The effects of anisotropy on Canadian foothills exploration : A case history

Margaret A. Stratton, Anadarko Canada Corporation, and Peter Vermeulen, Veritas Geoservices*

2005 CSEG National Convention

Geophysical Innovations Made in Canada 2005 CSEG National Convention

Summary

This case history demonstrates the impact of anisotropy on the results of exploration in the Canadian foothills. The results of recent drilling show the dramatic impact of anisotropy on the positioning of the pre-drill target location. This impact creates cost overruns from a drilling perspective as well as increased cycle time to production. In some cases, by optimizing the location of the borehole on the structure to encounter an area of increased fracturing, higher production rates have resulted. An intangible impact is a perception of increased technical risk on the play if the cause of the error in positioning is not fully understood. This analysis is based on drilling information gained from several wells in an area covered by a large 3-D seismic survey in the Alberta foothills.

Introduction

The primary reservoir unit in the central Alberta foothills is the Mississippian carbonate of the Rundle Group. The target horizon is overlain by a thick sequence of interbedded sandstone, shale and coals of Mesozoic age. Although there is ongoing exploration for secondary Mesozoic prospects in the area, the boreholes described in this case history target the Paleozoic carbonate at approximately 4000 meters in depth.

The exploration objective in the study area is the culmination of Laramide age thrusted carbonate sheets. The structures vary from 500 to 1 kilometer in width. Initial well locations were determined from the interpretation of pre-stack time migrated data.

Dips in the Mesozoic anisotropic overburden caused lateral mispositioning of reflectors on the pre-stack time migrated data. This is evident in the study area where two separate structures were drilled with varying results (Figure 1). These differences are due to the range of dips encountered in the clastic overburden.

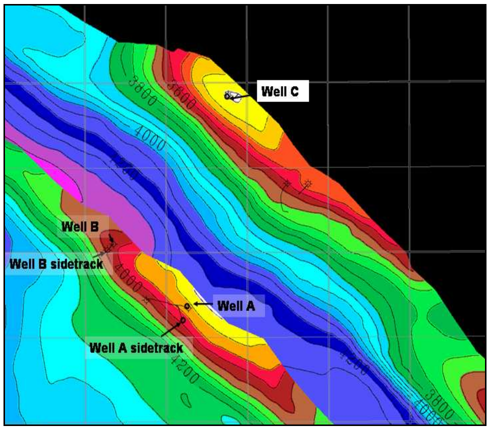

Figure 1. Structure map top of Nordegg

Interpretation and Drilling Results

The data was mapped on high quality 3-D data acquired in 2000 which provided a high degree of confidence in the lateral continuity of the structures. The primary seismic marker used in structural mapping is the Jurassic Nordegg with the Mississippian reservoir lying conformably below.

Well A in the western structure was positioned with the objective to hit the reservoir unit at -2352 subsea. The well was terminated when evaluation of open hole logs, sample cuttings and dipmeter data indicated that the well had drilled down the forelimb of the structure. At -2430 subsea, the well was terminated in the Fernie shale.The Well A sidetrack was offset 238 meters to the southwest at the reservoir level where it penetrated the Rundle with positive results. A similar history occurred down dip in the offsetting Well B which missed the structure out front in the initial well bore but was again sidetracked 167 meters southwest where it encountered the Nordegg and the underlying Rundle reservoir unit.

Seismic interpretation for both wells showed that the initial well bores were positioned optimally for encountering the thrusted Nordegg and Rundle reservoir on or near the crest of the anticline, however this was not confirmed from drilling (Figure 2). Dipmeter data from surface to TD in the initial Well A borehole showed that the overlying strata dipped an average of 20 to 50 degrees to the southwest. The well penetrated the Mesozoic Blackstone and Blairmore formations in which the dominant lithology is shale with some coaly and silty intervals. These overlying dipping clastic intervals can account for the required southwesterly offsetting sidetracks for Well A and Well B.

