PAPER E

CROSSWELL COMMON LATERAL POINT REFLECTION IMAGING

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ABSTRACT

A new method of crosswell reflection imaging is introduced in this paper. It uses previously described gathers (Smalley, 1992) and crosswell reflection velocity analysis (Smalley, 1993), (Smalley, 1994) along with a point to point imaging procedure described in this paper. A high resolution real data reflection image result is shown.

INTRODUCTION

Crosswell reflection imaging is a relatively new field in the crosswell seismology experiment. Some excellent results have already been obtained in crosswell reflection imaging (Lazaratos, et. al, 1992). The objective in this paper is to improve on the XSP-CDP mapping procedure by developing an algorithm that uses the reflection data itself to obtain the velocity model that is used to image the reflection data and therefore takes into account 2-D variation in the medium. The algorithm described in this paper is the Common Lateral Point (CLP) imaging method (Smalley, 1992). The benefits of using this method is that we take into account 2-D variation in the velocity structure which is particularly important as we go to wider well separations, and avoid use of tomogram velocities which may not be the best velocities for reflection imaging. However, the CLP reflection imaging method does keep the point to point mapping procedure of the XSP - CDP imaging algorithm (i.e. the same impulse response). This is important to enable signal to noise separation, particularly in dealing with the shear wave and converted arrivals.

WAVEFIELD SEPARATION

Before full wave form data can be imaged for reflections, it first has to be optimized for reflections. Crosswell data contain many different modes. While the data itself is very complicated, we can go through a fairly simple procedure to separate other wave modes from the reflections. The raw data is sorted into source and receiver gathers. Even though the imaging procedure used to image the reflections will involve sorting the data into different sorts of gathers, the source and receiver gathers provide a good domain in which to enhance the reflections. We aim to do three things to separate the reflections from the raw data:

1) Remove the direct arrival

2) Enhance all upgoing or downgoing events

3) Remove noise such as converted arrivals and tube wave noise.

Removal of the direct arrival requires:

1) Picking the direct arrival travel time from the raw data

2) Alignment of the direct arrival

3) Subtracting off the direct arrival through a trace mix.

Enhancement of the reflections requires:

1) f-k filter to separate upgoing and downgoing reflections.

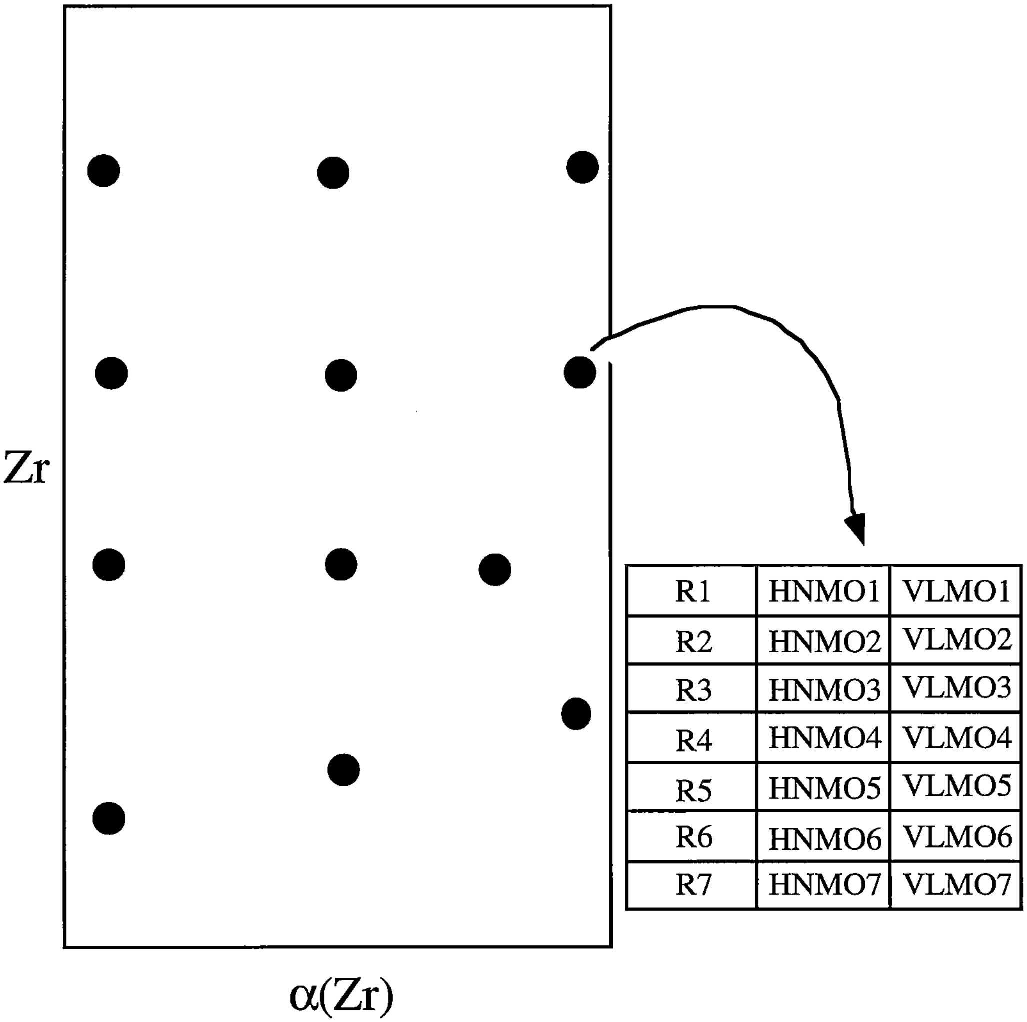
2) f-k filter to filter addition noise.

