The Study and Application of Low Relief Structure Interpretation and Mapping

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Abstract. This article mainly analysed seismic interpretation of low relief structure and some issues encountered during interpretation, then described the effects on the final interpretation results and how to solve the issues. Taking an example of the developed oilfield in South China Sea shows how to select the reliable one within 3 velocity models and make the final structure maps which showed minus errors. It indicates that reliable results should be based on the accurate analysis of the information.

1. Introduction
During seismic interpretation mapping, especially for low relief structure, some structural traps existed in time structural map, while not in final depth structure map. Based on the final analysis, this could be caused by dual factors which are in interpretation and mapping. This article compared two aspects which involved influential factors in structure mapping accuracy and errors reduction.

2. Influential factors of structural mapping accuracy

2.1. Differences between migration velocity and well velocity
There are many types of seismic velocity in accordance with the definition of seismic velocity. The most common one used in structural mapping is average velocity. Variable velocity mapping is usually the results of velocity model based on stacking velocity, and average velocity by well-constrained iteration method, and then time-depth conversion.

However, due to the errors existing in stacking velocity and sparseness of velocity spectrum, the variable velocity mapping often come with big errors. Pre-stack depth migration velocity is on the foundation of fine velocity modeling, which is for pre-stack migration, in terms of many manual corrections together with lower reliability, which has relatively big errors comparing to well velocity, that is why it only reflect the low frequency variation of big sets of layers.

2.2. Synthetic seismogram and seismic well tie errors
Firstly, detailed stratigraphic correlation should be done based on core lithology, petrographic lithology and well correlation, which could generate fine results of well tops. However, seismic events are integrated results of layers with different thickness in the underground. Seismic event only correspondent to the interface of impedance, but the well tops with geology interface does not mean with obvious impedance contrast. So, well tops are not exclusive to relatively strong seismic event.
Secondly, actual seismic wavelet is hard to get, during the process of synthetic seismogram, theoretic wavelet or statistic wavelet extracted from surrounding well seismic are adopted most of the time. Once the phase shifted on the seismic signal, the phase errors of seismic wavelet often contribute a lot on the well correlation results.

Furthermore, synthetic seismogram based on acoustic wave is the main effective way to get time depth relationship. But, in terms of borehole collapse and such measurement errors, the accumulated errors of logging are relatively large. Logging velocity is theoretically different from seismic wave velocity, and most of them has big different. As a matter of fact, VSP velocity should be relatively close to seismic wave velocity.

2.3. Seismic-well tie errors of deviated well
In seismic well tie of deviated well, because of deviation, the thickness of logging curve is apparent thickness transformed from measured depth. Without correction, the error of thickness of logging is much bigger with larger deviation and inclination angle.

2.4. Seismic interpretation errors
In seismic interpretation, it is easy to pick seismic reflection peaks, troughs or zero crossing. However, during to the limitation of seismic resolution, horizon picking and well tops are not quite the same. Assuming the seismic dominate frequency is 30Hz, and seismic velocity is 3600 m/s, seismic wavelength is 120m. If the stratum thickness is 10 m, then the corresponding time length in seismic section will be only 5.6ms, which is the resolution of seismic interpretation cannot reach.

3. Solutions

3.1. High resolution Seismic-well
Many factors may contribute to the final errors of seismic well tie, which we should take into deep consideration.
  1) Borehole collapse and mudding invasion effect on acoustic curve should be corrected.
  2) Statistic and comparison of time depth cure of multiple wells should be done to detect the variation of different wells and eliminate the systemic errors.
  3) Time variation effect should take full consideration in seismic wavelet extraction, which including wavelet frequency and phase shift and etc, extracting time variation wavelet by surrounding well seismic could promote the calibration resolution. If the well distance is not far, with small stratigraphic lateral variation, the similarity of seismic wavelets of wells should be big and kept.
  4) As for deviated wells, traditional ways of seismic well tie may have large different between synthetic and seismic itself, if with large trajectory, which may jeopardize the final results. Trajectory correction should be done by performing trajectory synthetic.

3.2. Fine seismic interpretation
As for low relief structure studies, seismic interpretation resolution is in high priority to maintain. At first, seismic interpretation should have high correlation with seismic event. In seismic interpretation, the interpretation density should be guaranteed, especially in the narrow-faulted area, strong changes and low relief structures, which needs high interpreted density, even as dense as 1*1, to avoid wrongly interpolation without enough control points.

