Modeling Diffractions of the Transmitted Wave

(A discussion)

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In previous discussions and applications of wave equation migration, the question of two-dimensional transmission effects has been ignored. Experience has shown that the assumption of negligible two-dimensional transmission effects has usually been a good one. However, with the proliferation of reflection data taken over the continental slopes where deep water and severe sea floor topography are prevalent, and over areas of thick permafrost cover, the treatment of transmission effects becomes rewarding if not essential.

In perfectly stratified media and considering only downgoing plane waves, the variations in velocity from layer to layer merely effect delays in the arrival time from reflectors. And just as migration is irrelevant in a flat-layered earth, so also is accommodation of any two-dimensional transmission effects. The example of statics corrections in land data is one in which transmission effects are of paramount importance. It is a fortuitous consequence indeed of the geometry and physics of this case which allows it to be treated well as a single channel phenomenon. That is, the decoupling of shot and receiver statics implies that to a large extent diffraction effects of transmission through the weathering layer-competent rock interface are negligible. This is obvious for the upcoming wave since the interface is so shallow, subsequent diffractions will not have had time to evolve to any significant degree before arriving at the geophones. Not nearly as obvious, but possibly as true in a large majority of practical situations, the receivable cone of energy from the shot subtends a small enough region of the interface such that a uniform time shift in the wavefront is the only result. (We may in the future find that instead the downgoing wave has merely become homogenized in its subsequent propagation to the reveivers via the reflectors. In this case, although the wavefront is now planar, a coda has been produced on the waveform which impedes meaningful deconvolution.)

In the example of land statics, transmission effects are important because of two conditions. First, the topography of the interface is not flat; second, velocity contrasts are large enough to produce significant differential time-shifting over shot or receiver intervals. We can speculate that a "hard" sea floor with severe topography and at depths typical of the continental slope regions would cause transmission effects to be important in a two-dimensional sense.

In this paper, and all subsequent to this, I will use the term "diffractions" loosely by applying it to transmission effects as well as reflection effects. In this way the genesis of familiar two-dimensional wave phenomena, such as focusing, hyperbolic tails, etc., are not differentiated by use of the term "diffractions".

Transmission diffractions have been described by Claerbout and Johnson (1971) (see Figure 1), and their cause is essentially identical to the case of reflected waves. If a wavefront is distorted by transmissions through a localized region of inhomogeneity, subsequent propagation through a region of homogeneity yields a diffracted waveform. On the face of it, we should in general then expect transmission diffractions just as we expect diffractions of the reflected wave. As mentioned earlier, this turns out not to be the case, since wavefront distortions are much more severe from reflections than from transmissions. Nonetheless, as we speculated earlier, we can expect situations where the sea floor acts as a diffractor to transmitted waves. Subsequent papers will treat the incorporation of sea floor transmission diffractions into the total migration picture.

The remaining figures in this paper are the result of calculations meant to predict the severity of sea floor transmission diffractions in various situations.

Reference

Claerbout, J. F., and A. G. Johnson, 1971. Extrapolation of time-dependent waveforms along their path of propagation, Geoph. Journ. Royal Astr. Soc., vol. 26, pp. 285-293.