While the f-k filter is a powerful tool it should always be used cautiously. The pass of the filter should be made as wide as possible while still filtering out the undesired noise. A pass that is too narrow can artificially mix the data. Converted arrivals are the biggest source of noise in reflection data, and should be the primary objective of the second f-k filter after upgoing and downgoing wavefield separation.

INPUT TO THE CLP REFLECTION IMAGING ALGORITHM

The input to the CLP reflection imaging algorithm consists of

1) Wavefield separated data optimized for reflections
2) A set of imaging HNMO and VLMO stacking velocities at control points in space.



R1	HNMO1	VLMO1
R2	HNMO2	VLMO2
R3	HNMO3	VLMO3
R4	HNMO4	VLMO4
R5	HNMO5	VLMO5
R6	HNMO6	VLMO6
R7	HNMO7	VLMO7

Figure 1. A grid of control points obtained from depth conversion and velocity analysis. At each control point is a 3 by N set of radial distances, HNMO and VLMO stacking velocities.

The procedure for wavefield separation was discussed previously. The control point locations and their corresponding HNMO and VLMO velocities (Smalley, 1992), (Smalley, 1993) are from the depth conversion and velocity analysis procedure in another paper in this volume. The set of control points make up a grid in [α(Zr),Zr] space (Smalley, 1992) (Figure 1). At each one of these control points is a 3 by N matrix of radial distances, HNMO and VLMO stacking velocities (Figure 1). In order to obtain a stacking velocity for all input traces that will be included in the final stack, interpolation between the control points is necessary.

CLP IMAGING PROCEDURE

The CLP imaging algorithm is shown below:

```
Reflection Depth Zr {

  Input traces {

     calculate polar coordinates [ $\alpha(Zr)$, $r(Zr)$ ]

     interpolate radial distance bounds[ $r(Zr)$ ]  {input from velocity analysis}

     if $r(Zr) > \min r(Zr)$ and $r(Zr) < \max r(Zr)$ {

       calculate incidence angle $\theta(Zr)$

       Interpolate appropriate HNMO and VLMO stacking velocities
       {input from velocity analysis}

       HNMO correction

       VLMO correction

       Extract sample at $t=0$

     }
```

```
        convert $\alpha(Zr)$ to $x(Zr)$
        }
    }
    stack over $r(Zr)$
```

This is similar to the procedure described in a previous paper (Smalley, 1992). The differences are

1) the determination of the radial distance bounds for a trace and testing to see if the input trace has a radial distances within the given bounds.

