Geophysical characterization of the near-surface at Priddis, Alberta

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ABSTRACT

We integrated well data with seismic reflection and refraction data and electrical resistivity data acquired at the same time as the refraction data on the University of Calgary lands at Priddis, Alberta, in 2012. The purpose was to derive a model of the near-surface so that we might predict the lithology to be encountered in wells that were planned to be drilled in the autumn of 2013 for the installation of a permanent downhole seismic recording and monitoring system.

There is a good match between the velocity model derived from the refraction survey, the interpretation of reflectors on the reflection data, the existing Rothney test well lithology and the electrical resistivity inversion. A sandstone penetrated between 65 m and 90 m in the Rothney observation test well was predicted to be encountered updip between about 25 m and 50 m in Well 1, drilled in October, 2013. Well 1 turned out to have three sandstones within this interval: at 23-28 m, 31-37 m and 46-50 m. A major resistive unit, interpreted to be a sandstone, correlates to strong reflectors on the reflection seismic data and a relatively high velocity on the seismic refraction data. We predicted that the top of this unit would be encountered at about 95 m depth in Well 1. Our predictions turned out to be accurate as Well 1 penetrated a sandstone from 91-102 m. A hard shale with sandstone ledges was penetrated at 124 m in Well 1 and slowed the drilling of the well. It projects onto the observation well deeper than the total depth. It correlates to a high amplitude reflection on the seismic data.

