

Successful Application of Point the Bit Rotary Steerable System to Sidetrack from Formation with High Compressive Strength

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Abstract

Rotary steerable systems have evolved considerably since their introduction several years ago, from bigger and more robust pads in “push the bit” systems to the newer generation “point the bit” systems.

The use and application of these tools have also expanded. In eastern Canada, a number of sidetracks have been performed from cement plugs using “point the bit” RSS in extended reach wells (6,325 m MD at 4,120 m TVD and 7,000 m MD at 4,376 m TVD) in formations with high compressive strength, where sliding with a downhole motor is difficult and adds significant risk to drilling operations. By performing this kick-off operation with a rotary steerable system, a complete bottomhole assembly (BHA) trip is avoided as well as part of the section is saved thus lowering the well construction cost.

This paper discusses the BHAs and operational considerations necessary to achieve this success. Three case histories are outlined where this application was successfully used to sidetrack an extended reach well in the openhole from a cement plug. Also, a previous sidetrack with a positive displacement motor (PDM) from a whipstock in the same well demonstrates the limitations of a mud motor in this type of well and conditions where weight transfer becomes a big challenge while trying to slide in these hard formations.

Introduction

Today’s drilling environment has not become any easier. There are harder and more abrasive formations, and longer and more challenging profiles in order to reach the reservoirs are very much standard in many places of the world. Continuous research for newer technologies and techniques to efficiently reach those reservoirs is being analyzed and developed, but the challenges get bigger and bigger.

In general, the use of rotary steerable systems in sidetracks has improved over motors in certain parts of the world but has become a big challenge in other places. In eastern Canada we faced the challenge where sidetrack with a mud motor was not possible because weight transfer while sliding and mud motor orientation was almost impossible while drilling deeper into hard formations. That left us with the rotary steerable system option, but we had 2 systems available: “push the bit” and “point the bit”. A decision to use “point the bit” was made based on which system would provide the best success in

deep, highly deviated and hard formations. “Point the bit” has no exterior moving parts; good durability while drilling in hard, abrasive formations where premature wear could influence tool performance; and also behaves in a similar fashion to a steerable motor but without the sliding component.

Mud motor technology

Standard steerable-motor directional drilling equipment is generally based on the tilt angle principle. A bend between 0.5° and 3° in the motor provides the bit offset necessary to initiate and maintain changes in course direction. Three geometric contact points (bit, near-bit stabilizer on the motor, and a stabilizer above the motor) approximate an arc that the well path will follow, and thus the curve rate or dogleg severity for the system. This curvature is formed and built by holding the entire drillstring still so that the bend can work in a preferential direction or in sliding mode. Conventional practice is to drill in rotary mode, rotating the drillstring from the surface to drill a straight path. If a change in direction is needed, the drillstring is stopped with the bent housing or tilt on the steerable system oriented in the desired direction. This orientation is called the toolface angle and is measured downhole by MWD systems. When drilling in this oriented mode, the entire drillstring has to slide. Drillstring drag problems become acute in extended-reach wells and cause problems in setting the toolface angle and applying weight to the bit and rate of penetration suffers. Techniques are needed to provide greater directional flexibility with rotary drilling in extended-reach wells. (See figure 1)

Directional Control

Steering by slide drilling is impossible at extreme horizontal distances. Drilling in the sliding mode results in several inefficiencies that are compounded by extreme distances. The motor must be oriented and maintained in a particular direction while drilling to follow the desired path. This orientation is achieved through a combination of rotating the drillstring several revolutions and working the pipe to turn it to the desired direction. At long distances, the pipe may need 10 to 15 turns at surface just to turn the tool once downhole, because the drillstring can absorb the torque over such a long distance. For the directional driller, this technique

is as much art as it is science. After the tool is positioned, drillstring torque is required to hold the motor in proper orientation against reverse torque created by the motor as the bit drills.