2) interpolation of HNMO and VLMO stacking velocities between control points.

The velocity analysis procedure will indicate over which radial distances we can get a coherent summation of signal over a CLP point. The interpolation of HNMO and VLMO stacking velocities is a linear interpolation in the order of:

1) radial distance $r(Zr)$

2) assumed reflection depth Zr

3) the angular coordinate $\alpha(Zr)$ in the polar coordinate system - representing the lateral location.

As stated previously, the CLP imaging procedure has the same impulse response as the XSP-CDP imaging algorithm (point to point mapping), but has a different way of sorting the data and obtainment of velocities for imaging. The comparison between the CLP and XSP-CDP algorithms are:

CLP imaging		**XSP - CDP**
Reflection depth	**parameterization of input traces**	Source or receiver gather
polar coordinates [$\alpha(Zr)$, $r(Zr)$]	**sorting of input traces**	Receiver or source number
2 - D reflection velocity analysis	**source of velocities for imaging**	1 - D travel time tomography
HNMO and VLMO stacking velocities	**velocities used for imaging**	Tomogram interval velocities
2 - D interpolation between velocity analysis control points	**accounting for velocity variation of imaging region**	1 - D raytracing based on tomogram interval velocities
Common ratio or lateral point gathers (Common $\alpha(Zr)$)	**CDP stacking**	1 - D raytracing based on tomogram interval velocities
Point to point mapping	**imaging operator or impulse response**	Point to point mapping

The differences can be highlighted as:

1) sorting of the data as it is processed through the algorithm

2) use of stacking velocities that have 2-D variation for CLP imaging as opposed to a set of 1-D interval velocities for XSP-CDP imaging.

ACCOUNTING FOR 2-D VELOCITY VARIATION: VELOCITY ANALYSIS VERSUS RAYTRACING

In order to do cross-reflection imaging we need algorithms that take into account that there will be variation in the velocity of the medium within the survey; both 1-D and 2-D. The XSP-CDP algorithm takes into account velocity variation by 1-D raytracing. The CLP imaging algorithm takes into account velocity variation by 2-D velocity analysis. Fermat's principle of minimum travel time and stationary ray paths says that a change in the velocity will have a greater effect on the travel time of the ray path than on the actual location of the ray path. Raytracing takes into account the deviation in the ray path due to velocity variation by use of a 1-D tomogram. The CLP imaging algorithm takes into account velocity variation by correcting the traveltime misfit by use of 2-D velocity analysis.

REAL DATA RESULTS

The preceding theory was applied to West Texas data site. In order to attenuate noise primarily due to converted arrivals, we can do an additional sort of the gathers according to incidence angle (Lazaratos, 1992). This is also shown previously in the CLP algorithm description. The angle domain has many properties for signal and noise separation (Lazaratos, 1992). We f-k filter in this domain to eliminate steeply dipping noise. We also needed to choose the appropriate spatial bandpass to optimize the signal. The choice for the appropriate f-k filtering is determined globally while the bandpass filtering is done on a more localized scale. The final results are shown in figure 2. We see excellent detail of the reservoir region (depths 2850 - 2950 ft.) as well as an unconformity at the bottom of the image.

CONCLUSIONS AND FUTURE WORK

We have described a new method for doing crosswell reflection imaging and have shown its potential on a real data set. In the future we want to standardize the velocity analysis so that we can get immediate feedback on the choice of velocities for imaging. Essentially we want to make the velocity analysis procedure automated on the same level as surface seismic imaging.

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REFERENCES

Lazaratos, S., Rector, J.W., Harris, J.M., and Van Schaack, M., 1992, High Resolution Imaging Of a West Texas Carbonate Reservoir: STP vol. 3 No.1 Paper E

Smalley, N., 1992, Crosswell Pre-Stack Partial Migration (Theory): STP vol. 3 No. 1, Paper M.

Smalley, N., 1993, Crosswell Reflection Velocity Analysis: STP vol. 4 No. 1 Paper G.

