Side-Scanning Seismic

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ABSTRACT

A proposal is presented here to use off-line energy (sideswipe), recorded on three-component (3-C) receivers, to create seismic sections. Assuming that the angle of incidence of the sideswipe can be found from the 3-C recordings, then a polarization filter can be designed to enhance arrivals from particular off-line distances or angles. These filtered events can then be stacked and migrated using full three dimensional geometry. This procedure could be used to construct off-line sections.

METHODS

One problem which may be encountered in 2-D (single line) surveying in regions of significant structure is that of side-swipe. That is, energy may be recorded on the seismic line which is not from geology directly below the line (Tucker and Yorston, 1973; French, 1974; Brown, 1988; Larner et al., 1983; Hospers, 1985). As Tucker (1982) says, "And sideswipe there will always be when lines are shot at other than more-or-less right angles to dip or structural trends." The dynamics of these off-line events are such that after data processing, they can often be found on the final section as coherent events. These misplaced events may be erroneously interpreted as true anomalies vertically below the line.

There are several possible remedies to this problem. First, let's consider a simple geometry for an off-line point scatterer half way between the source and receiver. From Figure 1, the approximate total traveltime t of the event will be:

$$t^2 = t_o^2 + \frac{4y^2}{V_{rms}^2(t_o)} + \frac{h^2}{V_{rms}^2(t_o)}, \qquad (1)$$

where

t_o is the zero-offset, two-way traveltime,
y is the off-line offset of the scatterer,
h is the source-receiver offset,
$V_{rms}(t_o)$ is the RMS velocity at time t_o .

From equation (1), we can see that off-line events will have a hyperbolic shape similar to that of in-line events: Thus the coherency with respect to NMO and migration. However, as the off-line events will arrive later than in-line events from the same depth, but with the same curvature (velocity), it may be possible to attenuate them using careful velocity filtering. This would be similar to multiple rejection.

If the line had been recorded with three-component (3-C) geophones, then we might have another option to attenuate off-line events. Off-line events will arrive at the 3-C geophone with some energy recorded on the y (transverse) channel. This energy may be very small if there is a significant low- velocity near surface or if the off-line distance is small and the anomaly deep. Whenever, transverse-channel energy is detected though, we could suppress its associated vertical channel energy. This would lead to vertical-channel recordings less contaminated with events from off the line.

Again, if we detect off-line energy, then it is more interesting to attempt to use it for further imaging. Consider the receiver geometry shown in Figure 2. If there is some motion amplitude r in the direction of propagation $\hat{r}$ then the Cartesian projections are:

$$\begin{aligned} z &= -r \cos\theta \\ x &= r \sin\theta \cos\varphi \\ y &= r \sin\theta \sin\varphi \end{aligned} \tag{2}$$

Suppose now that we have recorded off-line energy and via polarization analysis were able to determine the arrival direction, then we can conceive of a procedure to create an image of the off-line geology.

We can imagine two possible processing procedures: one where a section is made from a constant scan angle ϕ, the other where a section would be made of a constant offset y. Let's just consider the constant angle procedure as from it we can construct sections from various off-line distances. From Figure 2,

$$\tan\phi = \frac{y}{z}\,. \tag{3}$$

So that equation (1) becomes

$$t^2 = t_o^2\left(1+\eta^2\right) + \frac{h^2}{V_{rms}^2(t_o)}\,, \tag{4}$$

$$\text{where } \eta = \frac{V_{av}(t_o)\tan\phi}{V_{rms}(t_o)}$$

and V_{av} is the average velocity at time t_o

From equations (2) and (3)

$$\tan\phi = -\tan\theta \sin\varphi \tag{5}$$

So given a particular ϕ, we would polarization filter the data to keep only a range of angles about θ, and φ such that equation (5) holds. We could remove NMO (Δt) in equation (4) by subtracting

$$(\Delta t)^2 = t_o^2\,\eta^2 + \frac{h^2}{V_{rms}^2(t_o)}\,. \tag{6}$$

Having selected a side-scan or fan of arrivals and processed them to normal-incidence, zero-offset time, we can next migrate in the x direction. After imaging as above, we could stack these side scans into constant off-line bins to produce more conventionally interpretable sections (see Figure 3).

SUMMARY

A procedure has been outlined here to take single-line, 3-C data and from them reconstruct off-line sections. This procedure makes use of the 3-D Dix equation, and geometry off-line scatterers and 3-C receivers. The proposal is to polarization filter in the off-line direction, then stack and migrate in the in-line direction to make off-line sections.

