

Geosteering Workflow Considerations of How and Why?

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Summary

This extended abstract addresses key elements of a successful geosteering workflow. The success of a well or project can be determined by key performance indicators (KPIs). A review of previous work on the advantages of geosteering is presented and discussed with respect to quantifiable KPIs.

Introduction

Optimal wellbore placement is the ideal goal of all geosteering activities. At its best geosteering, is an inter-complementary and multidisciplinary approach to achieving this goal. However, each discipline may interpret “optimal” differently. To the geologist, it could simply mean no reservoir exits, or 100% reservoir exposure. For the reservoir engineer, optimal might mean a noticeable increase in production. A drilling supervisor may consider a cost-effective, below-AFE (budget), problem-free, and safely drilled well to be the most optimal scenario.

A company must balance the concerns of drilling, geology, and production in considering their well-placement strategy. A poorly placed well with respect to the reservoir targets will be of little benefit. While the tools and tactics to target the ideal zone within a reservoir could initially add to the cost, a collaborative approach that addresses the concerns of all interested parties will help to minimize misunderstandings and allow for an ideal range of possibilities regarding the well plan. Although a geosteering approach should follow a workflow, the plan can be flexible enough to incorporate a range of possibilities, allowing for each discipline to achieve its optimal benefits.

This paper describes important considerations that should be taken into account when planning and running a geosteering operation, including project size, budget availability, and given pre-drill data. A general workflow for a geosteering project is discussed, along with the elements to be considered for its success. To explore the quantifiable measure of geosteering success, a review of previous work and case studies are presented. Despite the large amount of information related to the benefits of using a geosteering approach in published articles, few articles are identified in which the advantages of geosteering are numerically outlined.

Considerations in Geosteering

Geosteering involves input from multiple disciplinary fields that can be broadly divided into three categories: drilling, geology, and directional. Coordination and cooperation among these disciplines are essential to the success of the geosteering process. Primary considerations from each field for understanding a geosteering project are mentioned below:

Drilling Supervision:

1. Well design – well-trajectory profile, anti-collision, doglegs, length, hole size, KOP, landing point, targets
2. Drilling parameters – hydraulics, drilling rate

Geology:

1. Available pre-drill data – seismic data, offset-well-log data, surfaces, formation type, change in geology along the wellbore, target formation thickness
2. Geological uncertainties – pinching, faults, reservoir heterogeneity
3. Contrast in trace-log data, which should guide the geosteering and determine bed boundaries
4. Pre-drill geosteering models and real-time geosteering software
5. Expected tool response in the reservoir and at the exits

Directional Drilling/M-LWD (Measurement – Logging While Drilling):

1. Motor – type, bend, rotary steerable or mud
2. Tools – tool selection, distance to sensor from the bit, look-ahead and/or look-around capability, depth of investigation, image selection
3. Inclination at the bit – distance from the bit, position in BHA (before or after bend), continuous
4. Survey – distance from the bit, frequency of survey, ellipse of uncertainty

Workflow for a Geosteering Operation

Data from the above-mentioned categories are critical to a geosteering operation. The workflow using these inputs can be categorized into three main phases:

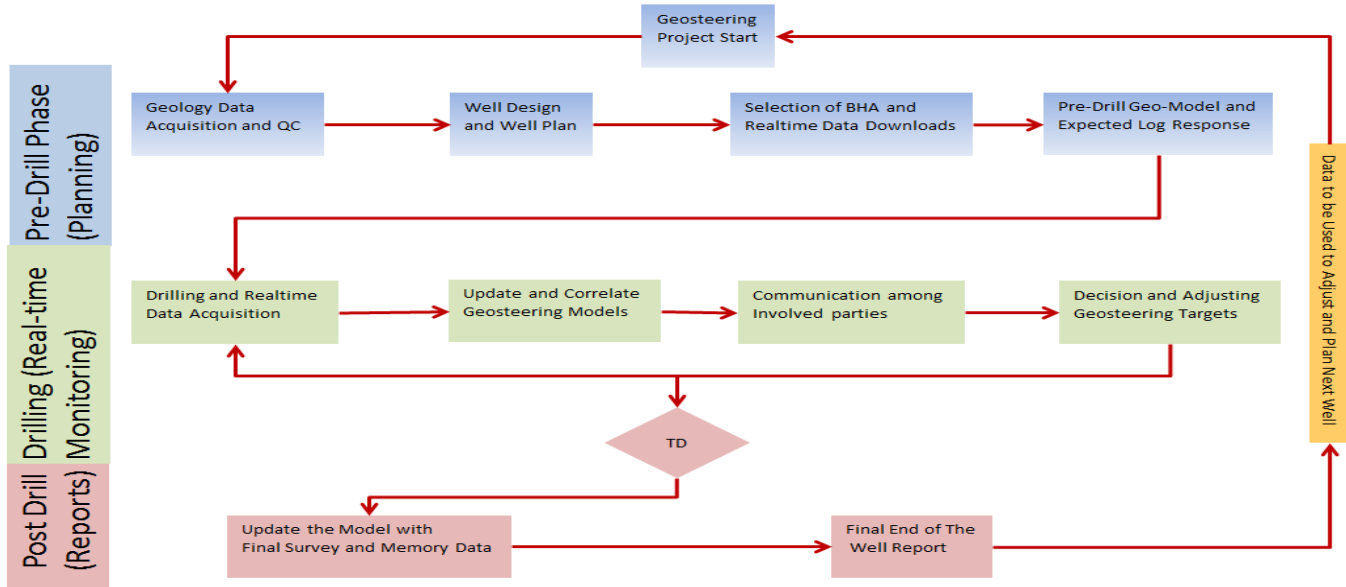
1. Pre-drill phase – planning
2. Drilling – real-time monitoring
3. Post-drill – final reports and logs

Pre-drill phase: All available information is used to design the well plan and understand the reservoir. Seismic, offset-log data, and petrophysical characteristics can be used to generate pre-drilling models. Expected responses are modeled in different geology-drilling scenarios and discussed with the team. Possible acceptable alternatives to the well plan are considered.

Drilling phase: Real-time data are analyzed / transferred into geosteering software and are correlated with modeled offset data. This correlation helps with locating the wellbore position with respect to the reservoir and provides the best method for deciding the future course of the wellbore. In case of geological uncertainty, more than one correlation and model can support the decision-making process.

Post-drill phase: All data are reviewed. Final surveys and data downloads from the tools can be used to refine models and interpretations. With final logs and reports, recommendations can be made to plan the next well in the pad or field (Fig. 1).

(Fig. 1) Geosteering Workflow



Geosteering Advantages

A detailed review of existing literature on the “benefits of geosteering” has revealed that although there are many articles that have outlined several advantages of geosteering, they are in descriptive form (Zimmer et al. 2010). These benefits include maximizing reservoir contact/exposure to increase production; reducing the drilling time and thus, drilling cost; improving directional control; eliminating sidetracks; reducing the tortuosity of the well; reducing the number of rig personnel; and post-well analyses that help in planning future wells in the pad/field. In any oilfield life cycle, geosteering operations usually have a time gap from production results, which is one of the reasons (apart from company policies for data release) that geosteering success or failure is not always mentioned as a benefit to reservoir performance. This has been observed in numerous geosteering operations, as well as interactions with clients. In a detailed search for technical papers regarding production increases as a result of effective geosteering, only 18 cited articles had some quantifiable measure of the advantages of geosteering (Table 1).

Conclusions

The objective of this article was to compile quantifiable evidence of geosteering benefits. Often, geosteering tools and techniques can be overlooked or dismissed owing to additional expense, especially by cost-conscious companies. In summarizing the available numerical data associated with geosteering benefits from various papers, articles, and case histories, we hope to encourage and promote further discussions on geosteering within a company’s culture.