Smalley, N., 1994, Crosswell Reflection Depth and Velocity Analysis, Paper F, this volume.

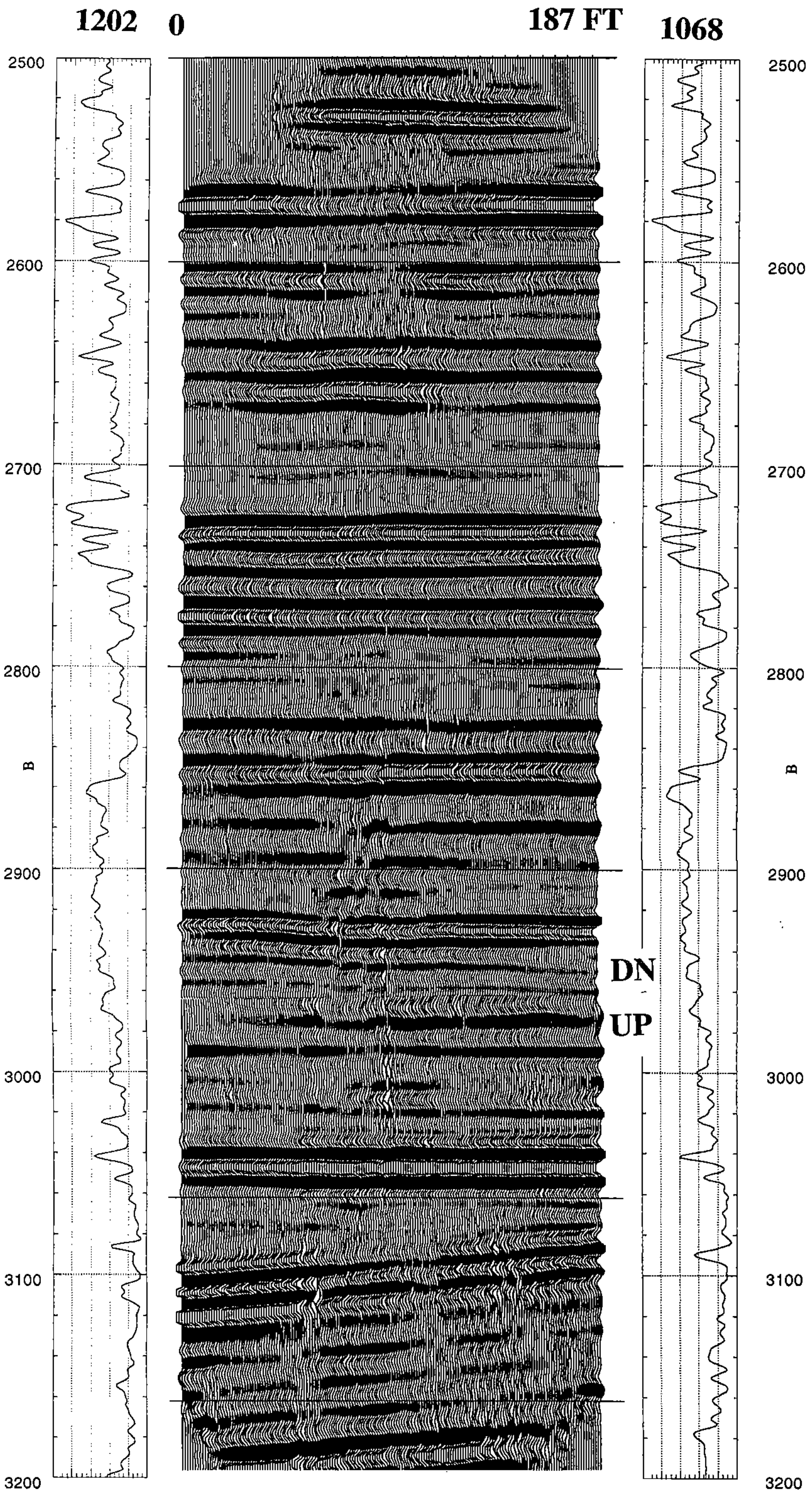

Figure 2. Composite Reflection Image