

Scaling in time-lapse seismic processing: does it make a difference ?

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ABSTRACT

Two time-lapse seismic lines, the 1991 survey and 2000 survey in the Pikes Peak heavy oil field have been processed with three scaling methods using the KTI processing package. The three scaling methods are conventional scaling, surface consistent scaling and two mean window scaling. The difference between the sections for the 1991 and 2000 survey was calculated using Pro4D. The three difference sections were obtained for each of the three scaling methods. Comparisons with production activities in this field showed that the conventional scaling method with multiple mean windows above the reservoir and one mean window including the reservoir gives the best result. Strong ground-roll and non-surface-consistent amplitude may cause the surface-consistent scaling to fail. The conventional scaling method may work better than the surface-consistent scaling method for land time-lapse data.

INTRODUCTION

Time-lapse seismic reservoir analysis is a procedure to acquire, process, and interpret repeated seismic surveys at the same location but at different production stages. Seismic processing is important as it is the foundation for interpretation. Ideal processing cancels the geology effect on the seismic sections when subtraction is applied to two time-lapse sections and images the dynamic changes within the reservoir. We should optimize our processing flow to obtain high-quality seismic sections to minimize non-reservoir related energy on the difference sections and maintain the true image differences caused by reservoir property change. There are many published examples dealing with cross equalization among time-lapse seismic surveys (Johnston et al., 2000; Lumley, 2001; Rickett and Lumley, 2001). Not many examples can be found on how to apply amplitude scaling for time-lapse seismic processing. In fact scaling is an important step for getting proper cross equalization. Care should be taken to insure the amplitude is properly scaled during cross-equalization. We might need to preserve the signal amplitude and suppress noise amplitude rather than preserve all amplitude from acquisition.

This paper compares different scaling methods for two time-lapse seismic surveys for a heavy oil reservoir in a time-lapse seismic monitoring study. The cross-equalized sections based on these three different scaling methods are obtained. The difference sections were generated and then compared with production activities.

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TWO TIME-LAPSE SEISMIC SURVEYS

Pikes Peak Field is located close to the border of Alberta and Saskatchewan. The producing reservoir is in the Lower Cretaceous Waseca Formation. It is about 450 metres below the surface. The reservoir's porosity is around 0.32~0.36 and with 80% heavy oil saturation. Steam drive technology has been applied to enhance recovery by reducing the effective viscosity of the oil. Husky Oil acquired a set of 2D swath lines in north-south direction in 1991. To investigate time-lapse effects, the University of Calgary and Husky acquired a repeat line on the eastern side of the field. The field parameters for the two seismic surveys are listed in Table 1.

Table 1. Field parameters.

	1991 Field Parameters	2000 Field Parameters
Date	February 1991	March 2000
Sweep length	6 Second	16 Second
Anti-alias filter	8-110 HZ nonlinear	3-164 HZ nonlinear
Source array	3 Vibrs over 20 M	2 Vibrs over 20 M
Geophone Freq.	14 HZ	10 HZ
Geophone Int.	20 M	20 M
Source Int.	40 M	20 M
Geophone array	9 over 20 M	6 over 20 M
Fold	30	66

The 1991 survey is not really a base survey, because production started in 1983 in the region of the southern part of the lines. We will show the detailed well activity in the production and isochron analysis section. Since there is no base seismic survey we have used the 1991 survey as the reference survey. Figure 1 schematically shows the relative locations between line H00-131 and H91-76S. Please note that the scale is not the same in X and Y direction.

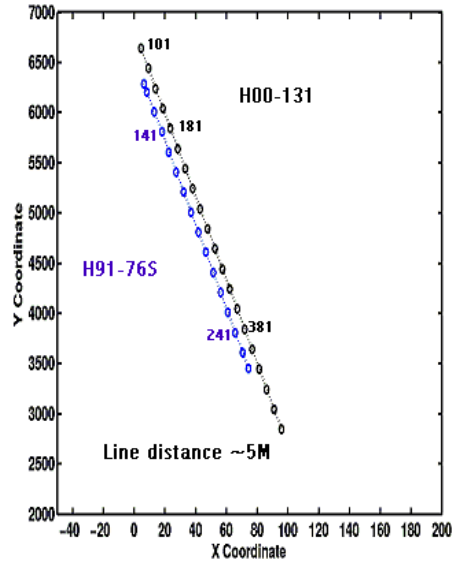


FIG. 1. Relative locations between line H00-131 and H91-76S. The scale is not the same in X and Y directions.

