**AADE-07-NTCE-55**

# Case Histories of New Expandable Anchor Technology in Successful Open Hole Sidetracking Campaigns

Julio Mayol, SPE, Smith International, Inc., Pete Ortez, David H. Arrington Oil & Gas; Danny Cruzan and Cameron Wallace, Smith International, Inc., Tony Contreras, Texas A&M University



## Abstract

This paper will present case histories of the successful deployment of novel expandable anchor technology for one-trip sidetracking operations in open hole, providing significant rig time and cost savings versus conventional techniques.

An expandable anchor was used in these sidetracking projects to eliminate operational issues associated with balanced cement plugs, including cement plug failure and extended drilling times required to sidetrack the well. Using the expandable anchor, sidetracking systems can be run in the hole to sidetrack the well in one trip. The efficiency advancements provided by the expandable anchor system have resulted in major time and cost savings in the Barnett Shale region of North Central Texas.

The expandable anchor features hydraulically-actuated blocks designed to engage open hole formations in a predetermined size range. A detailed description of the expandable anchor technology, the time and cost benefits the system provides and case history data are presented in this paper.

## Introduction

The Barnett Shale of North Central Texas is an extremely low permeability reservoir that requires stimulation techniques to obtain commercial production. The development of this field started in 1998, and 75% of the wells have been drilled since 2000.[1]

David H. Arrington Oil and Gas has implemented horizontal drilling and hydraulic fracturing to optimize gas production in this area. The horizontal wells are cased and cemented for bore hole stability and future well interventions. The horizontal section can range from 1,000 to 4,000 feet or more in length.

Typically, a 12 ¼ inch hole is drilled to approximately 1,000 feet and cased with 9 5/8 inch casing cemented to surface. An 8 ¾ inch pilot hole is drilled vertically into the Barnett Shale. After completing logging operations, a work string is run in the hole and a kick-off class H cement plug mixed with additives is placed to sidetrack the well. An 8 ¾ inch bit is run in the hole and the cement plug is drilled to kick-off point and the horizontal section of the hole is drilled to total depth. 5 ½ inch casing is run and cemented in place **(Figure 1)**.

Recently, an expandable anchor was used in these sidetracking projects to eliminate operational issues associated with balanced cement plugs, including cement plug failure and extended drilling times required to sidetrack the well. Using the expandable anchor, sidetracking systems can be run in the hole to sidetrack the well in one trip **(Figure 2)**. The efficiency advancements provided by the expandable anchor system have resulted in major time and cost savings in the Barnett Shale region of North Central Texas.

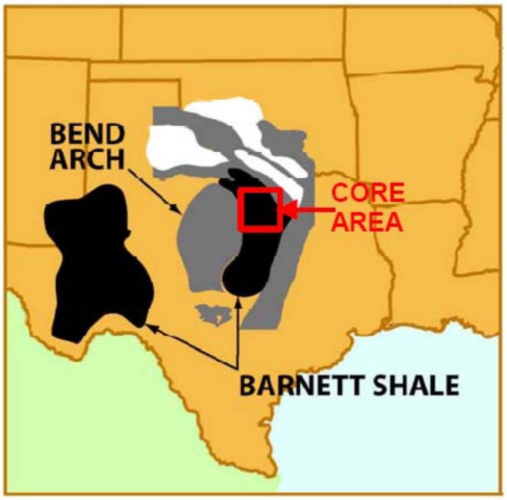
## Overview of the Barnett Shale

The Missippian-age Barnett Shale formation covers a large area, from the Fort Worth Basin through the Permian Basin of West Texas and New Mexico. The Barnett Shale is a marine shelf deposit that uncomfortably lies on the Ordovician-age Viola Limestone / Ellenburger Group and is comfortably overlain by the Pennsylvanian-age Marble Falls limestone. The area within the Fort Worth Basin lies at depths between 6,500 and 9,000 feet, and ranges from 200 to 800 feet in thickness. The core area of the field is roughly 500 feet thick. The productive formation is typically described as black, organic-rich shale composed of fine grained, non-siliciclastic rocks with extremely low permeability, ranging from 0.00007 to 0.00005 millidarcies.[1]

The significant productivity of the Barnett Shale formation is attributed to its proportion of total organic carbon (TOC) averaging 4.5 percent. A linear relationship between TOC values and gas content suggest a high potential to yield unconventional hydrocarbons.