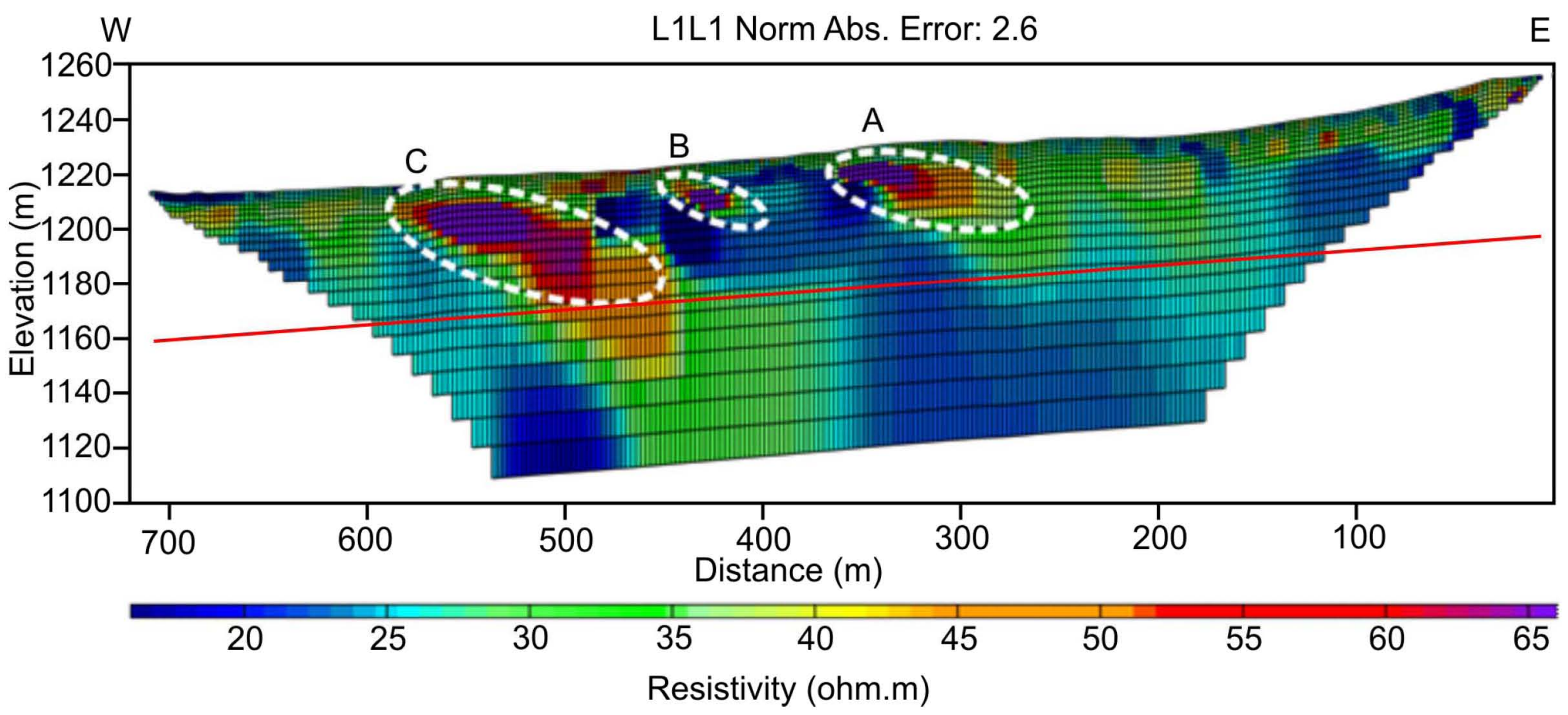

FIG. 2: Combined 5 m and 10 m unit electrode spacing apparent resistivity tomogram, 5th iteration.

ELECTRICAL RESISTIVITY DATA

For the electrical resistivity line, two different unit electrode spacings, 5 m and 10 m, were used to improve data density and both vertical and horizontal resolution in the near surface and to achieve a maximum depth of investigation.

We processed the resistivity data using a smoothness-constrained Gauss-Newton least-squares inversion. Prior to inverse modelling, noisy data and bad data points were edited from the pseudo-section. Forward modelling utilized the finite-element method to adjust the node positions to follow the topography. An L1 norm constraint was applied to both the data and the model to minimize the difference between the calculated and measured resistivities.

The approximate reliable depth of investigation, based on model resolution, is given by the red solid line in Figure 2, which is about 60 m deep. Overall, the resistivity ranges from 16 to 66 ohm.m, and the entire pseudosection is relatively conductive. The tomogram shows that the depth to the bedrock is about 5 m and that the upper bedrock is highly heterogeneous and dominated by sandstone and mudrocks. Three major anomalies (outlined by dashed white circles and labelled as A, B and C in Figure 2) are located at horizontal distances 280-360 m, 415-440 m, and 450-580 m. These are interpreted to be sandstones within the bedrocks, as they tend to be very resistive (> 52 ohm.m, red-to-purple colour).