PROCESSING AND SCALING COMPARASON

The two surveys were processed with the same processing flow using KTI's processing package. The basic processing flow was as follows:

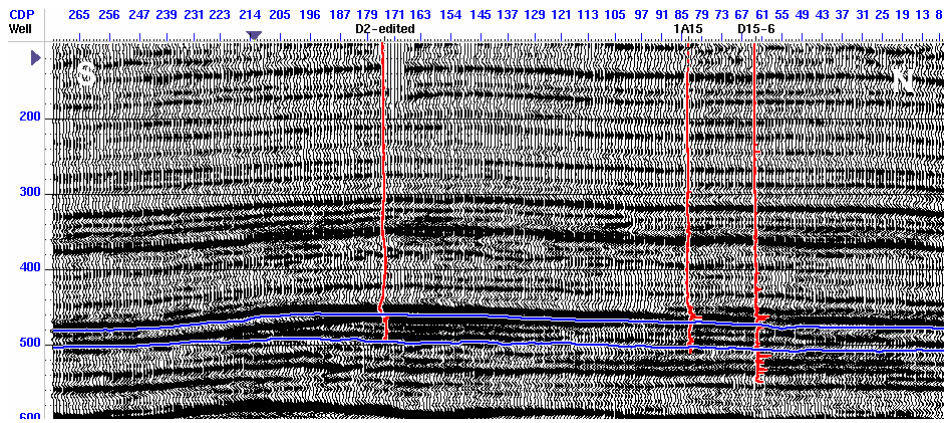
- Reformat
- Spherical gain recovery
- Geometry assignment and trace editing
- Surface consistent deconvolution and partial spectrum balance
- Weathering statics and surface consistent statics
- NMO and mute application
- TRIM statics, amplitude equalization, stacking
- Spectral balancing, FX predictive decon, finite-difference migration
- Phase match and time match (TRIM statics using 1991 as a model)
- Difference plot

Some aspects should be addressed here. Although the two surveys were both acquired in winter, the weathering layer still could be in different condition. We did weathering statics separately. The marker depth is around 200 ms in time and not exactly in the same location in time for the two surveys. Therefore the replaced weathering layer will not be in the same shape for the two surveys. To make the two surveys as comparable as possible, we limited offset to 1200 M which is the far offset for 1991 survey. The 2000 survey has offset as large as 1320 M. We also applied the same mute for both surveys. Because the weathering layer change could influence the deeper events we picked velocities for each survey individually and also calculated surface-consistent statics and residual statics (TRIM statics) individually. In the processing flow we highlighted “equalization” because we applied different scaling at this step. After post-stack migration, we did correlation to check phase and time shift with a window 250 MS – 450 MS which is just above the reservoir and below the weathering layer. After applying a global phase correction and time shift, we ran TRIM statics to adjust short-wave time-shift. At this stage we have obtained final stacks. Then, we do difference using Pro4D on the final stacks.

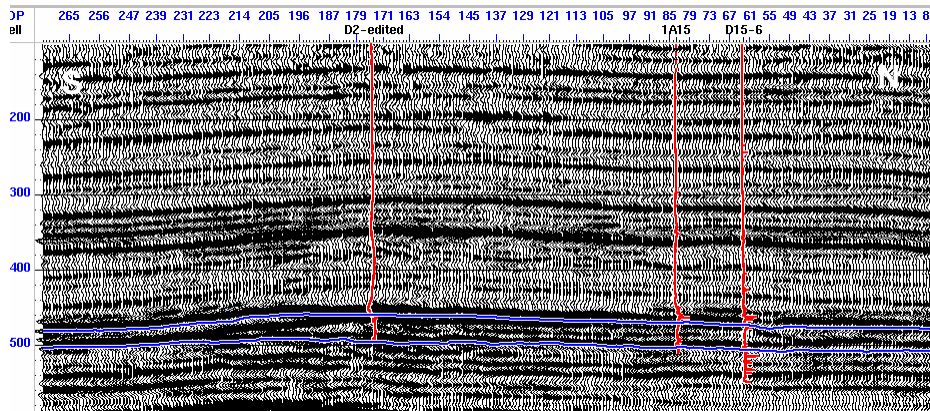
The scaling methods we tested were:

