





GEOSTEERING AND RESERVOIR NAVIGATION



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Remote geosteering and reservoir navigation

A true geosteering process is in place when three criteria are met:

- Real-time data streaming
- Continuous supervision while drilling
- Use of a specialized correlation software

Service includes

- Continuous supervision of drilling operations
- Continuous assessment of stratigraphic location of the drill bit in real time
- Correlation of drilling, MWD/LWD and mud gas parameters throughout the wellbore and to offsetting wells
- Use offset well information to optimally land the build section, by employing TVD logs with cross plot of offset data
- Continuous communication with directional drillers and Operator personnel, proactive adjustments to ensure wellpath placement remains within the acceptable stratigraphic window
- Proactively evaluate wellpath position in relation to existing and planned wellbores
- Reservoir navigation by providing forward looking targets ahead of the bit

Deliverables

Remote	Real-time data relayed from the wellsite is a day to day reality and has become very robust and reliable in the past few years	
Supervision	 Geosteering geologists acquire continuous drilling and MWD/LWD parameters to decide the optimal steering direction in real time at any distance. Decisions are instantly relayed to directional drillers. Geologists with extensive wellsite experience and specific training are key to the efficiency of a remote procedure system Geosteering geologists determine apparent dips and their extent along the wellbore and pinpoint Wellpath position relative to stratigraphic markers. They set targets ahead of the bit based on geosteering interpretation and geomodel Assessing the trajectory of the wellpath is the single most important aspect of geosteering. This is done by following established procedures and protocols 	
Directional drilling supervision	 Plotting actual well path against designed wellbore trajectory Identification of wellpath relative to stratigraphic markers (wellpath with TVD gamma and formation tops) Constant communication with directional drillers to ensure wellpath follows optimal trajectory best reservoir or best wellbore placement or optimal drill path MWD/LWD supervision: data stream monitoring 	
ReportingImage: Constraint of the second seco	 Key aspects of the drilling process are observed and can be optimized using Geosteering procedures: Assess hole condition by monitoring drilling parameters and mud properties, paying particular attention to any indications of overpressure zones, sticky hole or lost circulation Indicate position relative to stratigraphic markers (based on curve correlation), apparent dip estimation, look ahead of well trajectory Calculate statistics (in zone/out of zone, MWD data breakdown, gas data breakdown, reservoir quality summaries) Establish estimated timelines for events such as encountering critical formation tops, casing points, entering reservoir, and reaching total depth Estimate how long current bit is expected to drill effectively, and when the next trip is expected Generate detailed daily reports (geosteering correlations, landing assessments, striplogs, operations reports, data files, etc), to be distributed within the company and to partners as needed Generate comprehensive final reports (striplogs, final geological report, data files, etc) 	

Project management			
Project support	Chinook is prepared to offer technical and logistics support to room and field personnel, assist with personnel training, reporting and communication protocols.		
Management guidelines	 Chinook will manage the personnel of the geosteering team, by ensuring the following: Training: Chinook will assist in training geosteering geologists working in the room and in the field within the scope of this project. On-the-job training will be organized and supervised by Chinook for personnel that are new to the project. Safety and continuing education training will be facilitated by Chinook for all its sub-contractors, field and room personnel alike Personnel scheduling: Chinook will oversee the scheduling of geologists 		
	working in the remote operations room. While intermediate geologists will work mostly the night shift for the beginning of their work with the Operator, the long term goal is to rotate people on both days and nights shift. A geosteering geologist will start his/hers two-week hitch with one week of nights and then switch to one week of days		
	 Personnel replacement: In the event that someone has an emergency or needs days off during their scheduled work time, Chinook will provide qualified and well trained geosteering geologists to fill in as needed. While Chinook does not intend to make any permanent personnel changes, we can provide permanent replacements if any geologist working in the room decides to pursue other career opportunities or is unable to fulfill his/her duties in their assigned roles Reporting: Chinook will provide assistance with report templates and 		
	standards by improving reports and creating job specific report check lists. It is the responsibility of the geologists working in the room to fill in daily and final reports. Chinook will further copy-edit and round up files needed for the final reports, and will oversee the printing of the final reports after the		
	 striplogs. Chinook will provide day- to-day technical support regarding software and report issues Field personnel: Chinook will assist in the liaison between geosteering geologists and field personnel (wellsite geologists, rovers, sample washers, mudloggers). Chinook will provide technical and logistic support to the field personnel, according to the requirements of the Operator and the geosteering 		
	 geologists working in the room. This includes (but is not limited to) microscopes, digital cameras, sample washing equipment and sample washing supplies, etc Protocol implementation and control: A communication protocol will be established between the geologists working in the remote operations room, Operator personnel and field personnel. Chinook will assist in enforcing this by 		
	 clearly presenting all protocols to Chinook subcontractors (room and field personnel), by analyzing any breach of protocol and taking corrective actions if needed. Additional synergies can be achieved if both geosteering and field personnel are managed by Chinook Invoicing: Geosteering geologists will provide Chinook with their invoices on a per hitch basis and can expect prompt payment; Chinook can invoice the Operator on a monthly or AFE basis, thus ensuring easier processing of invoices for the Operator while providing timely payment to the geologists 		
	working in the remote operations room		