The Barnett Shale region has only recently proven itself as a viable gas play. The first discovery well was drilled in 1981, but nearly 17 years passed before commercial success was realized. In fact as recently as 1995, the U.S. Geological Survey did not include the region in its assessment of significant U.S. natural gas fields. Today, the USGS estimates more than 26.2 tcf of gas remains to be discovered in the heart of the Barnett Shale trend, making the area Texas' greatest gas producer and the 10$^{th}$ largest deposit of natural gas worldwide.

Advances in horizontal drilling and stimulation technologies have driven the production gains realized in the Barnett Shale over the past five to 10 years. Light sand fracs executed in horizontal wellbores have allowed drillers to access the tight Barnett Shale while avoiding porous, water-producing zones. These new techniques and technologies have led to more than 3,800 wells to be drilled in the Barnett Shale region, with a very low proportion of marginal producers. Current daily production of the Barnett Shale has reached in excess of 1.2 bcf per day.




Location of the Barnett Shale formation.[1]

### New Expandable Anchor Technology Features

A one trip whipstock system capable of sidetracking an open hole formation with sufficient rathole to deploy a directional drilling assembly, in combination with an extended gauge multi-ramp whipstock system, and a hydraulic activated expandable anchor, was chosen **(Figure 3)**.

The system is designed to guide the milling tool efficiently into the formation. The whipstock face contains multiple ramps, each with its own taper to enhance critical milling processes and facilitates a lower dogleg severity.

The milling assembly has two full gauge mills; lead mill and follow mill. The lead mill is geometrically matched to the angles on the whipstock to maximize cutting structure engagement with the formation while minimizing loads on the whipstock face. The lead mill was dressed with tungsten carbide cylindrical cutters and/or PDC cutters for increased wear resistance to drill the rathole to accommodate the directional drilling BHA planned for the open hole interval. The mill provides a hydraulic path from the milling bottom hole assembly to the whip and anchor via a hydraulic hose.

The follow mill dressed with crushed carbide is positioned above the lead mill to produce a full gauge rat hole as the mill progresses down the whipstock.

An indexing valve is employed to allow circulation of the drilling fluid through the drill string and enable operation of the MWD tool without setting the hydraulic anchor. The desired orientation of the whipstock face is verified with MWD or Gyro tool face information prior to hydraulic setting the anchor.

A running tool is required to set the expandable anchor. The expandable anchor features hydraulically-actuated blocks designed to engage open hole formations in a predetermined size range, eliminating deployment problems due to well bore irregularities **(Figure 4)**. The variable expansion capability insures reliable anchoring of the tool into the formation **(Table 1)**. This makes the expandable anchor ideal for open hole sidetracking operations in medium to hard formations.

The fully retrievable expandable anchor features axial and torsional load capacities greater than those of typical mechanical or hydraulic anchors.

### Bottom Hole Assembly (BHA)

A typical BHA was made up of the following components; drill pipe, MWD or Gyro orienting sub, crossover, indexing valve, running tool, bi-mill, whipstock and expandable anchor.

### Case Histories in Open Holes

The open hole sidetracking campaign in the Barnett Shale of North Central Texas has been very successful. At the time of this writing, eighteen sidetracking operations using expandable anchors have been successfully completed **(Table 2)**. The sidetracking jobs done so far ranged in depth from 3,924 to 7,948 feet. The average rathole was 9 feet drilled at 2 feet/hour. Summary of time comparison of cement plugs versus expandable anchors are shown in **Figure 5**. On average, using an open hole whipstock with an expandable anchor saved 2 ½ days and up to 4 days per well in the best case scenario. **Figure 6** provides cost comparison of cement plugs versus expandable anchors. On average, using an open hole whipstock with an expandable anchor saved approximately US$ 86,250 and as much as US$ 154,000 per well.

Two case histories using cement plugs and five using expandable anchors have been selected for further discussion.

### Conventional Cement Plug Sidetracking Operations

#### *Case History 1*

A 12 ¼ inch hole was drilled to 470 feet and cased with 9 5/8 inch casing cemented to surface. An 8 ¾ inch pilot hole was drilled vertically to 6,120 feet. After completing logging operations, a work string was run in hole and a kick-off class H cement plug mixed with additives at 17.2 ppg was placed at 5,101 feet. The work string was pulled out of hole and waited on cement for 18 hours.