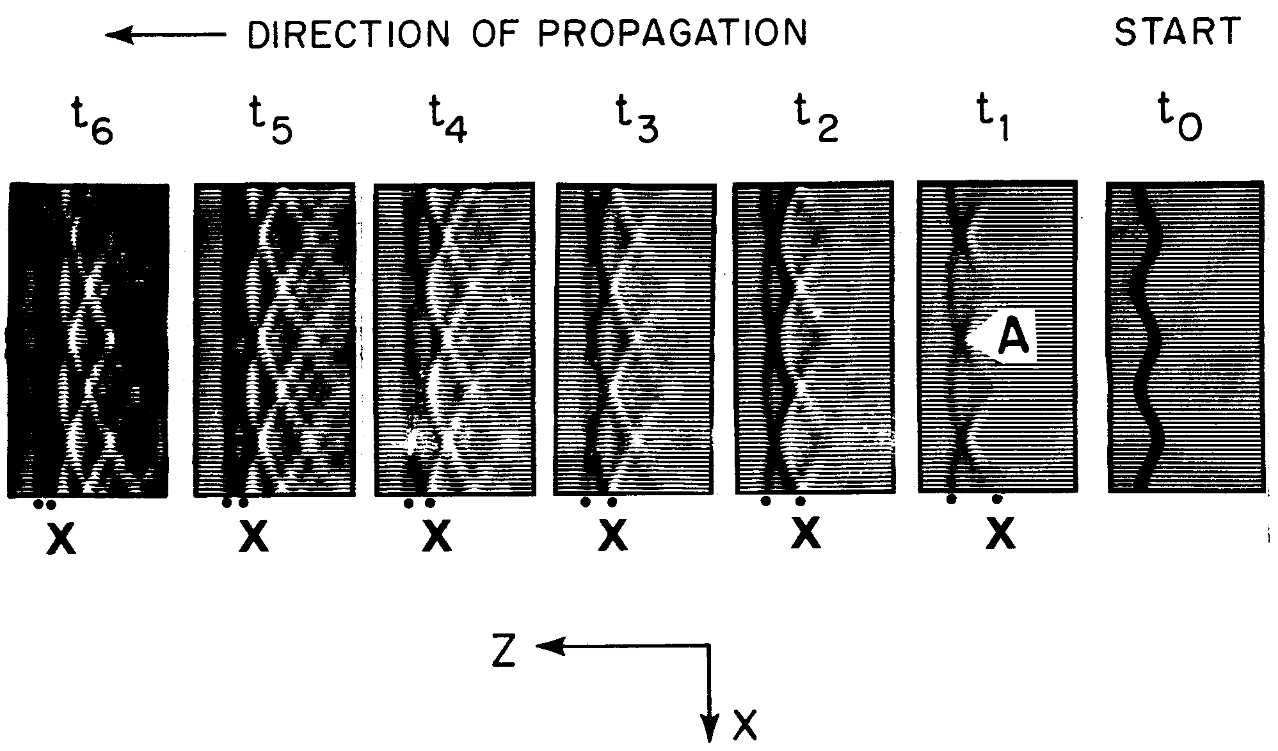

Figure 1. Disturbed plane wave propagating through a homogeneous medium. The first arrival of a disturbed plane wave heals itself during propagation. The wave coda or trail gets more and more complicated and energetic. In the trail, energy moves back away from the first arrival while phase fronts (marked by "X" move forward. Beam-steer signal processing (sum over the x-coordinate) enhances the first arriving signal but trys to destroy later arriving signals (the trail).

