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Obtaining a Solution to why the Witteman No. 1 Well failed and applying this solution to the new well Clifford #43-35-R Well

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Introduction

Petroleum resources are developed by drilling production wells into the resource bearing rock formations. Successful drilling and completion of production wells are essential to economic development of a field. An important aspect of this process is setting casing in a well. There are four different casings that can be used in a well. They are the conductor, surface, intermediate, and production casings (NaturalGas.org). The conductor casing is the first casing to be installed. It is only 25-50 long and used to prevent the top of the well from caving in when initial work is being done to drill the hole. The next type of casing that laid down is the surface casing. This casing is used to prevent contamination of the fresh water near the surface from being contaminated by leaking oil of salt water coming from the bottom of the well. The third piece of casing that is laid down is the intermediate casing. This casing is used to help minimize the effects of unusually high pressures that are associated when drilling a well. The last casing that is used is the production casing. This is the most important casing that is used. The purpose of the production casing is to form a conduit for the oil to flow through. This casing also helps to keep the oil from mixing with the other fluids that are associated when a well is drilled.

Casings begin to leak for a number of reasons. Over time the salt water that is associated with underground formations begins to corrode the casings. This is not desirable because this means that salt water will start to pour into the casing and then this will in turn cost more money get separate the oil from the water. There is also the chance that this saltwater could contaminate the fresh water that is near the surface.

This situation of a casing leak happened in a well named Witteman No. 1 in North Dakota. This well is located in the Sherman Field which is located in NE SE Section 35 T162N R82W in Bottineau County. This well is approximately 40 miles north of the city of Minot or approximately 14 miles south of the Canadian Border.

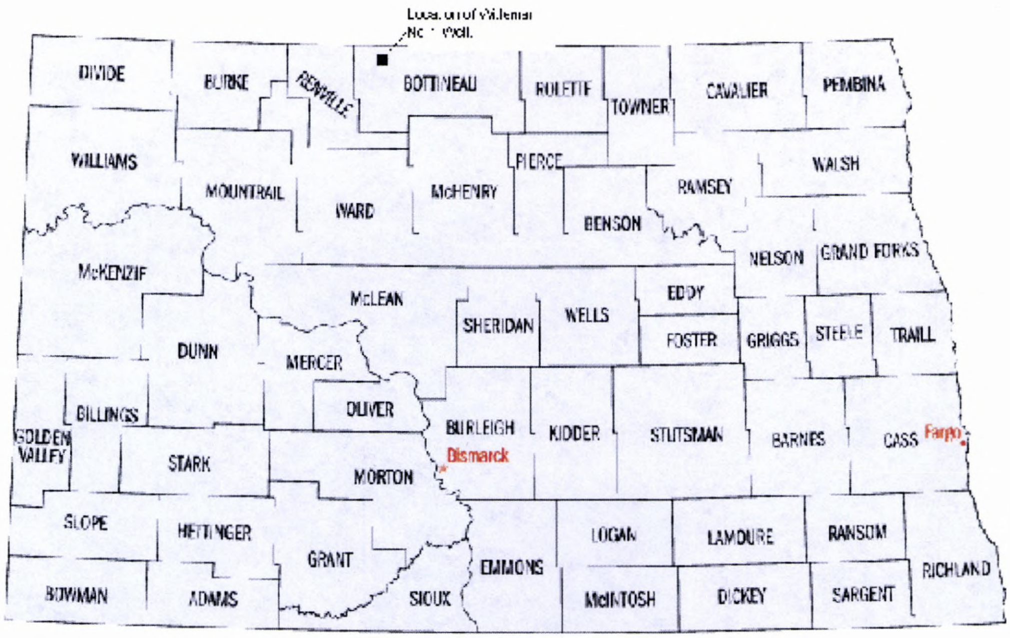

Figure 1. Location of the wells that are being studied.