An 8 ¾ bit was run in the hole and drilled the cement plug from 5,101 to 5433 feet in 24 hours. The sidetracking operation was successfully achieved.

#### *Case History 2*

A 12 ¼ inch hole was drilled to 1,300 feet and cased with 9 5/8 inch casing cemented to surface. An 8 ¾ inch pilot hole was drilled vertically to 7,200 feet. After completing logging operations, a work string was run in hole and a kick-off class H cement plug mixed with additives at 17.2 ppg was placed at

6,005 feet. The work string was pulled out of hole and waited on cement for 11 hours.

An 8 ¾ bit was run in hole and drilled the cement plug from 6,005 feet to kick-off point at 6,455 feet. Then drilling process started and continued to 6,902 feet with 35% of cement cuttings returning to surface and insufficient build rates being obtained.

The BHA was pulled back to surface and the kick-off plug was repeated with class H cement mixed with additives at 17.2 ppg. After 9 hour wait on cement, the top of cement was tagged at 6,140 feet and drilled to kick-off point at 6,256 feet with an 8 ¾ inch bit. The sidetrack was successfully achieved and the horizontal section of the hole was drilled to total depth.

## New Expandable Anchor Case Histories

### *Case History 1*

On November 23, 2005 a 12 ¼ inch open hole sidetrack was performed for a major operator in a well located in Winkler County, Texas.

A 12 ¼ inch hole was drilled to 4,500 feet. The BHA became stuck and after several unsuccessful attempts to retrieve the BHA, a decision was made to sidetrack the well. After discussing the sidetrack options with the operator, an open hole sidetrack with an expandable anchor was agreed upon.

Based on the log, a 13-3/8 inch whipstock and a 13 3/8 x 20 inch expandable anchor were picked up and run into the hole to 4,117 feet. Several attempts were made to work the whipstock assembly past 4,117 feet. A caliper log review showed washed out hole sections from 4,000 to 4,200 feet. The whipstock assembly was pulled up to 3,950 feet and a pump truck was rigged up to provide the needed pressure to set the expandable anchor.

After breaking circulation through an indexing valve, the system pressure was increased to the anchor setting pressure of 3,500 psi. The drill string was worked up and down with 20,000 lbs. to verify the anchor was set. The drill string was pulled to 55,000 lbs. to where the 12-1/4 inch bi-mill sheared from the whipstock.

The open hole was sidetracked from 3,924 to 3,930 feet (6 feet). A 300 psi pressure loss developed and the mill stopped drilling. The mill assembly was pulled out of the hole and laid down. A visual review by the field operator indicated heat checking damages were evident across the carbide inserts. Most likely, the indexing valve may have been the cause of the 300 psi pressure loss. No other leaks were found in the drill stem or mud pump.

A 12-1/4 inch bit was picked up and the remainder of the sidetrack was drilled to 3,941 feet to the bottom of the whipstock face. A directional BHA was run in the hole and the intermediate hole section was successfully completed.

### *Case History 2*

On January 30, 2006 an 8 ¾ inch open hole sidetrack was performed utilizing a 9 5/8 x 13 3/8 inch expandable anchor and a whipstock assembly for an operator in a well located in Johnson County, Texas.

An 8 ¾ inch vertical hole was drilled to 8,500 feet. After logging the hole and verifying the production zone, a cement plug was set high enough to kick off and drill a horizontal hole through the target pay zone. The problem with setting a cement plug was that the formation was time sensitive which made it difficult to complete the lateral section. After discussing the sidetrack options with the operator, an open hole sidetrack with an expandable anchor was selected.

A 9 5/8 inch whipstock and a 9 5/8 x 13 3/8 inch expandable anchor were picked up and run into the hole to 6,814 feet. Once the whipstock was oriented with a Gyro, the system pressure was increased to the anchor setting pressure of 3,000 psi and held for 10 minutes. The drill string was worked up and down with 20,000 lbs. to verify the anchor was set. The drill string was pulled to 55,000 lbs. to where the 8 1/2 inch bi-mill sheared away from the whipstock.

