Geological Factors Affect Horizontal Well Completions*

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Abstract

Objectives/Scope: Horizontal wells provide completion problems that are not typical in vertical wells. Horizontal wells traverse multiple layers of depositional surfaces within reservoirs and can cross multiple deposition types in a single lateral. Each of these geological boundaries may be problematic when attempting to effectively fracture treat these wells. Defining these features would be useful in the completion design. Methods, Procedures, Process: Dipole sonic logs were added to the evaluation program in an attempt to understand these parameters. These logs were run in an open-hole environment and then again after casing was set. Evaluation of the location within the formation is a valuable result of acquiring these logs. The effect of this relative location and the effect of the efficiency of the fracture treatment is now possible. Results, Observations, Conclusions: The well path was identified within the reservoir package and when boundary conditions were crossed extending into the adjacent horizon. Fracture-treatment placement was seemingly affected by the proximity of the well path to these boundary conditions. Anisotropy from the cased-hole log tends to more consistently reflect breakdown-pressure conditions observed in the treatments. Identifying these geologic features can change the expected placement efficiency of any treatment program. Novel/Additive Information: The ability to understand the relative placement of the wellbore within any geologic condition results in increased accuracy in the anticipated treatment behavior. The breakdown pressure can be minimized by the inclusion of this geologic context.

Objectives/Scope

Horizontal wells can often result in completion problems that are not typically experienced in vertical wells, as they traverse multiple layers of depositional surfaces within reservoirs. These wells can also cross multiple deposition types in a single lateral. Each of these geological boundaries may be problematic when attempting to effectively fracture treat these wells. Defining these features would be useful in the completion design.

Fracture treatments from horizontal wellbores do not behave in the same way as those from vertical wells. Desired treatment results are produced by fracturing the reservoir in such a way that the fluids have a path to the horizontal wellbore for production. Ideally, these fractures would extend from the top to the bottom of the productive interval. In addition, radial extension away from the horizontal well would be symmetrical.

Although there currently does not exist an electric logging method that can predict the migration of the treatment radially, rock mechanical properties can help in defining the vertical propagation of these treatments. Horizontal closure stress must be established from some source to define these closure-stress conditions. The logs that establish the horizontal closure stress must be run in a vertical pilot hole to validate their effectiveness.

In many operational situations, it is not always possible to accomplish these pilot-hole logs. The cost of the required pilot hole and logs is high. The calculated values for this closure stress may not always provide geological confidence as distance increases from the pilot hole.

Anisotropy, or the difference in rock mechanical behavior, can be established from logs run in a horizontal wellbore without reference to an absolute rock mechanical model. These anisotropy logs are relative, but can still provide conclusive information that can be used in perforation location selection and fracture-treatment design.

Methods, Procedures, Process

Dipole sonic logs were added to the evaluation program in an attempt to understand these parameters. The relative value of running these logs in an open-hole environment versus running them in a cased hole was to be evaluated. The imposition of the casing and cement to the completion could alter the anisotropy conditions in the well, and conclusions about the validity of each data set were desired.

Dipole sonic logs were run in an open-hole environment and then again after the casing was set. The entire horizontal well path was evaluated separately for each of the sets of logs.

Evaluation of the location within the formation is a valuable result of acquiring these logs. The dipole sonic logs include an orientation device that allows an analyst to determine the orientation of the measurements. This allows isolation to the vertical shear plane and also provides precise information for the location of the well path.

The effect of this relative location and the effect of the efficiency of the fracture treatment is now possible. This paper compares the location of the well in proximity to boundary conditions within the reservoir. The effect of that proximity to anisotropy will be evaluated.

Results, Observations, Conclusions

The well path was identified within the main reservoir package and when the internal boundary conditions were crossed, thus extending into the adjacent horizon. Figure 1 illustrates the well path for the investigation. The wellbore landed in the boundary condition between the Woodford C and the Woodford D.

At the fold point in the reservoir, the wellbore drilled into the C and was redirected downward to land in the desired location. After leveling out in the boundary, the well drops down into the D section as the dip of the beds rise. The effect of these positions within the various strata will be identified and discussed in the exhibits.

Figure 2 is an example of a section of the well where both the open-hole and cased-hole anisotropy is very high. In this segment of the well, the wellbore is very close to the bottom boundary of the Woodford D zone. This proximity may provide some contribution to the high anisotropy measurement, but there is no real supporting evidence that this conclusion is valid.

