Inversion and Interpretation of Multicomponent Seismic Data: Willesden Green Field, Alberta*

Roxana M. Varga[1], John C. Bancroft[1], and Robert R. Stewart[1]

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[1]University of Calgary, Calgary, AB, Canada (rmvarga@ucalgary.ca)

Abstract

In this study, 2D multicomponent seismic data and well logs from the Willesden Green, Alberta area are used to investigate an oil reservoir interval. The Upper Cretaceous (Turonian) Second White Speckled Shale (2WS) represents the zone of interest. PP and PS synthetic seismograms generated from well logs correlate reasonably with the surface seismic data. PP and PS inversion was applied to the vertical and radial components to yield P and S impedance. The geologic model consists of 2WS shale interspersed with sand, limestone, gas and oil, giving rise to a low Vp/Vs ratio. The oil-saturated 2WS interval shows a P-wave impedance decrease and S-wave impedance increase. The Vp/Vs estimate shows anomalous values over the zones of interest around the producing wells: 8-13-41-6W5; 8-26-41-6W5 and 6-15-41-6W5.

Introduction

The Willesden Green Oilfield is located in south-central Alberta, covers 50,827 hectares, and is the second largest Cardium field after Pembina (both in area and initial oil in place). Several productive horizons in this area (the Second White Speckled Shale, Cardium, Viking, and Glauconitic sands) continue to produce significant quantities of oil and gas.

The 2WS is picked on geophysical logs due to its high gamma response. As calcite percentage in the source rock increases toward pure limestone, the hydrocarbon potential decreases. A number of wells in the proximity have produced and still produce oil and gas from the 2WS. Because a number of penetrations of the 2WS shales have not produced oil, conventional P-wave prospecting was considered inadequate. In attempt to better delineate productive zones, multicomponent seismic surveys were undertaken and converted-waves (PS) were analysed along with the P-wave data.

Seismic Acquisition

In 1992, two 3-C seismic lines were acquired by Response Seismic Ltd. WG-1 an E-NE line crossed by WG-2 an N-NW seismic line. The location map is shown in Figure 1. The lines were processed for PP and PS reflections, including anisotropic analysis. VSP data acquired with vertical vibrator sources on line WG-2 were used for a more confident interpretation. The surface seismic surveys employed two vertical vibrators with 3-C receivers up to 2520 m offset. A 60 m source interval and 20 m receiver interval were used. The VSPs were also acquired with vertical vibrator sources and 3-C receivers over depth between 400 m and 2175 m.

Seismic Processing

The two lines were reprocessed in 2004 at Sensor Geophysical Ltd. Vertical and radial migrated stack were generated. The processing flow for the PP section was conventional and included surface consistent deconvolution, time-variant spectral whitening, refraction statics, trim statics, CDP stack and migration. The processing flow for the PS section included asymptotic CDP binning, surface consistent deconvolution, refraction statics, trim statics, CDP stack and migration.

PP, PS Interpretation and Inversions

Initial interpretation of the original data was undertaken by Stewart et al. (1993). The overall goal was to see if 3-C seismic data could help find oil in the productive interval of the Second White Speckled Shale (2WS). They found some anomalies in the areas of known production. But, because data processing and interpretation have advanced considerably since then, we were enthusiastic to revisit this data set.

As a first step in our interpretation, VSP data and corridor stack/VET from well 8-13-41-6W5 were stretched to tie the PP seismic data on line WG2 (Figure 2). Available log suites for most wells include P-wave sonic, density, gamma ray, resistivity and SP logs. The next step was the correlation of the PP seismic data with the well logs, using the Hampson-Russel software eLog and ProMC package, as in Figure 3. By convolving the reflectivity and the wavelet at the well location, the synthetic traces (in blue) were generated. After a reasonable correlation with the seismic section (over 80%), the P-wave impedance model was constructed by blocking impedance logs from the wells and interpolating the values between them. The 2WS shale horizon shows an increase of impedance in the non-productive area and an impedance decrease, at the producing well locations. The PP acoustic impedance was estimated by using a model-based inversion.

After PP inversion, we noticed an impedance decrease around the 2WS shale horizon at well 8-26-41-6W5 which is producing oil and gas from this horizon. On the same line WG2, one kilometre north, well 1-35-41-6W5 is not producing from the 2WS and the horizon shows an impedance increase in this area. The correlation of the PS seismic data with a shear log was accomplished as for PP seismic data. On both lines, the PS correlation was between 60-70% with the wells. After registration was complete, the PS data in PP time were inverted. From the PS model-based inversion result (in PP time) at well 8-13-41-6W5, we noticed a lateral impedance increase (between 4900-5900 m/s*g/cc) at the 2WS shale, the productive formation on line WG1.

