5. BASEMENT PROFILING WITH A DEEP-TOWED HYDROPHONE NEAR DEEP SEA DRILLING PROJECT SITE 417

George M. Bryan, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York

The capability of a seismic profiling system to resolve rough topography is a function of the effective angular beam width of the system and the height of the source and receiver above the rough interface. With a simple source and receiver, towed near the sea surface, the resolution of a rough reflector at great depth is particularly poor since source and receiver are essentially omnidirectional. Putting either source or receiver (or both) near the bottom in deep water will greatly improve the resolution. The problem of firing a low-frequency sound source near the bottom in deep water is a formidable one, whereas it is relatively easy to tow a hydrophone near the bottom at low speeds while firing an airgun near the surface.

Preliminary tests of such a system were carried out on R/V *Robert D. Conrad* in May 1977. The hydrophone was towed at drifting speeds of less than a knot, and a small airgun (20 in.^{3}) served as the sound source. The signal from the phone was brought to the ship via an electrically conducting towing cable. The test was made in about 5500 meters of water near DSDP Site 417 where the basement topography is rough and the sea floor relatively smooth. Figure 1 is a standard profile section made in the vicinity of the test area at a speed of 8 knots with the same airgun and a hydrophone array towed at the surface. Basement is about 0.3 s below the sea floor and gives an incoherent, highly reverberant return typical of a rough interface.

The test record is shown in Figure 2, together with the structure section inferred from it. The track of the test section, given in Figure 3, shows a drift rate of about half a knot. The only significant variation in sea floor depth throughout the test is a transition of about 50 meters which occurred midway in the run. On either side of the transition the sea floor is essentially flat. This permitted a rather simple reconstruction of the hydrophone height and thus the true depth (in travel time) of the sub-bottom interfaces. The abrupt change in phone height in the middle of the record was deliberate; the rest of the phone height variation resulted from uncontrolled kiting of the instrument as the ship drifted. The variation is easily corrected for when the sea floor is flat, but better control would be needed for the more general case.

The flat floor case is shown schematically in Figure 4. From the geometry we have

$$H = \mathrm{R}\cos\theta$$
$$\mathrm{R}_1{}^2 = \mathrm{R}^2 + h^2 - 2hR\cos\theta$$
$$\mathrm{R}_2{}^2 = R^2 + h^2 + 2hR\cos\theta$$

which can be solved for the receiver height h, the slant range R, and angle θ to a point beneath the receiver, in terms of the water depth H and the direct and bottom-reflected paths R_1 and R_2 to the receiver:

$$h = \frac{\mathrm{R}_2{}^2 - \mathrm{R}_1{}^2}{4H}, R^2 = \frac{1}{2}(\mathrm{R}_2{}^2 + \mathrm{R}_1{}^2) - h^2, \quad \cos\theta = \frac{H}{R}$$

Then for a path of length S reflected from a sub-bottom thickness ΔH, we have from Figure 5:

$$\mathrm{S}\sin\phi = H\tan\theta$$
$$\mathrm{S}\cos\phi = H + h + 2\Delta H$$

We eliminate ϕ and solve for 2ΔH in terms of H, h, θ, and S. This method ignores the velocity contrast at the sea floor

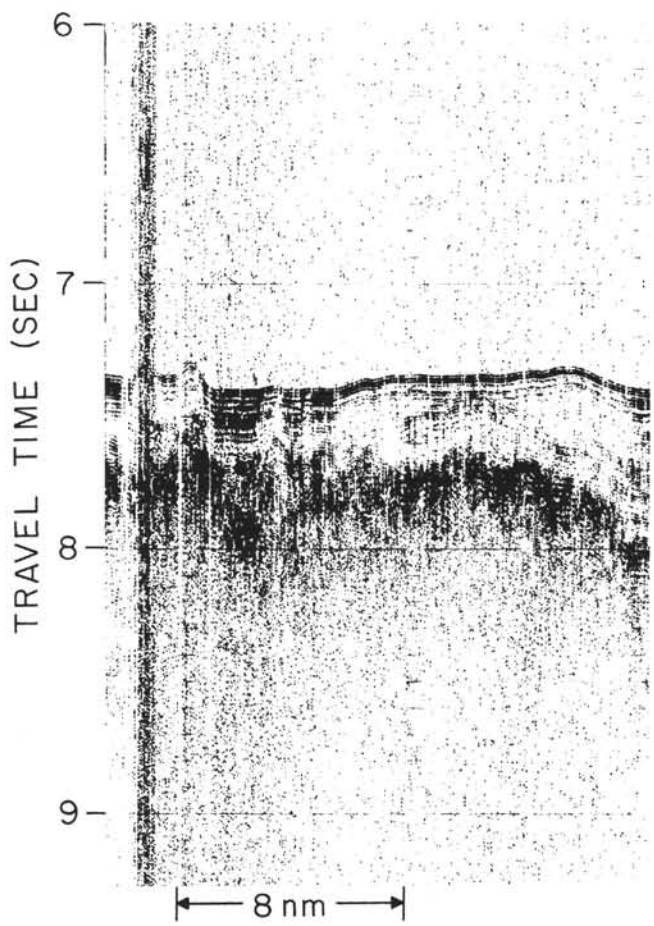

Figure 1. *Standard seismic profile made with airgun and hydrophone array towed at the surface at 8 knots. Record was made when leaving the test site.*