The open hole was sidetracked from 6,814 to 6,824 feet (10 feet) in 5 3/4 hours. The drilling parameters were; 381 gpm flow rate, 1,000 psi pump pressure, 60-80 rpm rotary speed and 5,000 to 10,000 lbs. weight-on-mill. The BHA was pulled out of the hole and a directional BHA was run in the hole to complete the horizontal hole section.

### *Case History 3*

On March 21, 2006 an 8 ¾ inch open hole sidetrack was performed utilizing a 9 5/8 x 13 3/8 inch expandable anchor and a whipstock assembly for an operator in a well located in Parker County, Texas.

An 8 ¾ inch vertical hole was drilled to TD. A caliper log was run and reviewed to select the anchor setting depth. A 9 5/8 inch whipstock and a 9 5/8 x 13 3/8 inch expandable anchor were picked up and run into the hole to 5,850 feet. Once the whipstock was oriented with an MWD, the system pressure was increased to the anchor setting pressure of 3,000 psi and held for 10 minutes. The drill string was worked up and down with 20,000 lbs. to verify the anchor was set. The drill string was pulled to 50,000 lbs. to where the 8 1/2 inch bi-mill sheared away from the whipstock.

The open hole was sidetracked from 5,817 to 5,825 feet (8 feet) in 5 hours. The mill stopped drilling and the BHA was pulled out of the hole. A directional BHA was run in the hole and the horizontal hole section was successfully completed.

### *Case History 4*

On November 27, 2006 an 8 ¾ inch open hole sidetrack was performed utilizing a 9 5/8 x 13 3/8 inch expandable anchor and a whipstock assembly for an operator in a well located in Johnson County, Texas.

An 8 ¾ inch vertical hole was drilled to TD. A caliper log was run and reviewed to select the anchor setting depth **(Figure 7)**. A 9 5/8 inch whipstock and a 9 5/8 x 13 3/8 inch expandable anchor were picked up and run into the hole to

7,305 feet. Once the whipstock was oriented with a Gyro, the system pressure was increased to the anchor setting pressure of 3,000 psi and held for 10 minutes. The drill string was worked up and down with 20,000 lbs. to verify the anchor was set. The drill string was pulled to 50,000 lbs. to where the 8 1/2 inch bi-mill sheared away from the whipstock.

The open hole was sidetracked from 7,271 to 7,277 feet (6 feet) in 5 hours. The drilling parameters were; 450 gpm flow rate, 1,700 psi pump pressure, 20-40 rpm rotary speed and 5,000 to 10,000 lbs. weight-on-mill. The BHA was pulled out of the hole and a directional BHA was run in the hole to complete the horizontal hole section.

### *Case History 5*

On December 1, 2006 an 8 ¾ inch open hole sidetrack was performed utilizing a 9 5/8 x 13 3/8 inch expandable anchor and a whipstock assembly for an operator in a well located in Johnson County, Texas.

An 8 ¾ inch vertical hole was drilled to TD. A caliper log was run and reviewed to select the anchor setting depth. A 9 5/8 inch whipstock and a 9 5/8 x 13 3/8 inch expandable anchor were picked up and run into the hole to 7,948 feet. Once the whipstock was oriented with an MWD, the system pressure was increased to the anchor setting pressure of 3,000 psi and held for 10 minutes. The drill string was worked up and down with 24,000 lbs. to verify the anchor was set. The drill string was pulled to 45,000 lbs. to where the 8 1/2 inch bi-mill sheared away from the whipstock.

The open hole was sidetracked from 7,914 to 7,923 feet (9 feet) in 2 hours. The drilling parameters were; 500 gpm flow rate, 1,900 psi pump pressure, 30-40 rpm rotary speed and 5,000 to 8,000 lbs. weight-on-mill. The BHA was pulled out of the hole and a directional BHA was run in the hole to complete the horizontal hole section.

## Conclusions

The use of novel expandable anchor technology for one-trip sidetracking operations has proven to be an excellent alternative to conventional balanced cement plugs open hole sidetracking techniques.

The efficiency advancements provided by the expandable anchor system have resulted in major time and cost savings in the Barnett Shale region of North Central Texas.