1) Conventional scaling

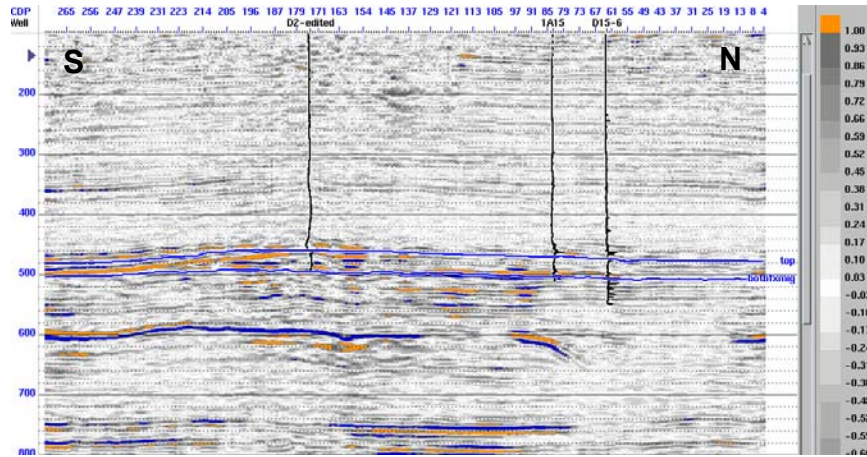
One mean window from 450 MS to 1400 MS with multiple mean windows above is applied. The reservoir is around 470 MS to 510 MS. The multiple windows at shallow depths suppress high-amplitude ground roll and the mean window keeps the relative amplitude around the reservoir. The relative amplitude between offsets may be changed.



a.

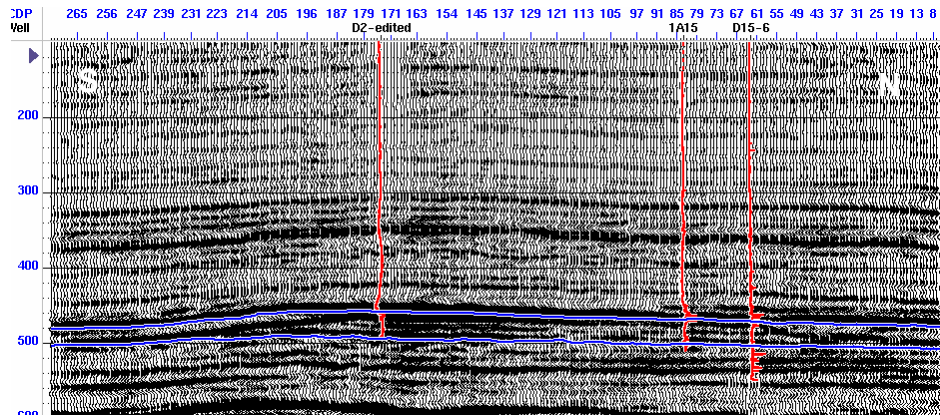


b.

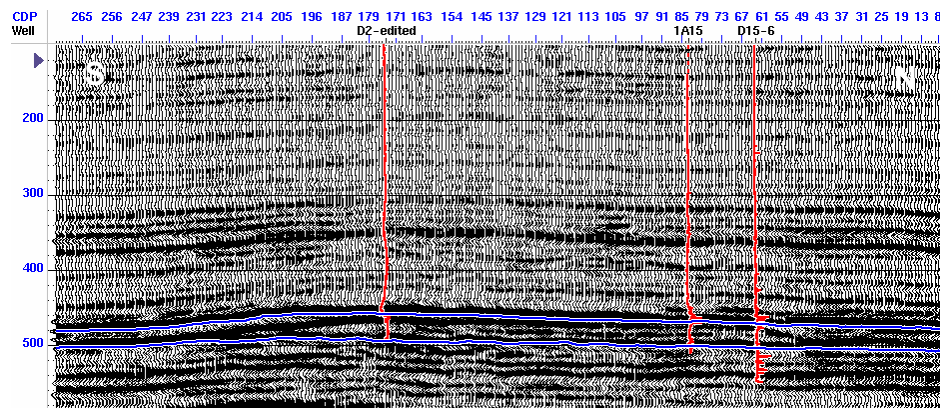


c.