Figure 3 is an example of the anisotropy response when the wellbore was in the middle of the Woodford D section. This is characterized as "mixed to medium" anisotropy in both the open-hole and the cased-hole data. This data seems to indicate that this portion of the reservoir will be more easily treated than the previous example. Distance from the boundary condition provides a fairly consistent anisotropy response, which indicates that successful treatment placement will be possible.

Figure 4 illustrates that the wellbore is mostly confined to the boundary condition between the C and D horizons. It is in this section in which the results from the two log runs diverge. The response from the open-hole log is very high in the center, which is within the boundary. When the wellbore is not confined within the boundary, the anisotropy response is low.

The cased-hole log seems to be in agreement with the open-hole log while within the boundary. When the wellbore is no longer within the boundary layer, but very near the contact, anisotropy is still high. This observation, combined with the data in Figure 2, tends to lead to the conclusion that close proximity to a bed boundary must create a condition that is restrictive to fracture treatment initiation.

Figure 5 leads to the conclusion observed in other exhibits. Any time the well path is within, or in close proximity to, any boundary condition, anisotropy is elevated. There is not an instance in this wellbore where that observation is not valid. This implies that some completion effect is changing the dynamics of the completion whenever the wellbore is near a boundary.

Novel/Additive Information

Fracture-treatment placement and breakdown pressure was affected by the proximity of the well path to boundary conditions. Anisotropy from the cased-hole log tends to more consistently reflect breakdown pressure conditions observed in the treatments. Identification of the geologic location within the reservoir and recognition of the geologic features can change the expected placement efficiency of any treatment program.

The conclusion that this effect on the cased-hole data is universal in any formation cannot be drawn from this data set; however, the strong correlation established from this data set may indicate that this is often the result. Additional investigation in other portions of this reservoir and in other target formations could lead to additional useful conclusions.

The ability to understand the relative placement of the wellbore within any geologic condition results in increased accuracy in the anticipated treatment behavior. Completion optimization can be assisted by understanding these geological events.