- The expandable anchor was successfully deployed in medium to hard formations. A caliper log is required to set the tool in a gauge hole section, away from washed out zones.
- On average, using an open hole whipstock with an expandable anchor saved 2 ½ days and approximately US$ 86,250 per well.
- In the best case scenario using a cement plug is US$ 22,500 more expensive, and will take approximately a day longer to complete.
- In the worst case scenario, using a cement plug is US$ 154,000 more expensive and about 4 days longer.


## Acknowledgments

The authors would like to thank David H. Arrington Oil & Gas, Inc. and Smith International, Inc. for permission to publish this paper.


## Nomenclature

*BHA = bottom hole assembly*
*MWD = measurement- while- drilling*
*PDC = polycrystalline diamond compacts*
*PPG = pound per gallon*
*TD = total depth*

## References


1. Fisher, M.K., et al: "Optimizing Horizontal Completion Techniques in the Barnett Shale Using Micro seismic Fracture Mapping". SPE paper 90051, presented at the SPE Annual Technical Conference and Exhibition held in Houston, Texas U.S.A., 26-29 September 2004.
2. Williamson, R.N., et al: "Lesson Learned from Combined Whipstock Operation: Set Whipstock/Mill Out/Cement Squeeze/Drill Out in One Trip". IADC/SPE paper 98120, presented at the SPE/IADC Drilling Conference held in Miami, Florida, 21-23 February 2006.
3. Smith Services, "Products and Services Catalog", SS-04-0061.


Table 1 - Expandable Anchor Specifications

| Anchor Size (in.) | OD (in.) | Maximum Expanded Diameter (in.) | Torque (lb-ft) | Push / Pull Capacities (lb) |
|---|---|---|---|---|
| 4 1/2 x 7 | 3.69 | 6.061 | 6,000 | 50,000 |
| 7 x 9 5/8 | 5.62 | 9.217 | 30,000 | 100,000 |
| 9 5/8 x 13 3/8 | 8.00 | 13.165 | 50,000 | 150,000 |
| 13 3/8 x 20 | 11.75 | 19.085 | 80,000 | 150,000 |

Table 2 - Expandable Anchor Number of Runs

| Anchor Size (in.) | Tool Size OD (in.) | Open Hole Size (in.) | Mill Size (in.) | Number of Runs |
|---|---|---|---|---|
| 7 x 9 5/8 | 5.62 | 7.88 | 6.25 | 2 |
| 9 5/8 x 13 3/8 | 8.00 | 8.75 | 8.50 | 15 |
| 13 3/8 x 20 | 11.75 | 12.25 | 12.25 | 1 |

