A case study: Enhanced 3D interpolation combined with 3D structural modeling from 2D seismic data

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Summary

Enhanced 3D interpolation presented in this case study is a method of guiding interpolation of 2D seismic data along 3D geological model, generated from 2D structural models and dip fields. This allows distances of kilometers to be interpolated, something that would otherwise not be possible with conventional interpolation techniques. Two case studies will be presented, one in the Cooper Basin (onshore), located across the state border of South Australia and Queensland, another in the Beagle Bedout offshore area in Northwest Australia.

Introduction

In the oil and gas industry, there are a lot of the 2D seismic data from 1960s or 70s to current. However, it is not easy to obtain a meaningful 3D interpretation from the existing 2D seismic data because the timing, amplitude, and frequency contents are different. Whiteside et al. (2013) developed a method to utilize 2D data for 3D interpretation, which is called 2D^{cubed}. This enhanced 3D interpolation is a method of guiding interpolation of 2D seismic data along 3D geological model, generated from 2D structural models and dip fields. This allows distances of kilometers to be interpolated, something that would otherwise not be possible with conventional interpolation techniques.

Workflow

The details of the method were written in Whiteside et al. (2013) and O'Keefe et al. (2017).

The methodology includes (Figure 1; O'Keefe et al., 2017)

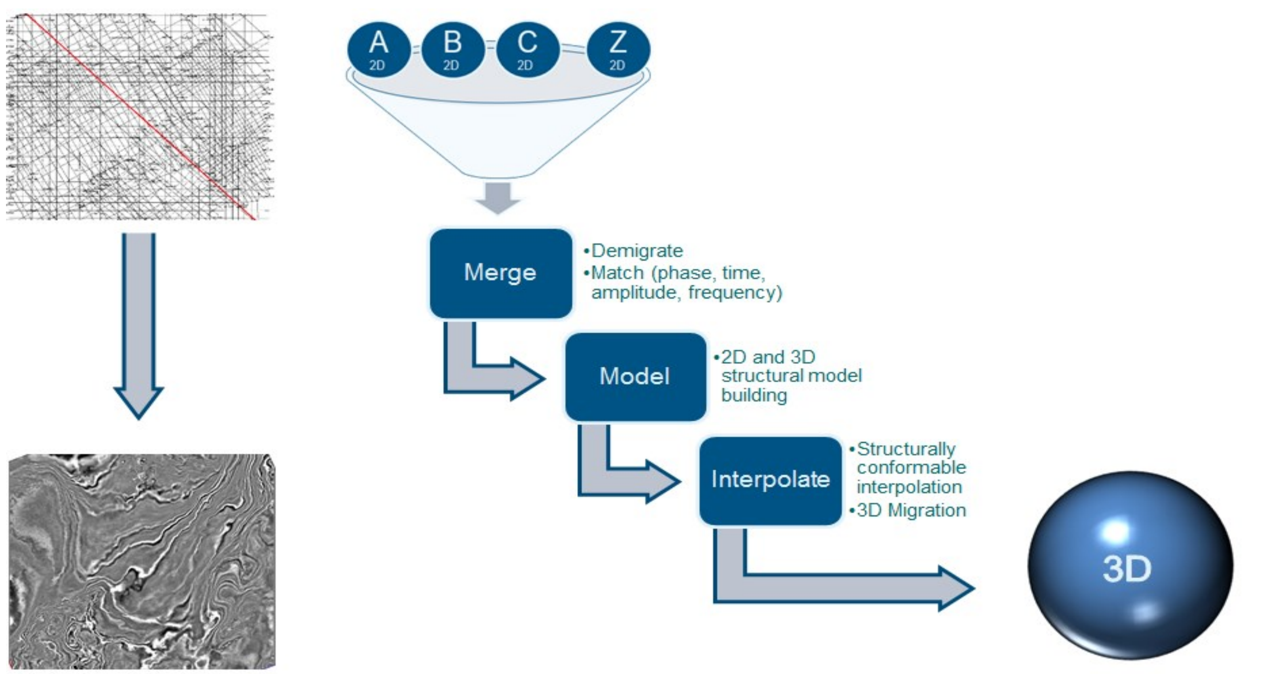

Figure 1: Workflow of the enhanced 3D interpolation

1. Poststack 2D demigration of input 2D lines to generate data closely resembling 2D stacks at zero-offset
2. Matching amplitude, phase, spectra, and time to minimize structural changes at intersection
3. Building 3D geological time model consisting of a dense set of horizons to guide interpolation
4. Interpolation of the 2D seismic to a 3D cube
5. 3D poststack migration

Case Study 1: Australia's North West Shelf

The project is located in the Beagle Bedout offshore area in Northwest Australia and covers 38,400 km^2 and consists of 42 surveys (Figure 2). The objective is to obtain a 3D seismic volume for evaluating regional structural features. The 2D surveys have varying acquisition: NS, NE, EW, SW and NW; and line spacing varying from 2 km to 8 km. The area consists of folds, faults, unconformities and complex stratigraphic features.