3.3. Velocity modeling
On the top of fine seismic-well tie, using velocity of drilling depth calibration to do errors analysis on migration velocity, which are used in the last mapping of data of depth domain that are usually conducted in following three methods.
  Method1:
Using drilling strata velocity, well tops and seismic horizons to conduct correction on pre-stack depth migration velocity, and then update pre-stack depth migration data.

- Fine structure pping

Method 2:
- Using drilling strata velocity and well tops to analyze pre-stack migration velocity, and then compute residual velocity of all wells.
- Conduct residual velocity modeling by variance analysis in geostatistical methods.
- Using residual velocity model to correct pre-stack depth migration data.
- Conduct uncertainty analysis on residual velocity model, and then do the structural mapping.

Method 3:
- Using drilling, logging data and horizons to build initial strata velocity model on target zone.
- Conduct velocity inversion on initial strata velocity model, make initial velocity model has minimum errors with prestack depth migration velocity by lease square method, which is the final velocity model.
- By compute residual velocity field on the final velocity model, and update the prestack depth migration data.
- Fine structural mapping.

Method 4:
- Conduct regression of velocity relationship between drilling and logging synthetic. This method is much more suitable in the velocity changing not fast areas, but the errors may increase dramatically in the fast velocity changing and large well distance area.
- Polynomial regression structure mapping
- Take concrete analysis on the actual data conditions, using the right velocity modeling, then accomplish the variable velocity mapping.

4. Case Study

4.1. Introduction

![Figure 1. Map of NanHai oilfield (time domain)](image-url)
Figure 1 is the time map of NanHai oilfield. For better reducing errors of interpretation, fine seismic well tie is conducted, and horizon picking dense reach 2*2 in the trap area. Seen from figure, trap is low relief with only 30ms (whole structure), with even lower relief in parts of faulted traps which is only about 15ms. Considering all above, the right velocity model is the key to accurate structural mapping.

4.2. Velocity modeling
For better comparison on the final results, Model 3 is adopted to conduct time depth conversion (model 3 did not conduct velocity inversion). (Table 1)

| No.  | Velocity models                  | Parameters                                                                 | Theory                                                                 | comments                                      |
|------|----------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------|
| Model 1 | $V_0 + KZ$  
(strata velocity and well velocity) | 1) TVD of 5 wells and synthetic seismogram of 21 wells  
2) 2 horizons | gridding well velocity, and interpolate wells constrained by horizons | Better results on well location and surface trend. |
| Model 2 | Bulk velocity model  
(synthetic velocity) | 1) TVD of 5 wells and synthetic seismogram of 21 wells  
2) 2 horizons  
3) Seismic velocity  
(average velocity and RMS velocity) | gridding well velocity, and interpolate wells constrained by horizons, then integrated with seismic velocity | Anomaly happened on parts of seismic data mapping results. (such as stripes) |
| Model 4 | Polynomial regression | 1) TVD of 5 wells  
Polynomial regression | polynomial regression by TVD of 5 wells | better results in well location, away from well location areas could not be controlled. |

4.3. Quality controls
For better control on the final results, we analyze them from results of 1D (well location), 2D (surface), 3D (cubic), in order to select the best final velocity model.

1) 1D (well location) QC

![Figure 2. Errors on well location after TVD conversion](image)
Table 2. Errors analysis based on 3 models

| Velocity model | Errors analysis (feet) | Target zone | Reference zone |
|----------------|------------------------|-------------|----------------|
| Model 1        | -6.15                  | 11.11       |                |
| Model 2        | -8.46                  | 11.84       |                |
| Model 4        | -7.08                  | 26.85       |                |

2) 2D (surface) QC

Besides the well location analysis, we conduct examination on the final structural map (Figure 3). Given the trend on the surface extension, Model 1 and model 3 have the same trend, but model 2 is smoother on few minor structure, while Model 3 without well constrain has the relative biggest errors.

Figure 3. Comparison of different velocity models

Figure 4. Final depth structural map (depth domain)
3) 3D (cubic) QC

Volumetric calculation is conducted on the different depth structure mapping of three velocity model, which are bounded by the spilling point. Model 1 and model 2 has quite the same results of volume, while model 3 is different from the other two. But all of three model has errors no more than 3%, which demonstrate that velocity models have different errors but not mistakes (Figure 4).

5. Conclusion

Based on different methods for low relief structure interpretation and the application of case study, 2 key points can be included:

1) By comparing different velocity models and conducting quality controls, Model 1 is approved to be the best one with good depth mapping results.
2) For different areas, only the most suitable velocity model is the best velocity model (key influential factors), but not the more complex the better for velocity model.

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