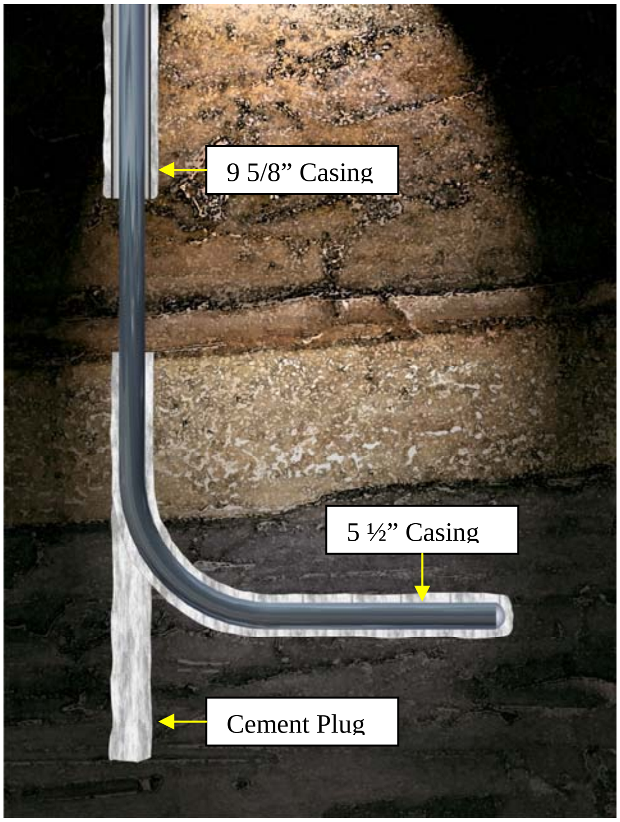



Figure 1 – Open hole sidetrack with cement plug

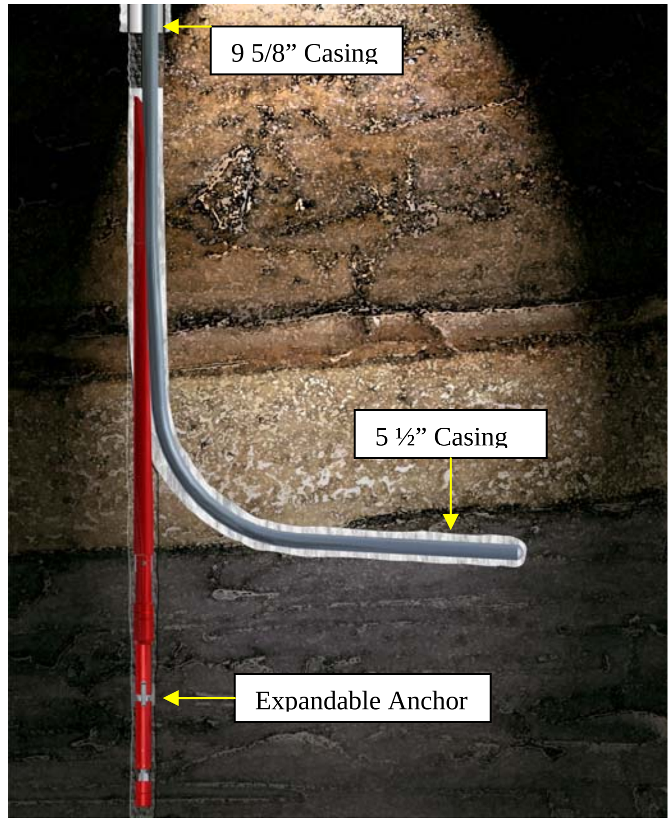



Figure 2 – Open hole sidetrack with expandable anchor


