An independent processing concept based on equivalent offsets: from statics to migration

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ABSTRACT

It is proposed that a procedure based on the principle of equivalent offsets and CSP gathers will provide the necessary tools for accurate prestack migration without the need to form CMP gathers or a stacked section.

The processing of conventional prestack migrations is based on the concept of CMP gathers and creating a stacked section, even if only used for static analysis. The objective of this paper is to outline a processing strategy that is completely independent of both CMP gathers and the stacked sections.

INTRODUCTION

Conventional processing is based on the use of common midpoint (CMP) gathers and stacking to produce an intermediate (or stacked) section. The theory of processing CMP gathers is based on horizontal reflectors, however approximations have allowed the processing of mildly structured data, or required additional processes such as DMO. Full prestack migration as a process, does not rely on the CMP assumptions, however it must still rely on the results of CMP processing to obtain a solution for statics and to evaluate velocities.

Prestack time migration by the equivalent offset method has also relied on intermediate CMP processing for statics. Resent work however, has shown that it may be possible to evaluate residual statics using the CSP gathers as a source for model traces. If that is the case, then data may be processed to prestack migrations without the need for conventional CMP processing.

Since residual statics are the last major step to independent prestack migration, a short review is provided to leads to the concepts of the new method.

CMP STATICS ANALYSIS

Most processing schemes convert the varying elevations of a project to some form of datum. These small (but sometimes large) elevation corrections are assumed to be vertical and use a surface velocity to make the corrections. Refraction analysis of the near surface also aids in this process by providing a more accurate model of the near surface. These models still contain some errors or statics which diminish the quality of the final section. These errors may be estimated and corrected at a later stage in processing by *residual statics* analysis.

Residual statics analysis improved greatly over the 1980’s with introduction of surface-consistent processing. It is assumed that the statics are associated with errors in the near surface, with that the static error for one trace separated into partial static at the source and at the receiver. Analysis of the traces in one shot record enable an estimation of a partial static related to that shot. Analysis of all traces recorded at a same receiver will also reveal a partial static associated with that receiver.

Surface-consistent statics

Surface-consistent statics analysis assumes partial statics of each input trace t_t may be associated with the appropriate static from its source t_s and receiver t_r, i.e.

$$t_t(i) = t_s(j) + t_r(k) \tag{1}$$

where *i* represents the input trace number, *j* the source number, and *k* the receiver number. The values for $t_t(i)$ are estimated by correlating each input trace with its appropriate model trace. We therefore have an over determined set of equations for estimating the values of $t_s(j)$ and $t_r(k)$. There are many numerical methods for accomplishing this task, but one simple method will be discussed to illustrate the process. Before proceeding, it should be noted that additional terms are usually added to equation (1) such as a noise term, or a term involving velocities. These terms are ignored to simplify the following discussion.

To proceed, we sort the statics $t_t(j)$ into shot order, i.e.

$$t_s(j) = t_t(i) - t_r(k)\,. \tag{2}$$

At this point we assume the receiver statics are zero (or that the sum tends to zero), and that an estimate of $t_s(j)$ is found by averaging the measured statics $t_t(i)$ that are associated with a particular shot. After all the shot statics are evaluated, equation (1) is solved for the receiver static $t_r(k)$, i.e.

$$t_r(k) = t_t(i) - \hat{t}_s(j) \tag{3}$$

where $\hat{t}_s(j)$ is now the previous estimate of the respective source static. The new estimate for receiver statics may now be substituted back into equation (2) to get an improved source estimate. Hopefully, repeated iterations between equations (2) and (3) converge to a stable (and reasonable solution).

The problems with this method are low frequency instabilities in the estimates of $\hat{t}_s(j)$ and $\hat{t}_r(k)$, and that of source coupling.

CMP coupling problems

When sources are located at multiple station intervals (e.g. four), a pattern in the CMP gathers form where contributing receivers cycle with the same multiple interval. The effect on surface-consistent statics estimation, is multiple independent static solutions. The consequence of these independent solutions is manifested by unique low frequency instabilities in each of the multiple solutions. Special schemes are required to stabilize these independent instabilities for an effective solution.

Model traces and NMO requirement

The model (or pilot) trace may be found by smoothing the brute stack with a process such as a dip limited FK filter. Each input trace is correlated with its appropriate model trace found at the same CMP location to provide the static $t_t(i)$.

The model trace may also be found by simply summing the traces in the appropriate CMP gather. After each iteration, between equations (1) and (2) , the model traces are usually updated to improve the convergence.

Any method using the above approach requires that NMO removal be applied to all traces. That is the only way all input traces (say within a CMP) can be correlated with a model trace. This requirement introduces significant complications to the statics estimation process. After the NMO removal, the trace is stretched with varying rates requiring the correlation be limited to a relatively short time interval. The resulting statics solution is then only valid for that particular time interval, although it is often assumed to apply to the entire trace.

RESIDUAL STATICS AND CSP GATHERS

Equivalent offset prestack migration provides an intermediate step of creating prestack migration gathers (Bancroft, et al 1994, 1996) for each migrated trace. Input samples are assigned an equivalent offset based on the distance of the migrated trace from the source and receiver, then summed into an appropriate offset bin of the CSP gather. These gathers are based on the principle of scatter points and are referred to as common scatter point (CSP) gathers. They are formed from all traces within the prestack migration gather with no time shifting, and produce high fold in each offset bin. The traces in the CSP gather are filtered, scaled, time shifted (similar to NMO removal), and stacked, to create the migrated trace.