Using the inversion of both PP and PS datasets, we take a ratio of them (Figure 4). We associate low values in the impedance ratios (1.6-1.8) with the productive 2WS formation. Higher values (1.9-2.2) are not associated with reservoir zones. Lower values (yellow) at the 2WS horizon of Vp/Vs are noticed in Figure 4, at wells 8-13-41-6W5 and 8-26-41-6W5. The lateral PS impedance increase on line WG2 is associated with those productive wells locations.

Discussion and Conclusions

At Willesden Green, PP and PS inversions with Vp/Vs sections are used to investigate correlations with the productive zones on three producing wells: 8-13-41-6W5, 8-26-41-6W5, and 6-15-41-6W5. The integration of well logs and multicomponent seismic has been described in this article. The calculated Vp/Vs values and the ratio of PP inversion over PS inversion were helpful for finding anomalies. The productive intervals have been interpreted as a PP impedance drop and an PS impedance increase.

Acknowledgements

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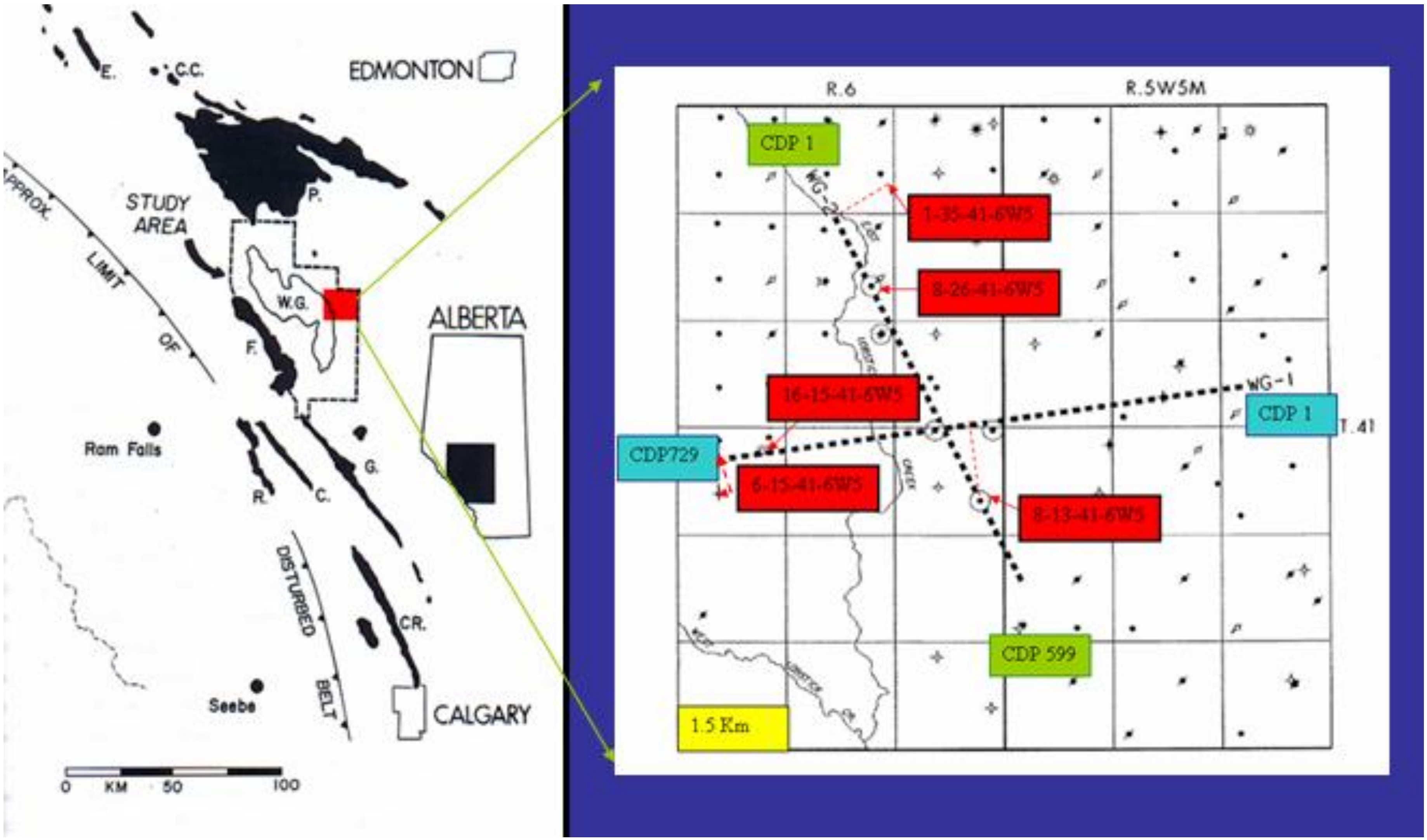

