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Casing failure analysis with software

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Abstract

Analysis on multi-finger caliper logs for five wells was performed in South America. As the result of the well analysis all the wells showed several locations with significant deformations (mostly in cross-sectional geometry) resulting in ovality and in some cases the bending of the examined pipe section. All of the measurement were made through the perforated sections. The deformations all line up with the depth of sandstone reservoirs while the intact or slightly damaged parts are in the depth of formations with high shale content. Wells showed significant signs of sand production resulting in a number of workover operations, pump replacements, swab activities.

1 Introduction

The wells were drilled between 2008 and 2010 and operate as producers using pumps without injection in the South American field. The perforated and logged intervals penetrate through sandstone reservoirs with average permeability range from 200 mD to more than 1000 mD.

This article describes the results of the software analysis of the log data for 'Well 1'.

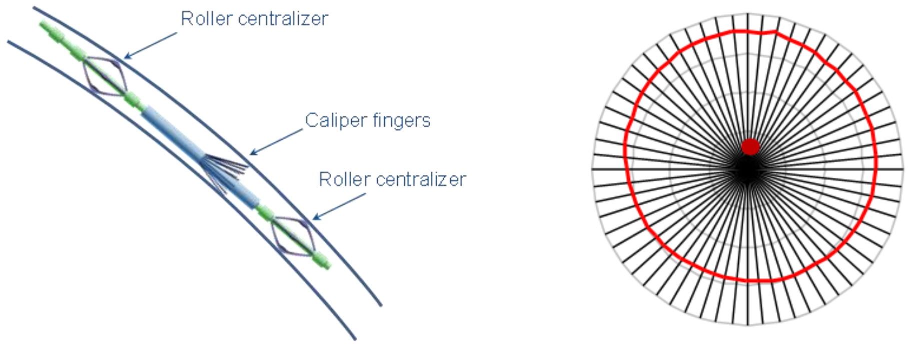
1.1 Overview

Multi-finger caliper data was interpreted using a software to determine the local trajectory in well tubulars. The software includes mathematical and statistical algorithms to calculate strain, ovality, trajectory and three-dimensional visualisation information for the logged casing to gain a more quantitative understanding of the type and magnitude of casing deformations.

The software uses the eccentricity of the caliper tool relative to the pipe centre, as shown in Figure 2.1, to calculate the local curvature of the pipe at each reading station. The curvature and well orientation determined at each station are then assembled to describe the local well trajectory. The convention for describing coordinate directions perpendicular to the well axis is given by the caliper arm position relative to the high-side indicator (or relative bearing measurement). Figure 2.2 shows the relationship of these relative directions.

2 Data summary

Well completion schematics are shown in Figure 2.1, indicating the depth range of production casing analysed and the perforated sections that is part of the logged section. Each well was logged through the perforated interval. The logged and perforated interval is summarized in Table 2.1. Depth correction was not needed. This article does not discuss deformations in the tubing sections of the wells. The logging company and the caliper type used was the same for each well.



(a) (b)

Figure 2.1 Caliper Tool Eccentricity Within a Well with Decreasing Hole Angle
(a) Caliper Finger Offset and (b) Cross-Section Showing Pipe Centre Offset

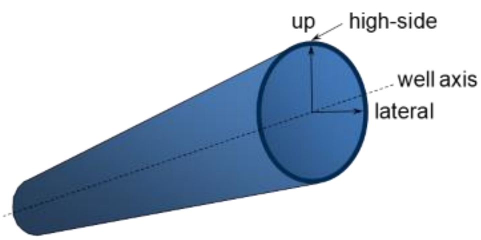


Figure 2.2 Relative Directions Used in the software

2.1 Data Collection Issues

In each wells the same type 2-7/8" multi-finger caliper tool by Hotwell was run with the 3-1/2" OMNI Directional thickness measurement tool and the two tools were rigidly fixed together. Besides the two original centralizer there was a third centralizer on the rigidly fixed tool as shown on Figure 2.2. The used software was originally developed and calibrated for only 2 centralizers. Additional centralizers can potentially throw off the algorithm that calculates the trajectory of the well.

Moving forward with processing the data in the software we set various combination of distances of centralizers to caliper arms. The first setup was run with distance A and B (see Figure 2.2 and Figure 2.3.) and the other run happened with distances A and B+C. After determining how much variability in the results we would see it proved to be the case that the there is some variability depending on how the data is processed by the software. A decision was made about using the first setup since the software has originally been calibrated for those two centralization points. We moved forward with one (A+B) configuration and interpreted the results of the other wells, too.

However, the general features are still apparent although the exact magnitude of the deformations are questionable.

Another issue regarding data collection is that rotation data is unavailable and has not been logged by the vendor as well. As a result of this the orientation of the features is not accurate because the spinning of the tool during recording the data cannot be followed. [1,2,3]

Table 2.1 Log and Perforation Intervals

Well	**Interval**	**Top MD (ft)**	**Bottom MD (ft)**
1	Log	2510	3307
	Perforation	2778	3125

* The details of the logging company and logging tool manufacturer are the same for all the five wells. (Hotwell, P/N 1236.0000, 2-7/8" Multifinger Caliper) The tool dimensions were provided with the log.

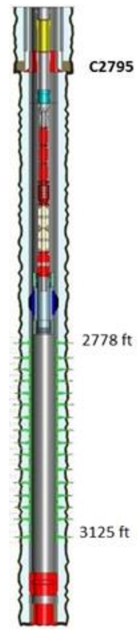


Figure 2.1 Well completion schematic for 'Well 1' (Top and Bottom MD of perforations shown)

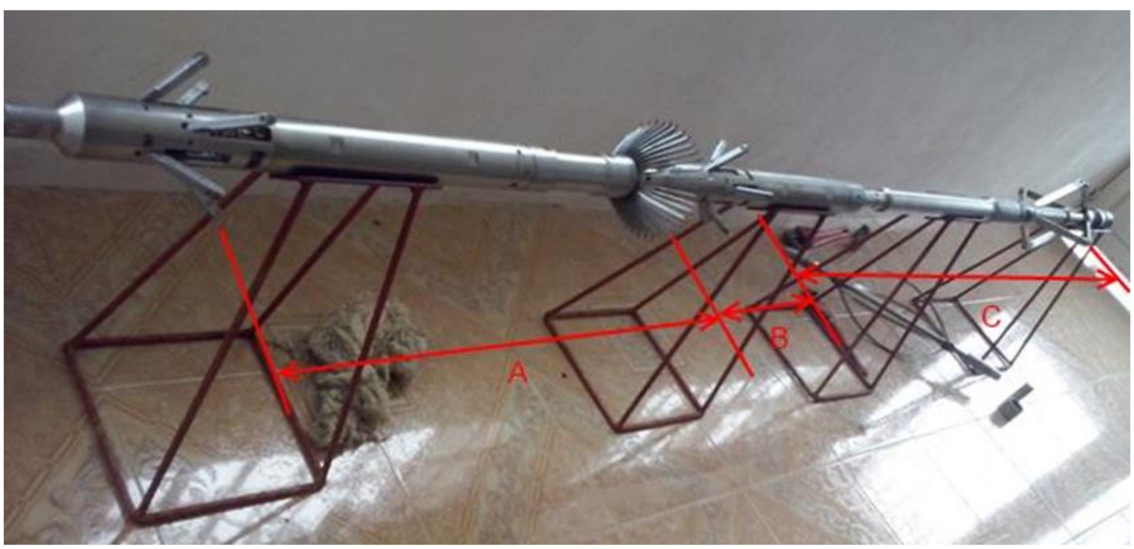


Figure 2.2 Caliper Tool Photo

Table 2.2 Caliper Tool Dimensions

Logging Company	Caliper Tool Description	Number of Caliper Fingers	A (inches)	B (inches)	C (inches)
Hotwell	P/N 1236.0000 2-7/8" Multifinger Caliper	40	34.0	8.5	70

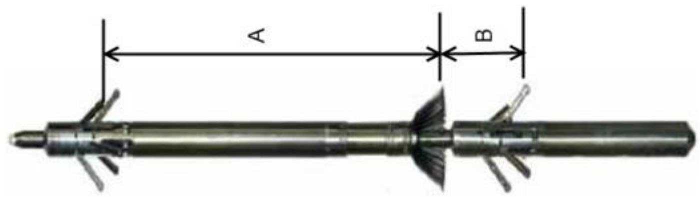


Figure 2.3 Caliper Tool Schematic

3 Analysis results

The following sections describe and compare the results of the analysis of the log data for 'Well 1'.

Along the analysis and data collection process we understood that every feature line up with the depth of sandstone reservoir with high sand content.

Wagg et al. [4] made research about casing deformation in relation with massive sand production in Northeastern Alberta. 20 wells out of 38 were deformed with 10 of these showing such severe deformations that production was no longer possible. The deformations in these cases were casing buckling and casing ovality caused by formation movement. The analysis therefore investigated the formation movements caused by sand production. The modeling results showed that sand production from a circular disturbed zone or from an enlarged disturbed zone centered on the wellbore would cause reservoir shortening. They identified this effect as the driving mechanism for buckling failures in these wells and also found that pressure draw-down has less effect on buckling type of failure. [4,5]

It can be seen that massive sand production that also happens in connection with the field operations analysed can cause formation movement and casing deformations. More analysis regarding the field formations could be useful for better understanding the driving mechanisms for casing deformations in the reservoirs in question.

3.1 Analysis Background

We started the analysis on the data with the accepted centralizers that are closer to the fingers and with rotation turned off.

After running the software with the data of each well we found the analysis show similarity between the features. There are no signs of shear in any of the logged sections however there are two places where results show sign of column buckle. Most of the failure type is severe or less severe ovality and cross-sectional change. These are local collapse events with intact pipe sections between those.

After understanding these similarities, we examined the petrophysical data and found relation between the type of rock and the places of deformations. Taking the petrophysical data and the ovality of the pipe we combined and color coded the Vshale data with the ovality with the depth of the features as shown for the well in Figure 3.1 to 3.2.

These graphs show that there is a connection between high sand content and collapse event.

Figure 3.1 Color code for the combined Vshale\Ovality graphs

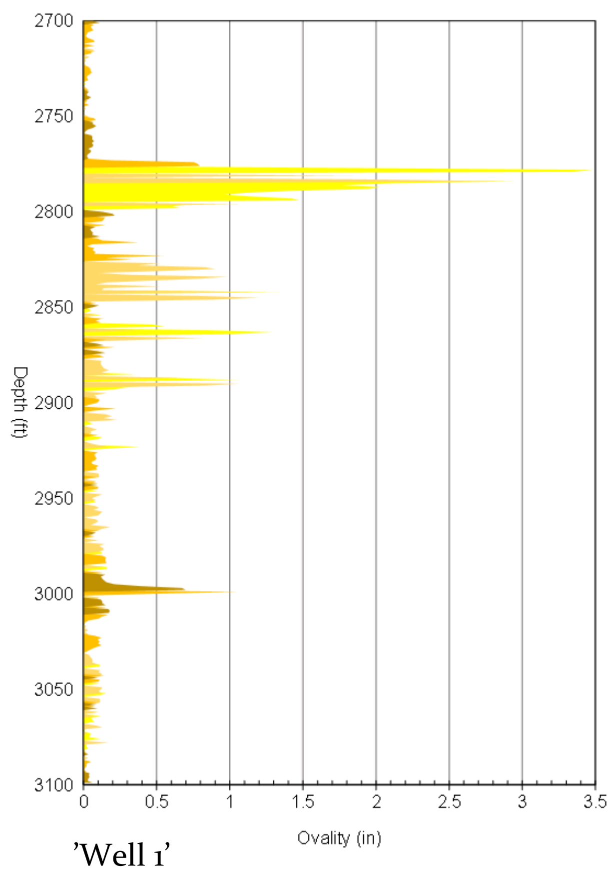


Figure 3.2 Combined Vshale\Ovality graph for 'Well 1'

3.2 'Well 1'

The 7" production casing of Well 1 was perforated 2778-3125 ft. Besides the changes caused by the perforation gun shots this section contains four major features and a scale build-up. Figure 3.3 shows the features and identified deformed sections on the Ovality and Dogleg Severity graphs.

This logged section of the pipe is in a relatively good condition with ovality less than 0.19 in (D_{max}-D_{min}) outside of the major localised deformation features discussed below.

The log depth did not have to be corrected compared the well completion drawings provided.

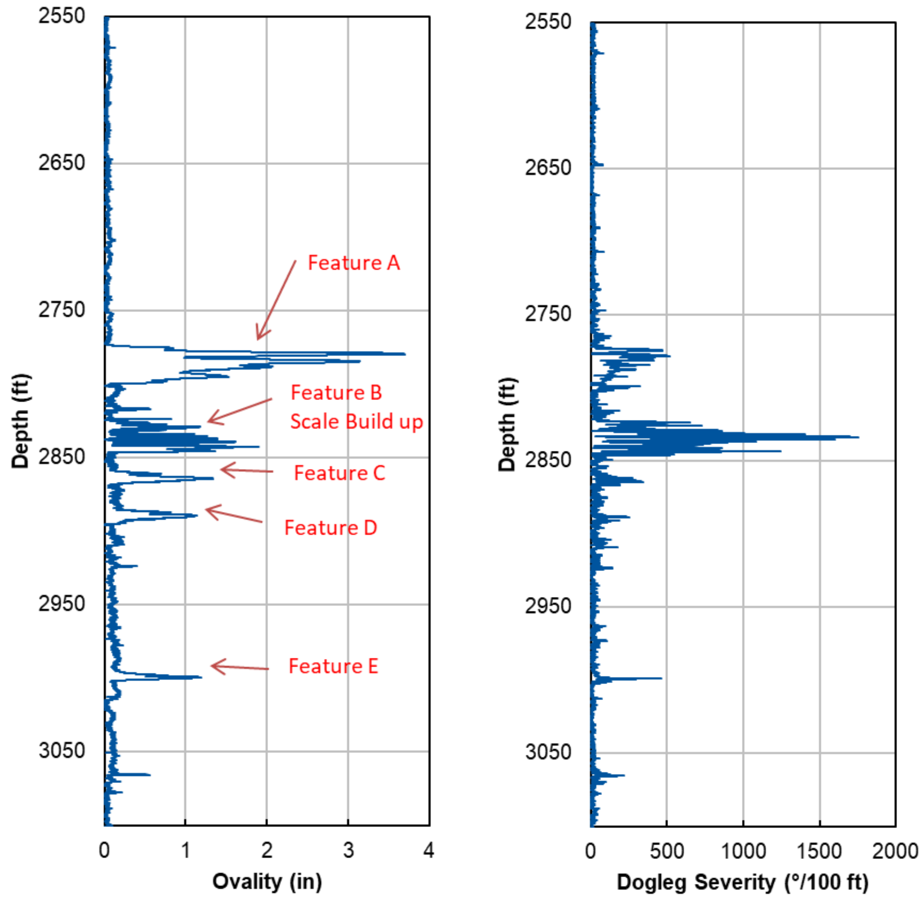


Figure 3.3 Ovality and Dogleg Severity for the Full perforated section of 7" casing 'Well 1'

3.2.1 Feature A (2773-2800 ft)

This feature identified at a measured depth of approximately 2780 ft. shows a severe ovality of the pipe as it can be seen on the cross-section Figure 3.4.

Figure 3.5 shows the three-dimensional (3D) interpretation of the well shape and trajectory. The image shows a local bend of the pipe at this point. Note that for clarity the aspect ratio has been magnified 8x but the radial, lateral and section offset has not been changed.

The peak ovality on the log is 3.7 in. and the peak dogleg severity of 516°/100ft as shown in Figure 3.6.

Note the well is near vertical and the orientation of the caliper tool was not reported.

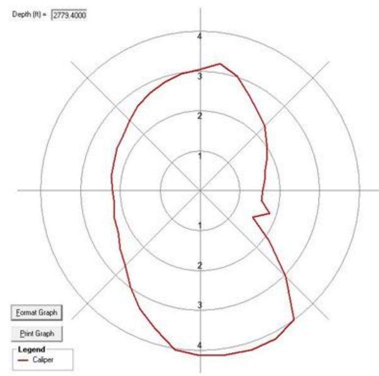


Figure 3.4 Cross Section through Feature A in 'Well 1' (2780 ft)

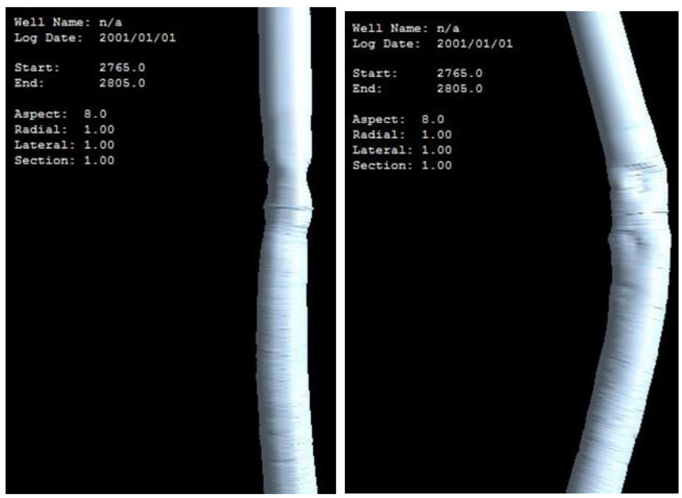


Figure 3.5 3D Interpretation for 'Well 1' Feature A (2780 ft); (left) front view and (right) side view

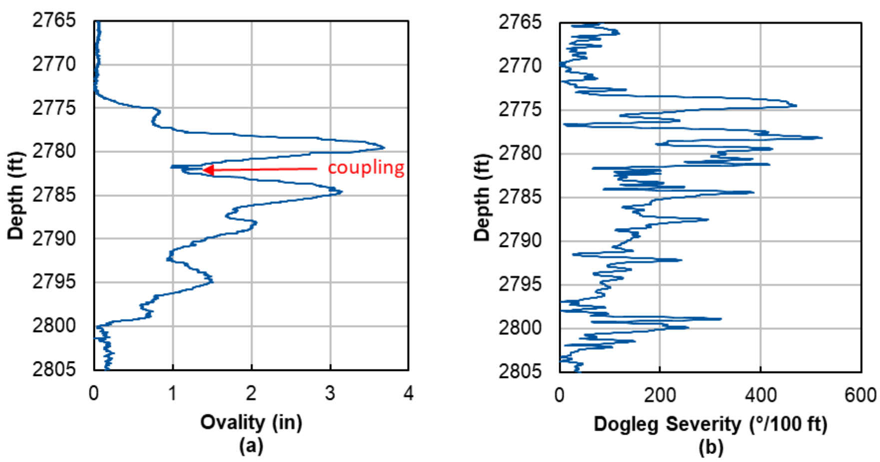


Figure 3.6 (a) Ovality and (b) Dogleg Severity for 'Well 1' (2780 ft)

The calculated min drift diameter with a range of tool length is shown in Figure 3.7. As shown on this figure 6 ft. long rigid tool can fit through this feature if it`s diameter is 1.49 in. In this well this feature is the limiting case for drift diameter for the full logged interval.

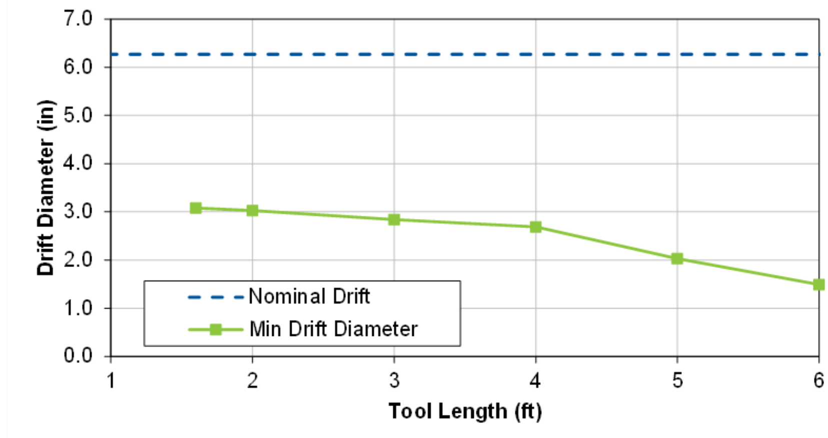


Figure 3.7 Calculated Minimum Drift Diameter for 'Well 1' Feature A

3.2.2 Feature B (2820-2850 ft.)

This feature shows a large-scale build-up centred at the measured depth of 2820-2850 ft. The casing string in this interval shows isolated sections with calculated ovality of between 0.8 in. and 1.89 in. due to what appears to be an accumulation of scale.

As it can be seen in the selection of cross sections in Figure 3.8 there is a big change in the pipe's circumference. This leads to the conclusion that the damage in this section of the pipe is uncertain. Note that on these cross-section images 10 sections at different depth are represented by the different shades.

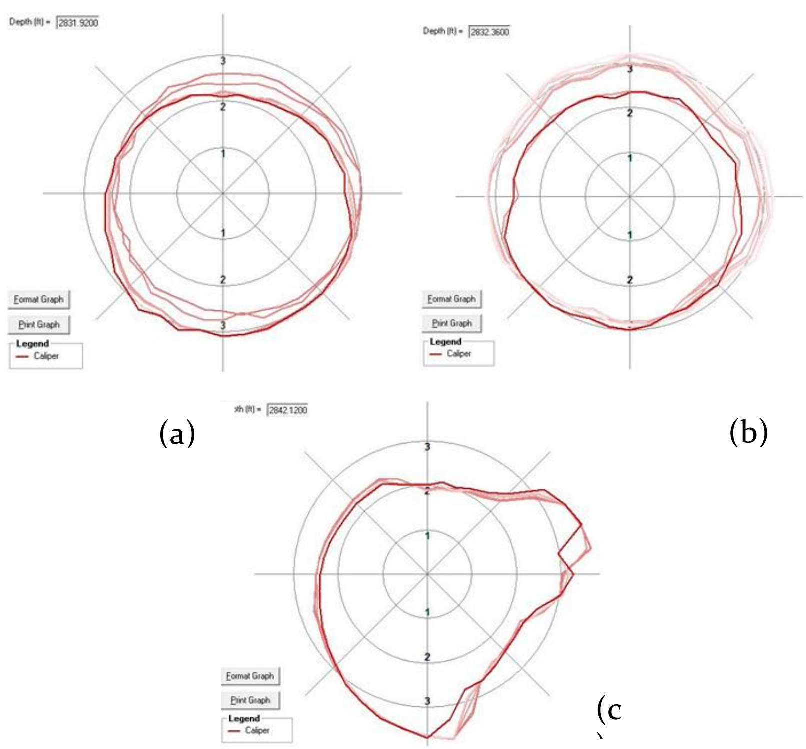


Figure 3.8 Cross Section through the scale build-up (2820-2850 ft)

3.2.3 Feature C, D and E

These features all show local ovality of the pipe as shown on the three cross section Figure 3.9 (a), (b) and (c). The peak of the ovality for these features are 1.34 in., 1.14 in. and 1.19 in. The sections with the increased ovality are 10 ft. long for Feature C and D (at 2856 ft. and at 2890 ft.) and are within one joint section close to the up and bottom connections but the pipe between the two features shows no sign of deformation as it can also be seen on the combined graph Figure 3.2. There is no sign of severe bending in the mentioned pipe sections as it is shown in the lateral displacement in Figure 3.11 (a), (b) and (c).

Feature E is at 3000 ft depth and is in midway between two couplings but also lines up with the depth of a high sand content reservoir section (see Figure 3.2).

The cross-sectional shape of these features indicates that the driving force of these changes, similar to the features in the other four wells, is the movement of the produced reservoir where the cross-sectional stresses are not the same.