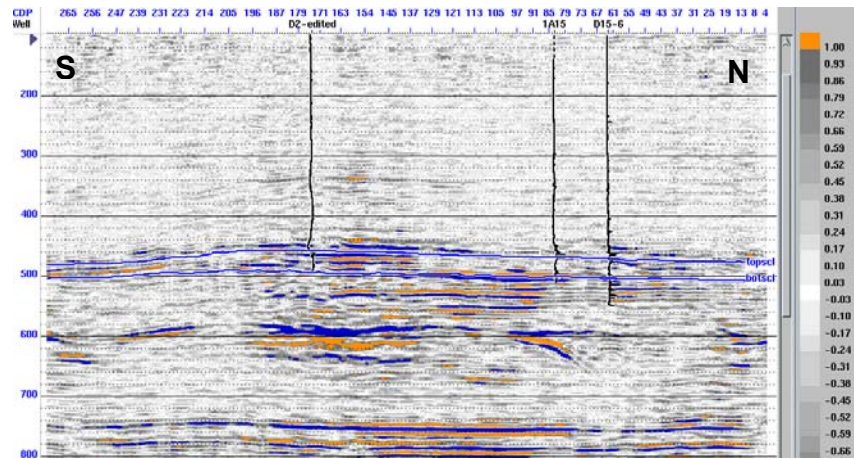
FIG. 2. Final migration stacks with conventional scaling for 1991 survey (a.) and 2000 survey (b.) and their difference (c).



a.

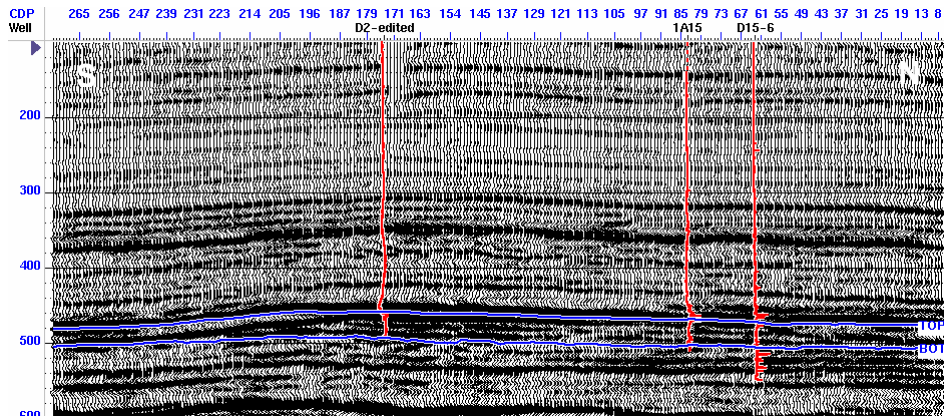


b.

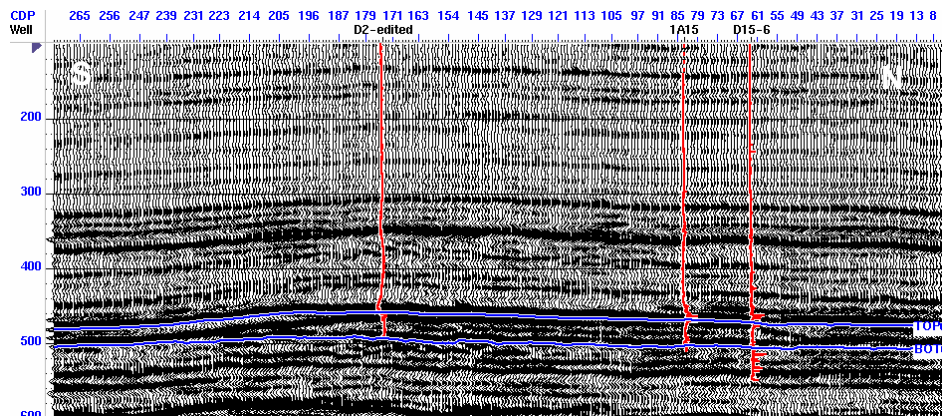


c.