By studying this particular case one can help prevent similar problems for other wells that are being planed in this area. In particular, the well that is going to be focused on is the Clifford #43-35-R well that will be drilled in the future.

Objective

The objective of this project is to investigate the cause of casing failure in Witteman No. 1 and to apply the findings to design a solution for preventing similar occurrence in the twin wells that are planned to be drilled in the area.

Geologic Setting

The Sherman Field is located in the northeast part of the Williston Basin and produces its oil from the Wayne Unit of the Mississippian aged Mission Canyon Formation.

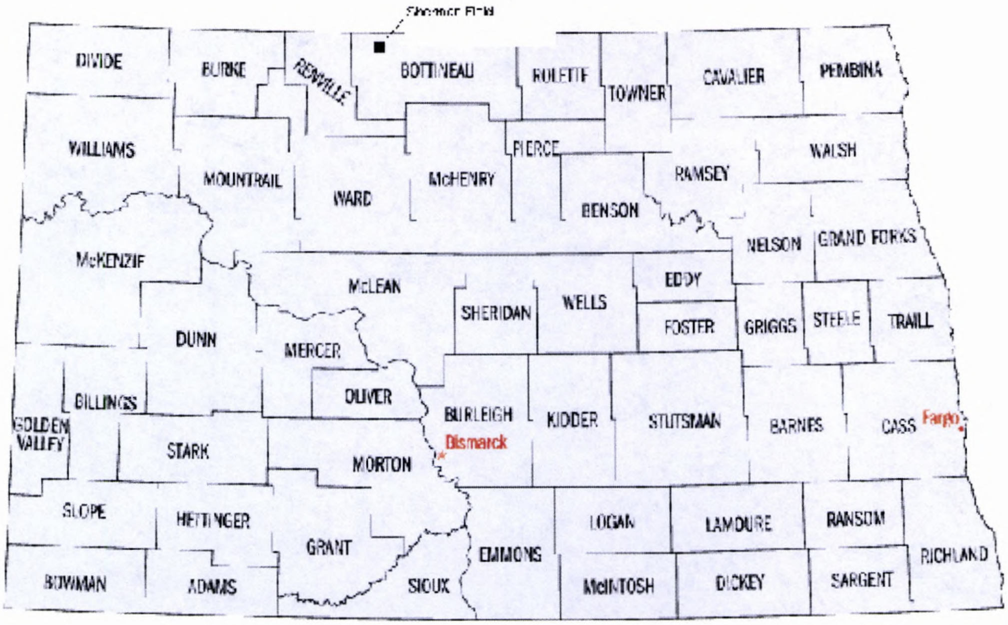

Figure 2. Location of the Sherman Field.

The Sherman Field oil accumulation is based on a structural closure within the Mission Canyon Wayne porosity zone.

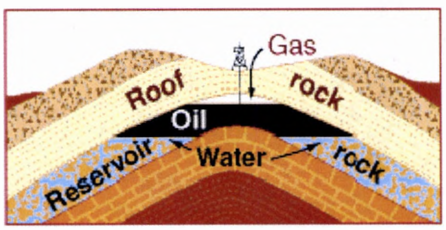

Figure 3. Possible picture of how a structural closure would look. Obtained from Why Files on Oil.

This structure is thought to be associated with differential salt dissolution of the underlying Devonian rocks. The reservoir rock is quite thin, approximately two to three feet thick. The rock porosity ranges from 25% to as high as 35%, and a permeability of 200 md is common here with a range of 150 to 250 md. The rock type of the Wayne Formation is dependent on the degree of dolomitization and cementation but is considered to be an excellent reservoir rock source for a hydrocarbon reservoir. The caprock forming the trap is a thick anhydrite rock.

The formations that were logged and sampled as the well penetrated the formations were the Piper, Spearfish, Charles Unconformity, Midale, State A, and the Wayne (Figure 4).

