SEISMIC IMAGING CONCEPTS

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There seem to be three alternative reflection seismic imaging concepts. The simplest is the *explosive reflectors model* in which one imagines that at t = 0 the reflectors all explode sending an upcoming wave to the surface. Except for its one way travel time this wave is thought to mimic a field recorded zero offset section. The resulting imaging concept is that the section can be downward continued, as if it were a wave, down to the reflectors where at t = 0 observed polarity and strength of the "explosive reflectors" depicts reflection coefficient location and strength. The range of validity of this imaging concept does not seem to be known. We believe that it is near enough to truth to be useful in the presence of lateral velocity variations. It is known to fail with multiple reflections. The most common mis-use of this concept is to regard a CDP stack as a zero-offset section.

The second imaging concept in reflection seismology is the one propounded in my book (FGDP p230) that *reflectors exist in the earth at places where the onset of the downgoing wave D is time coincident with an upcoming wave U.* A form of this statement which is particularly useful in multiple reflections work is found in the doctoral dissertation of Don C. Riley, *at any point in the earth, upcoming waves must vanish for all time prior to the first arrival of the downgoing wave.* Conventional velocity analysis may be regarded (FGDP p.255) as finding the velocity v which best fits the up-going wave U to the downgoing wave D as a function of the offset.

Unfortunately this imaging concept applies to waves and not to seismic sections. However, use of the superposition principle shows that it is generally applicable to wave stacks (sums over constant geophone) and use of the reciprocal principle shows that it is valid for sums over shot point. Unfortunately various approximations become involved before this imaging principle can be applied to common midpoint stacks.

The third imaging concept is to downward continue an entire experiment. Various means are developed to achieve downward continuation of both sources and receivers. The reflection coefficient information at any (x,z) is then seen in the limit of zero travel time and zero offset. The first part of this concept is that a downward continued wave is really the same as the wave recorded by a set of downward continued receivers. Thus we start by downward continuing the receivers. The second part is to apply the principle of reciprocity which says that the same seismogram will be recorded if shot and geophone are interchanged. After interchange we then have surface geophones and buried shots. Lastly we downward continue the surface geophones (which originally were the shot points). The end object is to get both shots and geophones down to the reflectors. Then the reflection coefficient information is found at zero travel time and zero offset. The downward continuation can be done in either of two ways. We could go all the way down with the geophones and then go all the way down with shots. Or we could switch back and forth between shots and geophones at many little steps of Δz. The choice of either of the two possible methods of descent is completely arbitrary and may be made for computational convenience.

Although experiment downward continuation seems to involve costly downward continuation before stack, the superposition principle and careful inspection of the downward continuation equations show that some kinds of stacked data can be used. Other kinds of stacks require assumptions and approximations.

These three imaging concepts are the products of the imaginations of geophysicists. Physics and Numerical Analysis tell us how to solve all the *forward* or *direct* problems, that is, problems where the media is given and the waves are to be found. It is self evident that *forward* problems are solveable in principle because all the computer needs to do is model the evolution in time of some physical process. In the case of the *geophysical inverse problem* we are given the waves on a surface and instructed to determine the media inside a volume. We don't know beforehand that solutions exist or are unique. So the *inverse* problem is one of much greater intellectual depth than the *forward* problem (although it goes by the modest name, *geophysical data processing*). An active group of mathematicians work on layered media inverse problems. When it comes to two or three dimensional inhomogeneous media we get some help from the fields of optics and holography. Unfortunately these fields work with air as the propagation medium and they provide no assistance with the problems imaging in the presence of velocity variation, estimation of the velocity variation, or multiple reflections.

In conclusion, there is no gospel of reflection seismic imaging concepts. It is up to us as individuals to find the best way we can. Physics tells us how to do the forward problems. That provides a check on our answers. Statistics provides guidelines for how to deal with experimental data, but only rarely does our experimental data fit the precise assumptions required by the classical statistics texts. Mathematics provides us with excellent tools to determine falsehood through inconsistency, but it gives us little constructive guide in geophysical inverse theory. It is up to us to apply the methods of deductive reasoning and inductive reasoning (study of examples) to find out what we can about solid earth imaging.