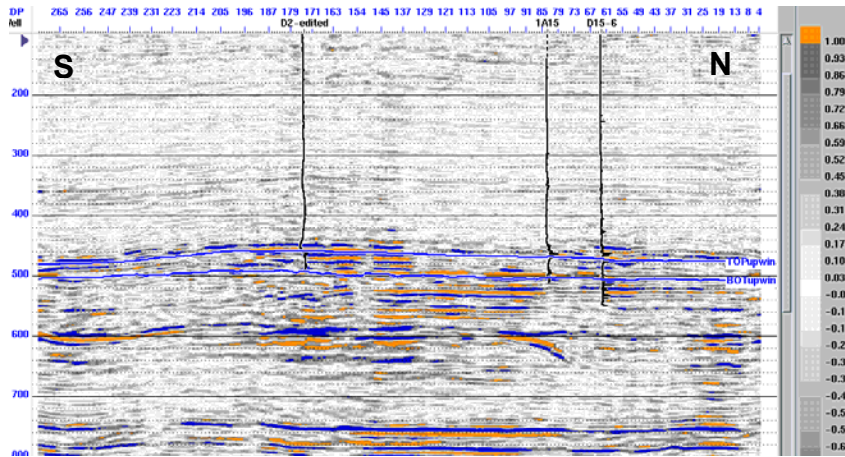
FIG. 3. Final migration stacks with surface consistent scaling for 1991 survey (a.) and 2000 survey (b.) and their difference (c).



a.



b.



c.

FIG. 4. Final migration stacks with two mean window scaling for 1991 survey (a.) and 2000 survey (b.) and their difference (c).

2) Surface-consistent scaling

An offset-dependent one-window scale is calculated on filtered data and then solved into the receiver, shot, and CDP component. We then applied this scale to unfiltered data.

3) Scaling with two mean windows

One mean window across the reservoir from 450 ms to 1400 ms with another mean window above the reservoir from 250 ms to 450 ms and multiple mean windows above the weathering marker was applied. We assume the relative amplitude in the 250 ms to 450 ms range should not change systematically. The change caused by scaling for both surveys should not be much.

