IV. A Central Problem in Seismic Waveform Analysis

We wish to state an extremely important unsolved inverse problem in seismology in simplest form stripped of all practical complications. It will be apparent that this problem is related to the problem of resolving stratigraphic traps.

Consider a transient time function being carried by a plane wave. The wave enters a region of weak 2D or 3D velocity inhomogeneity and propagates on through it to the other side where it is observed. The observations are distorted wave forms which now are variable along the wavefront. Tracking this wave either forward or backward in time and space is a fairly simple procedure with our difference methods provided that the velocity inhomogeneity is known. An example of something close to this is attached (Fig. 5 from p. 302 of Lecture Notes of Jon Claerbout). It is described in greater detail in "Extrapolation of Time-Dependent Waveforms along their Path of Propagation" by Jon F. Claerbout and Ansel G. Johnson, GEOPHYS. J. ROY. ASTR. SOC., 1971, v. 26, p. 285-293, which is also attached as an appendix. The inverse problem, which we believe to be important, is to deduce the material velocity variation required so that as the laterally variable observed wave is projected backwards through the inhomogeneity it becomes increasingly simpler until we get to the point of entry where it should turn into a simple transient waveform carried by a plane wave. We regarded this inverse problem as hopelessly difficult until very recently when we made some theoretical progress on it. The basic idea will be briefly indicated.

View frames labeled t_0, t_1, t_2, etc. in the figure as representing a

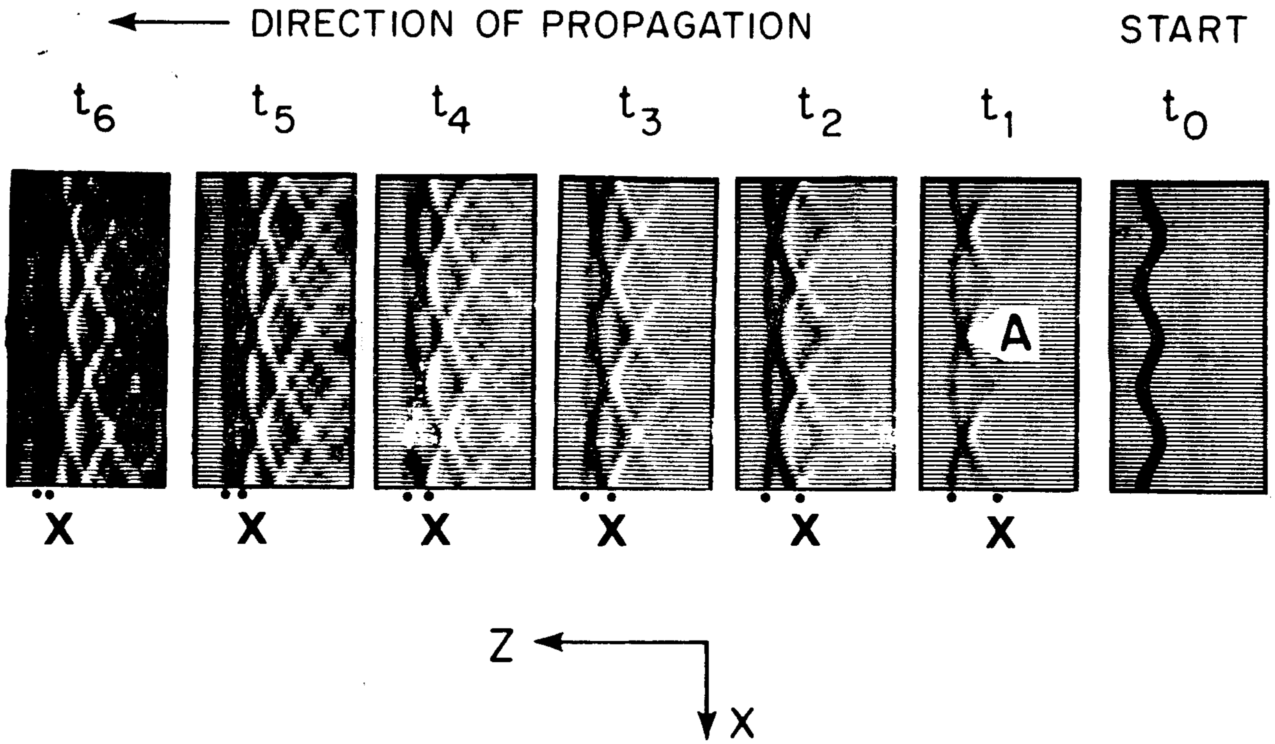

Figure 5. Disturbed plane wave propagating through a homogeneous medium. The first arrival of a disturbed plane wave heals itself during propagation. The wave coda or trail gets more and more complicated and energetic. In the trail, energy moves back away from the first arrival while phase fronts (marked 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).

wave pressure field P(x,t) observed at successive values of depth z_0, z_1, z_2, etc. (To the Fresnel approximation z and t are interchangeable.) Now notice that in the frame labeled t_0 an operation like "statics correction" could remove all the x variation of pressure from the frame. Next notice that the same is not true for frames t_2 through t_6. Now recall that the waves displayed actually encountered velocity inhomogeneity only right at or just before frame t_0. From these observations it is possible to assemble a "dynamic programming" type of estimation of the velocity inhomogeneity. When waves are back projected from z_j to z_{j-1} the velocity that is estimated should be such that a chosen functional of the wave field, $P(x,z_{j-1},t)$ is minimized. For instance, as a starting point, one could estimate the velocity which produces a $P(x,z_{j-1},t)$ which has the minimum x variation. Trial of this criteria shows that it is not completely satisfactory. However, it is our feeling that several more sophisticated criteria that may work in the regions where this simple idea failed should be investigated.