Another problem with slide drilling in high-angle wells is that cuttings removal suffers from the lack of drillstring rotation. In wells with high drag, the drillstring cannot be lowered smoothly and continuously, which prevents the motor from operating at optimal conditions. In combination, these factors result in a lower penetration rate compared to that during rotary drilling. For extended-reach wells, not only does penetration rate suffer, but also slide drilling is no longer possible. One more complication is that the directional control with a mud motor is the formation's compressive strength, which in this case is high and requires more weight-on-bit to drill it efficiently.

Rotary steerable systems Overview

The RSS technology has continued to evolve since it was first introduced in the late 1990s. Two types of RSS are presently available: "push the bit" and "point the bit" systems. The side force lifts the centre line of the BHA in the desired direction. Both tools use dynamic tool face control to continuously rotate all BHA components and both tools rely on 3 points of contact to create a bend.

The "push the bit" RSS relies on interaction between the pushing force and the wellbore. Pads extend dynamically from a rotating housing. (See figure 2)

The principle of operation and benefits of "point the bit" rotary steerable system is that the bit is pointed in the direction needed to go either through bending a shaft or having a built-in offset. This is analogous to steering with a bent motor.

In this case the "point the bit" RSS used operates with no sliding stabilizers or exposed steering mechanisms. Instead, an internal servomotor constantly controls the bit shaft toolface. The servomotor holds the tool face orientation of the angled bit shaft geostationary (not moving in respect to the formation). This produces consistent steering control in a variety of hole conditions. When steering with this RSS technology, the tool will rotate the offset in the opposite direction of the collar. If the motor is driven at collar rpm (but backwards), the toolface becomes stationary in the hole. The bit shaft now remains pointed in a constant direction. The tool is now steering while the collar is rotating. (See figure 3)

Benefits:

- All external parts rotate with String rpm
- Effective weight transfer.
- Improved hole cleaning which reduces the risk of stuck pipe and also less reaming. This also applies to "push the bit" technology.
- Ability to cut a through for open hole sidetracks.
- No dependence on friction with hole wall.

The main benefit for this application is that the "point the bit" RSS acts like a motor but with all the benefits of a rotary steerable system. (See figure 4)

Formation Compressive Strength

Unconfined Compressive Strength is the most commonly utilized mechanical property for bit selection and performance prediction. UCS denotes the maximum compressive load a material can withstand before failure. UCS can be determined experimentally by measuring the stress necessary to fail the material under a compressive load without the presence of any confining pressures (uni-axial testing). UCS does not inherently increase with depth since its measurement assumes an absence of confining pressures.

The software estimates several mechanical properties utilizing the logged compressional sonic values and material constants for the relevant lithology. The software utilizes additional log data if available, including shear sonic, porosity, and/or density. One of several UCS algorithms is used based on an internal logic that selects the most appropriate method. The UCS of an offset well at the Cape Island formation shows a UCS of 10,000 to 25,000 psi. (See figure 5)

Sidetrack #1

This sidetrack was performed from a whipstock with a mud motor at 5,775 m MD. The well was successfully sidetracked, but the BHA was hanging up making it very difficult to slide in the desired direction after just drilling 34 m. We also experience problems orienting the mud motor. Due to these difficulties, it was decided to pull out of the hole to pick up a rotary steerable system. Note that there was a successful "point the bit" RSS run after this sidetrack.

Sidetrack #2

After the experience with the mud motor on the first sidetrack from the whipstock and the challenges in this wellbore, it was decided to do the sidetrack with the "point the bit" RSS at 7,000 m MD.

A 150m long cement plug (density: 2,030 kg/m³, Class G + 35% silica flour + 16 l/ton dispersant, 10 l/ton fluid loss control additives, 12 l/ton high temperature retarder, 5 l/ton antifoam) was designed. At 24 hours, the compressive strength was 4,431 psi and after 63:03 h:min, the compressive strength was 5,391 psi. At this point in the wellbore, reaming both to get in and out of the hole, it was decided to place the cement plug with a stabilized string. This BHA was not ideal for cement plug placement and likely led to contamination.