In-House Remote Geosteering

Location: Operator's Office **Personnel:** 4 geosteering geologists, working 12 hours shifts in 2-weeks-on / 2-weeks-off hitches

Operation covered: One team can supervise multiple wells drilling concurrently (generally up to four wells) Dedicated team is screened by operator and takes part in pre-job meetings

Remote Geosteering from Chinook location

Location: At Chinook's office

Personnel: 4 geosteering geologists, working 12 hours shifts in 2-weeks-on / 2-weeksoff hitches; Dedicated team is screened by operator and takes part in pre-job meetings

Operation covered: One team can supervise multiple wells drilling concurrently (generally up to four wells)



GEOSTEERING SCENARIOS

Logistics:

- One office needed, can be shared with other remote supervision teams (drilling optimization, remote directional driller, remote MWD/LWD operator, completion coordination team)
- Multi-screen computer station set up in Operator's offices
- Computer station can cover multiple concurrent drills
- Geosteering software (Starsteer or other) provided directly by operator
- Existing Pason/EDR access

Advantages:

- Optimal data flow: located in the Operator's office, files can be distributed instantaneously on the company server
- If space is shared with remote directional drilling/MWD, decisions can be taken together
- Some information and interpretation can be included immediately in a shared geomodel
- Team gains in-depth background knowledge about project, resulting in high quality geosteering interpretation

Disadvantages:

- When rig internet is down, data files are not received in real-time (updates can still be received from rig personnel
- Rock samples cannot be reviewed in real time (a mudlogger on location can alleviate this issue)
- Requires overhead setup: room, security access, phone, computers

Logistics:

- Geosteering done from Chinook offices
- Software leased by Chinook, billed back to Operator
- Redundant internet connection provided by Chinook (DSL, Cable and Cellular)
- Dedicated work station in our operation room
- Dedicated phone line for 24 hours access
- Pason/EDR access (supplied by Operator)

Advantages:

- No additional setup needed at Operator/Client offices (room, security access, phone, computers, etc)
- For single rig projects, the service can be contracted for only such times when the rig is drilling, resulting in cost savings between wells or when supervision is not required
- Team gains in-depth background knowledge about project, resulting in high quality geosteering interpretation

Disadvantages:

- Communication with Operator done via Phone/Email/Secure data servers is not continuous in real-time
- Large files (such as final reports) and daily reports are not stored directly on Operator system (but can be sent via secure connection)
- No access to shared geomodel
- When rig internet is down, data files are not received in real-time (updates can still be received from rig personnel via email)
- Rock samples cannot be reviewed in real time (a mudlogger on location can alleviate this issue).