Figure 1. Location of Willesden Green Field, Alberta (maps from Keith, 1985, and Response Seismic Surveys Ltd.). On line WG1, two wells (6-15-41-6W5 and 8-13-41-6W5) were correlated with the seismic. On line WG2, three wells (1-35-41-6W5, 8-26-41-6W5, and 8-13-41-6W5) were correlated with the seismic.

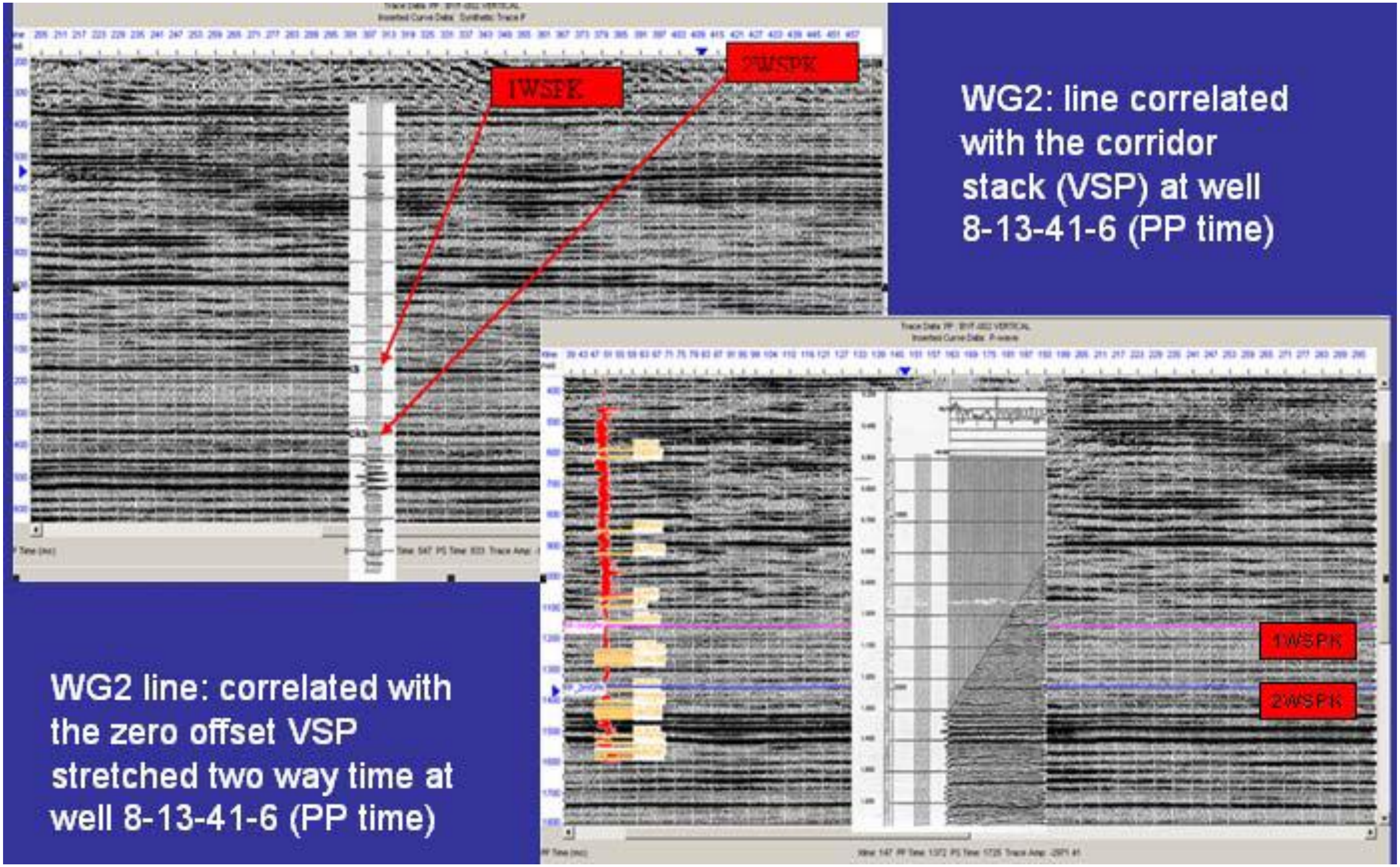

Figure 2. PP Interpretation: WG2 seismic line correlated with the corridor stack and the zero offset VSP stretched two way time at the well 8-13-41-6W5.