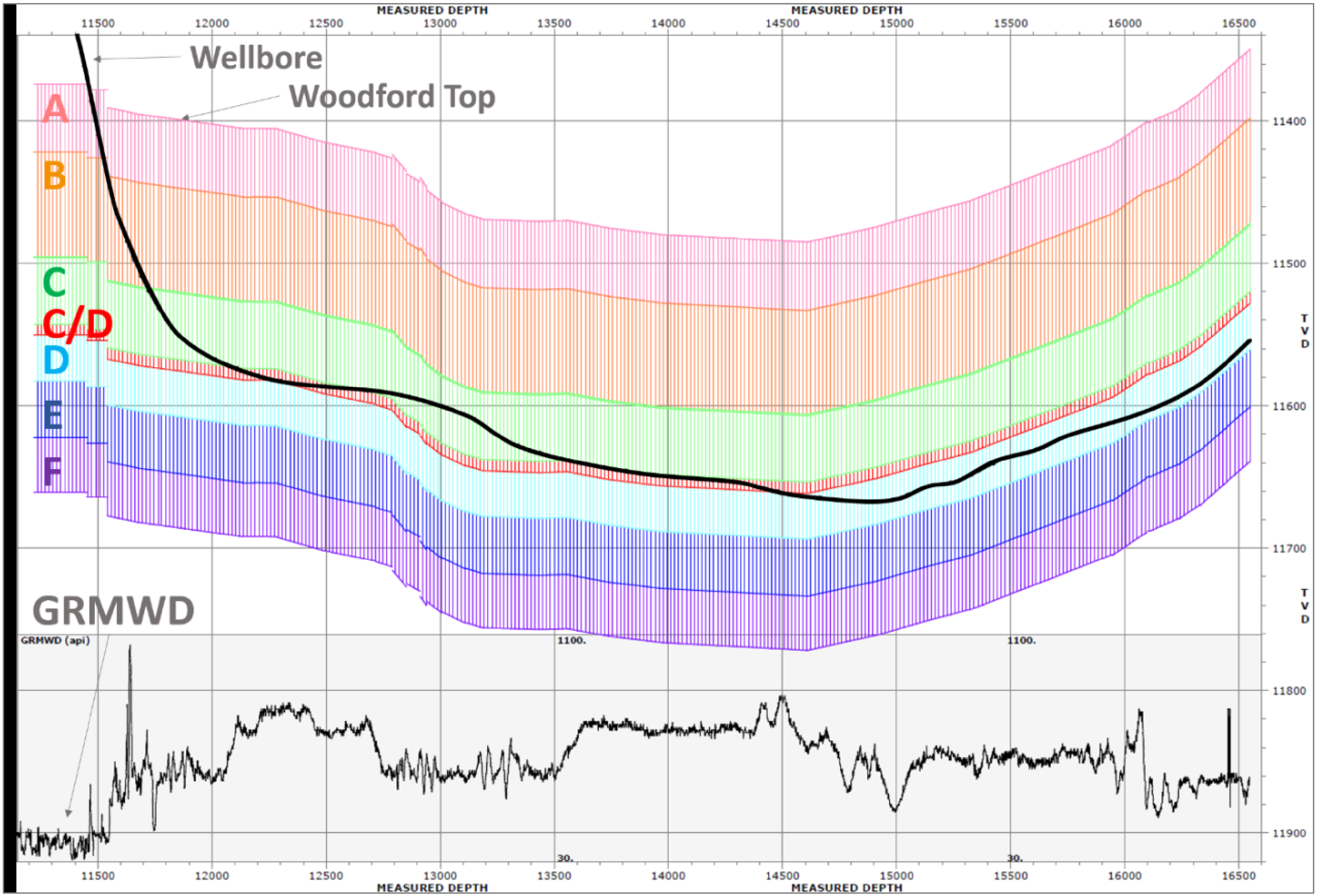


Figure 1. Location of Horizontal Well Path in the Target Formation.

