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Bryan Mound Collar Compression Study

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ABSTRACT

This report presents a study of collar compression for the wells at the Bryan Mound site. The study includes a comprehensive review of all available Multi-Arm Caliper (MAC) logs from the site, which has been used to identify specific wells that are experiencing casing restrictions at collar joints. A summary of wells with collar restrictions and the corresponding deformation depths has been provided. Additional site-wide analysis of Bryan Mound well temperature data, proximity to sulphur wells, pulsed eddy current (PEC) logs, and a general spatial analysis has been included to investigate any potential correlations with wells experiencing collar compression at the site.

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EXECUTIVE SUMMARY

The U.S. Strategic Petroleum Reserve (SPR) is a crude oil storage system administered by the U.S. Department of Energy. The reserve consists of 60 active storage caverns located in underground salt domes spread across four sites in Louisiana and Texas, near the Gulf of Mexico. Ensuring well integrity across each site continues to be an important priority within the SPR. The Bryan Mound site has a history of well deformation in the caprock, most notably around the 700' to 900' depth range. This deformation appears to be caused by casing compression which is most commonly observed at casing collars. In a typical collar joint for a non-lined well, a small increase in inner diameter is observed at the threaded casing connection. Collar compression is characterized by a decrease in the well inner diameter at the collar, which is likely a result of one section of casing being pushed inside an adjacent casing section at the collar joint.

Included in the report is an analysis of Multi-Arm Caliper (MAC) logs for each well at the Bryan Mound site, with a focus on identifying wells that experience collar restrictions and characterizing the resulting deformation. Collar restrictions have been identified in 24 of the 47 Bryan Mound wells and a summary of wells with collar restrictions and the corresponding deformation depths has been provided. An analysis of additional relevant datasets follows the well-by-well MAC analysis. This includes a spatial analysis of the deformation locations, well temperature logging data, pulsed eddy current (PEC) logs, and proximity of SPR Bryan Mound wells to previous sulphur mining wells.

At this time, Bryan Mound wells experiencing collar restrictions have been identified, in addition to wells that have mid-casing concerns within the areas of interest. All collar restrictions that have been identified at the Bryan Mound site have been found within the caprock. There is a history of sulphur mining within the caprock, which has undoubtedly left lasting impacts on the geology of the BM dome in the areas in which mining took place. At this time, it appears that differences in the presence of collar restrictions between wells is likely the result of individual well responses to localized variations in the Bryan Mound geology. Beyond a sitewide temperature increase in the caprock as a result of sulphur mining, there are no other general data trends that seem to explain the individual variation in well behavior.

ACRONYMS AND TERMS

| Acronym/Term | Definition |
|--------------|-----------------------------|
| BHF | Bradenhead Flange |
| BM | Bryan Mound |
| LAS | LIDAR Aerial Survey |
| MAC | Multi-Arm Caliper |
| MIT | Mechanical Integrity Test |
| PEC | Pulsed Eddy Current |
| SPR | Strategic Petroleum Reserve |
| TD | Total Depth |

1. INTRODUCTION

This report presents a comprehensive analysis of the Bryan Mound Multi-Arm Caliper (MAC) data, with a specific emphasis on identifying wells that have collar restrictions, which has been a noted phenomenon observed in wells across the site. In May 2024, BM-116A experienced extreme mid-casing section deformation and well failure, which has increased concerns about well integrity across the site. Although the BM-116A well failure occurred mid-casing and not at a collar joint, some discussion and analysis of the well failure has been included in this report and any other wells with mid-casing deformation concerns have been identified. Collar compression has typically been identified within the caprock, making it the biggest area of concern for well deformation at the site.

The report is separated into five main sections. Section 1 provides a brief introduction and outline of the report. Section 2 focuses on general information about the site including the geology of the dome and background information on the sulphur production that took place at BM. Section 3 gives a well-by-well analysis of the MAC data and identification of wells with collar restrictions or other notable deformation concerns. Section 4 explores several additional data sources such as temperature data and sulphur mining locations and provides further commentary on the BM-116A well failure. Finally, Section 5 provides a summary of findings from the data analyzed throughout the report and provides considerations moving forward for well deformation at the site.