The assembly sidetracked the well successfully after time drilling for 38m and 78.25 h. After 17.5 h there was 70% formation in the cuttings, but the inclination from the tool did not show any appreciable drop in angle. Time drilling continued and formation samples reduced to 30%. At this point time drilling rate was decreased and continued until 50m of cement were drilled. A decision was made to pull out of the hole and as a last attempt; weight was applied to the assembly. This caused the desired drop in inclination to sidetrack the well resulting in sidetrack #2. The lesson learned from this experience was to attempt drilling with weight once 70% formation is observed in the cuttings. A subsequent BHA was unable to enter the new wellbore, possibly as a result of

cement contamination, therefore, a third sidetrack attempt was required.

Sidetrack #3

The lessons learned from the first sidetrack were taken into account and applied for this sidetrack.

A 200 m long cement plug (density: 2,030 kg/m³, Class G + 35% silica flour + 16 l/ton dispersant, 10 l/ton fluid loss control additives, 10 l/ton high temperature retarder, 5 l/ton antifoam) was designed. At 24 hours, the compressive strength was 4,093 psi and after 45:00 h:min, the compressive strength was 5,086 psi. A cement plug was placed using a right BHA. The BHA consisted of diverter tool, stinger (317 m long) and drill pipes. There were less changes of contamination of cement plug with drilling fluids. A viscous pill was used below the cement plug to avoid plug sinking.

Sidetrack #3 procedures:

The cement plug was washed and reamed until 6258 m, at which point it was taking 7 Metric Tons Surface Weight On Bit and surface torque of 24 to 28 kNm, and spiking to 50 kNm. At this point it was felt that the cement plug was solid enough to start sidetracking.

The sidetrack was initiated at 6,248 m, with a trough being cut from 6,248 m to 6,258 m, then drilling ahead at 6,258 m to 6,280 m, without success. Again a trough was cut from 6,270 m to 6,280 m, to the top of cement at 6,280 m, and drilling began at 6,280 m to 6,315 m, without success. No changes on inclination were observed.

A discussion followed the first two attempts to sidetrack the well, and it was decided to try once again; but in addition to cutting the trough, a period of time drilling was to be conducted.

The trough was initiated at 6315 m to 6,325 m, with a setting of 156° at 100%. Three hours were used to allow the tool to side cut the well and produce the starting ledge for a sidetrack.

Once the trough was cut, time drilling was conducted in the following manner:

6,325 m to 6,327 m at 0.5 m/h

6,327 m to 6,334 m at 1.0 m/h

6,334 m to 6,338 m at 2.0 m/h

By 6338m we were running 3 to 4 MT SWOB, 135 rpm, and resulting in a surface torque of 24 to 32 kNm.

The well trajectory was dropped from 67.4° at 6319 m to 66.3° at 6333 m, as compared to the original well bore

Sidetrack well	Original wellbore
67.43° @ 6,319 m	67.80° @ 6,333 m
66.30° @ 6,333 m	67.83° @ 6,352 m
65.60° @ 6,343 m	67.81° @ 6,382 m
64.97° @ 6,353 m	

As can be seen from the checkshot surveys conducted at 10m intervals, the well was sidetracked to the low side and slightly off the original trajectory to the right side, with the azimuth changing from the original wellbore at approximately 135° to around 140° by 6,412 m.

Conclusions

The “point the bit” RSS allows the operator to perform a sidetrack at greater depths in an extended reach drilling well. The RSS would be the preferred choice over a whipstock system and its associated complications and attempting to sidetrack the well with a PDM at these greater depths.

The chances of successfully sidetracking a well where the motor assembly cannot slide with an oriented toolface are extremely small. Drilling off a cement plug in formations where the compressive strengths are equal to or harder than the cement plugs requires time drilling to initiate the sidetrack, complicating this fact is that the ability to even slide a motor at these depths may be in question.