Figure 3 – Extended gauge multi-ramp whipstock system


Figure 4 – Expandable Anchor

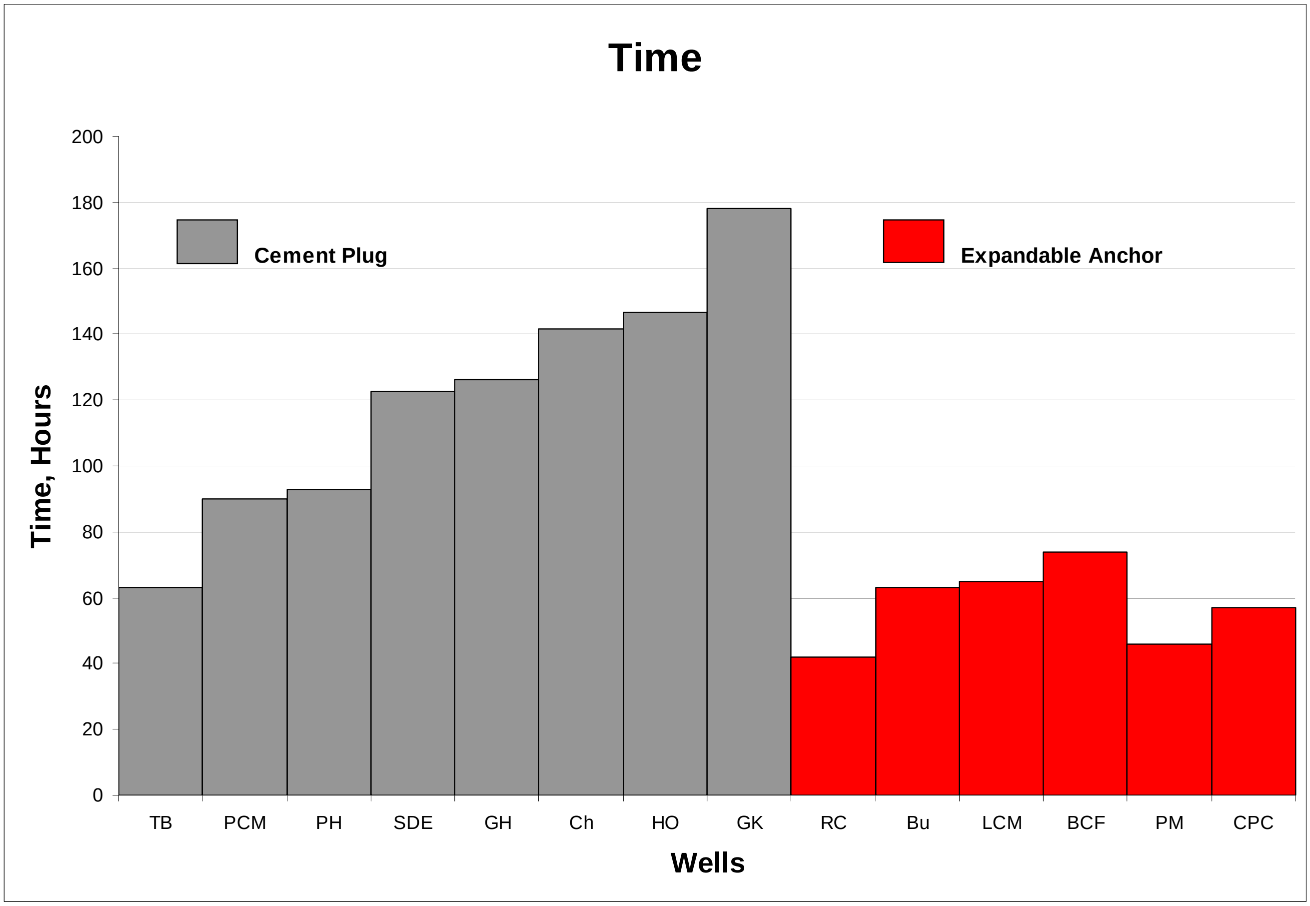



Figure 5 - Time comparison cement plugs vs. expandable anchors