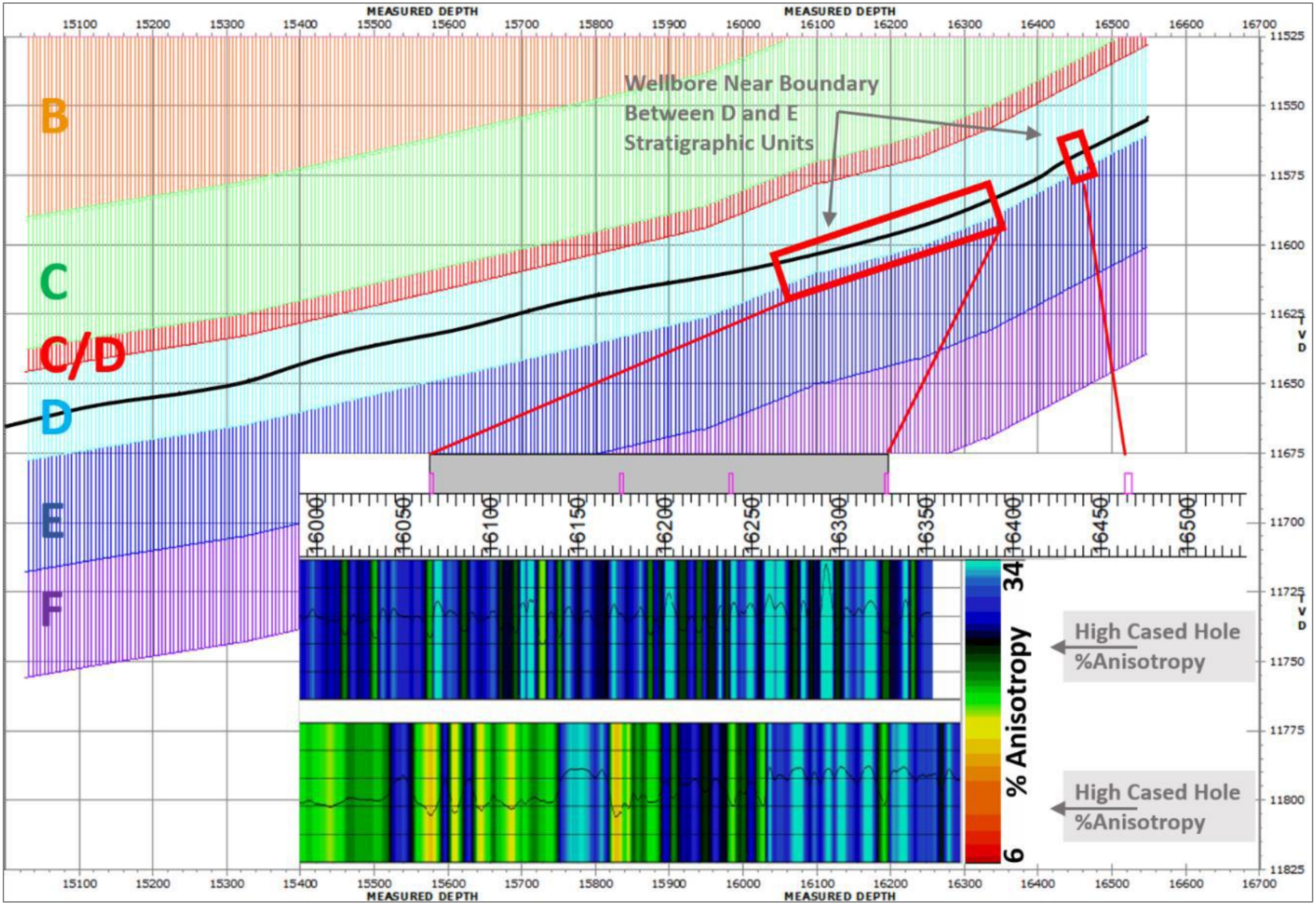


Figure 2. High Anisotropy in Open Hole and Cased Hole.

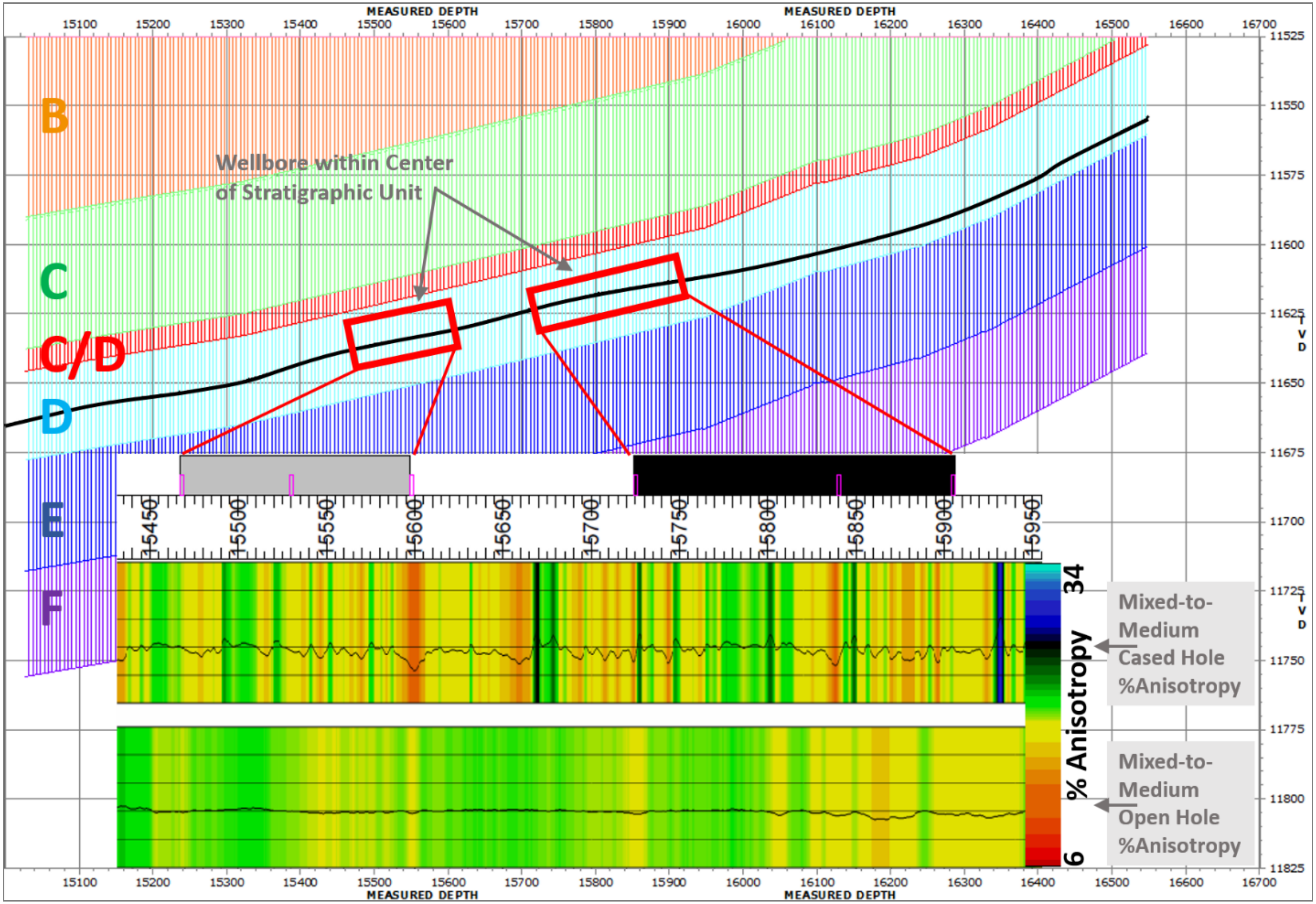
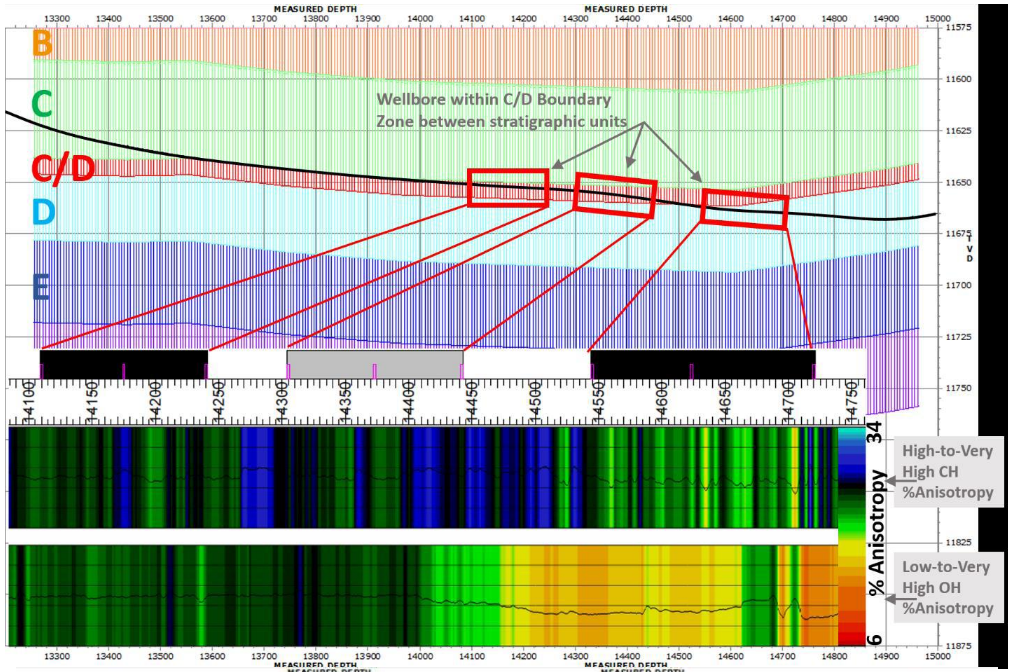