Successfully setting a whipstock system at the extended depth is not without risks. Setting the toolface in the correct quadrant, not to mention the preferred degree of accuracy would be highly doubtful. Then there are the additional complications of drilling off the whipstock face with a drill-ahead assembly and rotating a drilling BHA across the face of a whipstock. The advantages that “point the bit” RSS brings to sidetracking a well are numerous. The ability to orient the bit while rotating, allowing weight transfer as the time drilling process evolves, hole cleaning, and reducing the chances of differential sticking are some of the prominent benefits. The primary advantage, and this cannot be overlooked, is that the operator does not have to sacrifice a valuable hole to conduct the sidetrack, reducing the time and expenses involved in saving a major project.

When looking at the sidetracking of some of these extreme reach wells, there is only one logical choice to successfully complete the operation and that involves using a “point the bit” RSS tool.

Nomenclature

Define symbols used in the text here unless they are explained in the body of the text. Use units where appropriate.

<i>BHA</i>	= Bottomhole assembly
<i>SWOB</i>	= Surface Weight On Bit
<i>rpm</i>	= Revolutions per minute
<i>kNm</i>	= kilo-newton meter
<i>MT</i>	= Metric Tons
<i>RSS</i>	= Rotary steerable system
<i>MD</i>	= Measured Depth
<i>TVD</i>	= True Vertical Depth
<i>UCS</i>	= Unconfined Compressive Strength
<i>CS</i>	= Compressive Strength
<i>m</i>	= meters
<i>PDM</i>	= Positive displacement motor
<i>MWD</i>	= Measurement While Drilling

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Figures

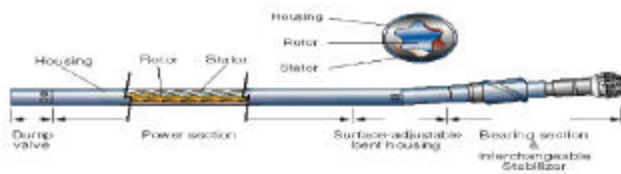


Figure 1. Mud motor components overview.

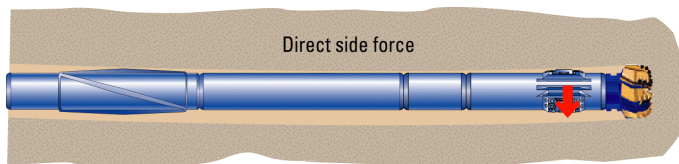


Figure 2. "Push the bit" technology.

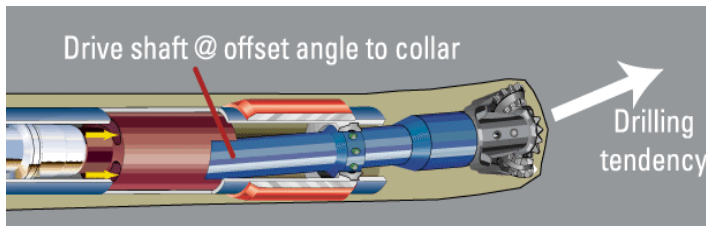


Figure 3. "Point the bit" technology.

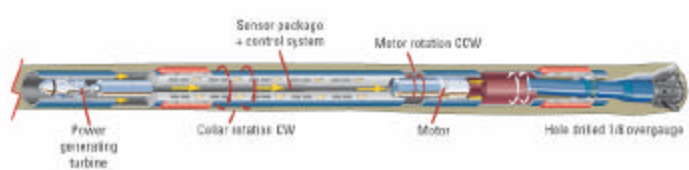


Figure 4. "Point the bit" technology showing major components.