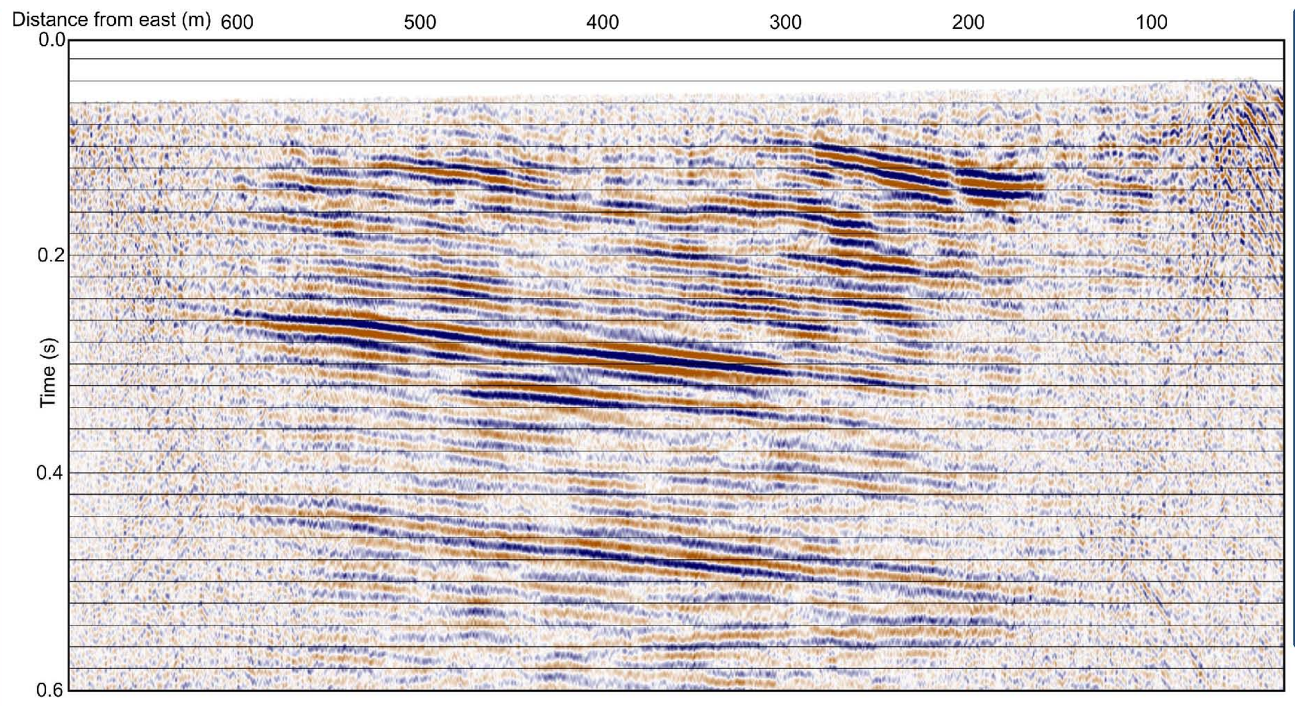

FIG.1: Post-stack time migrated seismic reflection line.