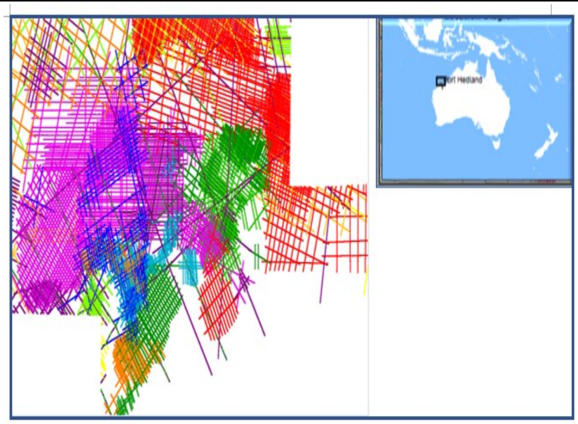

Figure 2: Location map of case study 1 – Beagle Bedout project

Input data preparation, demigration and survey matching:

The input data preparation for demigration and consecutive processing includes assigning x and y values, line and CDP numbers and scaling. The data is also resampled to 4 ms and windowed to maximum time of 6 s in order to avoid differences in sampling and maximum time of imaging and minimize noise.

After the 2D stacks for all surveys are verified, the data is demigrated using the corresponding velocities. In some cases, for lines without velocity, velocity data is obtained by 3D interpolation of available 2D velocities and extraction for missing 2D lines. The demigration is important because 2D migration does not properly position all events; and by demigrating and 3D migration after interpolation, events can be positioned more accurately (Whiteside *et al.*, 2013). The demigration is followed by trimming taper zones to exclude swings, merging lines, and survey matching. In the survey matching, a survey in a target zone with good frequency content and amplitude balancing is selected as a reference survey, and amplitude, phase and frequency spectrum of all data from other surveys are matched to the base survey. After matching, a line-tie adjustment is applied by calculating time shifts based on windows at every intersection. A maximum time shift of 15 ms at the top of the record and 25 ms at the bottom of the record is calculated. Figure 3 shows the result from survey matching showing better amplitude content and continuity of events.

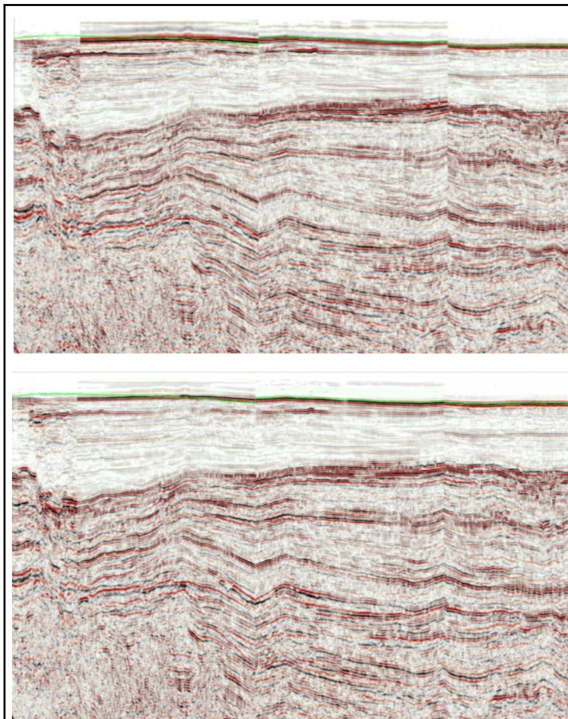

Figure 3: 2D data before (top) and after survey match (bottom)

2D and 3D structural modeling and 3D seismic interpolation

In the 2D modeling, a dip field and a dense set of horizons are generated from the survey-matched and tied data. The horizons are continuous between all 2D lines and follow the geological structure. Then the 2D structural model and dip field are used in the 3D model building., which results in a 3D structural model.