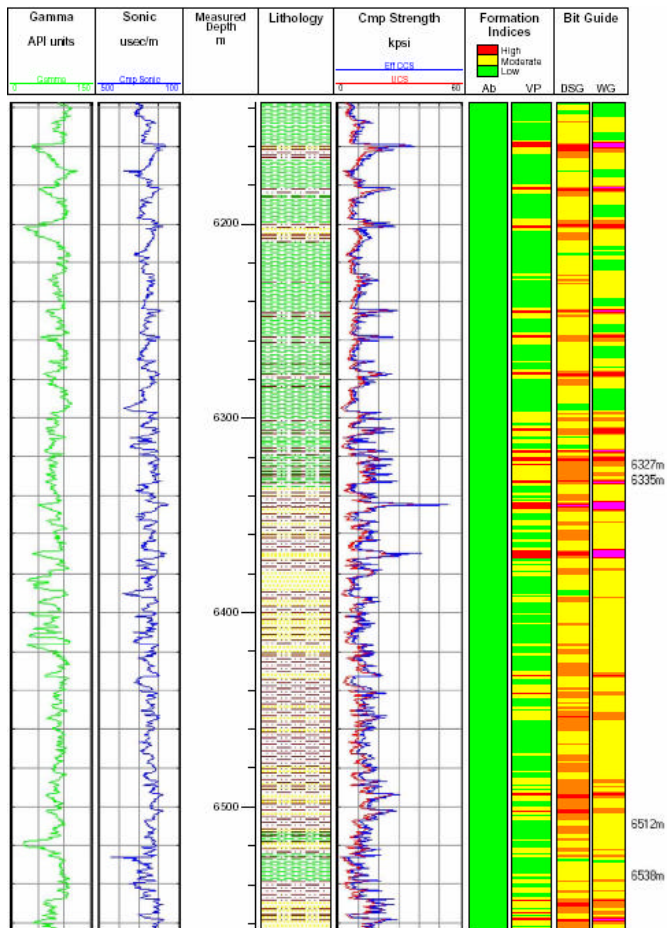


Figure 5. Offset well UCS in Cape Island formation.

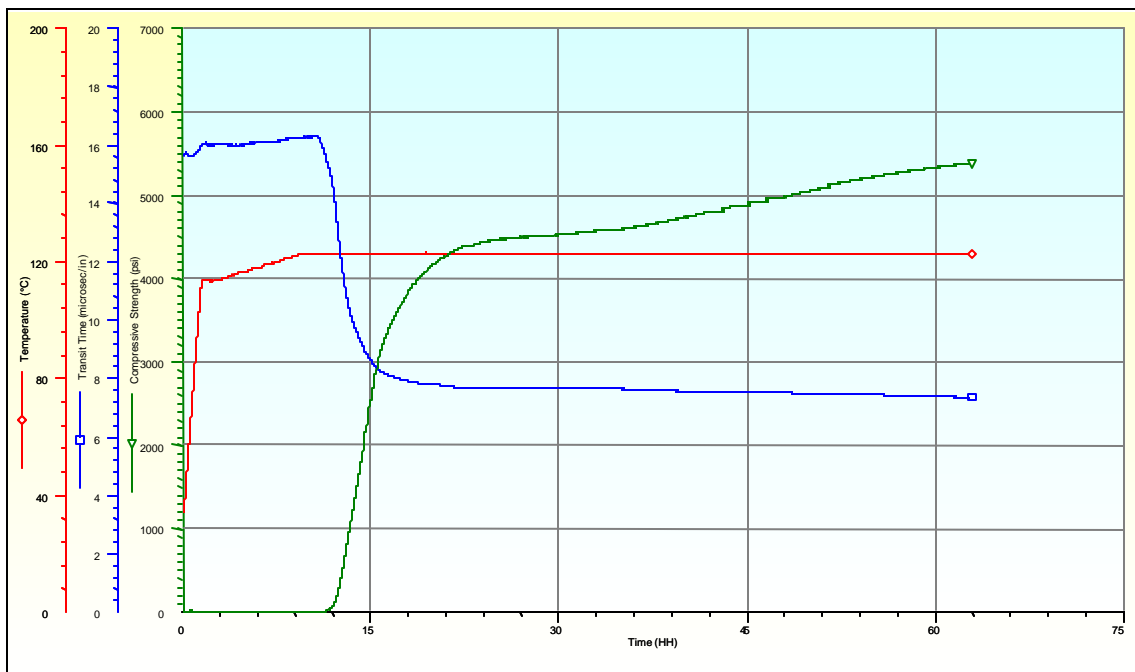


Figure 6. Sidetrack #2 cement plug CS data.