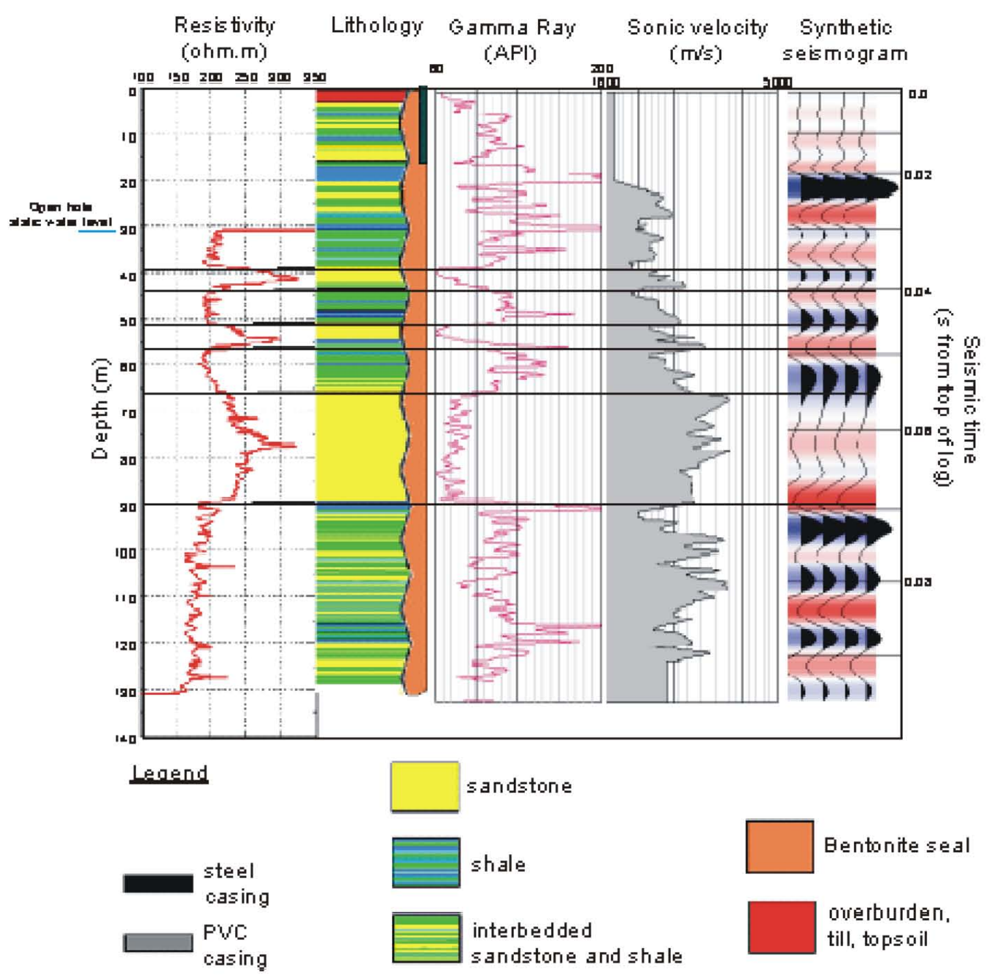

FIG. 3: The existing Rothney observation test well.

WELL DATA

A shallow well was drilled to 137 m 2007. It penetrated clastic rocks of the Palaeocene Paskapoo Formation. A major sandstone was encountered between 65 and 89 m depth, with minor, thin sandstones in the section above (Figure 3). The sonic log shows an increase in seismic velocity at the top of the sandstone and a decrease at the base. The synthetic seismogram, plotted in Figure 3 in depth, indicates a strong negative seismic response at the sand/shale interface at the base of the sandstone and a less definitive positive event at the top of the sandstone because of interference from earlier seismic reflections. The minor sandstones are too thin to be resolved by our seismic data

INTEGRATION OF RESULTS

All the geophysical data are plotted in Figure 4 with the well lithology and a synthetic seismogram in depth. The seismic refraction line, electrical resistivity profile and the Rothney test well were projected along strike to the surface location of the reflection line.

The sandstone encountered between 60 and 95 m in the Rothney test well is indicated by the shallowest yellow band in Figure 4. It correlates to a small, shallow resistive unit at about 430 m on the electrical resistivity profile.

From these integrated data we predicted the stratigraphy to be encountered in Well 1 (Figure 5). We predicted that the major sandstone encountered in the Rothney test well would be penetrated in Well 1 from about 25 m to 50 m below the surface. Well 1 encountered grey sandstones in this interval, from 23-28 m, 31-37 m and 46-50 m. An 11-m thick sandstone was found at 91-102 m and correlates to the resistive sandstone we predicted to be encountered at 95 m depth.

The drillers encountered a very hard unit, described as a shale with sandstone ledges, at about 125 m depth, which slowed the drilling considerably. This we correlate to a high amplitude reflection on the seismic data which was below the TD of the original Rothney observation well.

In summary, the integration of seismic data with electrical resistivity inversion and existing well data allowed us to predict with considerable accuracy the lithology to be expected in the new Well 1. We hope to be able to acquire geophysical logs in this well and to be able to examine the core to confirm the driller's report.

SEISMIC DATA

A seismic reflection survey was acquired in July, 2012 and a seismic refraction survey was acquired in September, 2012, both using a mini-vibroseis source and 3C geophones. The field data are dominated by high amplitude, low frequency surface waves which are source-generated. These wavetrains are attenuated through processing.

We picked first breaks on the refraction data and calculated refraction statics. A near-surface velocity-depth model was obtained through this inversion. The depths and velocities obtained through the refraction analysis are adequate for showing general trends but the absolute values are unreliable, as they change somewhat depending on the offset range chosen for the analysis.

We processed stacked and post-stack time migrated the reflection data (Figure 1). Reflectors that dip to the east can be seen clearly on this section. This dip is consistent with the 30° dip mapped on geology maps and seen in outcrop along the hill to the west of the field area.