CSP gathers and residual statics

The CSP gathers formed by the above process provide a potential model for surface-consistent static estimation. The significant advantage of a model derived from a CSP gather is that it contains no NMO removal and the estimated statics will apply to the entire trace.

The CSP gather has a much higher fold than CMP gathers, and that *all* sources and receivers (within the migration aperture) contribute energy. This advantage of a higher fold even applies at the ends of lines and may provide statics solutions. In contrast, CMP gathers have low fold and statics at the ends of line are difficult to estimate. Another advantage of the high fold in CSP gathers is every source and receiver (within the migration gather) contribute traces to each CSP gather, eliminating the coupling problem of CMP gathers.

The main advantage of using CSP gathers however is that the solution is virtually *independent of velocities* allowing a rapid convergence. The formation of the CSP gathers does have a slight dependence on the input velocities, so CSP residual statics are not totally independent of velocities. In contrast, the CMP method requires reasonably accurate velocities for a solution of residual statics, but also requires a reasonable statics solution for velocity analysis. The result is a number of iterations between velocity analysis and residual statics estimation.

The correlation time required for CSP residual statics is similar to that required by the CMP method as the number of correlations are proportional to the number of input traces and the number of sources and receivers. The CSP method may take more time extracting the model trace, due to mapping the input trace over the equivalent offsets.

Results using CSP gathers as models for surface-consistent statics

Preliminary result from tests using CSP gathers as models for surface-consistent statics show promise, and are reported in a companion paper by Li and Bancroft (Chapter 17). These results indicate the process to be working, but the problem of low frequency instability still remains. It is anticipated that the low frequency wavelength of the instability will be lower than the CMP instability as the migration aperture is larger than the source-receiver offset. Comparison tests with conventional CMP methods are not yet available.

COMPLETE PROCESSING BASED ON EQUIVALENT OFFSETS

It has be show previously that velocities may be accurately estimated from raw data, even before the application of residual statics (Bancroft and Geiger 1995). It now appears that use of equivalent offsets will allow accurate evaluation of residual statics. If this development of CSP based residual statics continues as expected, then a processing scheme that is completely independent of the CMP method may be developed as outlined in Figure 1.

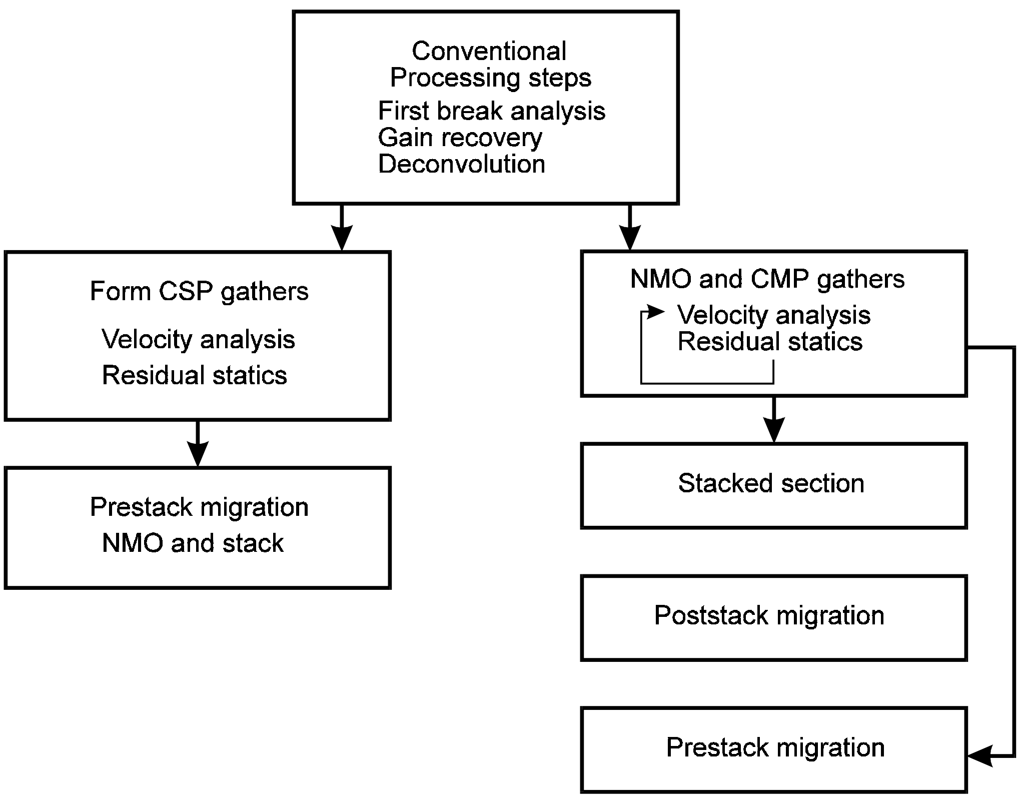

FIG. 1. Block diagram illustrating comparison between CSP and CMP processing.

The preliminary steps of first brake analysis, amplitude scaling, and deconvolution remain the same, but velocity analysis and residual statics will be solved using CSP gathers where convergence is expected to be much faster. The next step is prestack migration.

In addition, it has also been shown that prestack migration, based on equivalent offsets and CSP gathers, may be applied to rugged topography, and that it is possible to approximate a 2-D zero offset section. The method has also been applied to converted wave processing.

CONCLUSIONS

A processing method has been outlined around the principles of equivalent offset migration and CSP gathers and is independent of CMP gathers or stacked sections. Residual statics that are virtually independent of velocities and the first stacking produces a prestack time migration.

REFERENCES

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