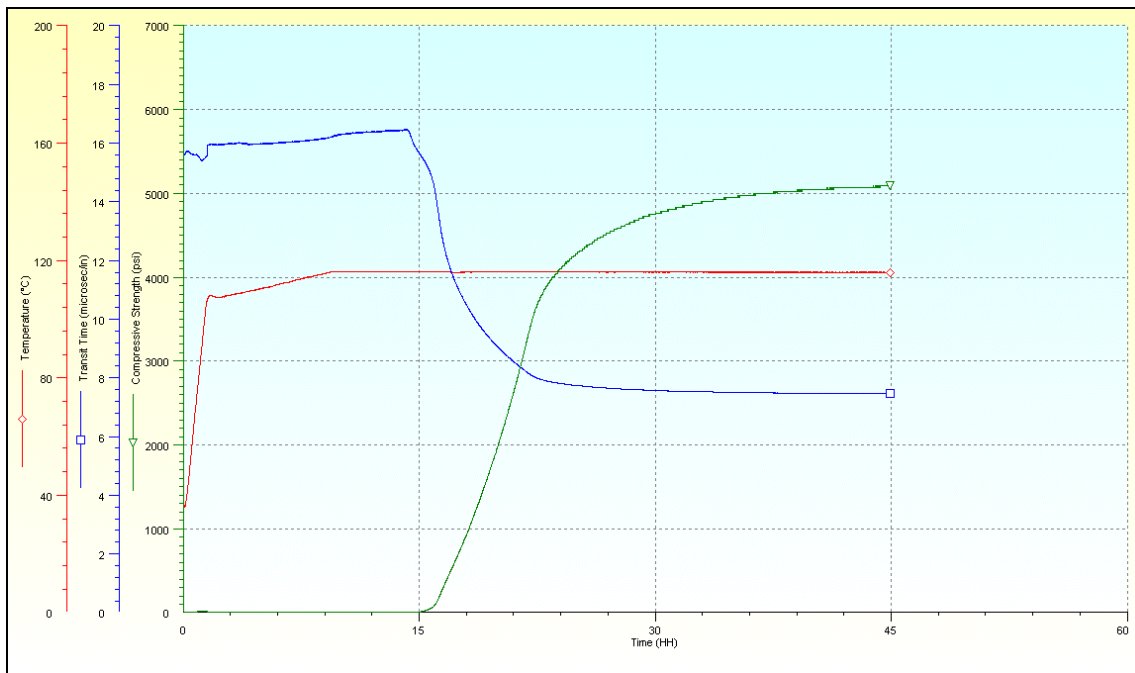


Figure 7. Sidetrack #3 cement plug CS data.