The input to the 3D seismic interpolation is the survey-matched and tied 2D data and the 3D structural model. During the interpolation, real traces are taken from the nearest lines within radius of 6 km and mapped to an output location using the structural model. The interpolated data show a less noisy and continuous 3D image of the subsurface (Figures 4 and 5)

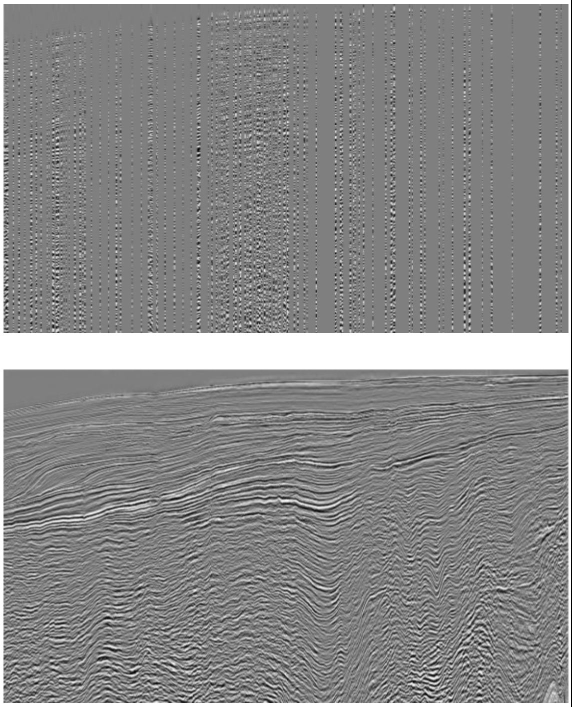

Figure 4: 2D data before interpolation (top) and after 3D interpolation (bottom)

3D migration and cosmetics

At this step, 3D velocity volume for migration is derived by a 3D interpolation of the original 2D velocities along the 3D geological structures. Then the 3D interpolated stacks are migrated using 3D Kirchhoff Time Migration. Following the migration, time-varying filter and signal enhancement are applied to increase signal-to-noise ratio and continuity of coherent events (Figure 5). The resulting image shows improved continuity of events, enhanced faults and events are more correctly positioned.

Case Study 2: Cooper Basin

The project area is in the Cooper Basin, located across the state border of South Australia and Queensland (Figure 6). The project started with 2D data from 21 different vintages, consisting of 1127 seismic lines. Among the lines for the work, only 71 velocity profiles matched to the seismic data.

The primary goal of the project was to convert 2D data from 21 vintage surveys to a migrated 3D volume by the enhanced 3D interpolation technology and workflow so that 3D interpretation is possible in the interesting area between 1.5 to 2.5 second.

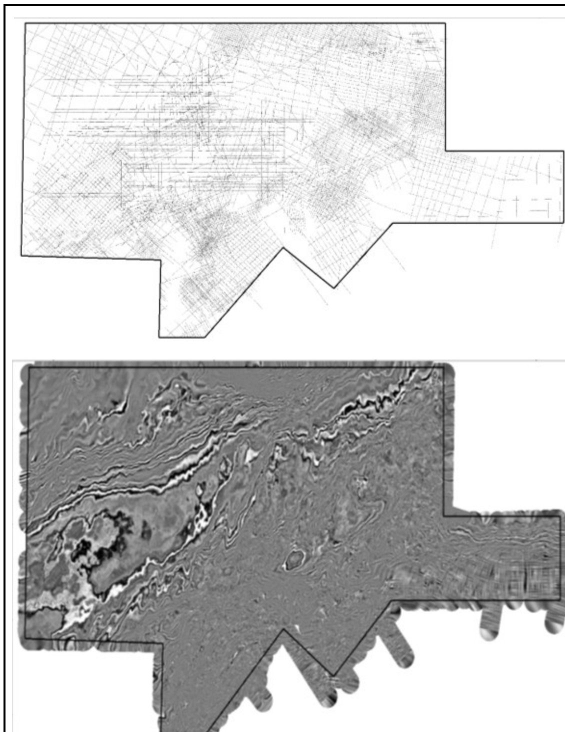

Figure 5: Comparison of Time slices: input 2D data (top) and 3D interpolated and migrated data (bottom)

In this project area, there exists a 3D survey which provides structural horizons. After 3D interpolation guided by the 3D structural model which was derived from the matched 2D seismic data, the horizons were overlaid on the interpolated data. The horizons from the 3D survey are almost perfectly tied to the seismic (Figure 7). It means that the 3D interpolation method presented in this abstract provides decently interpretable 3D image from 2D lines.

Finally, Figure 8 shows time slices before and after 3D interpolation. It is almost impossible to interpret 3D structure from 2D, but 3D interpolation makes it possible without 3D seismic survey.

