



Geosteering Techniques in Thin Coal Reservoirs

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Introduction

Thinly bedded reservoirs, including coal seams represent the frontier of today's E&P targets. Geometric drilling of these reservoirs is often precluded by a lack of closely spaced offset wells around the horizontal section, as well as the presence of unanticipated faults and structural changes that may require dramatic changes in well bore placement with respect to the reservoir section. The current challenge for geosteering is to stay in the productive interval of these increasingly thinner reservoirs.

New innovations in logging technology, such as the recently introduced Azimuthal Deep Resistivity (ADR) tool and Gamma-at-Bit Inclination (GABI) motor, are making this possible. These logging tools were used in drilling thin coal beds where the primary drilling requirement was to place the horizontal section as close as possible to the lower coal-seam boundary. These tools made it possible to geosteer close to the top and bottom of the thin coal beds without exiting. Tool measurements such as Azimuthal standoff enable calculation of the distance-to-bed-boundary, which is used to map the lower boundary of the reservoir. A field example demonstrates how this tool combination was also used to identify and map sub-seismic coal-on-coal faults and how this knowledge influenced well bore placement.

Methodology / Theory

Geosteering

The key to successful geosteering is accurate real-time reservoir knowledge. This knowledge is obtained using several different sources of information through out the planning and drilling of the well. During planning, information of the reservoir is obtained from seismic, offset well, reservoir positions, cores, and several other sources. Proposed well paths are planned as accurately as possible, placing the well in the best possible position with regards to the reservoir. Many times this process can be hampered by lack of information. If the well is drilled accordingly to the proposed well path it ends up being placed in poor reservoir or even out of the reservoir section. Geosteering can help prevent this by modifying the well path during drilling using all of the information used in planning the well along with information that is obtained in real-time.

Examples of sources for information during drilling, can be LWD tools (including new generation resistivity and gamma-at-bit tools), cuttings, surface data, 3D placement software, and well personnel. The geosteering specialist collects this information, analyzes it, and makes decisions in real-time to modify the well path so that it is placed in the best possible position with out exiting the reservoir.

Recently Halliburton help drill a well located in the Swan Hills area in Alberta, Canada. It was very important to place the well as low in the reservoir as possible without exiting, as the reservoir was only 1.8 m thick. No seismic and only one old offset well were available during planning of the well. The client decided to use geosteering for drilling the well due to the importance of placement of the well and lack of knowledge of faults and other unknown geologic structures.

In this well, Halliburton's geosteering team primarily use the Azimuthal Deep Resistivity (ADR) tool, Gamma/At-bit Inclination (GABI) motor, and StrataSteer 3D software. These tools along with other real-time information allowed the team to place the well in the best possible position for the client.

Azmuthal Deep Resistivity (ADR) tool

Halliburton's newest generation resistivity tool is called the InSite ADR tool. This tool measures multiple truly compensated resistivities at different depths of investigations, multiple truly compensated images at different depths of investigations, and multiple possible geosteering signals that are used to calculate distance to be boundary (DTBB). The ADR tool fires three frequencies at each of the six transmitters (three compensated spacings) which are then measured at three tilted antenna receivers. This data can be transmitted in real-time allowing the geosteering specialist to evaluate the reservoir while drilling.

Transmitting an image from one frequency and spacing resistivities allows the geosteering specialist to compare the high side resistivity with the low side resistivity. These two resistivities will differentiate when coming in contact with a boundary. The resistivities also react differently when crossing an upper boundary and a lower boundary of a formation, helping with the placement of well bore with respect to the reservoir. Transmitting two resistivities with different depths of investigation also allows a better evaluation of the reservoir.

Transmitting one or more geosteering signals (geosignals) also help with placement of the well bore. From the geosignal a distance to bed boundary (DTBB) can be calculated. The DTBB will indicate where the nearest boundary is located helping with well placement. Faults will also be mapped easily with DTBB. Sometimes an upper boundary and a lower boundary can be calculated near enough each other to estimate the thickness of the reservoir. The geosignal can also be used as a qualitative measurement in giving an idea of location of the well bore. In most instances, if the geosignal is positive, then the well is in the upper part of the reservoir, and if the geosignal is negative, then the well is in the lower part of the reservoir. This also helps with well placement.

Gamma/At-Bit Inclination (GABI) Motor

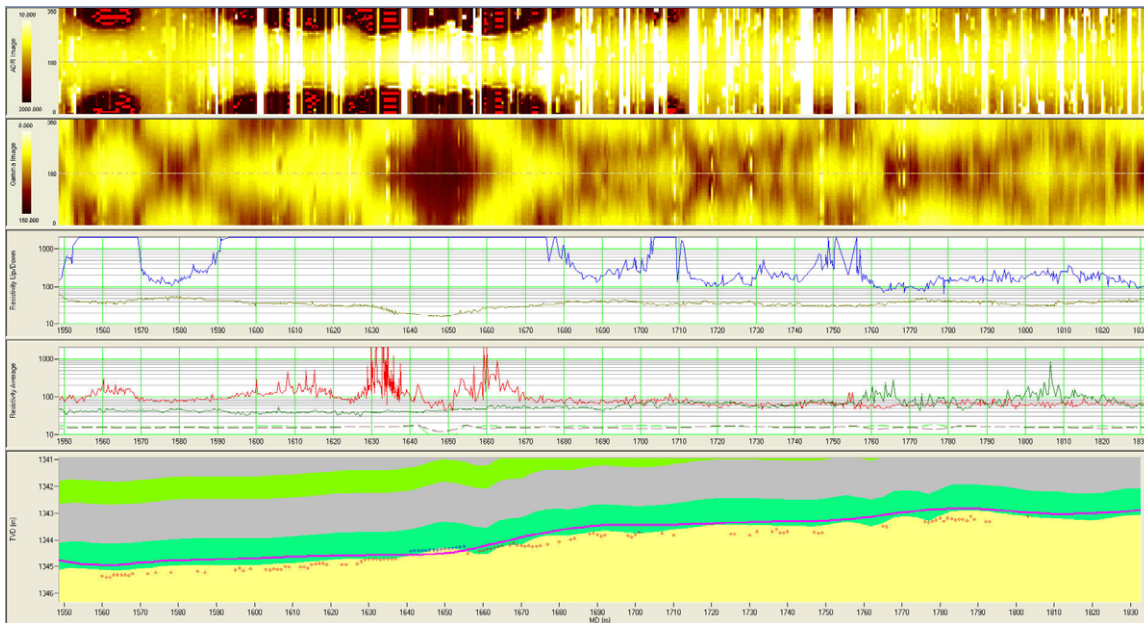
The GABI sensor provides two important measurements, located just behind the bit, for steering a well. The first measurement is the At-Bit Inclination, which helps with the direction of the well. Not only does it contribute to longer and flatter well bores, it provides immediate feedback about trajectory changes. The second measurement is an Azimuthal Gamma Ray. This close to the bit gamma ray detects adjacent beds and bed boundaries when being approached. The image also indicates the direction the will path; if it is going up dip or down dip.