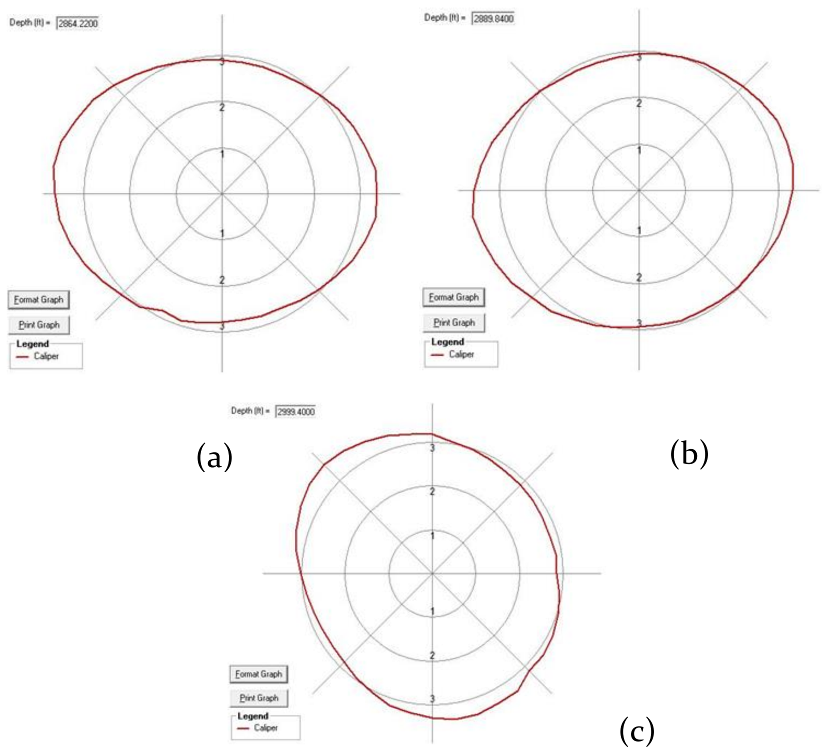


Figure 3.9 Cross Section through the ovality of (a) Feature C (2864 ft), (b) Feature D (2890 ft) and (c) Feature E (3000 ft), in 'Well 1'

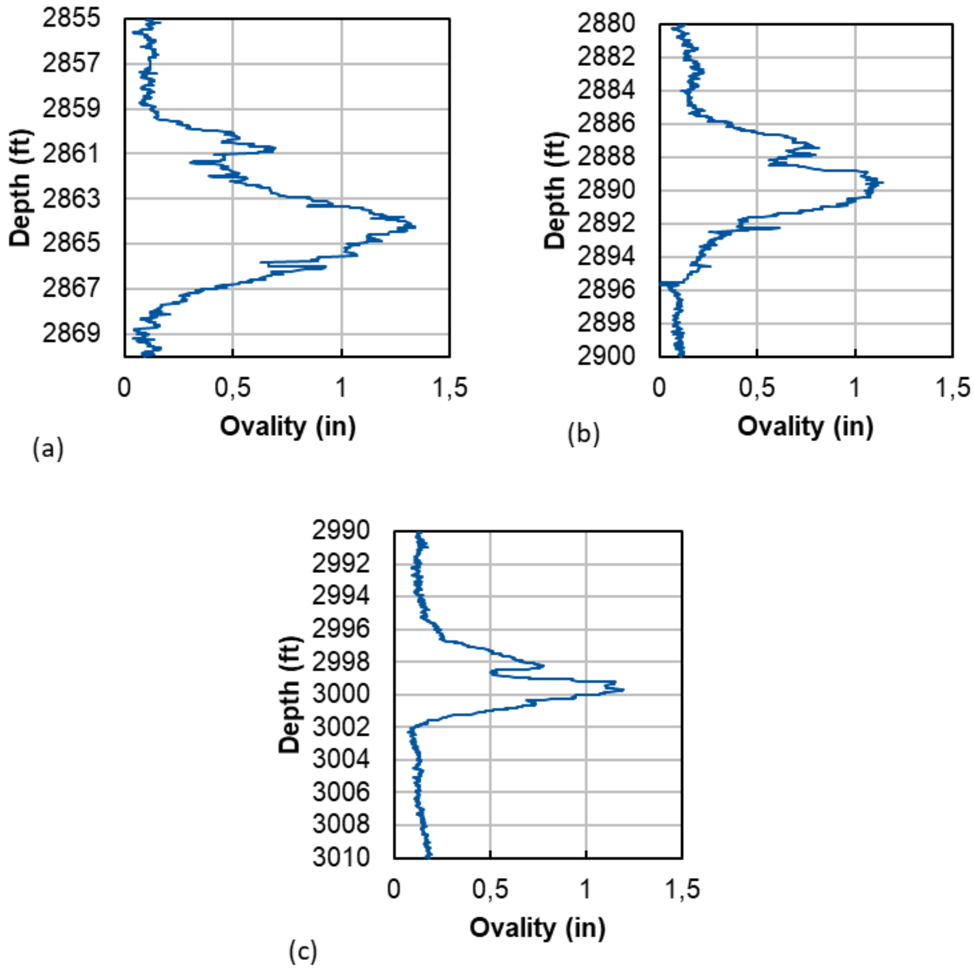


Figure 3.10 Ovality of (a) Feature C, (b) Feature D and (c) Feature E in 'Well 1'