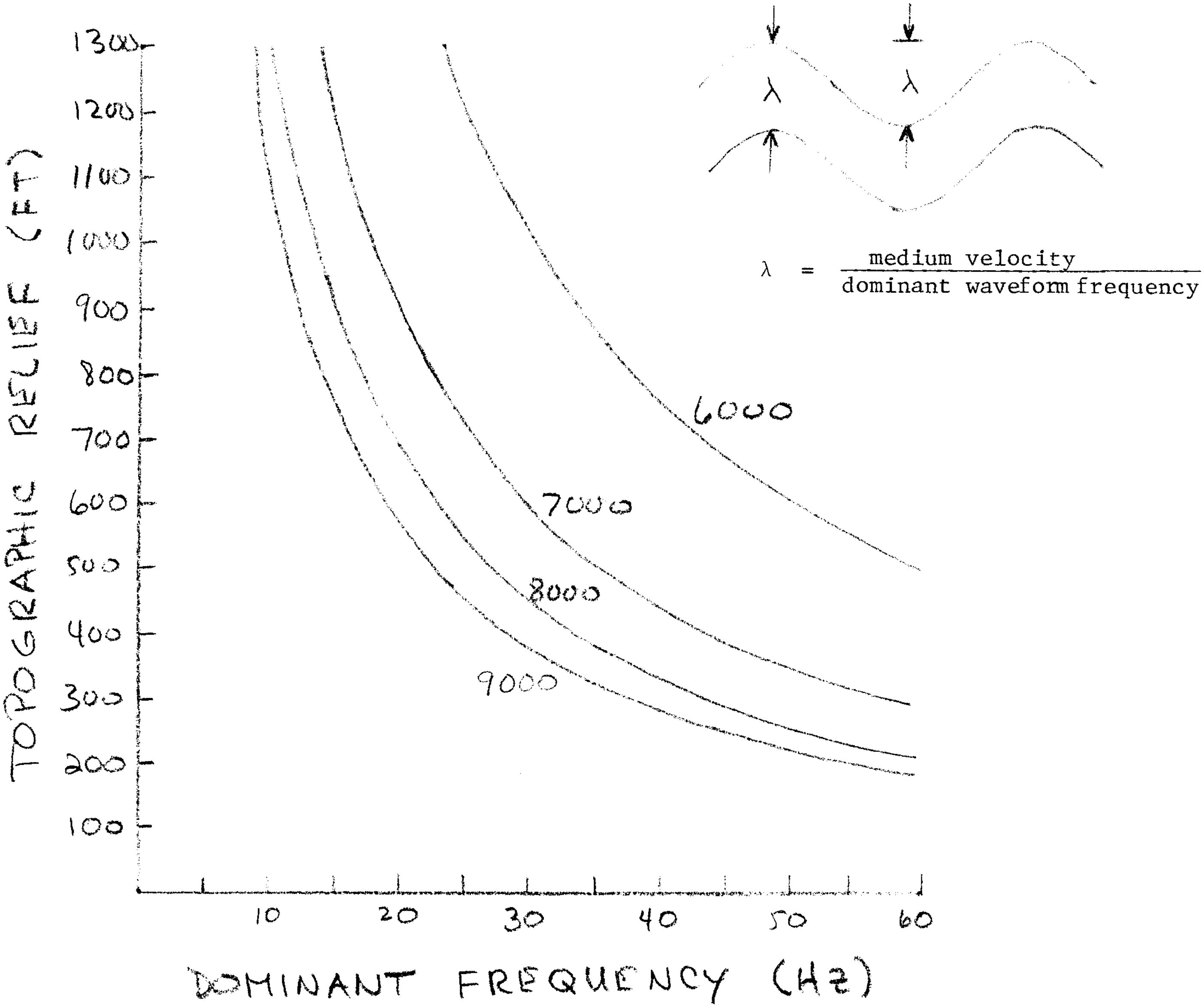

Figure 2. Topographic relief of the sea floor required to create wavefront disturbance of the transmitted wave (shown in the upper right) as a function of dominant frequency of the waveform. Four velocity contrasts are shown (water = 5000 fps).

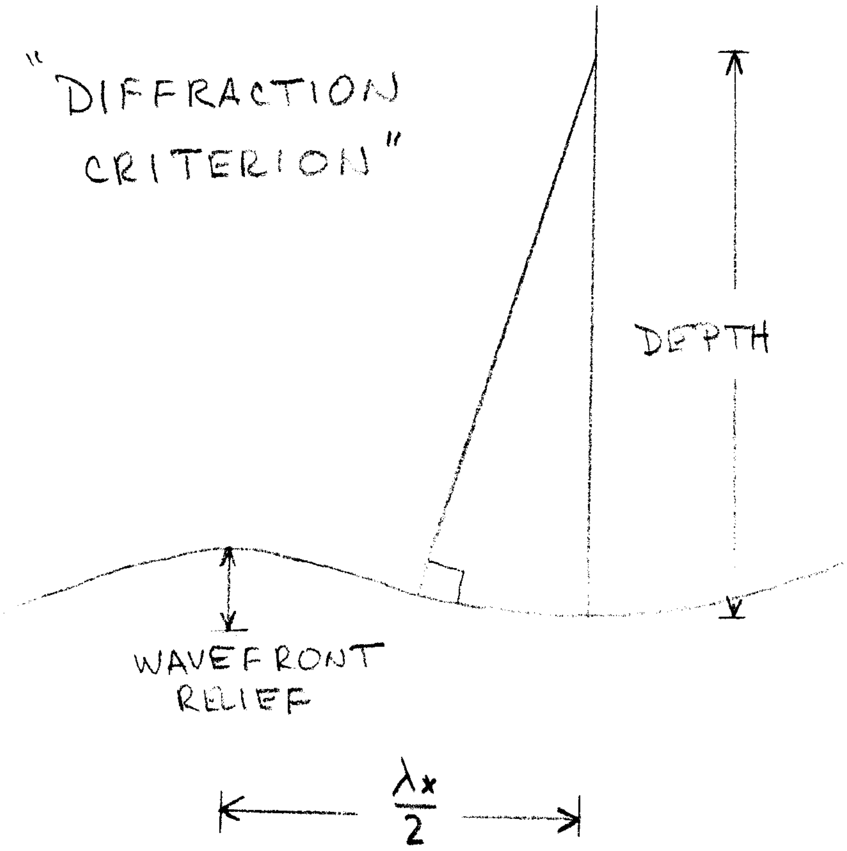

Figure 3. Arbitrary diffraction criterion giving a "depth" (propagation distance) after which diffraction produces a significant distortion of the wave field. Propagation is in the upward direction. The geometry shows clearly that this depth is a function of wavefront relief and horizontal wavelength.

