A METHODOLOGY TO IMAGE TECTONICALLY COMPLEX AREAS USING POLYSTACK™ AND PRESTACK DEPTH MIGRATION

Michel Barut, Eric de Bazelaire, Jean Ravat and Gérard Taveau

*S.N. Elf Aquitaine
Exploration Research Division
64018 Pau Cedex
France*

Marmousi data gave us the opportunity to check and control some new processes for the prospection of geologically complex areas.

We used classical and new software tools for the processing, such as Polystack™, migration by arcs of circles (MIC), post-stack and pre-stack depth-migration (MIGACOR) thus building a methodology to obtain the best possible image of the original model.

One of the key steps in our processing was the zero-phase source deconvolution which appeared necessary when comparing the first results from MIC with the two wells (1504 and 9004). After this special processing it was possible to tie the depth-

migration to the wells.

The main method for changing the macromodel to get closer to the original was the comparison between pre- and post-stack depth migrations.

Careful examination of the Iso-X gathers also gave precious information about the local modifications to be made to the velocities.

The result is fairly close to this original, more in the upper part of the section than in the lower central part, with some good indication of the eroded anticline structure located in the middle of the lowest part of the profile.

Marmousi data and geological surroundings are described in "Bourgeois et al (this volume)".

To find the original model from these data, we used the following method :

- 1 - seismic and well data processing
- 2 - initial model determination
- 3 - model control and enhancement.

The key point of the seismic data processing was the zero-phase source deconvolution which made it possible to tie depth-migrated seismic data from the Polystack™ [1] precisely.

Migration by arcs of circles (MIC) [2] built the base of the first macromodel which was controlled by the raw Polystack™ depth migration. Prestack depth migration (MIGACOR) [3] was used to check the macromodel. The comparison with the raw Polystack™ depth migration suggested in which manner to enhance the model.

A careful examination of ISO-X [4] [5] [6] helped to modify the velocities locally.

A.1 - SEISMIC AND WELL DATA PROCESSING

A.1.1 - First step

After examination of the data, it appears that no source signal was recorded. We have, then, processed the traces with the following parameters:

(see Figure 1)

PROCESSING BEFORE POLYSTACK	
MUTING : TRACE NUMBER :	96, 93, 92, 75, 57, 33, 13, 1
TIME :	0, 0, 460, 700, 1000, 1400, 1600, 2000 MS
BANDPASS FILTER	(5-10-35-70) HZ
DYNAMIC EQUALIZATION WITH A 600 MS WINDOW AND A 300 MS TAPER	
WIENER DECONVOLUTION WINDOW	: 300-2300 MS
OPERATOR LENGTH :	200 MS
PREDICTION LENGTH :	4 MS
BANDPASS FILTER	(5-10-35-70) HZ
HIGH FREQUENCY STATIC CORRECTION ON SHOT POINTS : 9-17-25-33	
CDF GATHER	
INITIAL AMPLITUDE SUPPRESSION TAPER	0 300 350 450 500 3000 MS
FACTOR	.4 .4 .6 .8 1 1

This processing was then followed by the Polystack™ [1] (see Figure 2). The Polystack™ was then used to generate a depth model by migration by arcs of circles (MIC).

The MIC processing [2] is based on the calculation of the optical images of the shot point through all the interfaces. Each interface is decomposed in a series of arcs of circles. The input of MIC is a series of velocity horizons extracted from the Polystack zoom. The output of MIC is a macromodel composed of the main interfaces and the mean value of the geological velocities for each layer.

Figure 1 - Standard processed traces

A.1.2 - Well Data Processing

The sonic and density logs of the 1504 and 9004 wells were processed to obtain, at the same scale as the depth sections, impedance logs and synthetic seismograms. We have also made a tentative correlation of the 1504 and 9004 wells' lithological logs. We have associated the main impedance contrasts with the assumed corresponding lithological changes and correlated these impedance changes between the two wells.

A.1.3 - Control of the MIC depth model

The macromodel of the MIC output was compared to the velocity logs of the wells. It was, then, easy to compare the location of the main impedance contrast on the wells and on the MIC results. We have found the following :

- migrated horizons were too deep. The differences were decreasing with depth,
- the first interval velocity seemed too high,
- the other interval velocities appeared correct or, at least, coherent with the Polystack results.

The explanation was found later :

Times of the horizons were exaggerated by a nearly constant value whose relative effect decreased with depth. The depth of the first layer was the most affected by this timing error. It was caused by a deconvolution problem. Therefore, we decided to re-

Figure 2 - Standard processed raw Polystack™

process the seismic data.

A.1.4 - Seismic Data Reprocessing

A.1.4.a - Seeking for the source signal

With the information given by the acquisition report, we modelised the water-gun signature and performed a source deconvolution. On some trace gathers the result shows a good energy concentration for the near surface horizons but still oscillating signals at times over 600 ms, due to the multiples of the water layer.

Figure 3 - Source deconvolved traces

Thus, we tried to extract the source signal from the traces : in this case, multiples are included in the source signal.

