# Irregular Surfaces and the Plus-Minus Method

There is one more step of sophistication that is required so that the refraction technique is useful. This occurs in environments where the interface has topography and is no longer approximated by a plane. If the curvature of the interface is not too great then we can still think of the refracted wave travelling along the interface. The wave travels at the speed of the lower medium. Consider the sketch to the right. Formulae which explicitly assume a plane interface (even dipping) do not work well enough. We need a better approximation.

We would like to be able to obtain the depth of the interface beneath the source and receiver. To do this we used the concept of *delay time*. Consider the diagram to the right. The travel time is where can be thought of as the time delay.

The delay time can be partitioned into two parts: (1) the "delay" associated with the source location and (2) the "delay" associated with the receiver location. Consider the delay at the source.

Let the delay time be denoted by

Finally, using the definition of the velocity triangle we can write

Thus the depth can be computed if the delay time, , can be measured.

We can write any general travel time so that it involves a delay at the source and a delay at the receiver or detector . It looks like this:

As in the diagram at the top of this page, and might be very different. To make progress we implement Hagedoorn's "Plus-Minus" method. This method will also make it possible to estimate depths under every geophone that has a refracted signal from both sources. This will yield several depths under the survey line rather than just two depths under sources, thus allowing more detailed image of the interface's shape.

## Hagedoorn's Plus-Minus Method

The geometry illustrates the two shots occurring at locations and . The point indicated by lies at any location (i.e. any geophone) between the two shots where refractions can be received from both shots. Let and denote the delay times at the two shot locations. Although the refracting interface is not flat beneath , the slope is not large an d the ray path lengths and are almost identical.

Let us write all portions of the travel times for signals that would travel between and , between and , and between and . These travel times are: