Fracture Detection and Reservoir Property Estimation using Full-Wave, Full Azimuth Seismic Data

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Summary

The XinChang field in the western Sichuan Basin of China produces gas from fractures in tight sandstone reservoirs. An integrated field study was performed using full wave (full offset, full azimuth multi-component) seismic data. The low (2% to 4%) porosities in these reservoirs has little influence on production. The key to locating the best well locations included lithology discrimination and identification of the fractured areas.

The impedances of the sands and shales are very similar and cannot be discriminated by P wave data alone. The addition of the converted wave data in this survey proved to be very effective in discriminating between the different lithologies. Shear wave splitting analysis also provided orientation and intensity of fracturing consistent with regional stress data, outcrop studies and well results. The integration of these results from the geologic, seismic and reservoir engineering data has led to the selection of 16 new well locations and early drilling success.

Introduction

The processing and interpretation of full offset full azimuth converted wave seismic data present both opportunities and challenges. The potential exists for improved lithology discrimination and fracture detection but in order to unlock this potential very innovative and precise processing is required. The interpretation of the processed converted wave results also require careful calibration against geological and well data and the characterization of good well locations requires integration with reservoir enginering data. Thus the success of a 3D 3C seismic survey requires collaboration between several different disciplines within both the operating oil company and the seismic contractor. Integration over the complete cycle from defining the survey objectives through feasibility study, survey design, data acquisition, data processing and interpretation is key to unlocking the potential of Full-Wave seismic data. This case history is an example where these elements worked together to demonstrate the value that can be obtained from suitably designed and executed full offset, full azimuth, converted wave surveys.

Survey Planning and Data Acquisition

The area had been explored with conventional P wave seismic data both 2D and 3D but this was not sufficient to identify good well locations in the deeper (5Km) reservoirs that were being developed. A 2D 3C test was conducted that showed good converted wave seismic data could be obtained from these deeper reservoir levels. These tests and other studies led to the design of a wide azimuth long offset 3D survey using digital MEMS 3C sensors. The template using 12 lines each of 264 three component sensors is shown in Figure 1, the shots are on either side of the receiver spread effectively doubling the width of the template to provide adequate offset and azimuth coverage. The maximum offset in this survey design is greater than 9000m and azimuthal coverage is complete beyond what is required to adequately image the reservoir at 5Km depth.

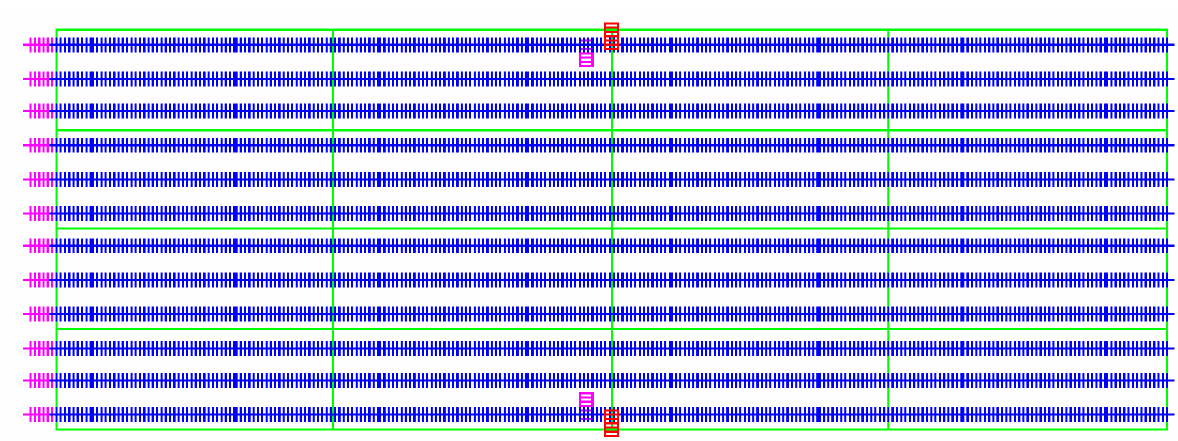

Figure1: The basic acquisition template of 12 lines each containing 264 3C sensors

This design led to a fold of 66 in the centre of the full azimuth, full offset, fully migrated part of the survey, this is illustrated in Figure 2 below.

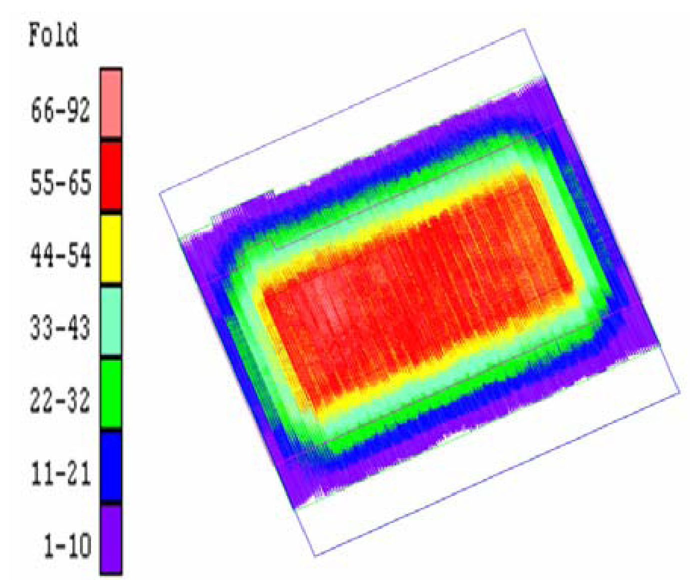

Figure2: The resultant fold averaged 32 reaching 66 in the heart of the survey

The data was acquired such that processing could extract lithologic plus fracture orientation and intensity information from combinations of the P wave and C wave data.

Data Processing and Interpretation

The data were conditioned to attenuate the variable and often quite strong source generated coherent noise and static corrections were calculated for the P wave and C wave. Rotation of the horizontal components of the acquired data from inline crossline to radial transverse was performed at an early stage of the processing. A key element in the processing was correcting for and identifying shear wave splitting. Figures 3 and 4 respectively show two inline sections before and after this procedure; a marked improvement in continuity and resolution of the data is evident.

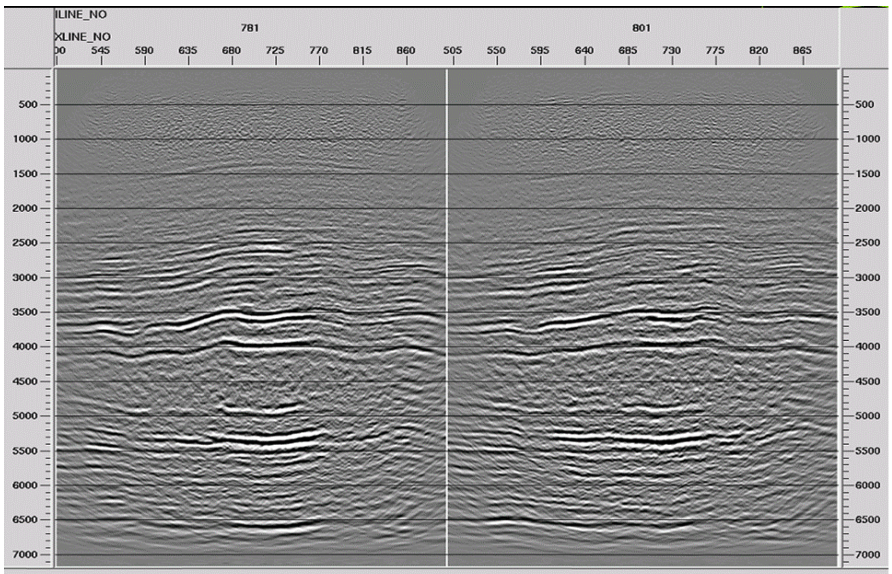

Figure3: Two inline sections before correcting for Shear Wave Splitting

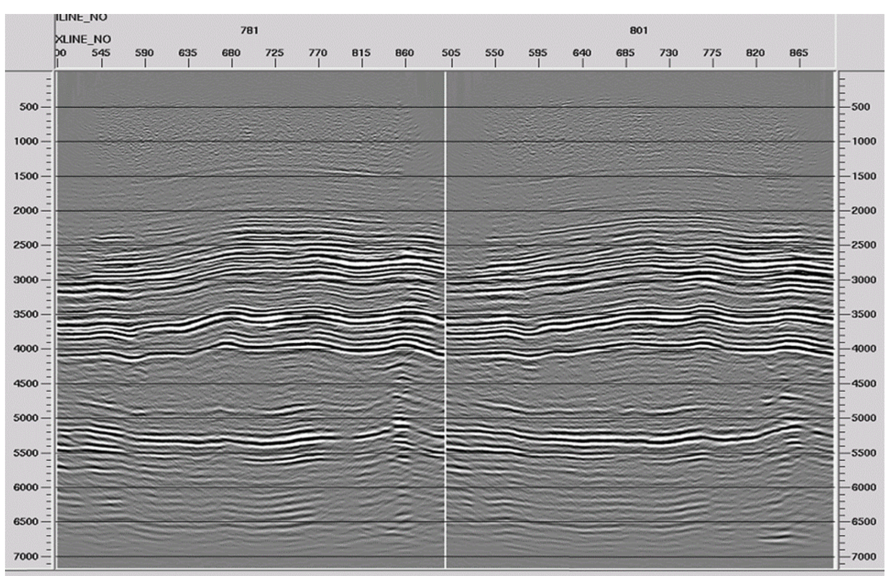

Figure4: Two inline sections after correcting for Shear Wave Splitting

The shear wave splitting process not only produces improvements in the image of the C wave it also enables information to be extracted with respect to both the regional stress field and local fracture characteristics. With the converted wave data processed to maximise its resolution very accurate registration of the C wave data with the P wave data was performed to generate attribute maps capable of discriminating lithology. These were combined with maps of fracture orientation and intensity to locate preferred drilling locations.

It was observed that the shear impedance generated from the C wave data was more geologically accurate than that derived using simultaneous inversion from the long offset P wave data, as seen in Figure 5 below.

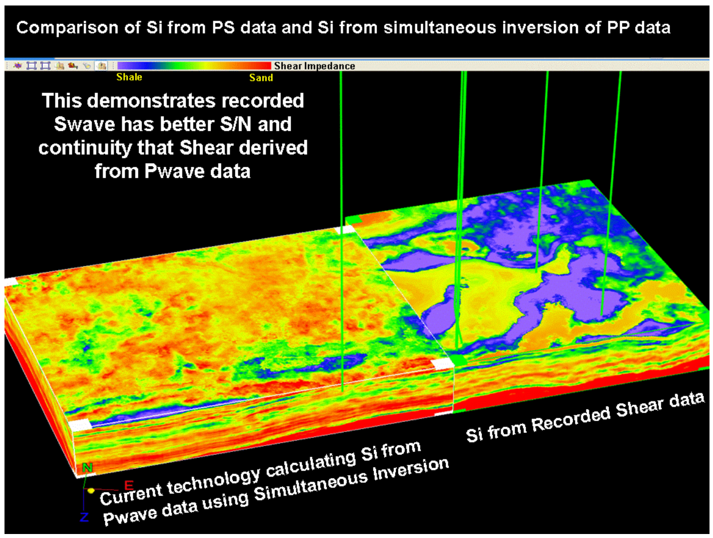

Figure5: Shear Impedance generated from Simultaneous inversion of the P wave data and directly from the C wave data

This accurate lithologic information combined with the fracture characterization was a useful indicator for good drilling locations as indicated in Figure 6 below.

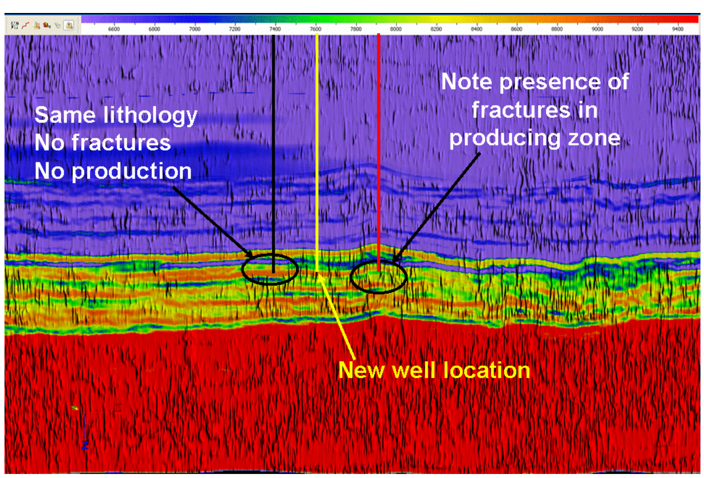

Figure6: Shear Impedance combined with fracture information

Conclusions

The information gained from properly acquired, processed and interpreted full wave multi-component data is valuable in identifying new well locations.

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