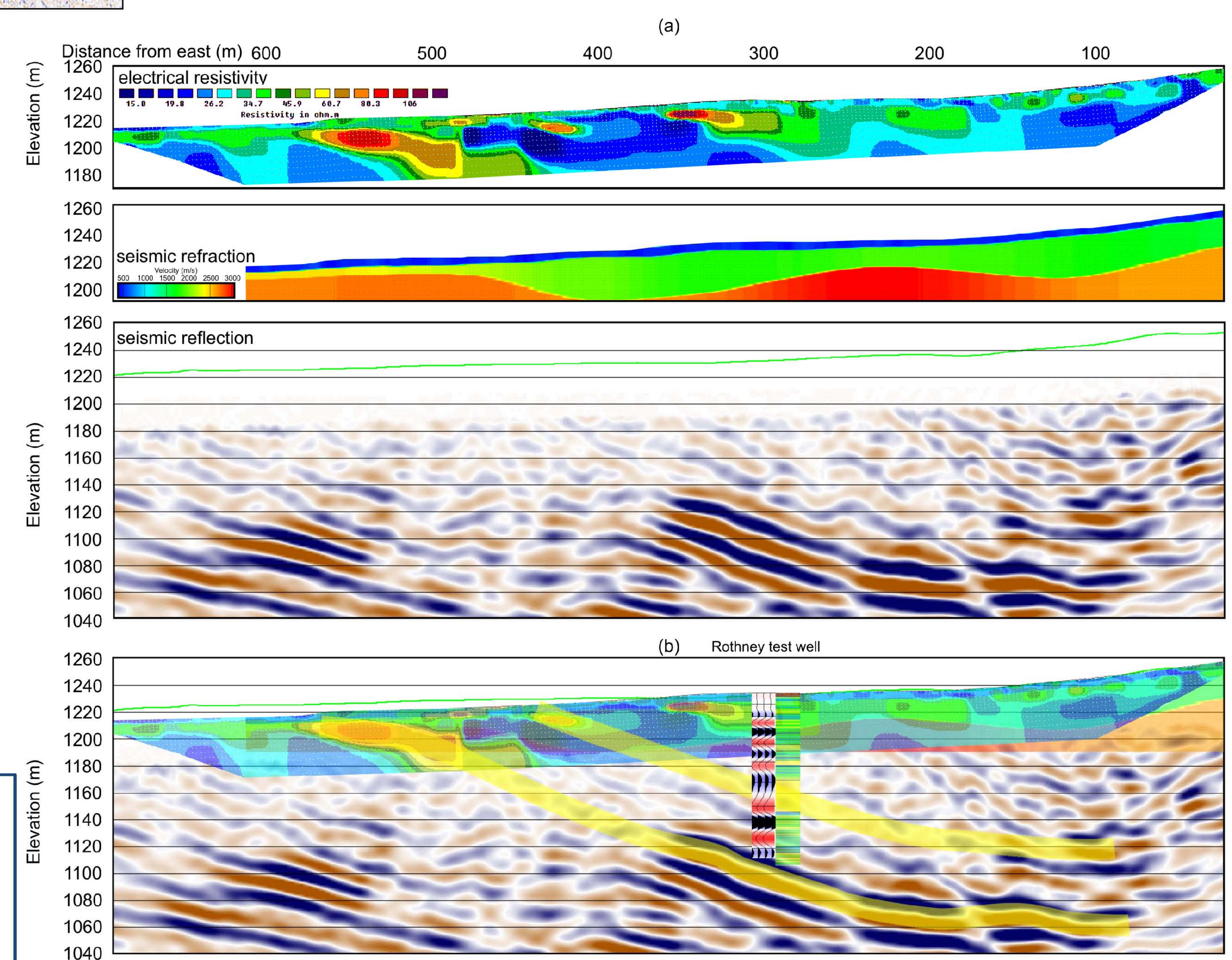

FIG. 4: Electrical resistivity profile, seismic refraction near-surface velocity model and seismic reflection data plotted separately (a) and then superimposed (b) with the Rothney observation well lithology and the synthetic seismogram in depth added. The refraction and electrical resistivity data were shifted laterally along strike to align locations.