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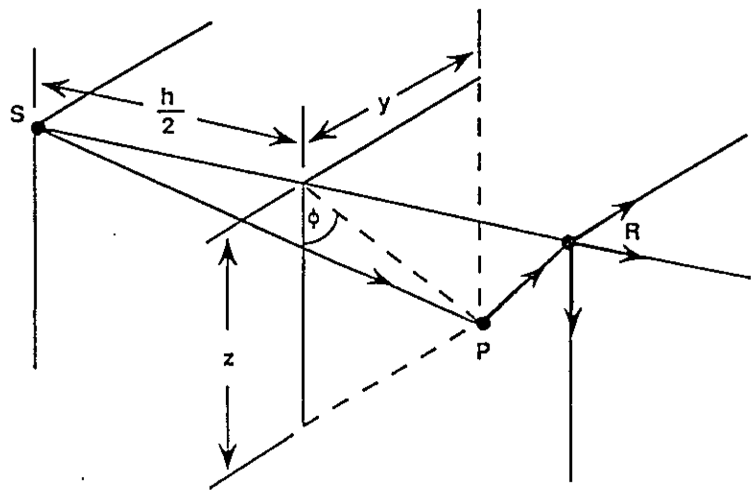

Figure 1. Geometry for source (S), 3-C receiver (R) and off-line scatterer (P).

3 - C Receiver Geometry

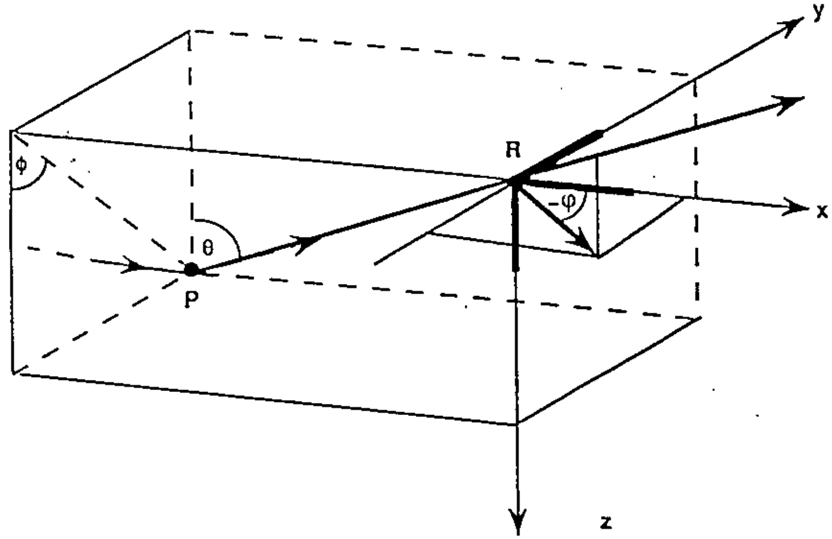

Figure 2. Detailed geometry of 3-C receiver (R) and scatter point (P).

Side-scan Seismic Sections

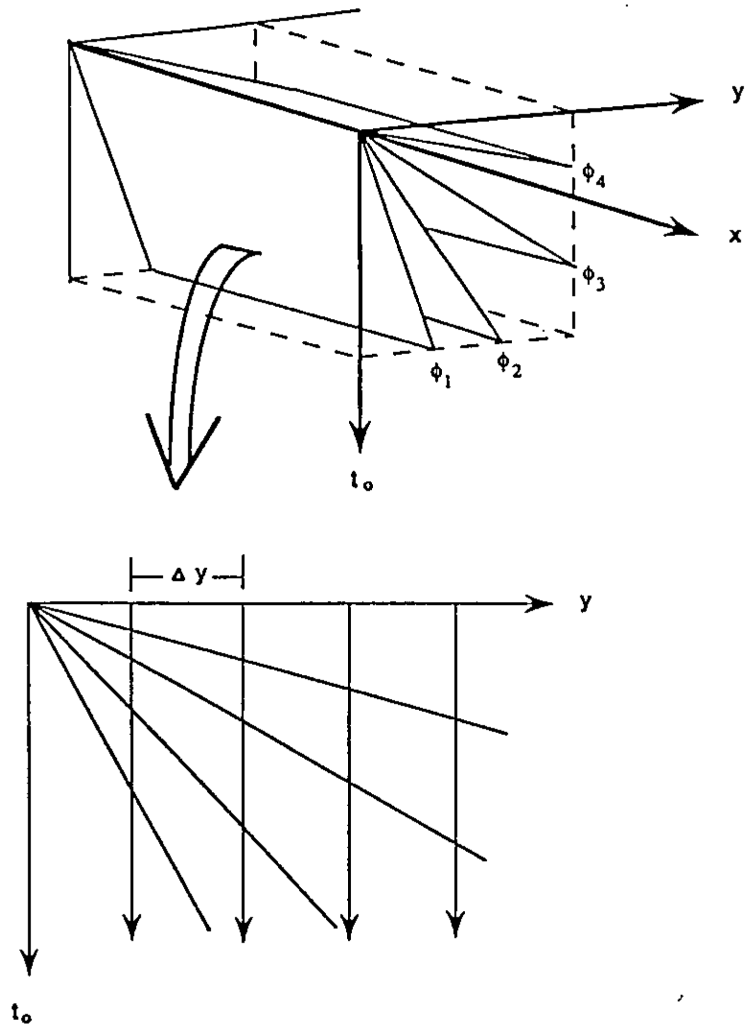

Figure 3. Constant-angle sections produced using polarization filtering and imaging could be stacked into various off-line distance sections.