Prestack migration to an unmigrated zero offset section

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ABSTRACT

The process of prestack migration of a 2D seismic data set using equivalent offset and CSP gathers creates an intermediate collection of traces - the CSP gather - that can easily be sorted and stacked to create an unmigrated section. Creation of the unmigrated section is insensitive to velocity except at steep dips. Thus the unmigrated equivalent offset section may be the ideal brute stack. In the process of full prestack time migration using the equivalent offset method, the unmigrated stack is useful for the identification of seismic events and structure for velocity analysis.

An unmigrated stack of a portion of the Marmousi model created with a single velocity function compares well with the best unmigrated section created by one of the original Marmousi participants.

INTRODUCTION

Equivalent offset prestack migration (Bancroft 1994 a,b) creates an intermediate step in the Kirchoff prestack migration process by creating a gather from all the input traces for each output trace. Samples from the input traces are mapped into an offset - the equivalent offset - based on the distances from the input trace source and receiver surface locations to the output trace surface location. Only those samples of the input traces that lie within the migration aperture of the output trace are stacked into the gather at an equivalent offset bin location. Samples from a given input trace may bin at a number of adjacent equivalent offsets.

When the CSP gathers have been formed, each CSP gather may be scaled and filtered, or processed similarly to CMP gathers. Conventional algorithms such as noise and multiple removal may also be used on the CSP gathers.

THE UNMIGRATED EQUIVALENT OFFSET STACK

Figure 1 is an illustration of a volume of 2-D data in the space of surface distance (CMP), half source-receiver offset h, and time (t). The 3-D box represents the volume of data with negative source-receiver offsets, or the volume of data that would be acquired with an end-on spread. An equivalent box would map out to the front and contain traces with positive source-receiver offset for a split-spread, although the convention of sign in the diagram is arbitrary. All traces within the volume (migration aperture) will map to an equivalent offset position in the CSP gather, shown in gray. A two-sided CSP gather is shown, with the front representing the positive equivalent offsets coming from traces where the CMP location is greater than the CSP location, and the back representing the negative equivalent offsets where the CMP location is less than the CSP location.

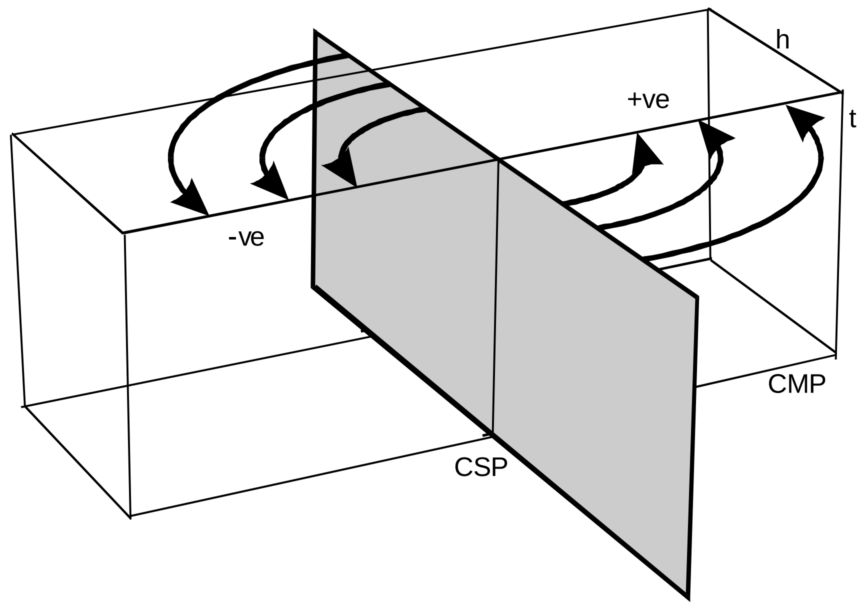


Fig. 1. Prestack volume of data from end-on spread. Two-sided equivalent offset gather where positive offsets are defined when CMP > CSP, negative offsets when CMP < CSP. The offset panels can be rotated and stacked into the CMP position equal to CSP + offset.