Benefits to a geosteering approach will vary from project to project. The data collected while drilling will provide a more comprehensive understanding of the reservoir, with the most common result being an increase in coverage through the pay zone. This increased reservoir exposure can be associated with many of the advantages found in Table 1, including significant increased production, reduced water cut, fewer sidetracks, and reduced operational costs.

Geosteering tools and techniques are becoming an integral part of drilling practice. The associated workflows offer the flexibility to ensure increased reservoir exposure compared to other well-placement techniques. Furthermore, the information gained while achieving an optimal well placement can be leveraged into future wells, ideally maximizing reservoir exposure and fully developing production, while minimizing critical drilling issues. Using a geosteering workflow can help evolve a drilling project to meet the challenges of improved efficiencies and productivity.

Table1: Advantages of Geosteering

Sn	Author & Affiliation	Publication	Year	Field, Country	No of Wells	Tools Used	Production Increase	Cost Reduction	Exits/Non Reservoir	Other Advantages	Drilling Time
1	Saleri, N.G. et al. Saudi Aramco	Jl. of Petroleum Technology	2003	Zuluf-Shaybah Saudi Arabia	14	NMR and other	Net/Gross ratio increased 13%			190% Increased net pay	
2	Carmen Lee et al CNRL	SPE-97809	2005	Primrose, AB, Canada	55	EWR, ABI		13% of Planned Cost	18% to 4% ST 0 from 10 per Pad	ROP 200%	4.2 to 3.6 days/well
3	Lawrence Chou Stat Oil	Oilfield Review	2005	Callanish, Norway	3	Deep Azim Res	Net/Gross ratio increased by 15%			30% Increased pay zone	
4	Anon Schlumberger	Case Study 06-DR-281	2006	Carbonates, UAE	1	Deep Azim Res Suite	400%				
5	Song Yu Xin et al Maniotok Energy	World Oil	2009	Lu Liang, W China	47	Deep Azim Res	20%			100% Payzone; 70% less water cut	
6	Anon Halliburton	Case History H07331 12/09	2009	Heavy Oil Field, Canada	1	Deep Azim Res				100% Pay zone	
7	Cuadros, J. et al. Mansarovar Ener.	E&P Magazine	2010	Girasol, Columbia	16	Deep Azim Res	250%-700%	20% of Planned Cost	Zero exit	100% Pay zone	40% less
8	Anon Schlumberger	Case Study 11-DR-0157	2011	Norway	1		240%				
9	Arvind Vilas Rao et al., ONGC	SPWLA-3 rd Symposium	2011	Cambay-Tarapur, India	2	Triple Combo	400-600%	\$14 million		100% Pay zone	
10	Anon Weatherford	Real Results 10334.00	2012	Lao, Columbia	2	Triple Combo	300%				
11	Anon Halliburton	Case Study H09941 2/13.	2013	Junin, Venezuela	1	Deep Azim Res, ABI				100% Pay zone	
12	Anon Schlumberger	Case Study 13-DR-0103	2013	Cuu Long, Vietnam	3		50%			0% Water cut	
13	Anon Schlumberger	Case Study 09-DR-0143	2013	XiJiang, S China	5	Deep Azim Res, RSS	280%			Prod decline rate 15 to 0%	
14	Anon Halliburton	Case History H010949 02/14	2014	Middle East	1	Azim Res, GR, PWD, RSS		\$400k			
15	Anon Halliburton	Case History H012035 12/15	2015	Manville, Canada	1	Azim Res, ABI				100% Pay zone	
16	Asong Suh et al.	SPE/ADC-173036-MS	2015	Cardium, AB	12	Azim GR, ABI			Reduced by 8%	30% Increased pay zone	
17	Susana G. Carrilero et al.	IPTC-18863-MS	2016	Mid Bakken, USA	2	GABI with Image				100% Pay zone	
18	Anon Halliburton	Case History H012089 12/16	2016	Ferrier, Canada	1	Azim Res, ABI		\$80k		100% Pay zone	

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