PIPER
SPEARFISH (3579 FT)
CHARLES UNCONFORMITY (3791 FT)
MIDALE (3797 FT)
STATE A (3866 FT)
WAYNE (4036 FT)

Figure 4. The formations that were logged and sampled along with the depth of the top of the formations.

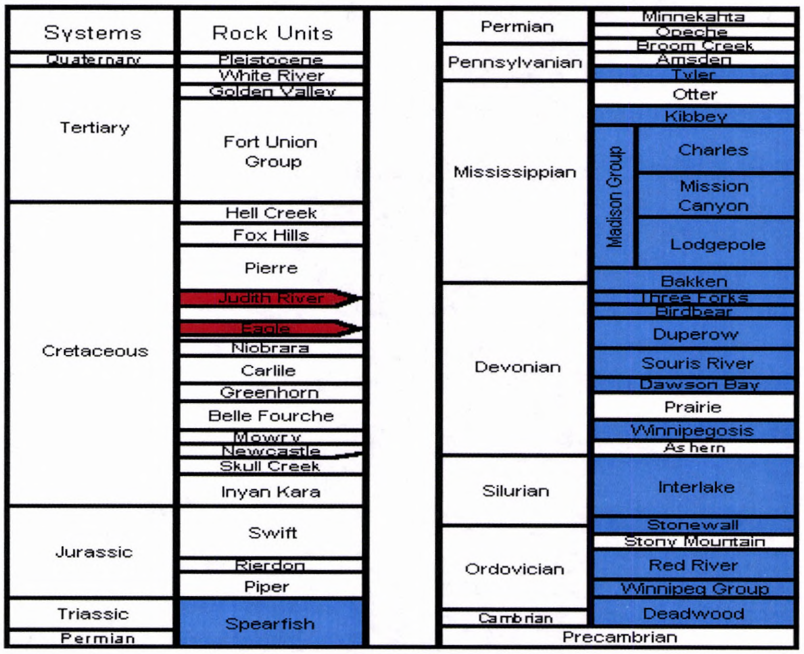

Figure 5. Geologic Column of Williston Basin. Obtained from ND Geological Survey.

The samples from Witteman No. 1 well that were collected were obtained from Neset Consulting Service of Tioga, North Dakota. The first samples that were collected were from the Piper Formation. 19 feet of core was collected, it consisted of a light gray, with no visible porosity Dolomite. The next set of samples was collected from the Spearfish Formation. These samples consisted of Interbedded Shales, Siltstones, and Sandstones with a layer of Anhydrite approximately 30 feet thick located at the bottom of this formation. The Shale's, Siltstone's, and Sandstone's all had a rusty brown color to them and were fairly soft in texture. The Anhydrite has a gray color and had abundant shale inclusions in it. The Charles Unconformity was next to be penetrated. This Unconformity was not visible in the sample collection but was picked by correlating from other open-hole logs. The next formation that was drilled through was the Midale Formation. This formation consisted of light gray, brittle Limestone, with spotty yellow fluorescence thought-out. Following this formation was the State A formation. This consisted of gray to cream Anhydrite. It was fairly firm in hardness, had traces of dolomite, and had no visible porosity present. The last formation that was drilled through was the Wayne Formation. The oil that is located in this area is in the top 2 to 4 feet of the formation. It consists of a pink tan Dolomite in the top 8 feet of the formation and a pale tan Limestone with traces of shale and dolomite. It was drilled to a total depth of 4160 feet below the ground.

Production of Sherman Field

The Sherman Field has produced a total of around 1,100,000 barrels of oil from 15 wells, at a depth of around 4000 feet since the field was started in 1980. There are now 15 wells that operate and are active in the Sherman Field to date. There are still an estimation of at least 1,500,000 barrels of oil in reserves.

Witteman No. 1 Well

The Witteman No. 1 well started being drilled on 7/15/1981 and finished on 9/11/1971. The total drilled depth was 4060 ft (Oil and Gas Commission of ND). The casing plan is as follows. It ran a surface casing of 8-5/8'' to a depth of 343 feet and a production casing of 4-1/2", 10.5#, to the bottom of the hole.