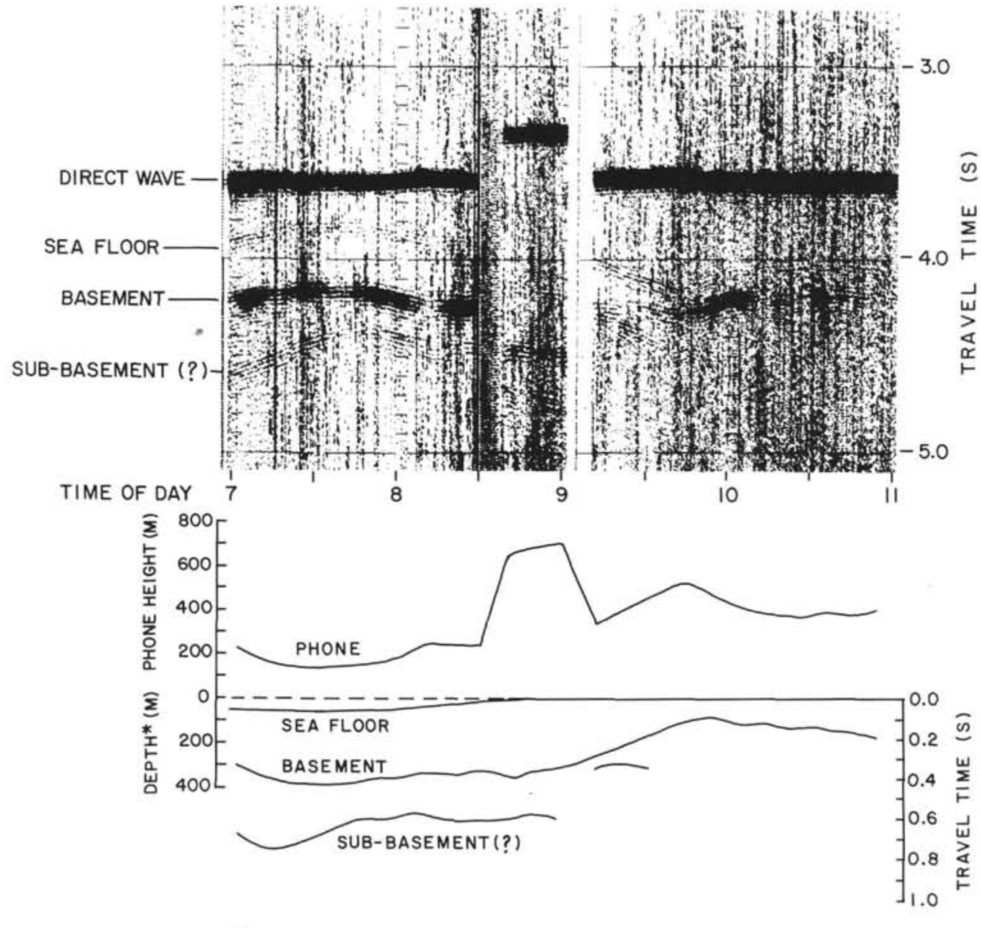

Figure 2. *Seismic record from deep-towed hydrophone, and seismic section inferred from it. Drift speed was approximately 1/2 knot.*

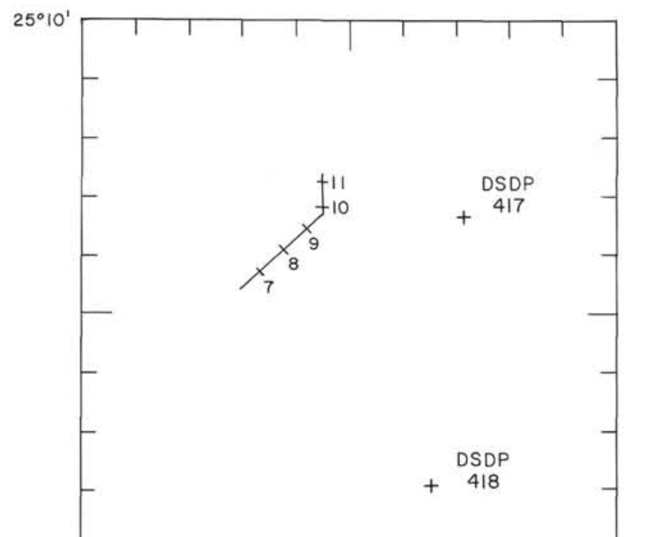

Figure 3. *Ship's track during recording of the record shown in Figure 2. Time of day is shown along track.*

and any resultant Snell's law bending. The angle ϕ ranged up to 22°, so that for reasonable velocity contrasts, bending through several degrees might be expected. An exact solution requires knowledge of the velocity structure.