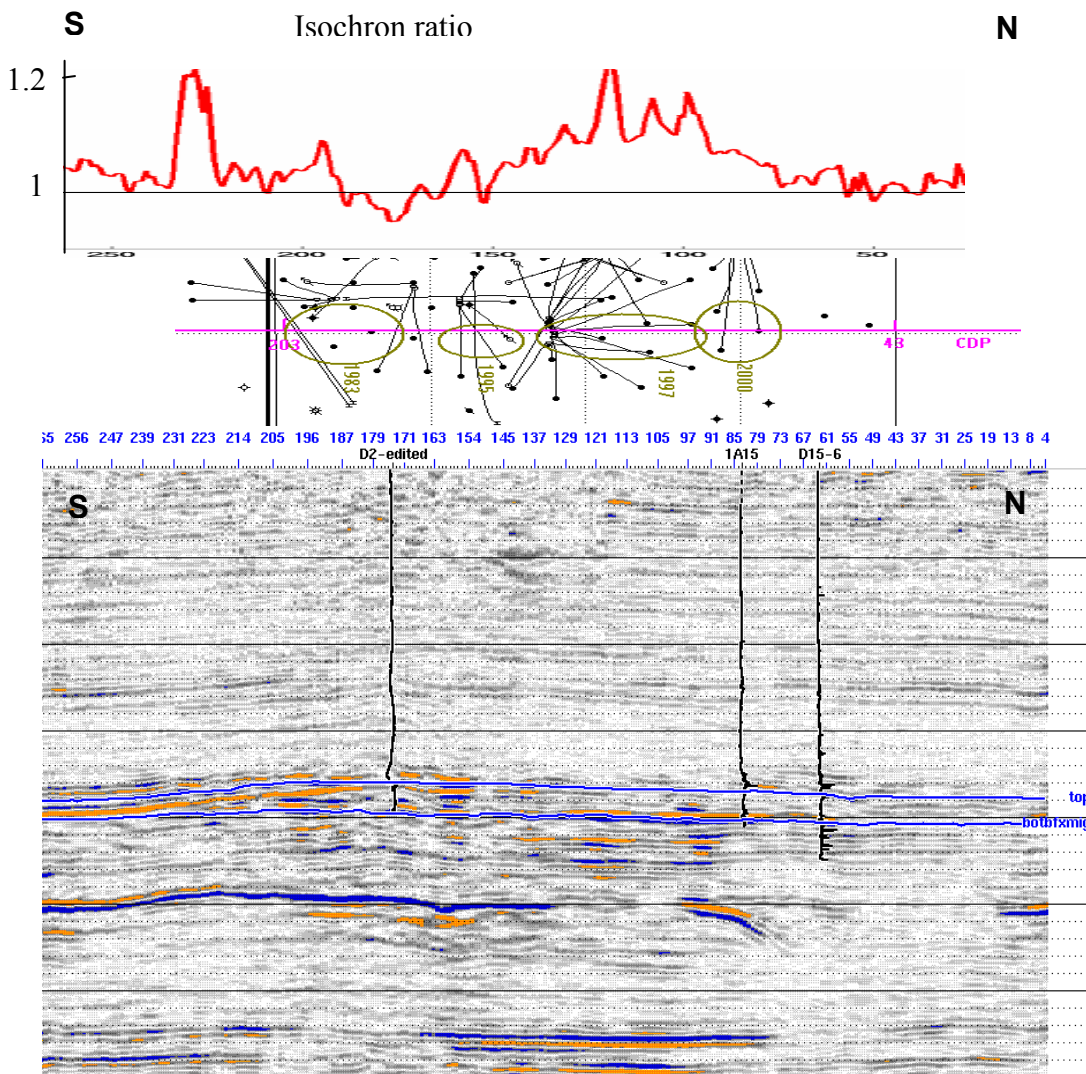


FIG. 5. Difference section from conventional scaling showing well activities and isochron ratio.