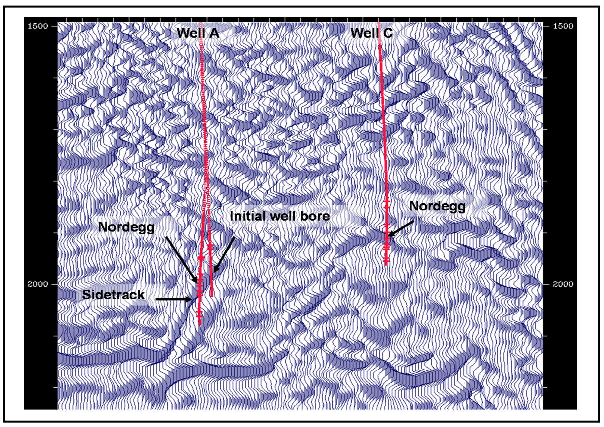

Figure 2. Portion of seismic profile through Wells A and C. Note lateral positioning error of Nordegg in Well A initial location.

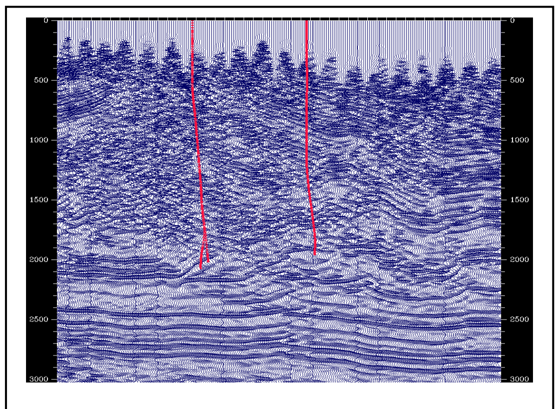

Figure 3. Seismic profile through east and west structures. Note conflicting dips in overlying strata at Well C. Strata in Well A has southwest dips as confirmed from dipmeter data.

Well C penetrated the Nordegg and Paleozoic section without a sidetrack. The overburden at this location has different dip and orientation than that on the Well A structure. The overlying Blackstone Group has approximately a 40 degree dip to the east. Below the main detachment in the Blackstone lies the Blairmore group which dips to the west. This differs from the Well A structure where all overlying sediments dip to the west. Conflicting overburden dips in the eastern structure could have possibly negated the anisotropic effect of dipping clastics (Figure 3).

The concerns over the effects of anisotropy based on the knowledge of the lithology and structural complexity of the area led to the decision to apply 3-D pre-stack anisotropic depth migration to a subset of the regional survey in which several Paleozoic tests could be calibrated. The processing was done concurrently with the drilling of a development well on a structure where the initial borehole missed the target horizon northeast of the leading edge.

Discussion

In dipping strata, the anisotropic symmetry axis is tilted causing reflection point smearing and lateral positioning errors due to sideslip effect (Vestrum, 2002). While the Thomsen parameters epsilon (ε) and delta (δ) may stay the same for the overlying geology, the dips of the strata may vary laterally which will affect the magnitude and direction of the reflector positioning and smearing (Vestrum, 2003)

Thomsen's parameters of ε= .11 and δ of .03 were used for the overburden based on previous foothills studies (Vestrum, 2003). Based on sonic information, the overlying sediments do not exhibit strong lateral or vertical velocity variations indicating that the overlying dipping strata has the largest impact on the seismic imaging. Bedding dip orientation determined from dipmeter data and seismic interpretation were used to guide the model.

Results of the anisotropic depth migration show the Nordegg reflector to be repositioned in alignment with the sidetracked well. The reflector position on the easternmost structure did not change dramatically but improved the well ties.

Conclusion

Drilling of exploration prospects located beneath steeply dipping clastic formations benefit from correcting for the effects of anisotropy by improving the accuracy of the location of the subsurface target. If a sidetrack operation can be avoided, the cost of properly migrating the data will be substantially less than the added sidetrack drill cost and the impact of longer cycle times to production.

Acknowledgements

The author would like to acknowledge Time Seismic for permission to show the seismic data used in this case history. In addition, I would also like to thank Anadarko Canada Corporation for permission to publish these results as well as recognize the efforts of Veritas Geoservices for their work on the seismic dataset.

References

Thomsen, L., 1986, Weak elastic anisotropy: Geophysics **51,** 1954-1966.

Vestrum, R., 2002, 2D and 3D Anisotropic depth migration case histories, 72nd Annual Internat. Mtg., Soc. Expl. Geophys.

Vestrum, R., 2003, Imaging Below Dipping Anisotropic Strata, PhD Theses, University of Calgary.