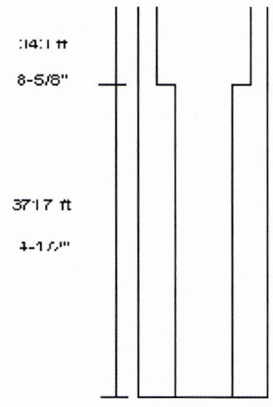

Figure 6. Diagram of casing (not to scale) that was used in the Witteman No. 1 Well.

The production casing was perforated at the depths of 4008-4010 ft. According to Jeff Dale, head geologist at the site, blowouts are not common in this area and the problem is not a concern. He has been working in this area for a number of years and came to this conclusion from previous wells drilled in the area. This is based on the low fluid pressure that is associated in the area due to the formation characteristics that is being drilled through.

Finding how much cement and how far it was poured in the hole could be a big factor why the casing leaked. Four hundred bags of class G cement was used cement the hole. With the casing dimensions and the type of cement, one is able to obtain a height that the cement was poured to. Using a value of 1.18 ft^3/sack for no additives (Applied Drilling and Engineering) and multiplying this by 400 sacks, a value of 472 ft^3 was obtained. From Applied Drilling and Engineering, an equation can be used to find the annular capacity. This is $A_a = (3.14/4)(\text{Outside Diameter}^{\wedge 2} - \text{Inside Diameter}^{\wedge 2})(ft^2/144\ in^2) = (3.14/4)(8.625^2 - 4.5^2)(1/144) = .2952913\ ft^2$. Take 472 ft^3 and divide it by .2952913 ft^2 and a value of 1598.42 ft is obtained. This means that the well was cemented 1598.42 ft up from the total depth of 4160 ft or up to 2562.6 ft from the surface.

The only log that was run in this well was a cased hole cement log. The log was not run from the top of the cement but below the start of the cement. For this reason, the top of the cement was not known at the time and consequently may not have been cemented above the Dakota Sandstone Formation. This could have been a big mistake. This formation is very porous and full of salt water, and the lack of cement there could be the cause for why the casing leak. The salt water could have corroded and thus penetrated though the casing and consequently contaminated the well with all this extra salt water. This is just one hypothesis that could have caused the leak in the casing. One way to prevent this is to make sure that the cement is poured above the salt water. Another approach would be to make sure that you are using a quality casing that can withstand more corrosion.

Clifford #43-35-R Well Approach

In approaching this well, one has to take into consideration what was learned in the Witteman No. 1 well. Technological advances in the recent years that allow more effective and complete characterization o the formations that are drilled. As noted above, there are several considerations that have to be looked at from the Witteman No. 1 well in what went wrong and how to fix the problems. Some considerations are that the cement may not have been placed high enough to stop the water from coming in from the Dakota Sandstone and that the perforations were not placed in the right spot to get optimal performance out of the well. More logs have to be taken to ensure that there is a proper cement bond and that the perforations are located in the right area. There are more state and federal regulations that also have to be considered. There also has to be protection from ground water contamination that could be affected if there is a leak in the casing.

Economic/Environmental Impact of Witteman Well

Economic impacts that resulted from the Witteman No 1 well were that it is not producing any oil at the present. This means that there is no cash flow that is coming in from this well. The well still had the capability of producing a cash flow before the casing leak occurred. Based on a production rate of 20 barrels of oil a day at $45 a barrel one is loosing $900 a day on potential withdraw of oil.

The environmental impact the Witteman No 1 had was that with the casing leak, there is a potential contamination of the water around the well. This could lead to contamination of drinking water for the people living around the well site. This could possibly lead to a liability issue. The oil company that owns this well could have a lawsuit dealt against them because of the contamination.