Figure 3. Mixed to Medium Anisotropy in Open- and Cased-Hole Data.



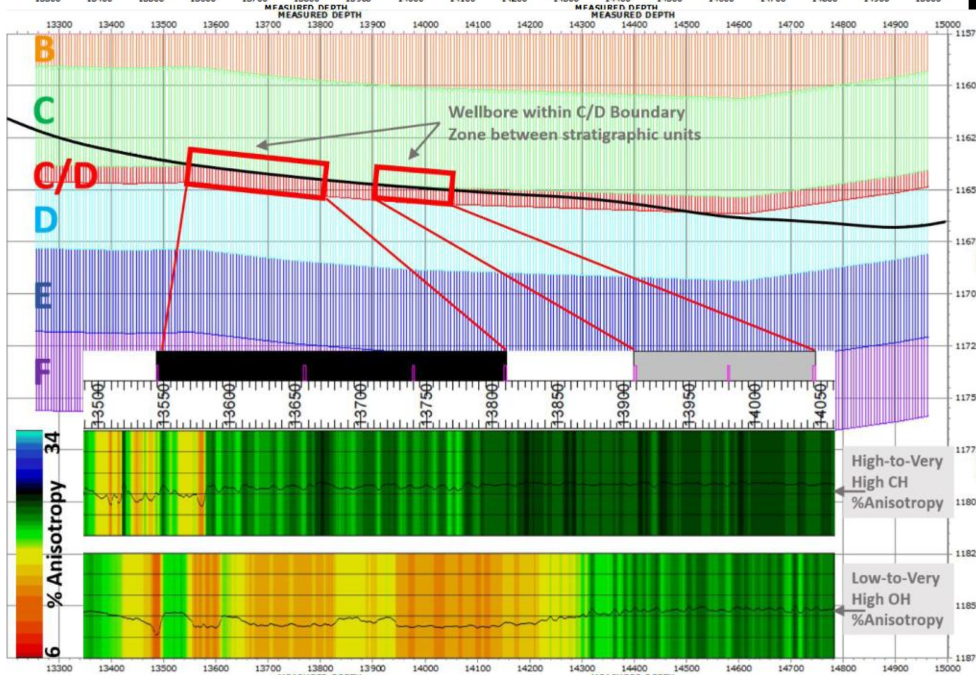


Figure 4. Effect on Anisotropy Measurements Near Boundary Contacts.