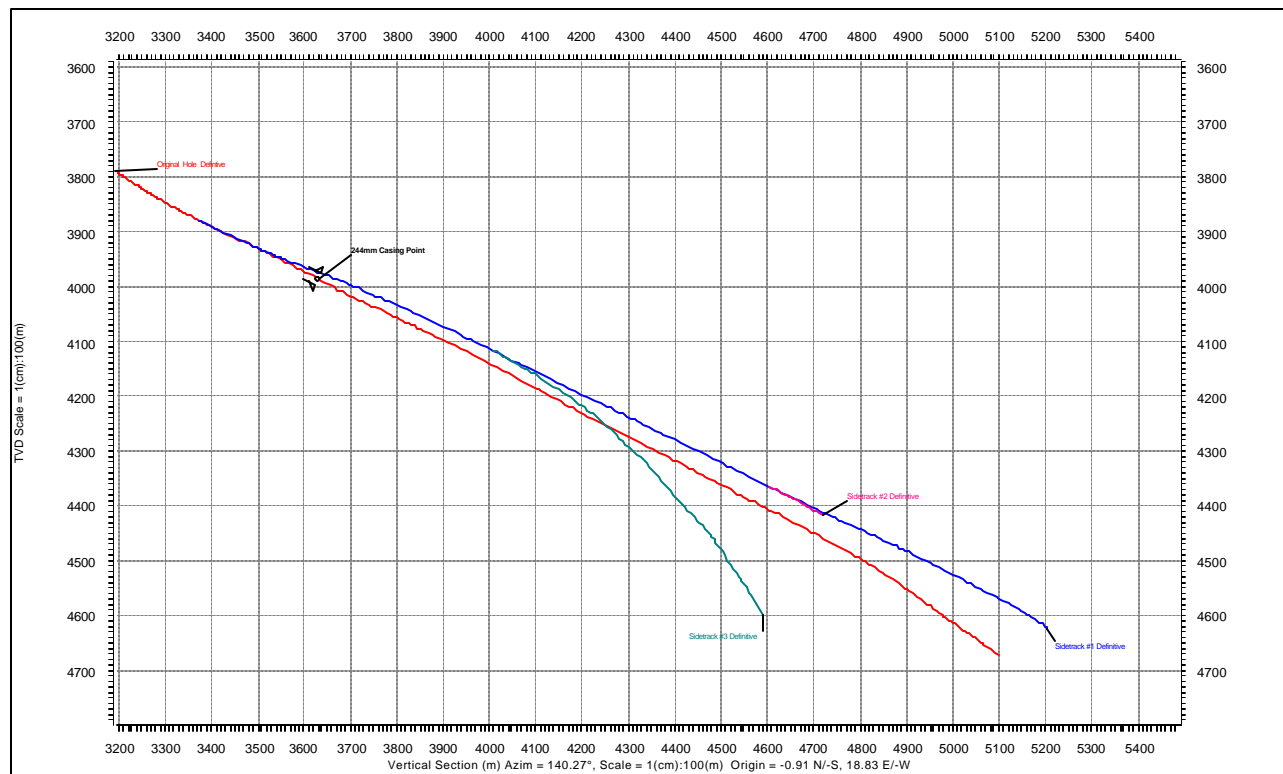


Figure 8. Well vertical section.

Tables

Table 1. Sidetrack #2 lithology summary.

Date	Interval (m)		ROP (m/hr)			Lith.	%	Description
	From	To	Avg.	Max.	Min.			
5/2/2006	7,010	7,040	1.74	7.43	0.34	Sltst	60	Siltstone: light to dark brownish grey, earthy rock texture, trace carbonaceous, trace calcareous, sandy, trace pyritic coal, soft to firm.
5/2/2006	7,010	7,040	1.74	7.43	0.34	Sh	40	Shale: light to medium grey and brownish grey, earthy lustre, trace carbonaceous, non calcareous, firm

Table 2. Sidetrack #3 lithology summary.

Date	Interval (m)		ROP (m/hr)			Lith.	%	Description
	From	To	Avg.	Max.	Min.			
5/22/2006	6,339	6,427	5.38	25.53	1.07	Sltst	70	Siltstone: %, light to medium grey, brown grey, earthy rock texture, carbonaceous, argillaceous, trace limestone, trace calcareous, trace sandy, firm.
5/22/2006	6,339	6,427	5.38	25.53	1.07	Sh	20	Shale: medium grey, brown grey, earthy lustre, trace carbonaceous, non to trace calcareous, firm.
5/22/2006	6,339	6,427	5.38	25.53	1.07	Ss	10	Sandstone: quartzose, greyish white to clear, very fine to medium grained, sub spherical to spherical, rounded to subangular, moderately sorted, point to point grain contacts, calcareous cemented, carbonaceous, trace pyritic, 3 to 20% intergranular porosity, patchy medium brown oil staining, patchy yellow to cream fluorescence, fair yellowish white moderately fast bleeding cut fluorescence.

Table 3. Sidetrack #2 cement CS table.

Time	CS
11:53 h:m in	50 psi
12:44 h:m in	500 psi
24:00 h:m in	4,431 psi
63:03 h:min	5,391 psi

Table 4. Sidetrack #3 cement CS table.

Time	CS
15:48 h:m in	50 psi
16:59 h:min	500 psi
24:00 h:m in	4,093 psi
45:00 h:min	5,086 psi