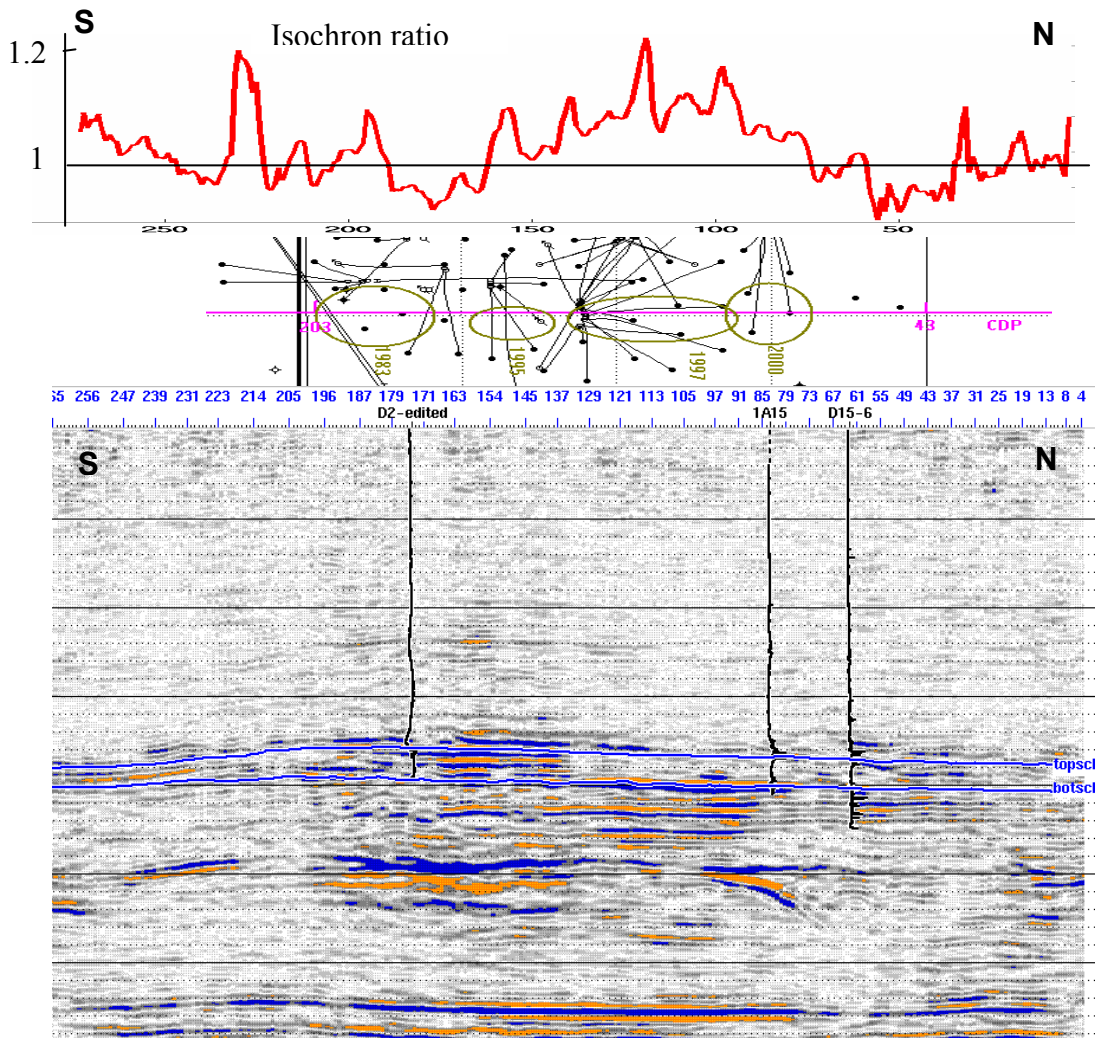


FIG. 6. Difference from surface consistent scaling showing well activities and isochron ratio.

The final stacks for the above three scaling methods for both the 1991 and 2000 survey and their difference are shown in Figures 2, 3, and 4.

PRODUCTION AND ISOCHRON ANALYSIS

Comparing these three difference plots, we can see that most parts are similar but there is still some difference among them. For conventional scaling the northern part of the line (small CDP number) has a relative small difference compared to the southern part. But for the other two scaling methods both the northern part and southern part have considerable difference in energy. On all the difference plots, the difference in the middle of the line is larger than the two ends. Especially, there is a large difference below reservoir between CDP 96 to 149. This difference must be a reflection of a large reservoir property change. To further discuss which of the difference plots is best we have to investigate the production activity and do some isochron analysis. From the Accumap system we obtained well activity around this location. We tied three well logs to the final stacks to identify the reservoir top and bottom. Then we picked the reservoir top and bottom for the six stacks and calculated the travelttime ratio, the ratio from 2000 survey

over the one from 1991 survey. Figures 5, 6, and 7 have the difference sections from the three scaling methods plotted with well activities and isochron ratios. Theoretically the isochron ratios should be the same for the three scaling methods. Figures 5 to 7 have almost the same isochron ratios except for a value drop between CDP 100 to 250. This is probably due to a random error.

