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PARADIGMS AND PITFALLS USING 3-D DATA FROM INDUCTION LOGGING TOOLS

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INTRODUCTION

Standard logging tools have only one z-oriented transmitter coil and one z-oriented receiver coil, allowing only vertical-vertical transmitter-receiver configurations (that we write as “Z-Z”). This configuration minimizes problems with a borehole response, tool misalignment, and interpretation. Unfortunately, many formation features give little or no response to such a configuration - for example, anisotropy is not resolvable using the conventional array. A feasible solution to this difficulty is to develop "triaxial" tools, which generate or measure fields, which are not traditional and constitute a major advance in the industry, but there is a great deal that needs to be learned about the data quality control and interpretation. These logging tools are equipped with x-y-z oriented coils that have the ability of measuring magnetic field using different transmitter-receiver configurations, and these are: “Z-Z”, “Z-H”, and “H-H” (H, meaning horizontal in x or y directions).

Numerical experiments demonstrate that horizontal sources give fields, which are exquisitely sensitive to near borehole effects. This means that eccentering and tool flexure can lead to significant data noise. Array focusing is one means of correcting for these effects provided that the prior information concerning the borehole environment is available.

Vertical sources with horizontal field measurements are a modality, which has been used. This arrangement does minimize the effects of a borehole, and thus it can be numerically modeled without including the computationally expensive borehole.

Using “Z-H” transmitter-receiver configurations can gives us some information about non-axial symmetry responses, but what this really means?.

Different scenarios can gives similar non-axial symmetry responses and we look into some of them.

The use of horizontal transmitters or receivers, rise the question of how accurately we need to have the transmitter-receiver orientations in the field to be able to account for repeatability of the measurements. We also look into this problem. We started to develop a modeling effort as the only way to use data obtained form horizontal transmitters or receivers in an induction-logging tool.

Unfortunately, retaining the vertical source only leaves many formations unresolved. For example, uniaxial anisotropies are unresolved. Also, flexure of a long tool will introduce horizontal source components, whose horizontal field response can be large. Also geometric effects can be particularly pronounced in cross-well surveys.

A large amount of information in the data suggests a large number of interpretation parameters and a great deal of work in computing the response of even simple models. There are situations when the investment in interpretational infrastructure is just not cost-effective and conventional logs provide perfectly adequate information.

NUMERICAL RESPONSES

EM simulations for Tz-Rz and Tz-Rx configurations

Our previous calculations (Bertete-Aguirre H, et all, 2001) have shown that Tx-Rx arrays are extremely sensitive to the near borehole environment. It is appealing to speculate that Tz-Rx array will be less sensitive to borehole effects while maintaining some exploration directionality. To test this hypothesis we also calculated sensitivities for more three cases: a traditional Tz-Rz concentric array, a Tz-Rx concentric configuration and a Tz-Rx non-concentric configuration. The computational domain is shown in **figure 1**, the modeled borehole is a smooth 40 cm diameter cylinder of length 40m and resistivity 0.1 ohm-m, situated in a 100 ohm-m isotropic earth, discretized using 200 and 300 cells along the long axis., but the EM array has only one transmitter at 2026 m and one receiver at 2028 m. **Figures 2 through 3** show the sensitivities (given in Appendix 1) for these three configurations. As illustrated, the Tz-Rz sensitivities are less rapidly changing and propagate more deep into the formation. The sensitivities for the Tz-Rx configurations are more rapidly changing and strongest in the vicinity of the transmitter, then more affected by near-borehole anomalies or borehole irregularities than the conventional configuration (Tz-Rz). Displacing the transmitter from the vertical axes seems to increase the sensitivity of the horizontal receiver. This is due to the introduction of vertical electric current for this case.

