A Proposal for Wave Theory Analysis of Statics Corrections

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The subject of statics corrections is a long-time familiar one in reflection seismology. Seismic traces are differentially time-shifted to correct for velocity anomalies in near-surface weathering layers. We would like to be able to extend this concept to velocity anomalies at greater depth where we do not expect time-shifting alone to provide a satisfactory description. Diffraction in the transmitted wave now becomes more significant. Our numerical solutions to the scalar wave equation allowing us to extrapolate wave-forms forward or backward in time invites an approach to this "statics" based on sounder physical principles. Following the speculation of Jon F. Claerbout (beginning on page 179 of the March 1974 SEP report), we conjecture that it would be perfectly reasonable to "back out" the time-shift after we have downward continued the wave field to the depth of which this waveform distortion occured. We therefore expect, in general, to see a time-shift for every Δz of migration, so that we may depict the sequence of events as in figure 1.

As a consequence, we are faced with two fundamental problems. The first is to determine at what depth ("z-step") this time-shifting has occured; the second is to determine the nature of the time-shifting. The second problem is similar to that faced in statics corrections today, with the added complication that there will in general be more than one depth where a time-shifting is required, so it is implicit that the time-shifting be done for only one Δz at a time, without interferring with time-shifts more properly associated with other depths.

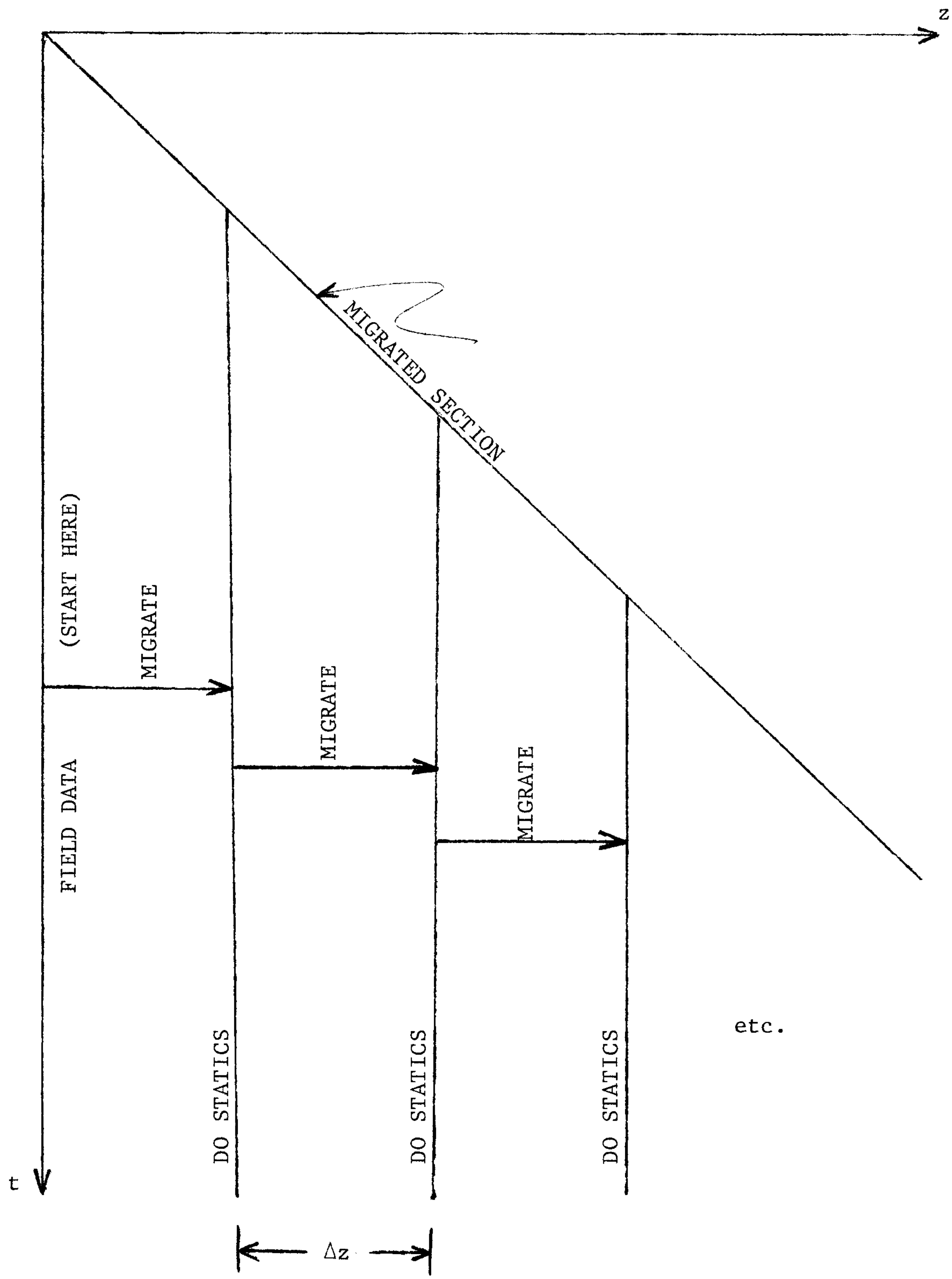

Figure 1. Time-shifting ("statics") is done at each Δz to back out waveform distortion at depth $n\Delta z$ which led to transmission diffractions at the surface.

We have recently begun to address ourselves to the problem of determining at which point time-shifting is required. We begin with the assumption that the diffracted waveform becomes less complex as we migrate back toward the focus (the point at which time-shifting has taken place). An important aspect now becomes, "what is a good measuring stick for complexity?"

We are familiar with the concept of entropy in thermodynamics and information theory as a measure of the disorder or randomness of a system, and we would like to draw a parallel so that this concept may be useful to us. We have looked at some entropy-related functions of the wave field, such as expressions (1) and (2) below, in an attempt to identify various foci and are encouraged by the results.

$$\sum_{x,t} \ell n \left(\sum_{x,t\ \text{gate}} p^2 \right) \tag{1}$$

$$\sum_{x,t} \left(\sum_{x,t\ \text{gate}} p^2 \right) \ell n \left(\sum_{x,t\ \text{gate}} p^2 \right) \tag{2}$$

We would like to be able to define a gate in expressions (1) and (2) small enough to retain resolution in x and t, but large enough so that our logarithmic functions are not disturbed by spurious zeroes.

An alternative approach, one which we are just now beginning to investigate, is not to test for a needed time-shift at all, but to proceed to estimate a statics correction at each Δz. To make the statics correction robust, we would define the time-shift of a trace (relative to a contiguous trace) as Δt, 0, or $-\Delta t$.
There will then be two stages to the statics correction. The first is the test: is one trace offset from another? The second is the shift.

Although there are many questions yet to be answered in this approach, the possibilities of processing statics corrections in this way is appealing because they are indeed based on sounder physical principles. When a statics shift is caused by a velocity anomaly at depth, the data at the surface may have been diffracted to the extent that mere time-shifting will not significantly improve the data. We believe that wave-equation migration offers a promising tool to a more complete statics analysis.