DIP CORRECTION OF VELOCITY ESTIMATES

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An earlier paper "How to Measure RMS Velocity with a Pencil and a Straightedge" presented the velocity estimation formula

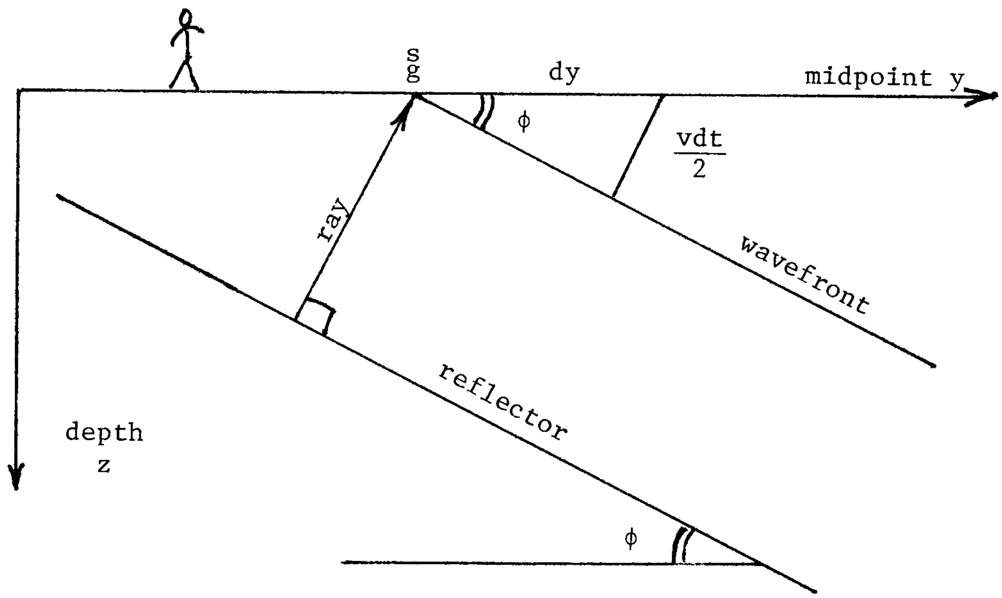
$$v^2 = \frac{f}{t} \frac{df}{dt} \tag{1}$$

where t is two way travel time, and f is offset and df/dt is a slope measured at (f,t) on a common midpoint gather. It was shown that for flat reflectors in a stratified medium the estimator (1) determines exactly (at any offset with no straight ray approximations) the root mean square time average velocity of the medium. The time average however is not for a vertical path but for a path with a Snell's parameter $p = (\sin \theta)/v$ given by the measured $p=dt/df$.

Now we will show how the estimator (1) must be modified in the presence of dipping reflectors. The correction which we will give will be exact for any dip angle and any offset f . However the dip correction given will be for constant velocity media and I don't know whether or how it should be modified for stratified media.

First we need to define and determine the dip. Start with a zero offset section and measure the stepout dt/dy , that is, the change in two way travel time dt as seen between midpoints separated by dy .

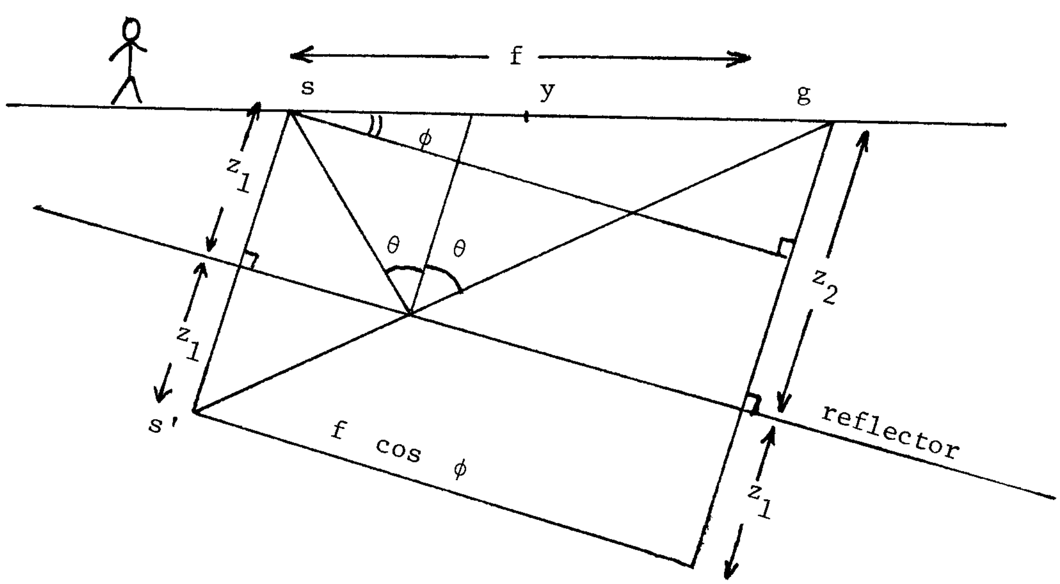
From the diagram



we see that

$$\sin \phi = \frac{v}{2} \frac{dt}{dy} \tag{2}$$

Equation (2) may be used to determine the dip angle of the reflector. But there is a catch. Equation (2) contains the velocity. So we will need to know the velocity to get the dip. The following diagram shows the raypath from a shot at s to a dipping reflector and thence to a geophone at g .



Auxiliary lines show the distance z_1 from the surface to the reflector along a perpendicular to the reflector, the distance z_2 from the geophone to the reflector, and an image shot s' . Observe that the normal to the reflector at the reflection point does not intercept the surface at the midpoint y between the shot and receiver. Consider fixing the midpoint y and changing the offset f. What will really be important is that increasing f will decrease z_1 but increase z_2 in such a way that $z_1 + z_2$ remains constant independent of offset. The time from s (or s') to g is given by the Pythagoras relation

$$v^2 t^2 = (z_1 + z_2)^2 + (f \cos \phi)^2 \tag{3}$$

Now we may differentiate (3) with respect to offset f at a constant value of midpoint y . Here is where it is important to note that $(z_1 + z_2)$ does not change with offset even though both z_1 and z_2 separately change. We get

$$2 v^2 t \frac{dt}{df} = 2 f \cos^2 \phi$$

or

$$v^2 = \frac{f}{t} \frac{df}{dt} \cos^2 \phi \tag{4}$$

Thus we have discovered that the simple velocity estimator (1) should be corrected by the cosine of the dip angle. Unlike most (all?) of the results in the literature these results are exact even for wide offsets and steep dips.

We may now directly obtain the dip and the velocity by simultaneously solving equations (2) and (4). The equations for velocity and dip are then,

$$\phi = \tan^{-1} \left[\frac{1}{2} \frac{dt}{dy} \left(\frac{f}{t} \frac{df}{dt} \right)^{1/2} \right] \tag{5}$$

$$v^2 = \frac{\frac{f}{t} \frac{df}{dt}}{1 + \frac{1}{4} \left(\frac{dt}{dy} \right)^2 \frac{f}{t} \frac{df}{dt}} \tag{6}$$