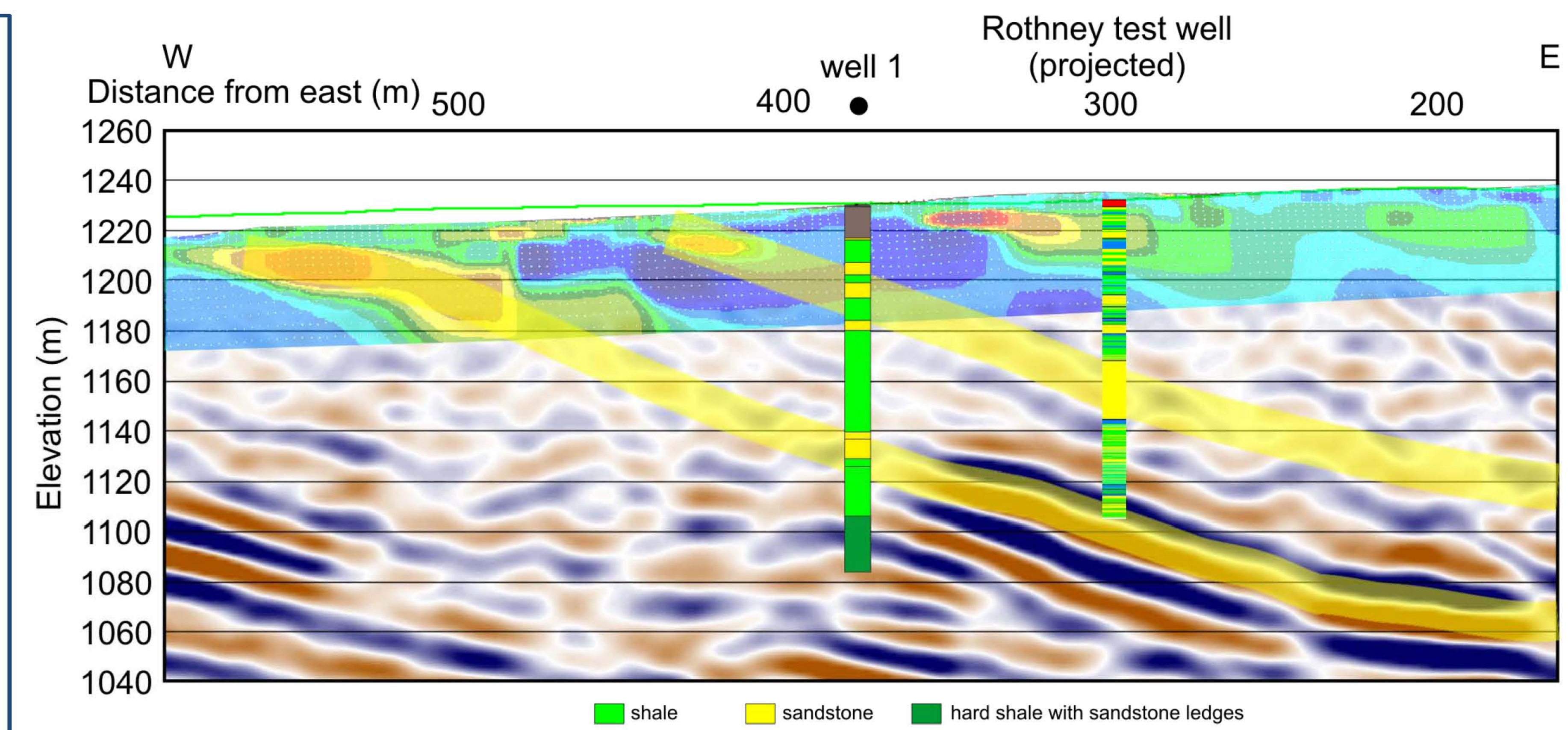

FIG. 5: A zoom of Figure 4 with the lithology of Well 1 overlain. Sandstones predicted to be encountered updip of the Rothney test well are annotated in yellow.