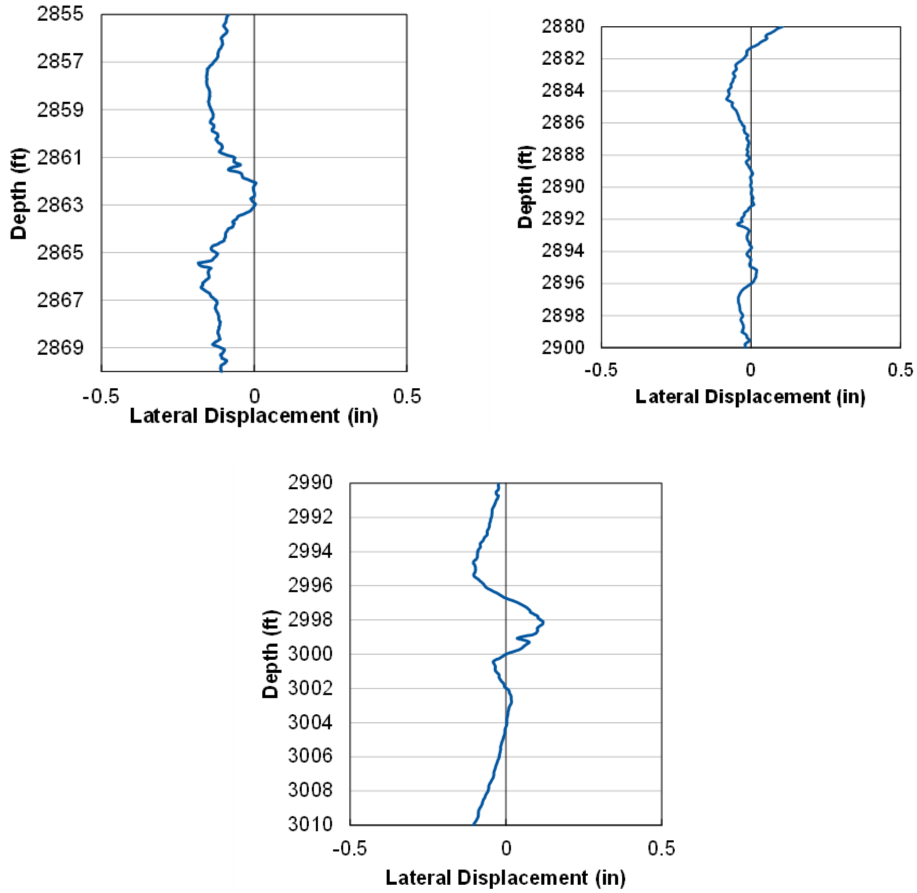


Figure 3.11 Lateral Displacement of (a) Feature C, (b) Feature D and (c) Feature E

4 Conclusions and recommendations

All of the wells showed several locations with localised collapse, exhibiting increases in local curvature and ovality that are likely caused by compressive strength perpendicular to the axis. In general, wherever the same feature has been logged only once, the deformations though could show significant worsening over time and in some cases may progress sufficiently to limit access to the well. Repetitive logging of these wells over time can help better understanding of the movement in the surrounding formations and the changes in the driving forces. The major deformations in the five wells are local collapses and bending of the pipe and these deformations show correlation with the sand production from the reservoirs. More research is recommended to be done regarding sand production and the effect of the moving sand on well integrity.

The logs used a tool with 40 arms and gave an accurate representation of the state of the casing but anything that is connected to the caliper tool should be with a flexible joint. The extent of the progress of the deformation over time therefore could not be accurately quantified in all cases. The key findings 'Well 1' are summarised below.

'Well 1'

1. One major collapse deformation is present at the top of the depth of the perforated section and this is the location of the minimum drift diameter for the full logged interval of the casing.
2. There are several ovality type features present within the perforated interval.
3. The log shows an accumulation of scale in an approximately 70 ft. long interval.

5 Acknowledgement

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6 References

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