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2. BRYAN MOUND SITE

2.1. General Site Background

Bryan Mound is one of four SPR sites situated along the Gulf Coast of the U.S. It is located in Brazoria County, Texas, approximately 60 miles south of Houston, Texas (Figure 2-1).



Figure 2-1. Locations of the four SPR sites on the Gulf Coast. The four sites are Bryan Mound, Big Hill, West Hackberry, and Bayou Choctaw

The Bryan Mound Site is composed of 20 active caverns, with 47 total wells. The site has a mixture of pre-existing caverns that were acquired by the SPR and caverns that were subsequently developed by the SPR specifically for petroleum storage. This has resulted in caverns having anywhere between 1-3 wells. The well configurations at Bryan Mound typically have a 16" or 13 3/8" outer diameter for the innermost casing. Several of the wells at this site have been remediated with a liner, resulting in a reduced diameter for the innermost casing.

The Bryan Mound caprock is generally circular in map-view and the shallowest caprock elevation is documented at -682 feet and is located in the northwest region of the caprock (Lord 2007). The caprock is known to have three main zones. The uppermost zone consists of limestone with water or sulphur filled pore space. The middle zone is a transition zone and consists of limestone, gypsum, sulphur and anhydrite. The lowermost zone consists mainly of anhydrite. The caprock is approximately 300 feet in thickness. The Bryan Mound salt dome is generally cylindrical and flat across the top. The shallowest documented salt intercept is at an elevation of -1043 feet and is located in the center of the dome (B. L. Roberts 2015).

2.2. Sulphur Mining at Bryan Mound

In the early 1900's sulphur was discovered in the caprock of the Bryan Mound dome and was extensively mined from 1912 – 1935 by Freeport Sulphur. A 2015 Sandia report provides an in-depth review of the sulphur extraction process that took place at Bryan Mound (Kirby and Lord 2015).

Sulphur was found at depths of 700'-900' in the Bryan Mound dome through a series of exploration wells and was subsequently mined using the Frasch process. Patented by Herman Frasch in 1891, the Frasch process involves injecting large amounts of hot water (around 330° Fahrenheit) into the earth, in order to liquify the sulphur, which is then brought to the surface. One well was said to be able to remove sulphur from an area of about one-half acre. Freeport Sulphur, the dome operator at the time, reported that when drilling into the dome they found approximately 760 feet of gravel and caprock, followed by about 150 feet of sulphur bearing limestone, with the sulphur deposits ending from around 900 to 1100 feet. Beds of pure sulphur ranging in thickness from a few inches to several feet were noted. It is reported that during the sulphur extraction process at Bryan Mound 1897 wells were drilled and a total of approximately 5,000,000 long tons of sulphur was produced. The effects of this extensive mining have likely led to increased temperatures and a more cavernous caprock in areas most affected by the sulphur production.

3. BRYAN MOUND WELL DEFORMATION

3.1. Multi-Arm Caliper Log Data

Multi-Arm Caliper (MAC) logs have historically been used to identify deformation in wells across the SPR. MAC logs taken at Bryan Mound are typically performed with a 56 or 60-arm radial tool, which is raised throughout the length of the casing. The data produced from a MAC logging event provides radial measurements for each arm with depth. Sandia has developed a systematic way to quantify and evaluate this data so that it can be compared across wells of different configuration. A Sandia report published in 2021 provides an in-depth explanation of the current Sandia MAC evaluation process (B. Roberts 2021). In order to evaluate well integrity at Bryan Mound, MAC logs have been analyzed for each well at the site. The following analysis of the Bryan Mound collar compression focuses mainly on minimum diameter measurements throughout the wellbore, which have been calculated from the radial arm MAC data. It should be noted that all minimum and average diameter values discussed in this report are inner diameter values. Additionally, the expected casing inner diameter for a given outer diameter may differ depending on the casing weight. Although these minimum diameter measurements are only a small portion of the entire MAC well evaluation process, they are the best way to identify the decrease in diameter which is typically observed at a casing collar and is the focus of the deformation analysis in this report.