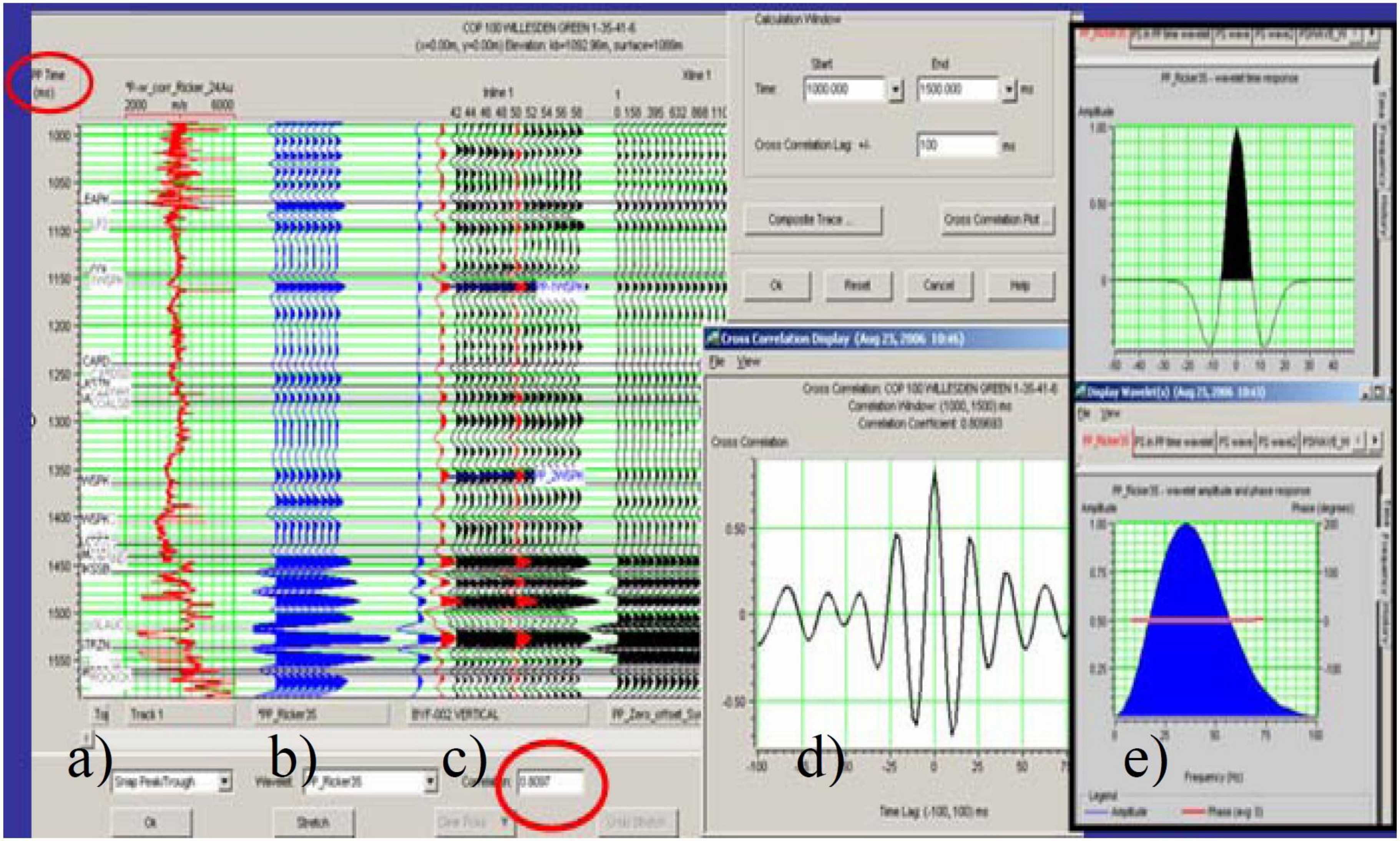

Figure 3. Synthetic, seismic and well log correlation at well 1-35-41-6W5: (a) P wave sonic, (b) zero offset synthetic, (c) PP seismic, the correlation of 80% with seismic, (d) the cross-correlation plot showing almost zero phase, and (e) used wavelet.