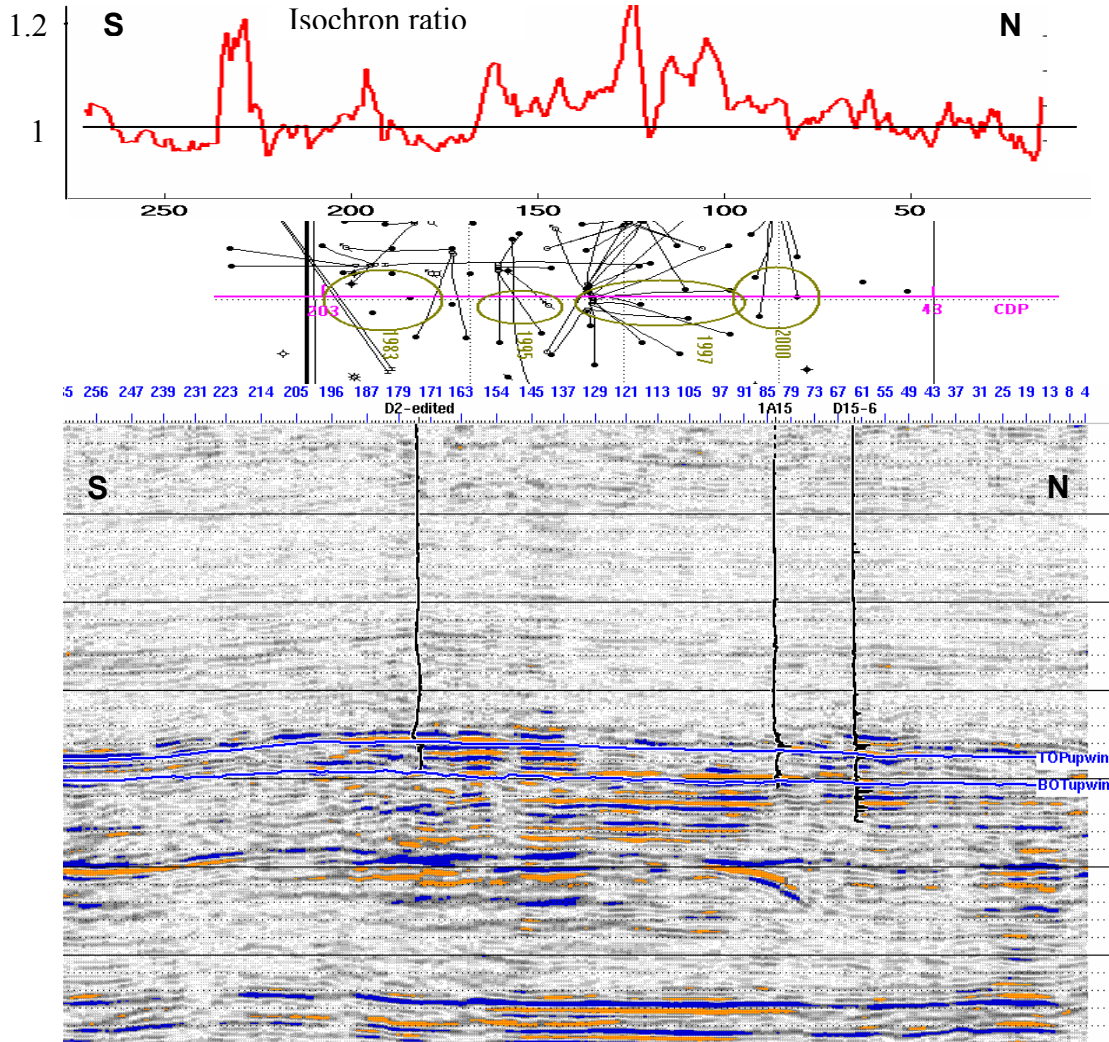


FIG. 7. Difference from two mean window scaling showing well activities.

Well activities are marked by year in a group. Production started from the southern part of the line (left) in 1983. At the time when the 1991 survey was acquired, the production in this part had been carried out for 8 years. The reservoir had already been heated up. The average temperature in this region should be similar in 1991 and 2000. The rest of the reservoir had not been heated in 1991. In 1995 and 1997, two groups of wells had been drilled and started for thermal recovery. The temperature in 1991 and 2000 in this region is much different. The temperature difference caused velocity differences (high temperature causes velocity decrease) and traveltime difference. This is why the difference in the central part of the line is more than the difference in the southern part. In 2000, the production around the north part had just begun for two months previously and the temperature should not have been high in this region yet.

Therefore, there should not be a large difference in the northern part of the line. Given all of the above considerations, conventional scaling (Scaling 1) gives a reasonable result.

Theoretically, surface-consistent scaling should be better than the other two scaling methods but this is not true in some real cases. This has been noticed by Lumley (Lumley, 2001) among others. For the land seismic survey, source and receiver coupling with ground is hard to obtain uniformly. This can be detrimental for achieving true amplitude in a seismic survey. Surface-consistent scaling should work in theory, but when there is unbalanced amplitude from trace to trace, surface-consistent feature is not well maintained. The issue might be how to correct them to gain a better image but not maintain them, especially for the matching window for cross-equalization. For these two time-lapse lines, ground-roll noise is quite large, and it is very strong on the 2000 survey. The conventional multiple-window scale greatly enhanced the signal-to-noise ratio. In a situation where the original amplitude is not surface consistent, one mean window with the same level for both surveys ensures the trace level is about the same.

CONCLUSIONS

Three scaling methods were investigated for two time-lapse seismic lines at the Pikes Peak heavy oil field. The processed difference sections were compared with isochron analysis and production activities. The conventional scaling method with multiple mean windows above the reservoir and one mean window including reservoir gave the result most consistent with production information. The cause for surface-consistent scaling failure could be due to strong ground roll and non-surface consistent amplitude. For land time-lapse seismic processing, the conventional method may work better than the surface-consistent processing method. Time-lapse seismic processing should be set to preserve the signal amplitude and suppress noise amplitude rather than preserve all amplitude from acquisition.

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