3.2. History of Well Deformation

The Bryan Mound site has a history of well deformation in the caprock, most notably around the 700' to 900' range. This deformation appears to be caused by casing compression which is most commonly observed at casing collars. The unlined wells at the Bryan Mound site have short thread coupling (STC) joints. In a typical STC collar joint for a non-lined well, a small increase in diameter is observed at the threaded casing connection. Collar compression is characterized by a decrease in the well diameter at the collar, which is likely a result of one section of casing being pushed inside an adjacent casing section at the collar joint due to axial compression.

An example below shows data from well BM-5, where a casing compression has been identified around 797'. Figure 3-1 shows minimum diameter measurements for the entire 13 3/8" casing. In the minimum diameter data, a clear decrease in the inner diameter of the well can be identified in the collar at approximately 797'. Although identifying a decrease in the minimum diameter curve is a good first check, is not sufficient enough to conclusively say that there is a collar restriction at that depth. There are several cases where a decrease in the minimum diameter is caused by a single arm reading or debris in the well that is only present in a small number of radial arm measurements at a given depth. A suspected casing restriction should always be confirmed with a comprehensive review of radial arm data from the MAC log at the depth of concern. Even in cases where a decrease is seen in the maximum diameter curve as well, signaling that all diameter measurements at a given depths have been reduced, the radial arm data provides a better picture of what is going on and can help characterize the uniformity and severity of the collar restriction. Figure 3-2 shows radial arm data taken from the 2013 MAC log run on well BM-5, with cross sections taken both at and above the collar restriction. From this data, a clear and uniform decrease in the diameter can be observed at 797'.