The gather traces now lie at specified offsets about the common scatter point (CSP) location. Scatter points located beneath the surface location of the output trace can be considered as lying on the image ray. The scatter points will appear as diffraction hyperbolas in the CSP gather, with the shape of the hyperbola determined by the scatter point time T_0, the root-mean-square (RMS) velocity of the subsurface, and the equivalent offset. Prestack migration is accomplished by applying normal moveout and stacking to the traces in the gather.

In conventional 2-D post-stack migration an output migrated trace is formed from input traces lying within the migration aperture on either side of the output trace. A simplified model for poststack migration can be considered as a three-step process. First, form a volume by rotating the traces from the zero-offset CMP space on either side of each output trace into the space of offset (the reverse of the arrows in Figure 1). Second, scale and filter the traces appropriate to the migration operator. Third apply normal moveout to the traces and stack them to the output trace location.

The formation of the unmigrated equivalent offset stack can be viewed in simple terms as the reverse of the conventional 2-D migration procedure. However, the starting point is two-sided CSP gathers. The gathers can be filtered and scaled appropriate for migration (or not, if desired). The unmigrated stack is created by mapping the CSP gather traces to a CMP position based on the CSP location and the equivalent offset using the following simple formulas:

$$CMP > CSP: \qquad CMP = CSP + h$$

$$CMP < CSP: \qquad CMP = CSP - h,$$

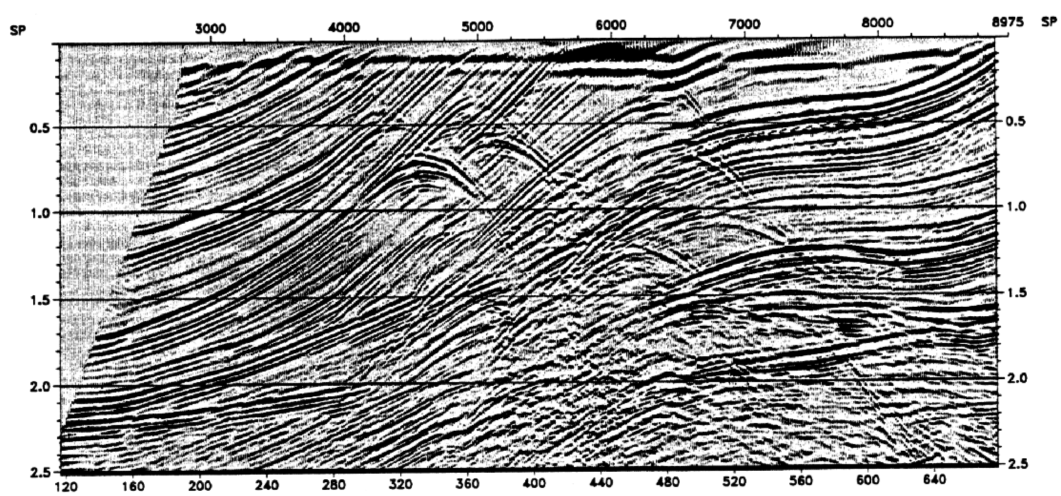
This process is illustrated in Figure 1 by the arrows indicating mapping of the two-sided CSP gather back into the zero offset plane. Thus the unmigrated stack can be produced by a simple trace header manipulation, resort to CMP and stack. Diffractions in the CSP gather will map into the stack about the origin position of the scatter point. These diffractions will sum to constructively and destructively interfere, thereby recreating the unmigrated structure in the section.

Raw CSP gathers can be produced with a very inaccurate velocity model. Thus a brute unmigrated stack can be produced with almost essentially no knowledge of the subsurface velocities. In practice, a single regional function can produce an excellent image.

BENEFITS OF AN UNMIGRATED STACK

The primary benefit of an unmigrated stack is the opportunity to identify events that stack well and should therefore become coherent events in the final migrated section. Continuity and reflection strength, although mispositioned, will provide guidelines for semblance analysis and percentage velocity stacks. The zero-offset unmigrated section is an ideal starting point for depth migration.