On-site geosteering

Location: At the rig

Personnel: 2 wellsite geologists working 12 hours shifts on a rotation basis

Operation covered: One team per well, wellsite geologists on location for intermediate and lateral sections



Combination geosteering and wellsite geology

- **Location:** At the rig and office in town (in-house or at Chinook's facility)
- **Personnel:** Single wellsite geologists at the rig,
- working back to back with geosteering geologist in office; alternately, a 24 hour remote supervision can
- back a single wellsite geologist

Operation covered: One wellsite geologist per well, wellsite geologists on location for intermediate and lateral sections, remote geosteerers in

town covering multiple rigs

Logistics:

- Geosteering done from rig
- Software leased by Chinook, billed back to Operator
- Internet and data connection provided by rig operation
- Pason/EDR and/or WITS/WITSML access (supplied by Operator)

Advantages:

- No additional setup needed at Operator/Client offices (room, security access, phone, computers, etc)
- The service is contracted for only such times when the rig is drilling, resulting in cost savings between wells or when supervision is not required
- Team combines petrographic observations with geosteering interpretation
- Real-time data flow possible even in case internet connection is down
- Rock samples are examined concurrently with geosteering

Disadvantages:

- Communication with Operator done via Phone/Email/Secure data servers is not continuous in real-time
- Large files (such as final reports) and daily reports are not stored directly on Operator system (but can be sent via secure connection)
- No access to shared geomodel
- When rig internet is down, data files are not received in real-time (updates can still be received from rig personnel via email)

Logistics:

- Wellsite geologist is traveling to the rig as usual and are based at the rig in rig shacks or command center
- Remote geosteering geologist or team set up in Operator's offices or at Chinook facility
 - Computer station can cover multiple concurrent drills
 - o Geosteering software (StarSteer or other) provided by Chinook
 - o Existing Pason/EDR and/or WITSML data access

Advantages:

- Access to cuttings information can be integrated in the interpretation (not continuously)
- Direct communication with on-site directional drilling, MWD and drilling personnel is possible (but not continuous)
- Real-time data flow possible even in case internet connection is down
- Continuous supervision covered by wellsite and remote geologist
- Only one geologist in the field reduces cost and safety risk due to travel
- Geosteering advantages (well position, statistics, etc) is retained throughout the well
- Cost reduction achieved by using a team of geosteering geologists for multiple wells drilled at the same time

Disadvantages:

- One field geologist for every rig, safety risks due to travel
- Communication with Operator done via Phone/Email
- Lower speed internet connection at rig makes transfer of large files often slow
- Wellsite geologists have other concurrent duties that can interfere with geosteering data processing and interpretation



Night geosteering Location: At Chinook's office Personnel: One geosteering specialist working cross-shift with Operator area geologist Operation covered: Real-time operations supervision and geosteering for 12 hours per day, in order to provide relief and assistance to operator employed area geologist.	 Logistics: Geosteering done from Chinook offices Software leased by Chinook, price included in interpretation Data provided by Client/Operator (Surveys, MWD/LWD data, offset log data, formation tops and target windows) or via WITSML Shared work station in our operation room Advantages: No set-up fees, work is performed in Chinook's operation room Reduced cost as only one geosteerer per day is employed For single rig projects, the service can be contracted for only such times when the rig is drilling, resulting in cost savings between wells or when supervision is not required Disadvantages: Supervision is not continuous Responsibility is shared between operator and geosteerer Project files need to be transmitted daily between operator and geosteering geologist Typically no access to geomodel
On-demand geosteering Location: At Chinook's office Personnel: on call geologist/geo- steerer Operation covered: When needed, or on-call geosteerer can quickly run data through a geosteering software and create a punctual interpretation. This approach is especially useful when the location of the wellpath relative to formation markers is not known or when a second opinion is needed.	 Logistics: Geosteering done from Chinook offices Software leased by Chinook, price included in interpretation Data provided by Client/Operator (Surveys, MWD/LWD data, offset log data, formation tops and target windows) Shared work station in our operation room Advantages: No set-up fees, work is performed in Chinook's operation room Quick turnaround: an initial interpretation is typically delivered in 1-2 hours, a complete report is delivered within a day Interpretation only employed when needed, payment required only when service is employed Supervision is not continuous Personnel may not have in-depth background knowledge about particular projects (depending on who is on duty when the service is required)