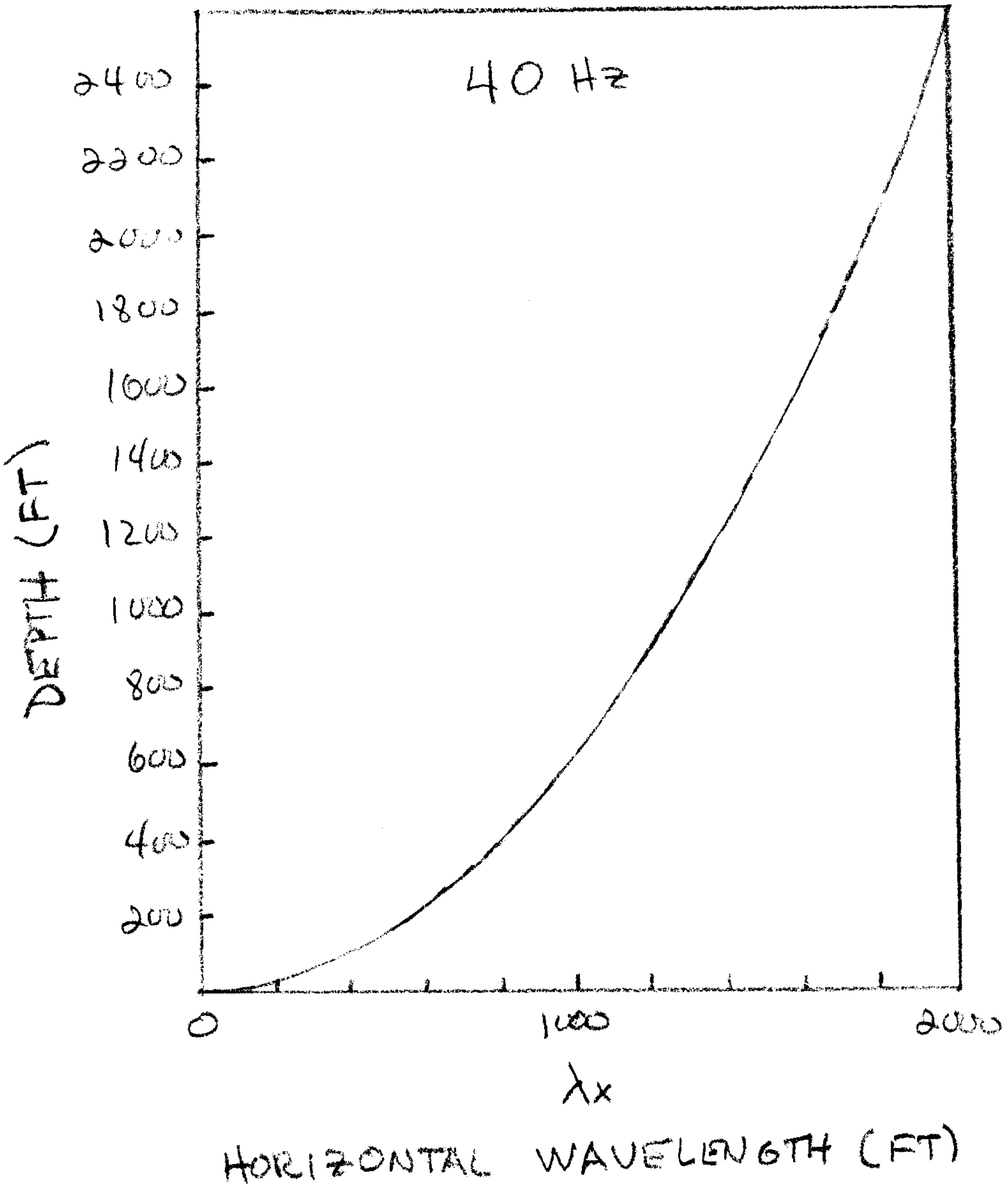

Figure 4. Minimum depth of sea floor as a function of horizontal wavelength (of the sea floor topography) for the upcoming sea floor transmitted wave with a 40 Hz waveform distorted as in Figure 2 to have met the "diffraction criterion" (see Figure 3) by the time it reaches the surface receivers.