The nearest sonobuoy line, about 100 km to the northwest, yielded an average compressional wave velocity of 1.79 km/s in the upper 400 meters of sediment. The reconstructed basement topography in Figure 2 is corrected for this velocity but not for the Snell's law bending, which did not exceed about 4°.

A reflector arriving about 0.2 to 0.3 s later than the basement arrival has been tentatively labeled sub-basement. Although this should be taken with a good deal of skepticism, we have been unable to find a reasonable explanation for this event in terms of side echoes or multiple reflections. If the signal is real, it implies the presence of a sub-basement reflector at a depth of 480 to 720 meters within the basement, given the formation velocity (4.8 km/s) determined for the upper levels of the crust at Site 417 by means of the oblique seismic experiment (Stephen et al., this volume).

The coherence and lack of reverberation in the basement return from the deep phone are in striking contrast to those from the surface phone (Figure 1). The horizontal parameter of roughness apparently lies somewhere between the diame-

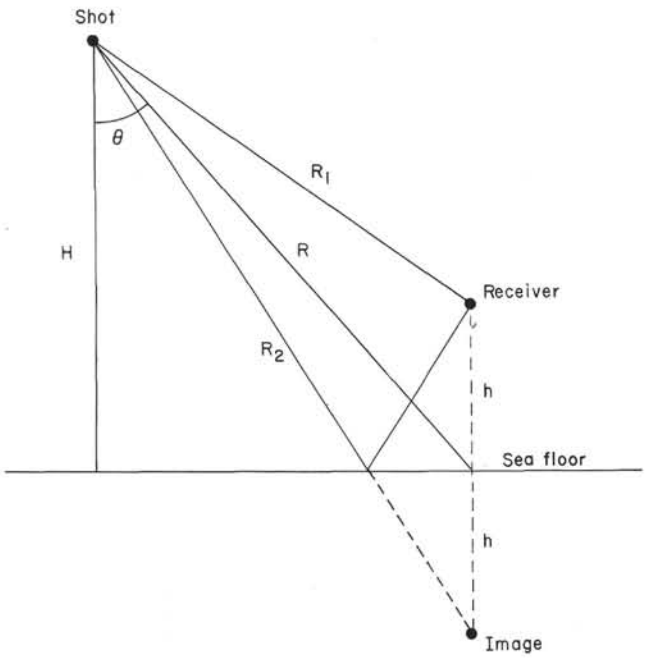

Figure 4. *Reconstruction of receiver height above sea floor.*

ter of the effective insonified area (several kilometers) and the wavelength of the seismic signal (about 10 to 100 m).

The signal-to-noise ratio as seen in Figure 2 is obviously rather poor. In this preliminary test, the towing cable was unfaired and there was no protection against flow noise at the hydrophone. Vertical motion of the phone resulting from the roll and heave of the ship is a serious source of flow noise. Nonetheless, the results demonstrate the feasibility of resolving rough basement topography with a relatively simple system.

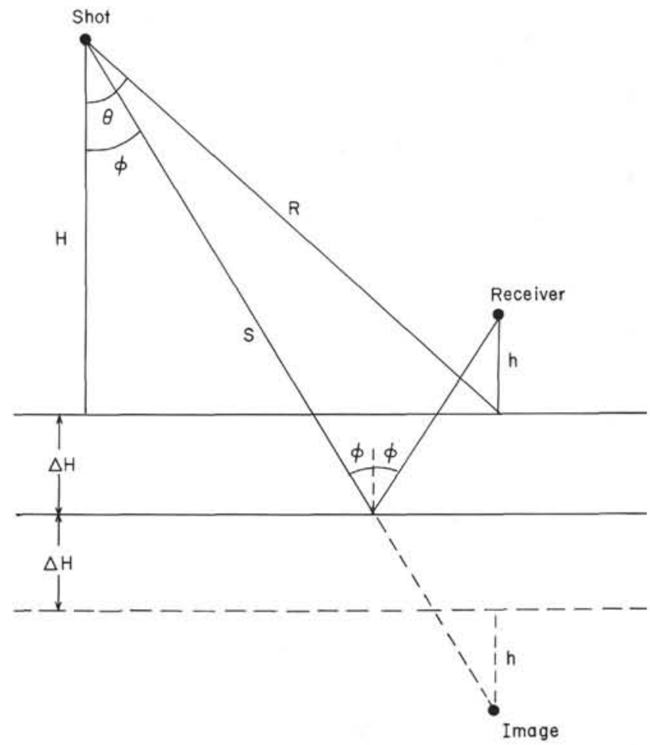

Figure 5. *Reconstruction of basement depth below sea floor, ΔH. Snell's law bending is neglected.*

ACKNOWLEDGMENTS

This work was supported in part by the Office of Naval Research under Contract N00014-75-C-0210. The help of Brian E. Tucholke in carrying out the experimental work is gratefully acknowledged.