Three steps were used :

- Processing of the Batch velocity Analysis of Polystack (BAP) [1].

- Extraction of the source signal from this BAP between 1 and 2 seconds.

- Calculation of the deconvolution operator to obtain a pseudo-dirac distribution at zero time shift.

A.1.4.b - Reprocessing sequence

The followings steps were used for reprocessing :

- High-frequency static correction at shot points 9, 17, 25, 33.

- Source deconvolution.

- Dynamic equalization with a 600 ms window.

- Spectrum flattening and filtering with a trapezoidal filter : 7-14-30-40 Hz.

- Muting by time versus offset :

offsets : 0, 290, 300, 2575, 2600

times : 0, 0, 284, 2428, 2428

- Polystack (see figure 3)

A.1.4.c - Provisional Model Determination

After processing the Polystack™ (see Figures 4 and 5), we generate by use of MIC the new picked horizons. The new macromodel obtained was controlled and completed with the 1504 and 9004 well information to build the provisional model (colour figure 8).

Another control was done by using the depth-migrated raw Polystack (Figure 6) with the same velocity macromodel.

A.2 - INITIAL MODEL DETERMINATION AND ENHANCEMENT

We used the following information and documents :

- well information, impedance logs and lithological logs,
- time-migrated raw Polystack™,
- depth-migrated horizons by MIC and interval velocities,
- depth-migrated raw Polystack™ (see figure 7).

With geologists, we tried to imagine modifications of the provisional model which were based on controlled data and on results of depth-migration after-stack.

A.2.1- Methodology for enhancement

A.2.1.1 - Techniques used

We used MIGACOR, a before-stack depth-migration program working shot gather by shot gather [3]. We have migrated only one shot out of

Figure 4 - Source deconvolved raw Polystack™

Figure 5 - Source deconvolved Polystack™

Figure 6 - Raw Polystack™ depth migration : provisional model

four. This gives us the ability to gather the same X coordinate traces (Iso-X).

Raw Polystack depth migration gave us easy control of every model. The comparison between the two images in depth, one of them obtained before stack (MI-GACOR), the other one after stack (Raw Polystack), gives two types of zones.

- The first zone is where the results are close. In this case, we are sure that the stacking processing is correct and the velocity field of the macromodel is close to the actual one.

- The second zone is where the results are completely different (for instance, a smile appears on the after-stack migration and does not exist on the migration before-stack). In this case, we are sure that it is impossible to stack correctly : a sharp detail is missing on the velocity field (see figures 7 and 8).

From these measurements and with different optical rules, it is possible to change the velocity field and to enhance the current model.

A.2.1.2 - Hypothesis on the model

Geologists easily con-vinced us that a salt dome existed in the lowest and central part of the section. Also, it was evident to everybody that the base of this "salt" layer was flat, and inclined.

This is how the initial model was defined (see colour figure 8).

Figure 7 - Raw Polystack™ depth migration : initial model

Figure 8 - Prestack shot gather depth migration, one shot out of four : initial model

A.2.1.3 - Methodology

After every prestack shot gather depth migration following the control of a new model by a Raw Polystack™ depth migration, we used the well data to control the left and right end of the lines and tried to correlate the few horizons which the three wells seemed to have in common.

Later, we interpreted the velocity variations in terms of three " $V_o + kZ$ " laws, which were integrated into our third current model (see Figure 9).

The effect on the iso-X gathers is shown when comparing Figures 10 and 11.

When the velocity field is locally close to the actual one, the patterns on the Iso-X gathers are

close to a straight horizontal line. When the velocity field is too fast, the patterns are curved down. When this field is too slow, the patterns are curved up. This method can also be used to modify the velocity field in a "good" way.

Figure 9 - Prestack shot gather depth migration, one shot out of four : 3rd current model

The main geometrical criterium to change from one model to another was to flatten the "base of salt " by changing the shape and velocity of this assumed dome and that of the low-velocity layer draped on it. Progressively, the faulted zone appeared clearly and an anticline-like form appeared below the "base of salt" flat layer - figures 12, 13.

At this step, the seismic horizons on the fifth model (Figure 13), suggested that there is no blind zone corresponding to a salt dome but a lot of different layers with a possible anticline form. However, we did not pay enough attention to this observation.

Evolution of the 4th current model to the last-but-one model was driven by two goals :

- to stabilize the horizon below the dome
- to obtain the correct location of the fast marker that is situated between 1000 and 2000 m.

If the first point was not reached looking at the full sequence of models, we can observe that the salt dome area was constantly reduced from the initial to the last-but-one model.

To locate and shape the fast markers, we use an optical interpretation.

For this we used the raw Polystack™ depth-migration and the prestack depth-migration MIGACOR simultaneously. On the sections there appeared two

Figure 10 - Iso-X gather : initial model

Figure 11 - Iso-X : last model

types of areas :

- either the figures of the two migrations were close to each other : this meant that the set of before stack ray paths could be reduced to the

normal ray and the associated velocity. This proved that the normal ray existed, to the poststack migration was physically correct.