StrataSteer 3D software

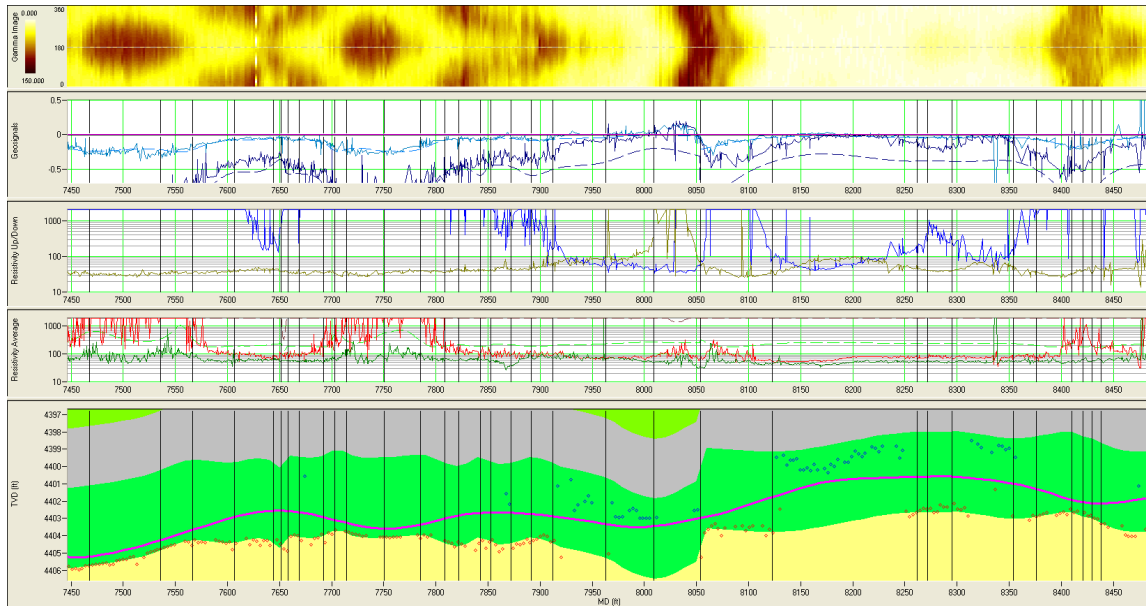
With the combination of these two tools and the StrataSteer 3D (SS3D) software an accurate picture of the geology and well placement can be mapped. The SS3D combines the resistivities, gamma rays, images, geology, and well bore placement into one screen making a powerful tool for the geosteering specialist. With all of the information at the touch of the fingers, the geosteering specialist can make real-time decisions to prevent a reservoir exit, and to place the well bore in the best possible position.

Sample Data

The following are examples from the Swan Hills area well that was drilled in Alberta, Canada using the ADR tool, GABI motor and StrataSteer 3D software. The goal of this thin reservoir was to stay at its bottom for a maximum production of methane gas.



Above is an example ADR data with GABI image and DTBB calculations. The GABI image (lower image) shows the direction of bed dip with respect to the well path. DTBB is indicated in red dots on the geology plot (at the bottom) showing that the well is placed near the lower boundary of the coal seam. The upper resistivity and the lower resistivity comparison also indicate that the lower boundary is being approached (polarization horns).



This is also an example of ADR data, GABI image and DTBB calculations along with geosignal data. DTBB indicates a lower boundary along with a possible upper boundary of the formation. A fault also occurs at approximately 8050 m. This can be determined by the up and down resistivity track along with the geosignals. As the fault approaches, the lower resistivity is polarizing, indicating that the top of the reservoir is approaching. When the fault occurs, the upper resistivity is polarizing indicating that the bottom of the reservoir is approaching. The geosignals also indicate this. Upon approach, the geosignal is increasing so that is towards the middle of the track and even above the middle of the track. After the fault, the geosignal is below the middle of the track again.

Conclusion

It is possible to drill thin reservoirs in real-time with today's technology. As fields become more difficult to drill and produce it is important to place the well bore in the best possible reservoir during drilling. Geosteering the well in real-time is the only way to do this. With the new ADR tool, a GABI motor and Strataster 3D software along with geosteering specialist this is possible. The ADR tool can calculate DTBB, and indicate which boundary is being approached. The GABI motor can indicate bed dip and Strataster 3D software puts the information together for the geosteering team to make quick and accurate decisions.

References

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