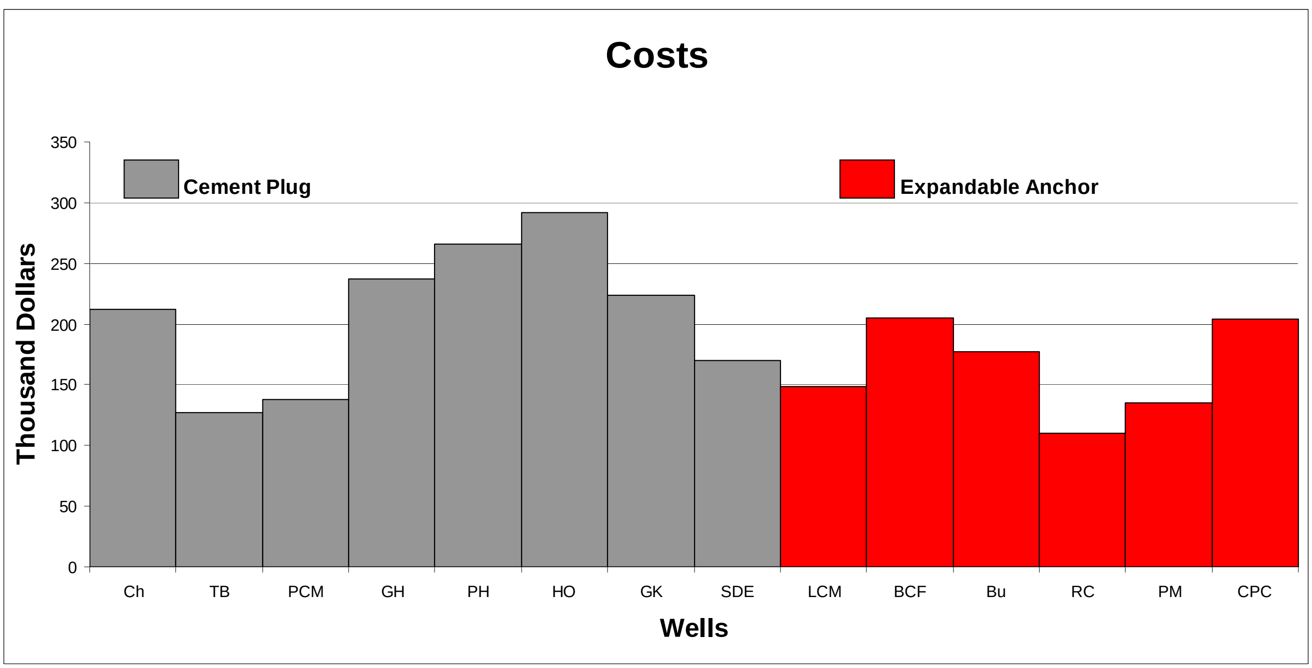



Figure 6 - Costs comparison cement plugs vs. expandable anchors

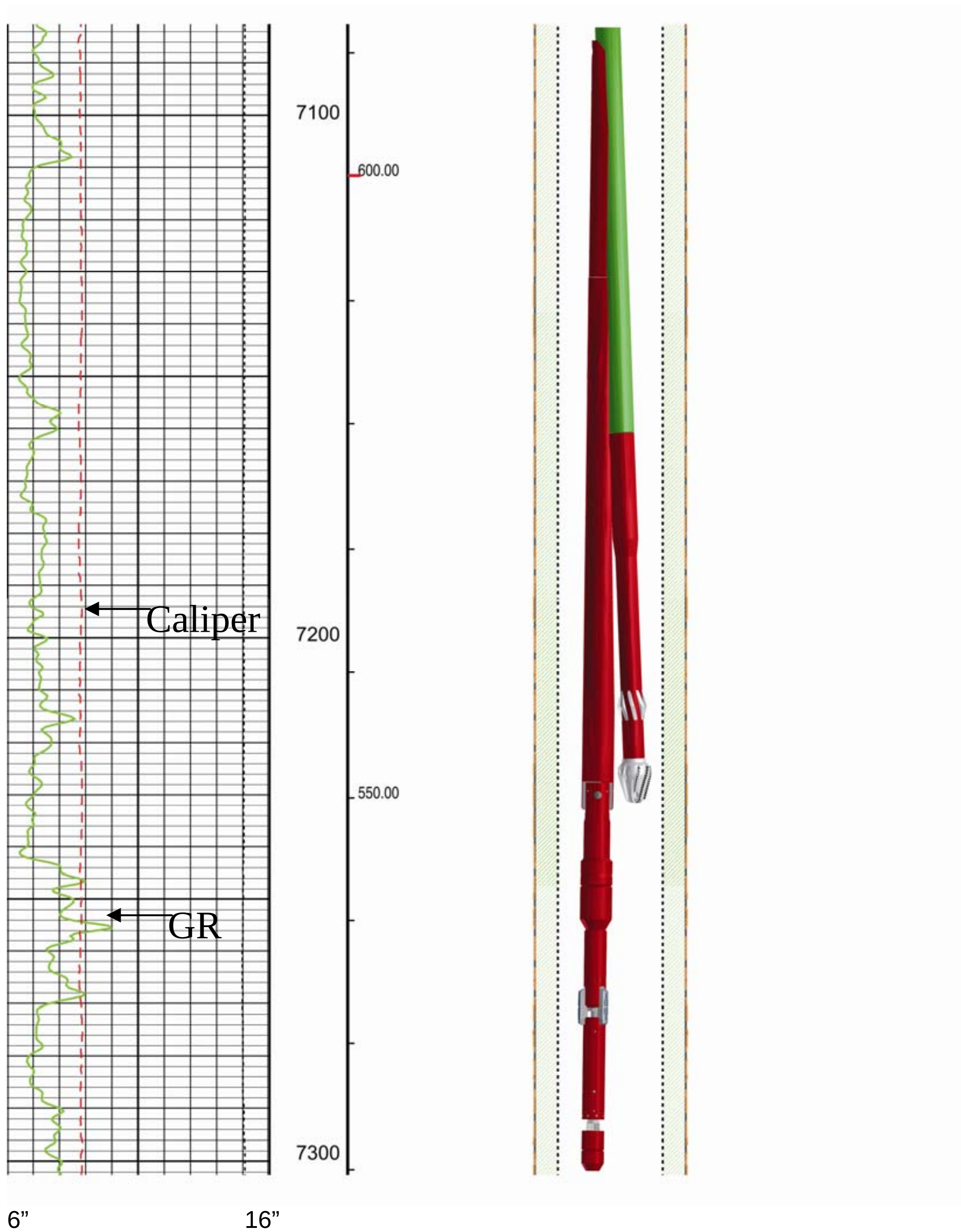



Figure 7 – Caliper Log