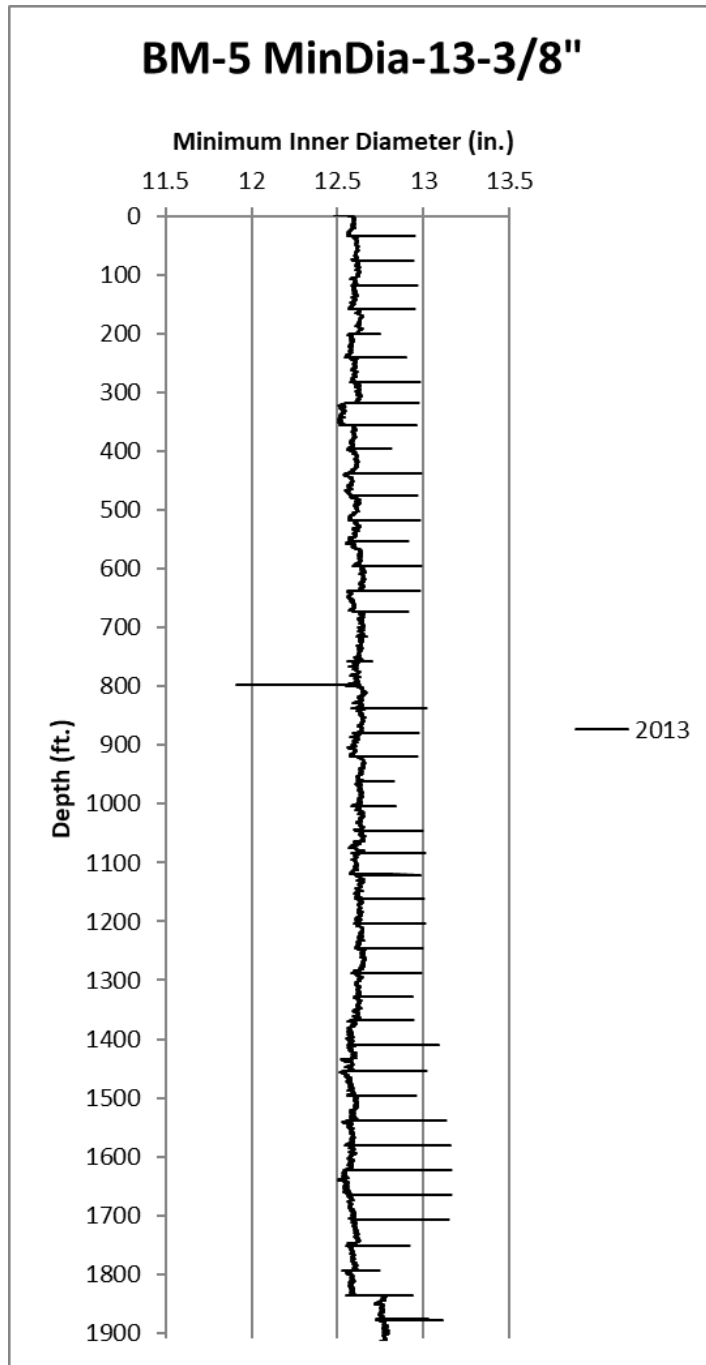


Figure 3-1. BM-5 minimum diameter curve from 2013 MAC data

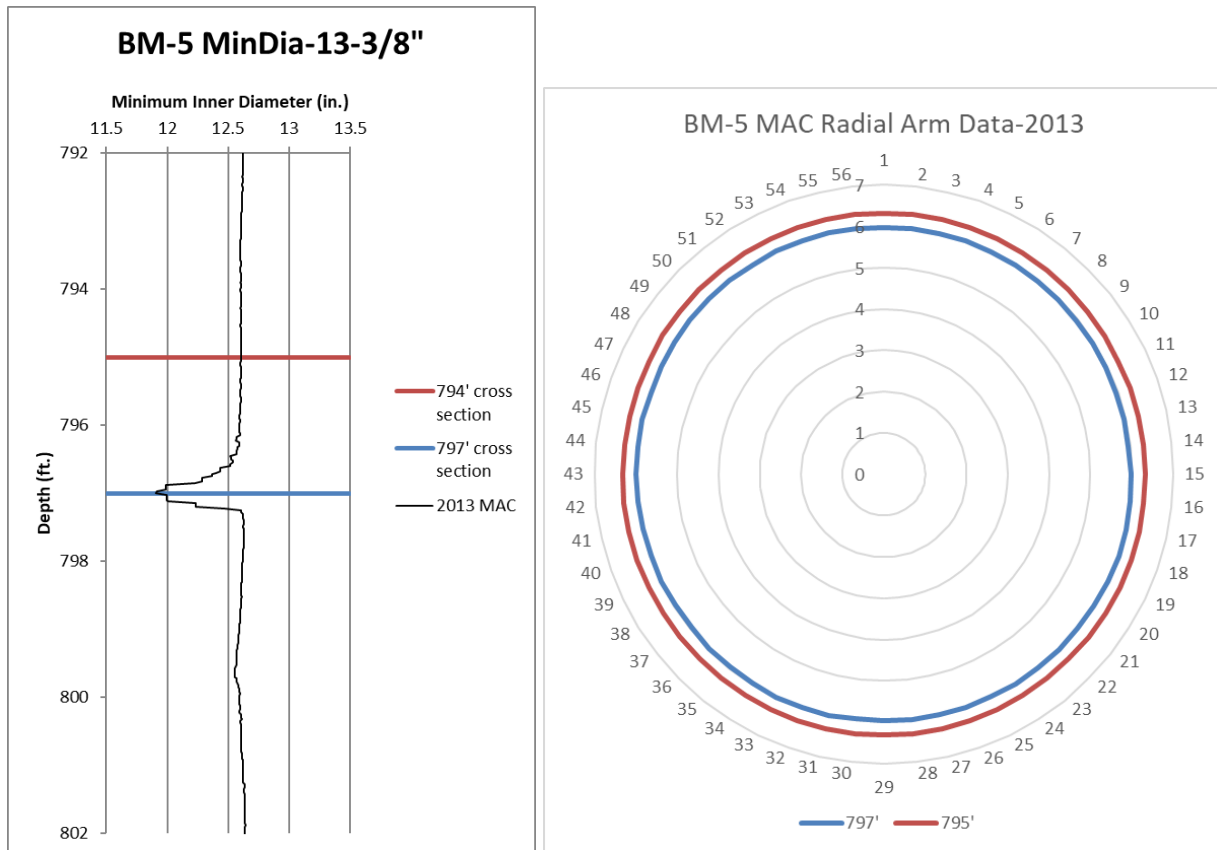


Figure 3-2. Cross sections of BM-5 2013 MAC data at the depth of casing restriction (blue) and above the restriction (red).

A 3D visual of the radial arm data near the casing collar restriction can be seen in Figure 3-3. As observed in the cross sections shown above, a clear restriction in the casing can be seen at 797'. Again, this is the opposite of what we would expect to see at a typical STC casing collar. Figure 3-4 provides an example of a normal casing collar in BM-5, with a small collar kick at the joint location as expected. There are several cases in this report where a radial restriction is present at a casing collar but appears minimal in the MAC data. It should be noted that even in cases where a collar restriction is present but not severe, the absence of a normal collar kick is likely indicative of a compression issue at the collar.