LEVEL OF SERVICES				
Quicksilver	Coverage:			
	Up to 8 rigs per station, reports every 4 hours, wells supervised in the lateral section only			
Applicable for geosteering of large number of similar wells, service only deployed in the lateral section	 Deliverables: Geosteering correlation sent every 4 hours while drilling the lateral section A snapshot of the geosteering correlation, pinpointing of stratigraphic position; Report every 4 hours Survey details, bit position in relation to stratigraphic markers; extrapolation of trajectory and formation tops intersection; in/out of zone statistics End of well report: Structure data (with apparent dip and fault blocks); formation tops position; well data (surveys and MWD/LWD LAS files). 			
Titanium	Coverage: Up to 4 rigs per station, reports every 4 hours, wells supervised continuously			
Applicable for geosteering of unconventional reservoirs (shale oil, shale gas, tight gas), supervision of build and lateral sections	 Build assessments every 2-4 hours Geosteering interpretation: every 4 hours in the lateral section Target projections ahead of the bit Striplogs compiling all available data End of well reports Regulator compliant reports, logs and data 			
Diamond	Coverage: Up to 2 rigs per station, reports every 4 hours, wells supervised continuously.			
Applicable for geosteering of unconventional reservoirs (shale oil, shale gas, tight gas), supervision of wells from spud to TD, as well as pre-spud and completion	 Deliverables: Build assessments every 2-4 hours Geosteering interpretation: every 4 hours in the lateral section Striplogs compiling all available data End of well reports including Regulatorcompliant reports, logs and data Interpretation of drilling data; applicable to wells drilled on the same pad or regionally: Identification of most drillable horizon, as well as hard or clay horizons to be avoided Identification of most prolific zones based on ROP/Gas response Recommendations for drilling optimization; Integration of completion data 			
	Operations Geology			

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Chinook REMOTE GEOSTEERING EXPERIENCE



http://chinookpetroleum.com/wellsites/?geoid=GEOST&geoname=Remote-Geosteering



Notikewin, Falher, McMurray, Sparky, Wilrich, Clearwater, Shaunavon, Livingstone, Doig, Basal Quartz, Glauconitic, Exshaw, Ellerslie, Viking, Wolfcamp, Torquay, Swan Hills, Cattle Creek, Bohena, Cummings, Dunvegan, Pekisko, Jean Marie

+35

Operators

Kaybob, Etsho, Ferrier, Pouce Coupe, Gold Creek, Tony Creek, Twinning, Sundance, Fox Creek, Swan Lake, Wildhay River, Wapiti, Waskahigan, Pedley, Elmsworth, Mann Lake, Hardy, Willston Green, Saxon, Tower, Trail, Sundown, McKinley, Laprise, Blackstone, Sunrise, Two Creeks, Altares, Nipisi, Redrock, Waterton, Valhalla, Eastend, Princess, Kiwigana, French, Doe, Bantry, Rapdan, Caroline, Kirby, Notukeu, Moonah, Frenchman Butte, Kindersley, Poplar Hills, Jayer, Swan Hills, Birdtail, Dewhurst, Washington, Gunnell, Leismer, Halkirk, Pembina, Fortune, Medicine River



Consultants with Geosteering experience on active roster



CHINOOK SERVICES

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Wellsite Geology	 Petrographic analysis of drill cuttings Porosity/Permeability estimation Directional and wireline supervision Mudlogging SAGD and Oil Sands Delineation Services
Remote Geosteering	 Monitoring of drilling, MWD, Mud gas Assessment of stratigraphic location Optimal placement of wellpath Reporting
Reservoir Evaluation	 Basin Analytics Reservoir Evaluation Prospect Generation
Petrographic studies	 Petrography striplogs Petrographic features Reservoir evaluation Digital photography Digital data exports
Field and Laboratory	XRF Analysis and Quantitative interpretationXRD Analysis
Geochemistry	GCMS (Gas Chromatography Mass Spectrometry)Grain size analysis (stacked sieves or petrographic)
Drilling and	 Drilling Engineering and Operations Drilling Performance Optimization Abandonment Studies
Completions	Manpower Services
International Operations	 Project Management Geoscience projects Drilling and completion projects Safety and compliance