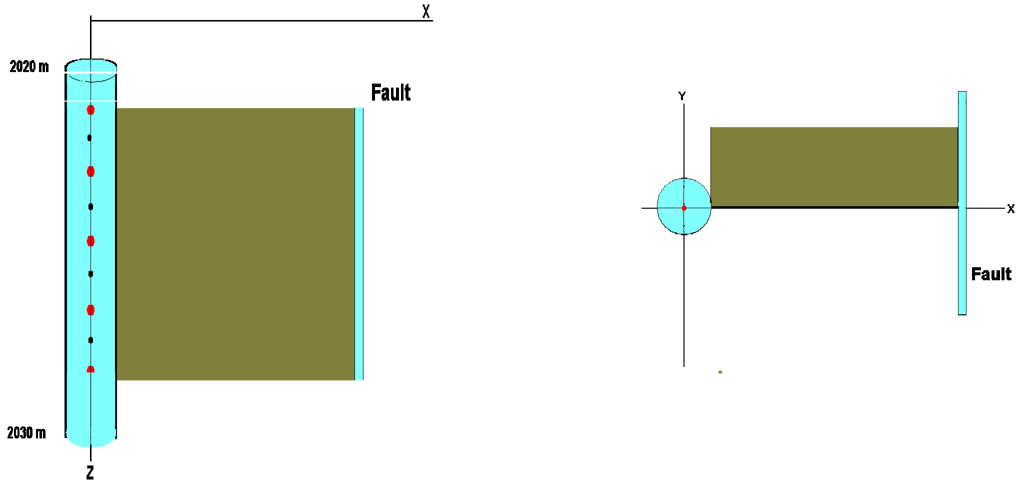


Figure 1a and 1b. Computational domain in green.

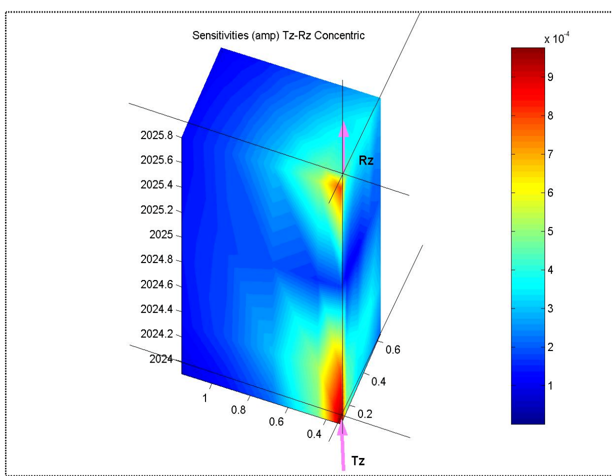
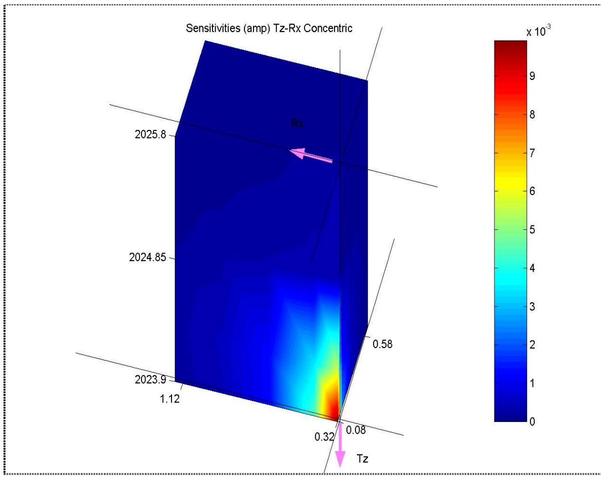


***Figure 2**. Sensitivities in a traditional Tz-Rz concentric array*



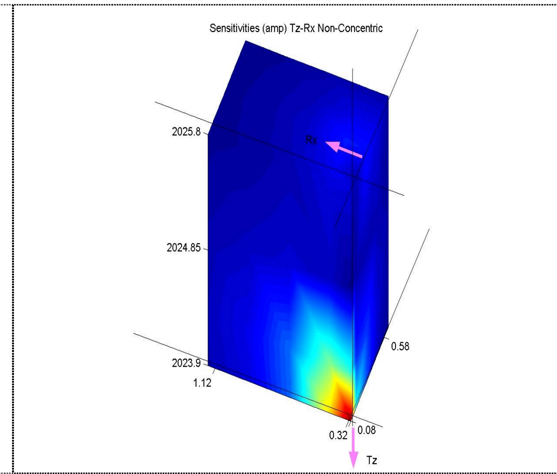


Figure 3 (left). *Sensitivities in a Tz-Rx concentric array*
Figure 4 (right). *Sensitivities in a Tz-Rx non-concentric array*

CONCLUSIONS

We have developed a computational environment to evaluate 3D-electromagnetic sensitivities for high borehole-to-formation contrast resistivities to simulate the effects of a triaxial induction logging tool in a geothermal reservoir. Numerical EM modeling shows the need for simulating the possible responses of the triaxial tool using previous knowledge of the site to overcome the highly undermine system when using a single borehole.

We particularly like the notion of using prior information concerning the borehole parameters to adeptly focus the triaxial induction tool fields. Our numerical experiments demonstrate that this approach should enhance formation resolvability.

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