MARMOUSI EXAMPLE



, Figure 2. Unmigrated stack of Marmousi data obtained by Prakla.

A portion of the Marmousi data set (Versteeg and Grau, 1991) was processed to produce an unmigrated stack. Figure 2 is the complete unmigrated stack result as obtained by Prakla . Figure 3a is an extract of a portion of the stack between CMP 240-440. Figure 3b is the equivalent offset unmigrated stack produced with a single velocity function. The strength and continuity of events in this highly complex imaging problem is remarkable, given that no moveout was applied to the data. The position of events on the inmigrated CSP section seems to be shifted to the left, but this may be because of geometry inconsistencies between two different versions of the Marmousi data set. The original version of the data set contained errors that were corrected in later distributions.

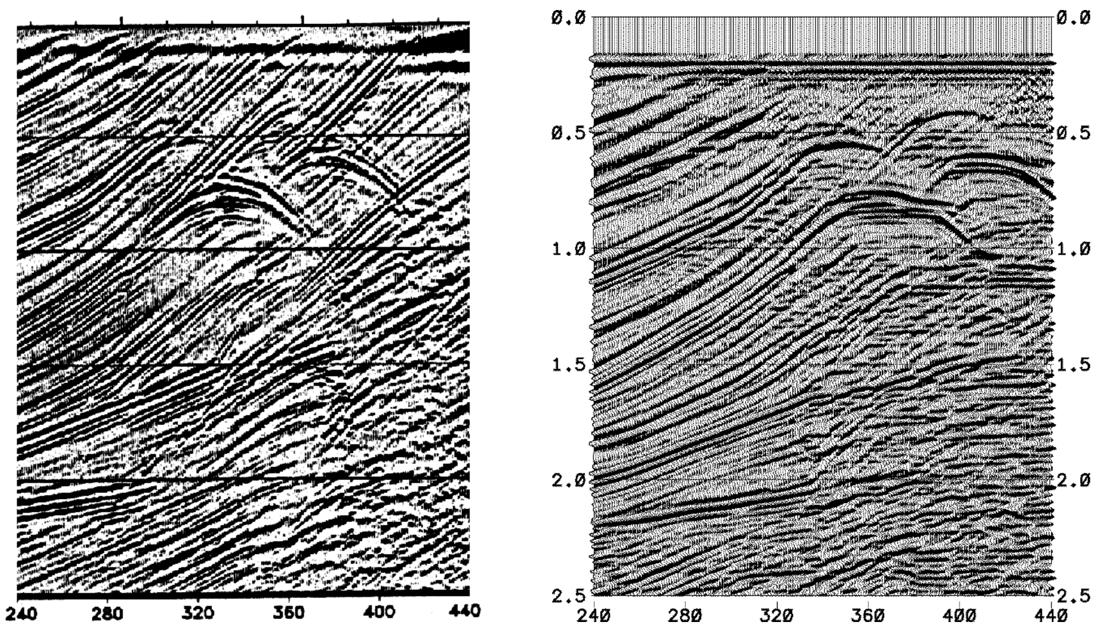


Figure 3 (a) CMP range 240-440 of the unmigrated Prakla stack on the left. (b) Unmigrated stack on the right obtained by equivalent offset gather resorting and stacking.

CONCLUSIONS

CSP gathers can be resorted and stacked to produce an unmigrated section. No prior knowledge of velocities is required.

REFERENCES

Bancroft, J. C., and Geiger, H. D., 1994a, Equivalent offset CRP gathers [for prestack migration]: Expanded abstracts, SEG National Convention, Los Angeles

Bancroft, J. C., Geiger, H. D., Foltinek, D. S., and Wang, S., 1994b, Prestack migration by equivalent offset and CSP gathers: CREWES 1994 Research Report.

Versteeg, R, and Grau, G, 1991, The Marmoussi Experience, EAEG.