Suspected Reason Why Witteman Well Failed

Looking at where the top of the Dakota Sandstone Formation is which is at a depth of 2488 ft, there is a very good chance that the salt water from this formation corroded the casing and caused the leak that the Witteman No. 1 well suffered. The cement that was poured in this well was not enough to cover the top of this formation. It was found that the cement was poured to a depth of 2562.6 ft from the surface. This is not high enough to cover the Dakota Sandstone which is at a depth of 2488 ft. This means that there was 74.5 feet that was not cemented. This is a major problem that most likely caused the casing to fail. The solution to this problem is to make sure that the entire formation is cemented. This can be checked by running the proper logs. Using a cement bond log will ensure that the cement is properly in place and that the cement is high enough to ensure that this problem will not occur again.

Designing the Clifford #43-35-R Well

In designing the Clifford well, there has to be better decision making in order to insure that the well is drilled properly. This includes that more logs have to be run to insure that the cement is in the proper place and to pinpoint the exact depths at which the different formations are at.

The location of the Clifford well is only 50 feet away from the original Witteman well. Being this close to the original location it is safe to assume for this design that the geology will be nearly the same as the Witteman well. That is the formations that will be drilled through will be of the same composition and at the same depths.

When drilling this well there this is so much new technology in logs out there that can be used in order to make sure that well is drilled properly and at the right depth. Schlumberger has a new high resolution log (www.slb.com). This log takes reading much faster and closer together to get a better looking picture at where you are at and the porosity of the formation. This is important because the pay zone that is trying to be reached is only 2 feet thick. With better resolution a more accurate estimate of where the pay zone is at can be accomplished.

Do to tougher laws set by the sate to protect fresh and usable water sources a longer surface casing is going to have to be used for the new well. The Witteman well had a surface casing that was 343 ft long. The new Clifford well should have a longer surface casing than this. Adding around another 150 feet to this value should be sufficient in protecting the usable water sources. This would mean that the Clifford well would have a surface casing of at least 150 feet long. This casing would have an outside diameter of the same as the Witteman well of 8-5/8".

The Witteman well had a production casing of an outside diameter of 4-1/2". This was standard for the oil wells that were being drilled in the area in the early 1980's. Development in the technology of bigger pumping units, for the Clifford well a production casing of 5-1/2" should be used. This casing would then run to the bottom of the hole which is 4060 ft long. This should increase the amount of oil that can be extracted from the well and thus increase productivity of the well. This means that with increased productivity there will be an increase in the amount of cash flow that the well will produce. This would be the basic design of the Clifford well.

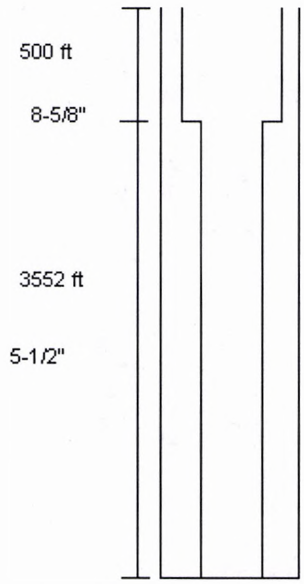

Figure 7. Diagram of casing (not to scale) that will be used in the Clifford #43-35-R Well.

The cementing process was the factor that lead to the Witteman well failing. More accurate calculations and a better log reading must be taken into consideration for the new Clifford well. The same cement that was used in the Witteman well will be used in the Clifford well. The cement will consist of a class G cement. It will have the same properties of the old cement so it will have volume of 1.18 ft^3/sack. The number of bags of cement is not yet known. Since the top of the Dakota Sandstone is at a depth of 2,488 feet from the surface the cement must be laid higher than this depth. To error on the safe side, cement should be laid from 2,000 feet from the surface to the bottom of the hole. This error is to take into account of the salt water seeping into the formation above it and eroding the casing causing the well to fail. Finding the angular capacity like that was done for the Witteman well is the next step. A_a = (3.14/4)(Outside Diameter$^{\wedge 2}$ – Inside Diameter$^{\wedge 2}$)(ft^2/144 in^2) = (3.14/4)(8.625^2-5.5^2)(1/144) = .2407489 ft^2. Finding the number of bags that should be used can now found. Knowing that the cement has to be laid up to 2,000 feet and the bottom of the hole is 4,160 feet a distance of 2,160 ft needs to be filled with cement. Using (ft^3/sack)(# bags) = (distance filled with cement)(Aa) a value of 441 bags of cement have to be used in order to assure that the cement covers the salt water that has the potential of corroding the casing and causing it to fail.