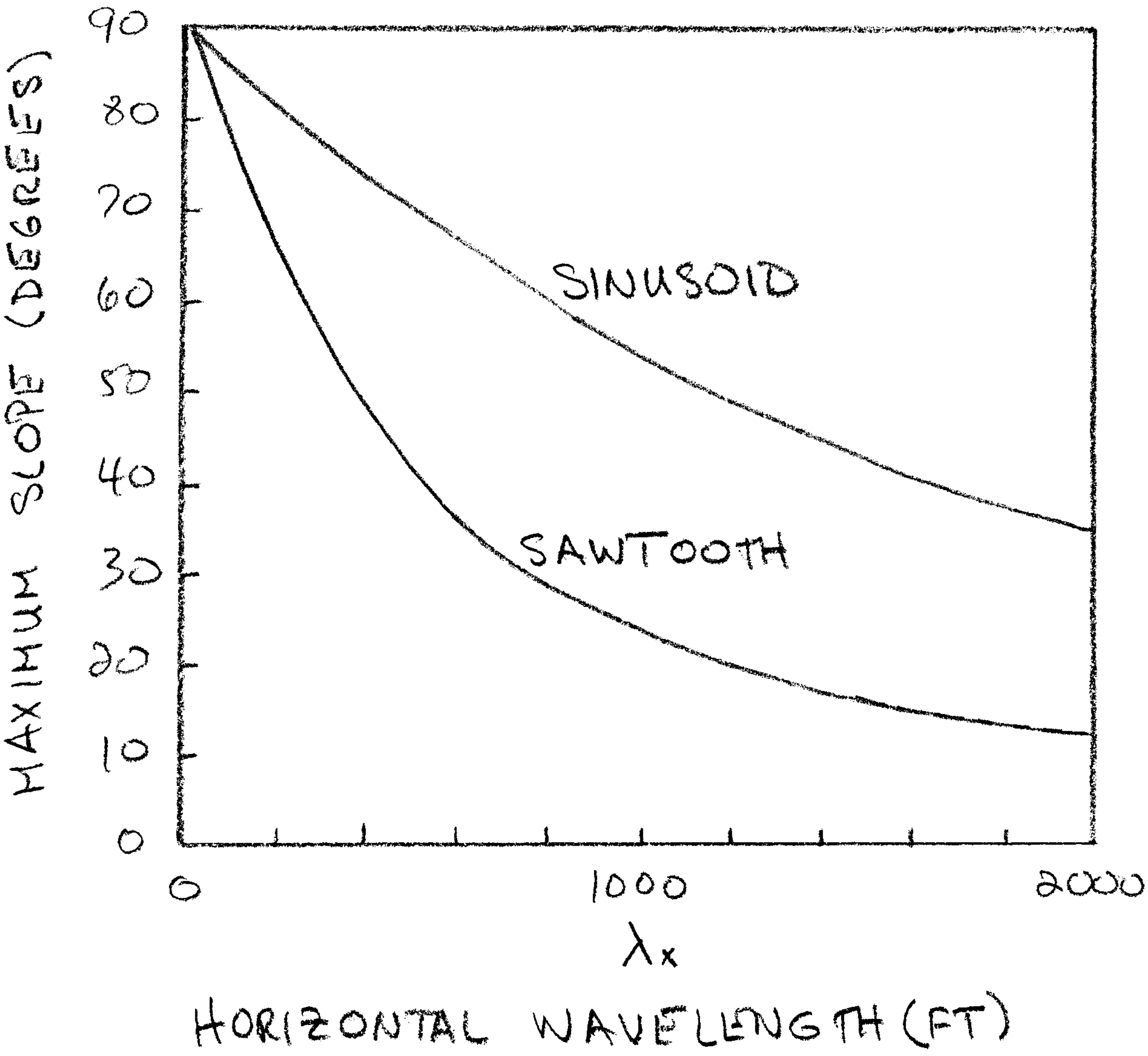

Figure 5. Maximum slope of the sea floor required to create the disturbance of Figure 2 for a 40 Hz waveform as a function of horizontal wavelength of the sea floor topography.