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How well do you know your Well Survey? A Geologist's Perspective on the Impact of Unanalyzed Surveys

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Introduction

Often, reservoir parameters, drilling processes, completions and production optimizations are intensely analyzed, questioned, adjusted, and reviewed in individual wellbores and project areas. Each of those parameters, processes, or techniques can be improved with increased information, knowledge and understandings. Geological maps, reservoir models, completion plans, and production predictions are all tied to a wellbore position that is thought to be accurate and precise. The accuracy and confidence in downhole surveys and wellbore positions is rarely questioned, reviewed or re-evaluated.

This presentation is intended to be educational for geoscientists and engineers to increase their knowledge and understanding of downhole surveying and wellbore positioning. Leading to a change in questioning how surveys and drill plans are evaluated, analyzed, and used. Survey accuracy, precision, and wellbore uncertainty in relation to geomagnetic models and systemic tool errors will be discussed. Using outdated or incorrect geomagnetic models and not analyzing for systemic bottom hole assembly (BHA) errors or other uncertainties, can lead to serious consequences in wellbore placement and therefore, potentially impact project planning, wellbore collisions, wellbore completions, reservoir modeling and well production.

Survey Measurement and Analysis

Modern directional wellbore surveys are real-time measurements of depth, inclination, and azimuth at single discrete points in a wellbore. From these measurements, the True Vertical Depth (TVD) and location (northing/easting or latitude/longitude) of a well are calculated. Multiple survey points along the length of the well are combined to determine a well path. These measurements use standardized sets of parameters extracted from geomagnetic models as references in determining the well's position relative to Earth's magnetic field. The parameters used are: magnetic declination, magnetic dip angle, and total magnetic field intensity. These standardized parameters are constant regardless of tool or directional company, but the actual values themselves fluctuate not only based on physical location in the world, but also based on the continuous movement of magnetic north. If this continuous shift in magnetic north is not being accounted for, then major impacts on where a wellbore is truly drilled, and where it should plot on a map, can occur. This is especially true in locations closer to magnetic north or regions where magnetic anomalies can occur.

As a wellbore increases in inclination, there is not only an influence of Earth's magnetic field on a survey measurement but also Earth's gravitational influences, tool calibration variabilities, and magnetic interference from BHA's. The combination of these errors creates a margin of error known as an Ellipse of Uncertainty (EoU). Ellipses can be drawn at survey points and measured on a wellbore, the size of which increases from wellhead to total depth, especially in lateral sections of horizontal wellbores.

An EoU is the statistical analysis of the probability of a wellbore being within a specified area around a survey point. A survey point is a measured position of a wellbore and the true location of that wellbore will be somewhere within the calculated EoU. There will always be an EoU - the more magnetic interference present, the bigger the EoU and the greater the uncertainty of where a wellbore is in relation to the measured or calculated survey position. By using correct and up-to-date geomagnetic models and performing multi-stage analysis on measured surveys, EoU's along a wellbore can be greatly reduced. By reducing the EoU in relation to each survey point, the confidence in the entire wellbore position will inherently increase and the calculated inclination and azimuth values will be closer to true than on an unanalyzed survey or wellbore.

Wellbore Positioning and Planning

Magnetic north is continuously shifting. Using an outdated geomagnetic model in well planning will mean the wrong reference geomagnetic parameters will be applied. If that occurs, before a drill bit even breaks ground, it is pre-determined that the wellbore will have a misleading EoU and may not plot where it should in relation to the live geomagnetic model at the time of drilling. Once the bit breaks ground, there is still potential for tool calibration issues and downhole magnetic interference which can further increase the EoU and accordingly, the accumulation of the errors will significantly decrease the confidence of a wellbore position.

As a singular well, this may not be an issue, but when wells are being planned at higher densities - closer well spacing and infills between previously drilled wells; on multi-well drilling pads; or in multi-zone wellbores; then there is a need for increased confidence in wellbore positioning. Survey analysis is not going to solve all queries tied to a wellbore's position, but it may reduce concerns related to well density. Imagine having a closer to true wellbore position and the comprehension impacts for reservoir modeling, geological mapping, completions, production, hard boundaries, anti-collisions, and drilling. All these factors have an impact on well planning, project planning and multi-discipline reservoir understanding. Survey analysis must be considered for all wells, regardless of their worldly locations.

Geologist's Perspective: Impact of Unanalyzed Surveys

From a geologist's perspective, a horizontal well plot is used to communicate changes in formation, reservoir, and wellbore expectations or results. Knowing where a horizontal wellbore plots on a map has an impact on mapping decisions, understanding reservoir changes, potential completion or production issues, and future planning. After a well has been drilled, geoscientists adjust interpretations and explain results, both expected and unexpected. Often, formation mapping and interpretations are adjusted to reflect wellbore results based on the final physical location provided at the end of drilling a well. Rarely is a wellbore position questioned. Or if it is, there is rarely an opportunity to review the data used to create the wellbore plot and re-evaluate. Geoscientists and engineers are constantly re-evaluating every other aspect of a wellbore, evaluating the positions of horizontal wellbores need to be considered also. There will always be an accumulated margin of error, with or without survey analysis, but knowing the potential size can be the first step towards an all-encompassing re-evaluation, or rather a pre-evaluation, of a wellbore. By acknowledging wellbore position uncertainty from the beginning of the life of a well, the confidence in interpretations, mapping, modeling, and understandings will change; fundamentally for the better. Examples outlining the above will be presented.

Summary

Geoscientists rely on horizontal wellbore positions and well plots to be accurate and precise. All well surveys, whether analyzed or not, have an Ellipse of Uncertainty (EoU) at each point. This ellipse increases in size from wellhead to total depth and impacts where a true wellbore position could be; the impact can be more significant in horizontal wells. Using current geomagnetic models and performing survey analysis to remove systemic errors and magnetic interference will reduce the size of an EoU. By reducing an EoU, the confidence in a survey and wellbore position increases, especially for wells in northern regions or near magnetic anomalies. With increased understanding of survey management and analysis, the detrimental impacts of uncertain wellbore positioning on modeling, mapping, and planning will be reduced. Survey analysis is not meant to replace techniques that may improve reservoir or project area understanding but instead, to complement those understandings by increasing the confidence in wellbore positions and as a result, in interpretations, mapping and modeling.

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