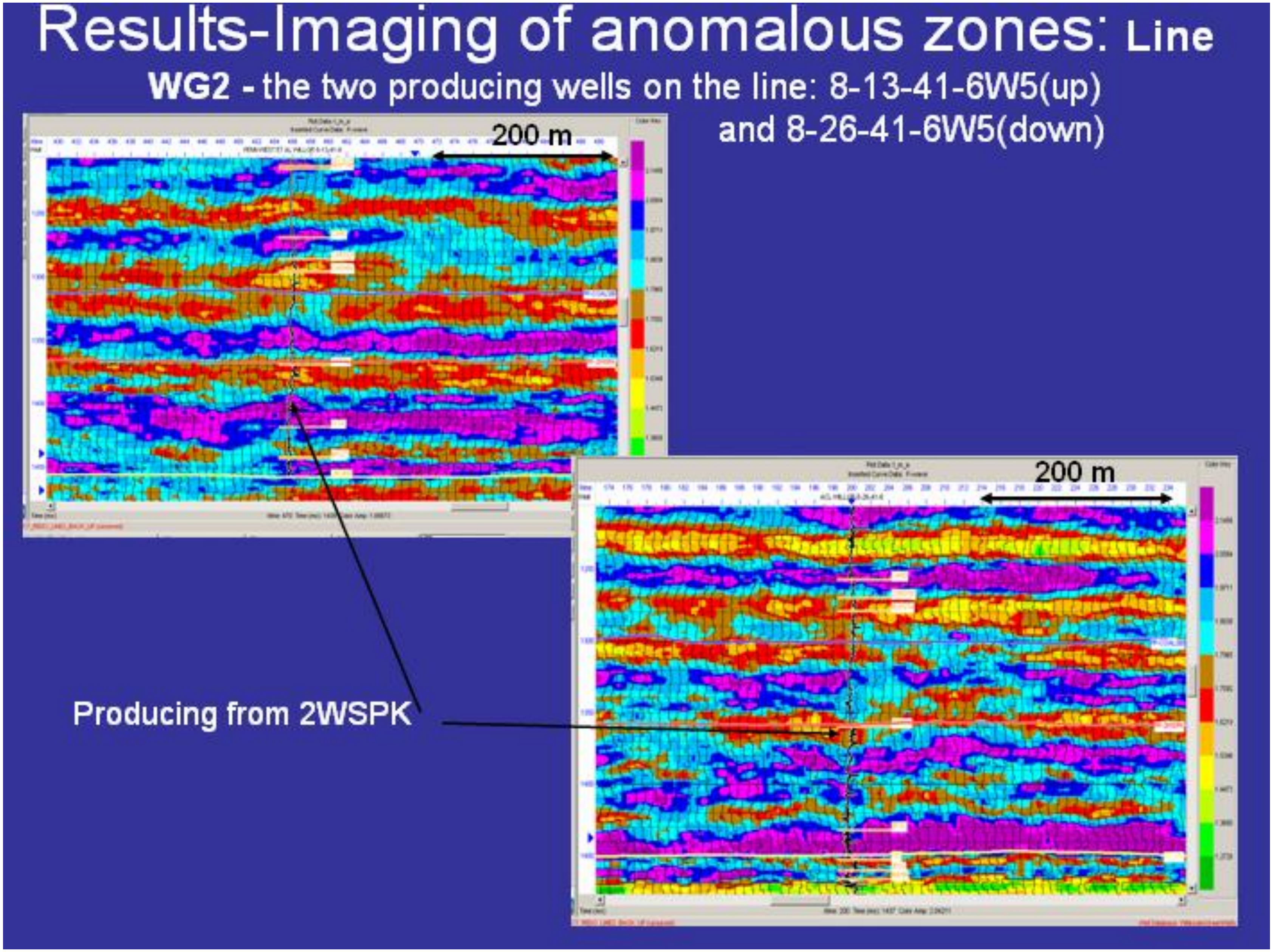

Figure 4. Delineation of anomalous zones: the ratio of the PP inversion to PS inversion in PP time on line WG2 at the two producing wells 8-13-41-6W5 and 8-26-41-6W5.