Conclusions

Enhanced 3D interpolation combined with 3D structural model from 2D data makes it possible to do 3D interpretation from many different vintages of 2D seismic. Although this methodology sometimes reduces the detail structures of 2D seismic, it is very helpful to obtain a regional interpretation. Furthermore, the enhanced 3D interpolation might maximize the usage of the existing 2D data.

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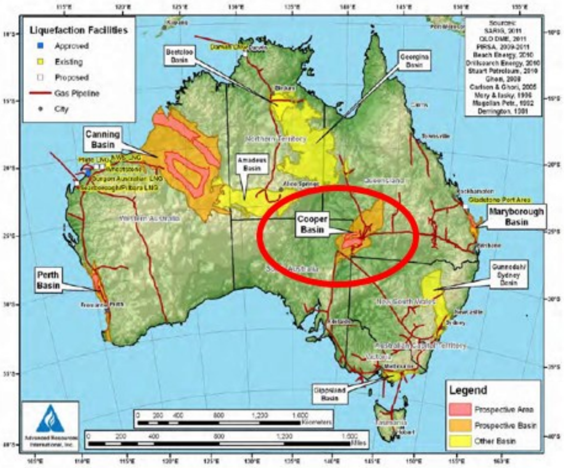

Figure 6: Location of the case study 2 – Cooper Basin

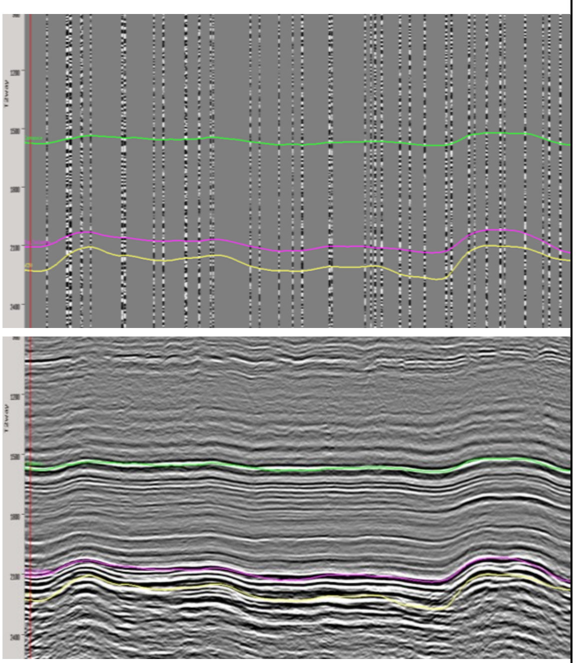

Figure 7: 3D survey structural horizons are overlaid on before 3D interpolation (top) and after 3D interpolation (bottom). 3D interpolation combined with 3D structural modeling predicts the real 3D geologic structures adequately.

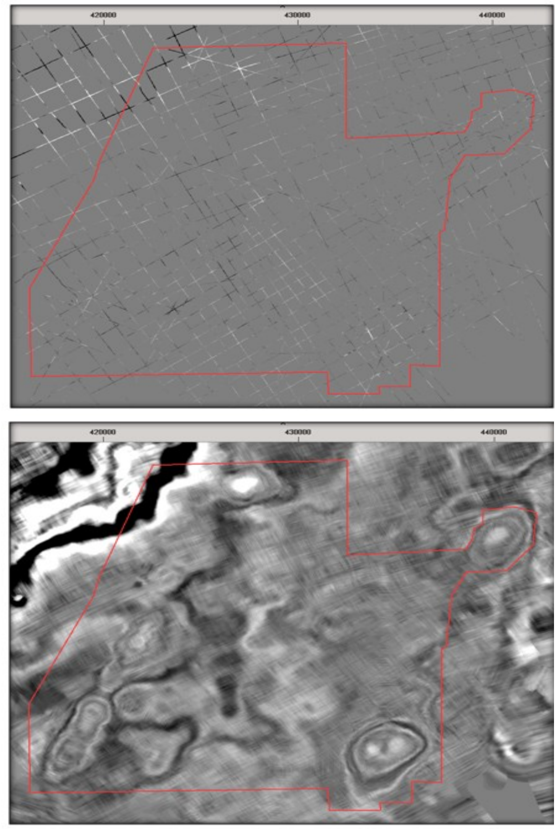

Figure 8: 2D seismic (top) and 3D interpolated data (bottom). The structures in 2D are preserved in 3D interpolated data.

Acknowledgments

The authors would like to thank Steve Hightower, Yi Huang, Subodh Notiyal, and Amit Pendharkar for their valuable contributions during the project. We thank the management of TGS for permission to publish this study results and images. The authors thank Connie VanSchuyver for proofreading.

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