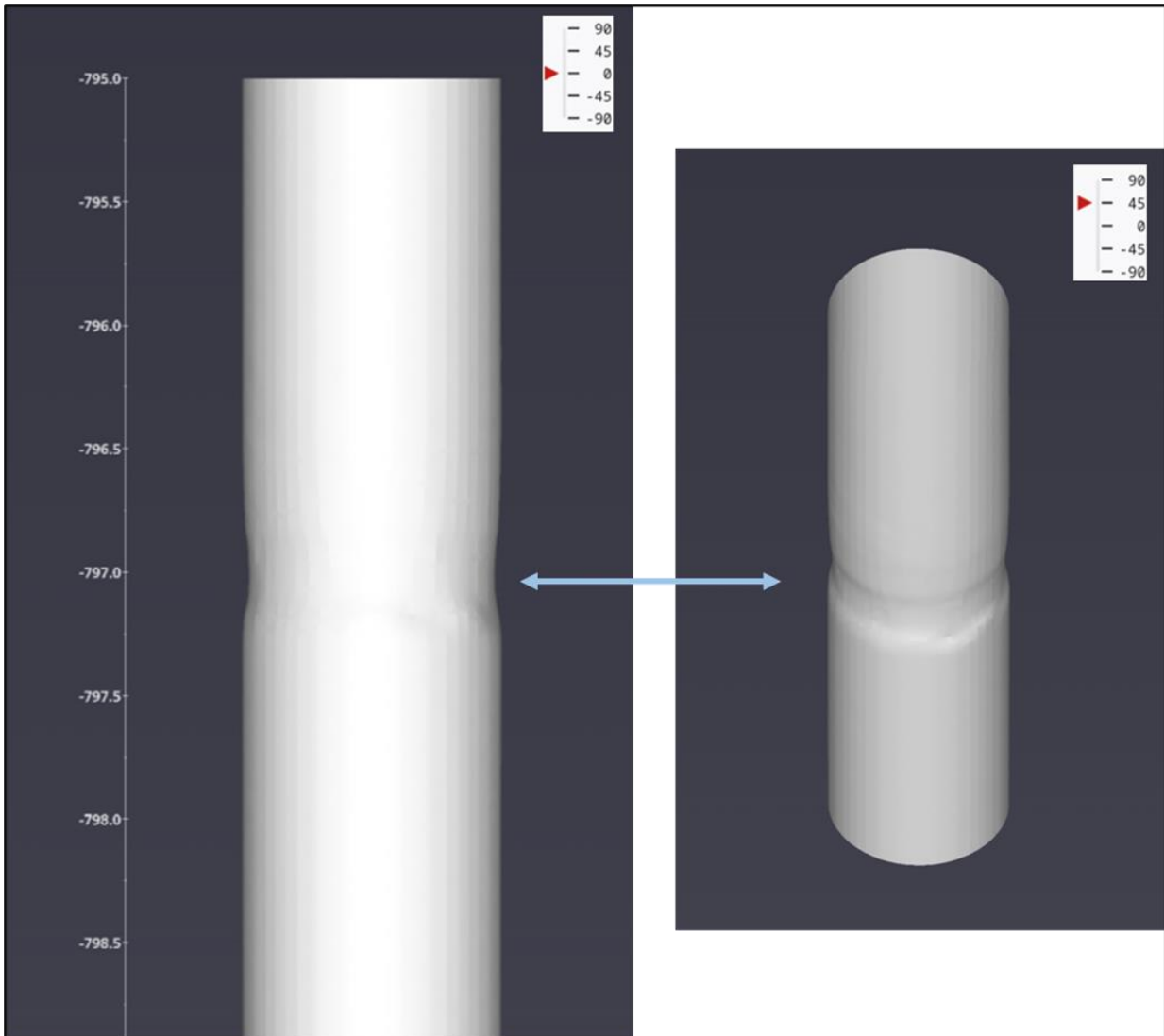


Figure 3-3. 3D visual of BM-5 2013 MAC radial arm data at the casing restriction

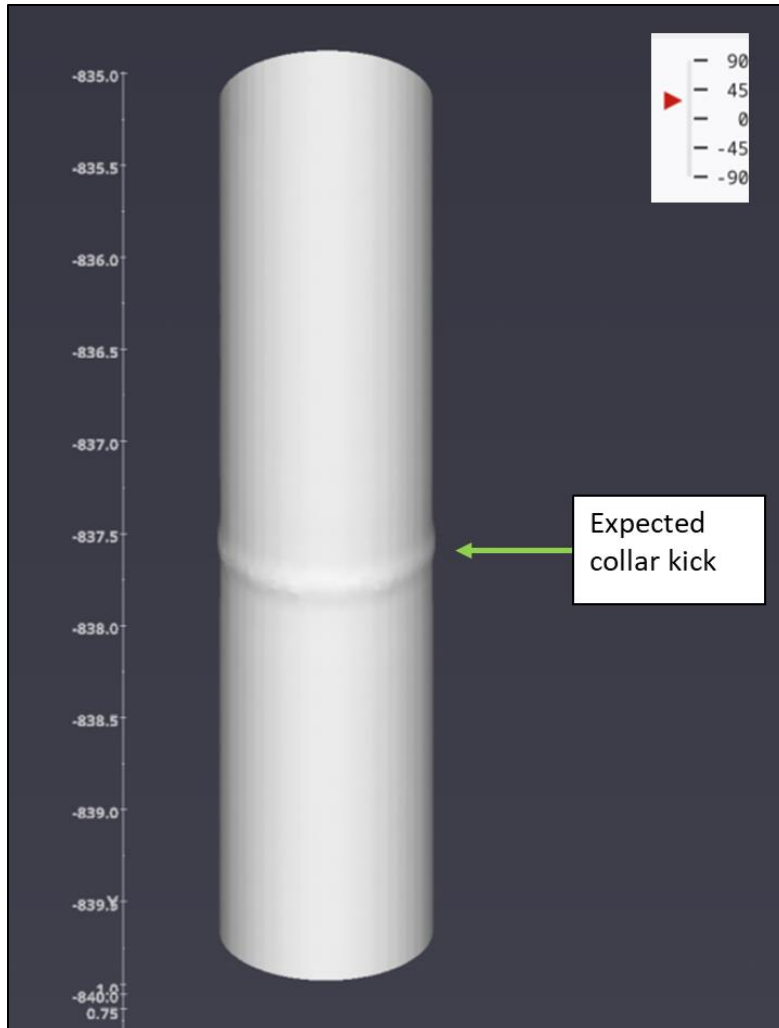


Figure 3-4. 3D visual of normal collar joint in BM-5

Well deformation as a result of casing compression has been observed in 24 of the 47 wells at the Bryan Mound site, with varying degrees of severity. The table below provides a summary of which wells have experienced this type of deformation and the depth at which it occurred. If the same casing restriction was observed in multiple MAC surveys for a given well, the exact depth of the restriction was recorded from the most recent survey that showed deformation. Although the BM-116A well failure occurred mid-casing section, it has still been included and highlighted in the table for reference. The well-by-well analysis in Section 3.3 covers the history of deformation and current status of each well in greater detail.

