerned with the type of bottom, these charts are of interest in this context also, for they show the sediments in a more reliable manner than do the navigation charts.
3. In the same way sediment charts may be of some help to a submarine which is searching for a place to rest on the bottom.
4. Finally the charts indicate areas of SAND sediments, where acoustic devices installed on the bottom are most likely to provide long-range detection under conditions of downward refraction.

AVAILABLE PUBLICATIONS

The Navy Department has available the following publications concerning the prediction of maximum echo ranges and the use of the bathythermograph by surface vessels and submarines:

* (a) Restricted, non-registered publication: "Instructions for the Care and Use of the Surface Vessel Bathythermograph Types CTB 40080 and CTB 40120".

* (b) Restricted, non-registered publication: "Installation, Operation and Maintenance Instructions for the Model OAM Surface Vessel Bathythermograph".

* (c) Confidential, non-registered publication: "Prediction of Sound Ranges from Bathythermograph Observations".

▲ (d) Sound Ranging Charts of the Oceans - Restricted.
H.O.1400 R - North Atlantic Summer, North Atlantic Winter
H.O.1401 R - North Pacific Summer, North Pacific Winter
H.O.2600 R - South Atlantic Summer, South Atlantic Winter
H.O.2601 R - South Pacific Summer, South Pacific Winter
H.O.2603 R - Indian Ocean Summer, Indian Ocean Winter

▲ (e) Bottom Sediment Charts - Confidential and Restricted - showing acoustic effect of bottom character in waters less than 100 fathoms deep.

▲ (f) Confidential, non-registered publication: "The Use of Bottom Sediment Charts".

* (g) Confidential, non-registered publication: "Calculation of Sound Ray Paths Using the Refraction Slide Rule".

For submarines, the following additional publications can be obtained:

* (a) Restricted, non-registered publication: "Instructions for the Installation, Care and Use of the Submarine Bathythermograph Types CTB 40079 and CTB 40131".

* (b) Confidential, non-registered publication: "Use of Submarine Bathythermograph Observations".

▲ (c) Confidential, non-registered publications: Submarine Supplements to the Sailing Directions, for areas of strategic importance.

* Requests should be addressed to the
Bureau of Ships, Washington, D.C.

▲ Requests should be addressed to the
Hydrographic Office, Washington, D.C.