Along with using more cement for the Clifford well, a better log reading has to be taken in order to ensure that the cement is set right and that it is high enough. The Witteman well could possibly not have failed if a proper cement bond log was taken. Because the log did not start at the top of the cement, the top of the cement was not known and thus did not take into consideration of the Dakota Sandstone. The Clifford well should have the cement bond log start at 1950 feet to ensure that the top of the Dakota Sandstone is covered and there is a strong bond in the cement.

The casing should also be perforated at a depth of 4,007.5-4,010.5 ft. This practice is performed to make holes in the casing and cement so the oil is able to flow into the production casing. The use of perforations is also to help fracture the rock around to allow more oil to flow freely around the well hole. Since the Clifford well is a vertical well, the perforations can be shot in any direction (Oilfield Review). The well will be perforated for 3 feet. The pay zone is only 2 feet thick but there is a chance that the gun is off by a couple of inches. For this reason, an extra .5 foot will be perforated to create maximum productivity. According the Jeff Dale, head geologist, the typical perforation is 4 shots per foot with an outside diameter of 3-3/8" inches. These shots are arranged in an alternating spiral formation going down the gun.

The Clifford well also has the possibility of becoming a horizontal well in the future. Should this happen, more aspects need to be taken into consideration in the perforation process. According to Oilfield Review, for maximum results the charges should be set off along the maximum horizontal stress. In order to make sure that perforating toll is lined up in the correct orientation, careful measurements and passes in the hole have to be done. The first pass that the perforating tool makes, is to determine the natural orientation of the tool. Once this is found, a second pass is made to align the shots that will be used with the maximum horizontal stress on the surrounding rock. The tool is then pulled back out of the hole and loaded with real charges and sent back down the hole. A log then is run to ensure that the gun is at the correct depth to perforate the pay zone that the oil is in. Once this is verified the charges are set off and the perforation process is complete.

Economic Impact of Clifford #43-35-R

The economic impact that the Clifford well will sustain could differ based on how accurately the perforations were placed for the oil to flow. Based on other wells in the area the Clifford should be able to produce around 45 barrels of oil a day for the first 12 months of production. After the first 12 months an average of 20 barrels of oil per day should be expected. At an average oil price of $45 a barrel, the first 12 months should produce around $739,125 of revenue and $328,500 for each year there after. There is believed that the Clifford well would be able to produce 150,000 barrels of oil over its lifetime.

Conclusion

Looking at the geology that was associated with the Witteman No. 1 well, the conclusion that was assumed for the casing leak was based on the fact that salt water corroded the casing. The salt water was associated with the Dakota Sandstone that the well penetrated as it was drilled. The reason that the casing did not withstand the corrosion of the saltwater is thought to be that the cement that was used was not placed properly in the well hole. It was found that the cement was placed 75 feet below the top of the Dakota Sandstone. This meant that 75 ft of the casing was susceptible to the corrosion of the saltwater. The new wells that are to be drilled in the area would then need to be cemented above the Dakota Sandstone. The Clifford #43-34-R well in particular would be cemented up to 2000 feet below the surface in order to insure that there is no seepage that is occurring do to the Dakota Sandstone seeping into other formations. The new well design will be different from that of the Clifford Well. The Clifford Well will have a surface casing of 8-5/8" to a depth of 500 feet and a production casing of 5-1/2" to a depth of 4060 feet.

Acknowledgments

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