REVERSE TIME MIGRATION OF CMP-GATHERS
AN EFFECTIVE TOOL FOR THE DETERMINATION
OF INTERVAL VELOCITIES

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Abstract. One of the most important steps in the conventional processing of reflection seismic data is common midpoint (CMP) stacking. However, this step has considerable deficiencies. For instance the reflection or diffraction time curves used for normal moveout corrections must be hyperbolae. Furthermore, undesirable frequency changes by stretching are produced on account of the dependence of the normal moveout corrections on reflection times. Still other drawbacks of conventional CMP stacking could be listed.

One possibility to avoid these disadvantages is to replace conventional CMP stacking by a process of migration to be discussed in this paper. For this purpose the Sherwood-Loewenthal model of the exploding reflector has to be extended to an exploding point model with symmetry to the line $P_{EX}M$ where $P_{EX}$ is the exploding point, alias common reflection point, and $M$ the common midpoint of receiver and source pairs.

Kirchhoff summation is that kind of migration which is practically identical with conventional CMP stacking with the exception that Kirchhoff summation provides more than one resulting trace.

In this paper reverse time migration (RTM) was adopted as a tool to replace conventional CMP stacking. This method has the merit that it uses the full wave equation and that a direct depth migration is obtained, the velocity $v$ can be any function of the local coordinates $x, y, z$. Since the quality of the reverse time migration is highly dependent on the correct choice of interval velocities such interval velocities can be determined stepwise from layer to layer, and there is no need to compute interval velocities from normal moveout velocities by sophisticated mathematics or time consuming modelling. It will be shown that curved velocity interfaces do not impair the correct determination of interval velocities and that more precise velocity values are obtained by avoiding or restricting muting due to non-hyperbolic normal moveout curves.

Finally it is discussed how in the case of complicated structures the reverse time migration of CMP gathers can be modified in such a manner that the combination of all reverse time migrated CMP gathers yields a correct depth migrated section. This presupposes, however, a preliminary data processing and interpretation.

Introduction

For several decades the common midpoint (CMP) multiple coverage technique, introduced by Maine (1962), has been broadly accepted in the acquisition of reflection seismic data. In this paper we prefer the designation CMP instead of CDP, which stands for common depth point, or better, common datum point (Hubral and Krey, 1980). (Compare also Ottolini et al., 1984). The data processing which follows the field work, and which was carried out in the analogous technique in about the first decade when this method was used, comprises dynamic corrections and stacking. In the overwhelming majority of seismic surveys these two steps are...
probably still carried out in the conventional manner, though of course no more with analogue means.

But conventional dynamic corrections, or normal moveout corrections, and to a minor degree stacking too, have serious deficiencies. They mainly occur when the 'dips' of the horizons are strong and conflicting, especially when the angle of emergence is large, but these problems have been successfully attacked by various authors. In some older papers the process of migration was carried out before stacking on 'common offset sections', stacking itself remained only as a final step (Sattlegger et al., 1973). More recently 'prestack partial migration' and 'dip moveout stacking' have been introduced and developed in various papers (Claerbout et al., 1980), followed by normal dynamic corrections and stacking. Thus the interpreter must neither renounce on 'unmigrated sections' in the classical sense nor on strong dips.

However, besides the problem of strong dips there are other disadvantages which impair the result of conventional normal moveout corrections and stacking. First, the reflection or diffraction time curve must not be a hyperbola. The so called 'optimum stacking velocity' may result in a least mean square hyperbola which shows considerable deviations from the real reflection time curve. This in turn means obtaining faulty zero offset reflection times and normal moveout velocities $v_{NMO}$ (Hubral and Krey, 1980) as well as impairing high frequencies of the signal. Increased muting is often the main proposal of the data processing engineer. But this would decrease the final signal-to-noise ratio, especially the attenuation of multiple reflections, and the precision of velocity spectra.

Another unfavourable feature of conventional dynamic corrections is that frequency changes by stretching on account of the dependence of the normal-moveout corrections on reflection time. These changes are especially annoying in the far offset traces at small to medium reflection times. Undesirable, but legal muting in the data processing ensues.

Still more undesirable effects may occur in conventional dynamic correction and stacking by normalizing or weighting of amplitudes or by filtering.

Therefore the conventional CMP-stacking calls for a revision, at least in special cases. Various steps have already been carried out in this respect. Schulz and Sherwood (1980) try to avoid the normal CMP stacking, by downward continuation of shot and geophone gathers until they reach a certain depth where 'normal' data processing may be applied without reluctance. Ottolini and Clearbout (1984) replace CMP-stacking by migrating CMP gathers in the $p, \tau$ domain. Other papers in this context are Gazdag et al. (1984) and Schulz (1982).

In this paper we are guided by the following considerations. CMP stacking very much resembles the Kirchhoff migration by summation along hyperbolas. This should not cause a surprise since the main function of migration operators is to collapse the hyperbolic diffractors of time sections into point diffractors. Thus, we were thinking that improvements could be obtained by replacing the conventional CMP-stacking procedure by a genuine migration process. We decided to choose