- or the figures were different. Two classes of phenomenons created these differences :

- the straddle reflections [7]
- the wedge effect [8].

Straddle reflection were detected when migration smiles existed on poststack-migration only.

The wedge effect was located at the vertical of the edge of the wedge : after stack, this gave a smile centered at this edge.

These observations gave us the key to fairly well locating the fast marker on the last-but-one model.

Towards the end we tried to draw a last model with interpreted layers over and under the salt "triangle" which their thickness and velocity were computed to flatten the erosion surface of the base of salt (colour figure 9).

The depth-migrated raw Polystack (Figure 14) showed a fairly correct image of the time section over this "salt triangle" and a image correct in part under the eroded surface.

The prestack depth-migration (Figure 15) shows the last result. When we compare the section to the true model, it appears that :

Figure 12 - Prestack shot gather depth-migration, one shot out of four :
4th current model

Figure 13 - Prestack shot gather depth-migration, one shot out of four :
5th current model

- the first thousand meters are perfectly identical to the true model.

- the left part to the abscissa 5000 and to the depth 2400 m the horizon and specially the fast bars are also correctly found. The left part of the anticline form is well suggested.

- the right part from the abscissa 6800 to the end of the section and to the depth 2000 m is very close to the true model, particularly the fastest bars around 1200 m and 1900 m deep,

- in the central area, i.e. abscissae 5000 to 6400 and depth 1000 to 2300 m, the image obtained does not fit exactly, for example,

- at abscissa 5500 and depth 1600 m, the dipping horizon is not entirely identical to the true marker,

- at abscissa 6500 and depth 1600 m, a strong event does not correspond exactly to a fast bar,

- if the right flank of the anticline is suggested on our result, the top and the inner part of it is not clearly visible,

- on the bottom part of the section, i.e. under the salt edges, 2400 m on the left part, 2000 m on the right part, we find indication of the left dip of the eroded structure and an horizon to follow the bottom of the "bright spot". Some events could be correlated on the right to change in the velocities of the exact model. These observations are much easier to interpret when the true image is known.

This indicates that our last image was not completely exact but contained a good proportion of correct events.

A.2.2 - Conclusion

It seems that the process began to diverge when we introduced geological advice... It seems better to end the geophysical process before interpreting the results in terms of geology, because everything can exist in nature...

B - ACCURACY

We are working on several different ways to have indicators which could help to speed up the model enhancement.

Figure 14 - Raw polystack™ depth-migration : last model

Figure 15 - Prestack shot gather depth-migration, one shot out of four : last model

- To check the quality of the seismic data processing :

- sensibility of the migration by arcs of circles (MIC) to the location of the horizons,

- strong deformation of multiples on iso-X gather. This gives a criterion to detect before stack some residual multiples in the data.

- To estimate the velocity error depth-migrated shot gathers and iso-X gathers could be used to evaluate the sign of the interval velocity error.

C - CONCLUSIONS

The processing of MARMOUSI synthetic data was a really fruitful experiment for our

Polystack™ and Migacor programs.

It was, also, a good opportunity to use a methodology which was disturbed by lack of time in its final part : model enhancement.

This experiment brought forth the following results :

- the importance of a very careful source deconvolution process,

- the ability of the Polystack™ to give a stack and a velocity field even in a complex tectonized area,

- the ability of the depth-migrated raw Polystack™ to control the temporary velocity-depth model,

- the robustness of the MIGACOR process.

tive prestack migration, *58th SEG Meeting, Anaheim*, P427-430.

(5) LEMOINE D., VERPRAT M., 1989, Residual Velocity Analysis from prestack depth-migration, *59th SEG Meeting, Dallas*, 1242-1246.

(6) BORONAD P., KESKES N., VERPRAT M., 1989, Stacking Migrated shot profiles by image processing, *59th SEG Meeting, Dallas*, 1253-1257.

(7) BAZELAIRE E. de, VIALIX J.R., 1988, Optical interpretation of seismic events. Part. 1 : an explanation for some unexplainable reflections, *50th EAEG Meeting, The Hague*.

(8) BAZELAIRE E. de, VIALIX J.R., 1988, Optical interpretation of seismic events. Part. 2 : distorted NMO Curves can tell where to drill, *50th EAEG Meeting, The Hague*.

BIBLIOGRAPHY

(1) BAZELAIRE, E. de, 1988, NMO revisited : Inhomogeneous media and curved interfaces : *Geophysics*, 53 - n° 2, 143-158.

(2) THORE P., BAZELAIRE E. de, 1989, Automatic determination of interval velocities and depth patterns : General Case, *59th SEG Meeting, Dallas*, 858-860.

(3) AMESTOY P., GARDNER G.H.F., LARSONNEUR J.L., LEISS E.L., 1987, Phase shift-based prestack depth-migration for laterally varying velocities, *57th SEG Meeting, New Orleans*, 737-740.

(4) VERPRAT M., PERROUD H., LANDA E., HAAS A., 1988, Structural inversion by iterative