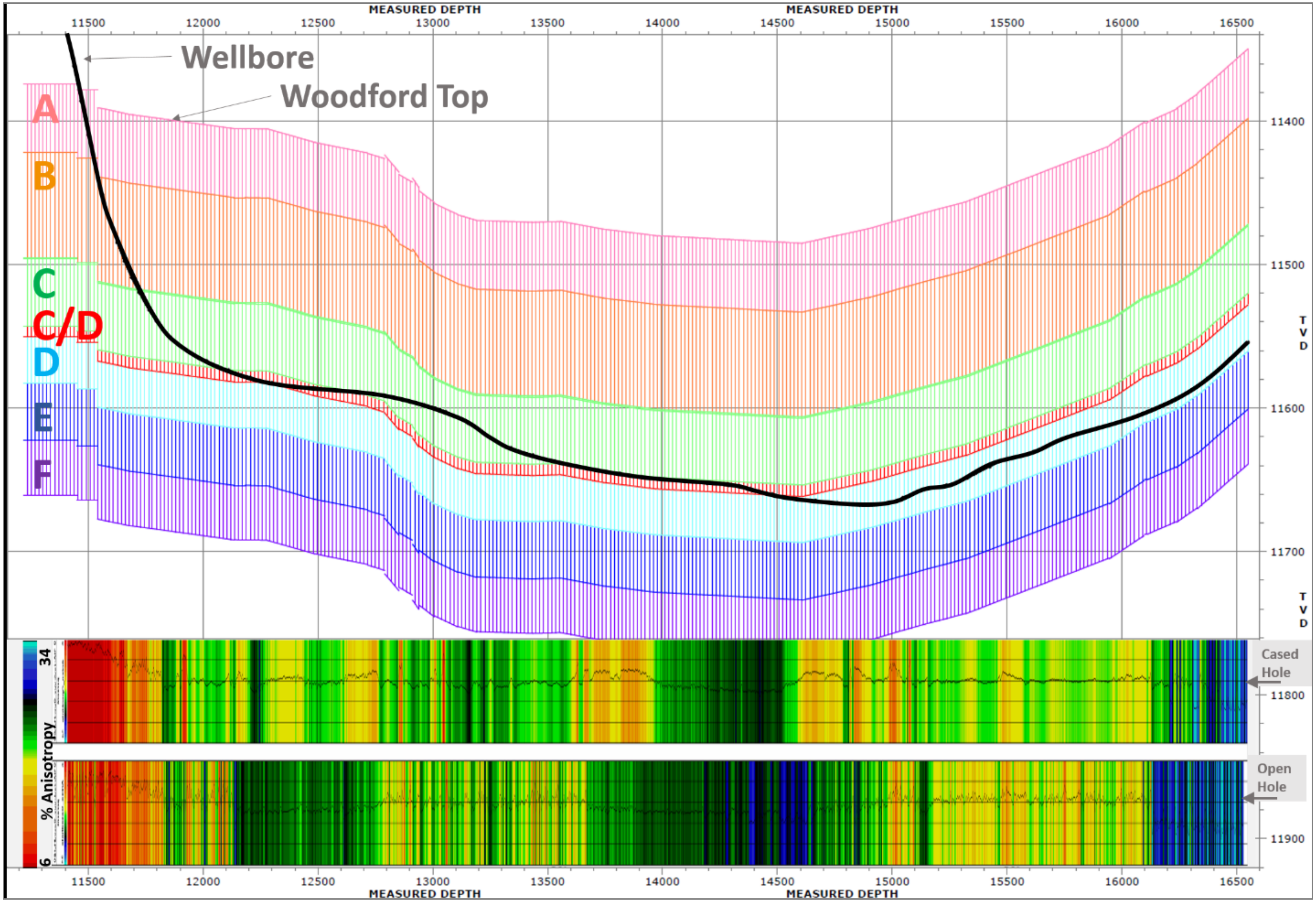


Figure 5. Complete Well Path and Anisotropy Description.