Table 3-1. Summary of BM well collar restrictions

| Well | collar restriction depth (ft. rel. BHF) | collar restriction depth (ft. rel. MSL) |
|---------|---|---|
| BM-001A | 845.5 | 834.1 |
| BM-002 | | |
| BM-002A | | |
| BM-004A | | |
| BM-004B | 878.1 | 864.3 |
| BM-004C | | |
| BM-005 | 797.0 | 789.8 |
| BM-005A | 750.1 | 742.9 |
| BM-005C | | |
| BM-101A | 898.7 | 892.4 |
| BM-101C | 902.6 | 896.3 |
| BM-102B | 867.6 | 862.7 |
| BM-102C | 907.4 | 901.5 |
| BM-103B | 999.5 | 993.7 |
| BM-103C | | |
| BM-104A | 905.9, 942.8 | 896.1, 933.0 |
| BM-104B | 881.6 | 871.9 |
| BM-104C | 804.7, 885.3 | 795, 875.6 |
| BM-105B | 810.8 | 797.7 |
| BM-105C | | |
| BM-106A | 881.9 | 866.4 |
| BM-106B | 834.2 | 818.5 |
| BM-106C | 848.3 | 832.0 |
| BM-107A | | |
| BM-107B | | |
| BM-107C | 835.9 | 820.9 |
| BM-108A | 865.3 | 849.3 |
| BM-108B | 873.9 | 858.6 |
| BM-108C | | |
| BM-109A | 828.8 | 812.8 |
| BM-109B | 825.9 | 810.3 |
| BM-109C | | |
| BM-110A | 844.7 | 829.2 |
| BM-110B | | |
| BM-110C | | |
| BM-111A | | |
| BM-111B | | |
| BM-112A | 887.3 | 876.3 |
| BM-112C | 873.6 | 862.6 |
| BM-113A | | |
| BM-113B | | |
| BM-114A | | |
| BM-114B | | |
| BM-115A | | |
| BM-115B | | |
| BM-116A | | |
| BM-116B | | |

3.3. Well by Well Analysis

The following section is a well-by-well analysis of MAC data at the Bryan Mound site. The focus of this analysis is to identify wells that have deformation as a result of casing collar compression and provide a current status for each well to the best of our knowledge. Although the emphasis is on collar compression in the wells, if there are any other areas of concern worth mentioning they have been noted. In cases where a well that has previously shown collar compression has been lined, the restriction at the collar is likely still ongoing, even if it can no longer be observed as a result of the liner. In cases where the depth values were not consistent between surveys, they were aligned to match the depths reflected in the most recent MAC log for a given well. This was done by aligning the collar kicks, which are known repeatable reference depths.

3.3.1. BM-1A

BM-1A has a total of three MAC logs from 2012, 2014, and 2015. The 2012 and 2014 MACs were taken on the 13 3/8" casing. The well was then lined, and the 2015 MAC was taken down the 10 3/4" liner. Figure 3-5 shows the minimum diameter curves for the logs taken on the 13 3/8" casing. In the 2012 and 2014 logs a casing restriction for this well was identified at a depth of 845.5'. Although there appears to be a slight progression in the minimum diameter between the 2012 and 2014 MACs, it is difficult to say whether this a true worsening of the restriction, or is a result of normal variation between the two logs. Figure 3-6 shows the 2015 log taken on the liner and does not show any signs of casing restriction at this depth. There is a slight decrease in the minimum diameter from the 2015 log around 541', however this does not show up in the average and maximum diameter curves and is the result of a single reading from one of the radial arms.

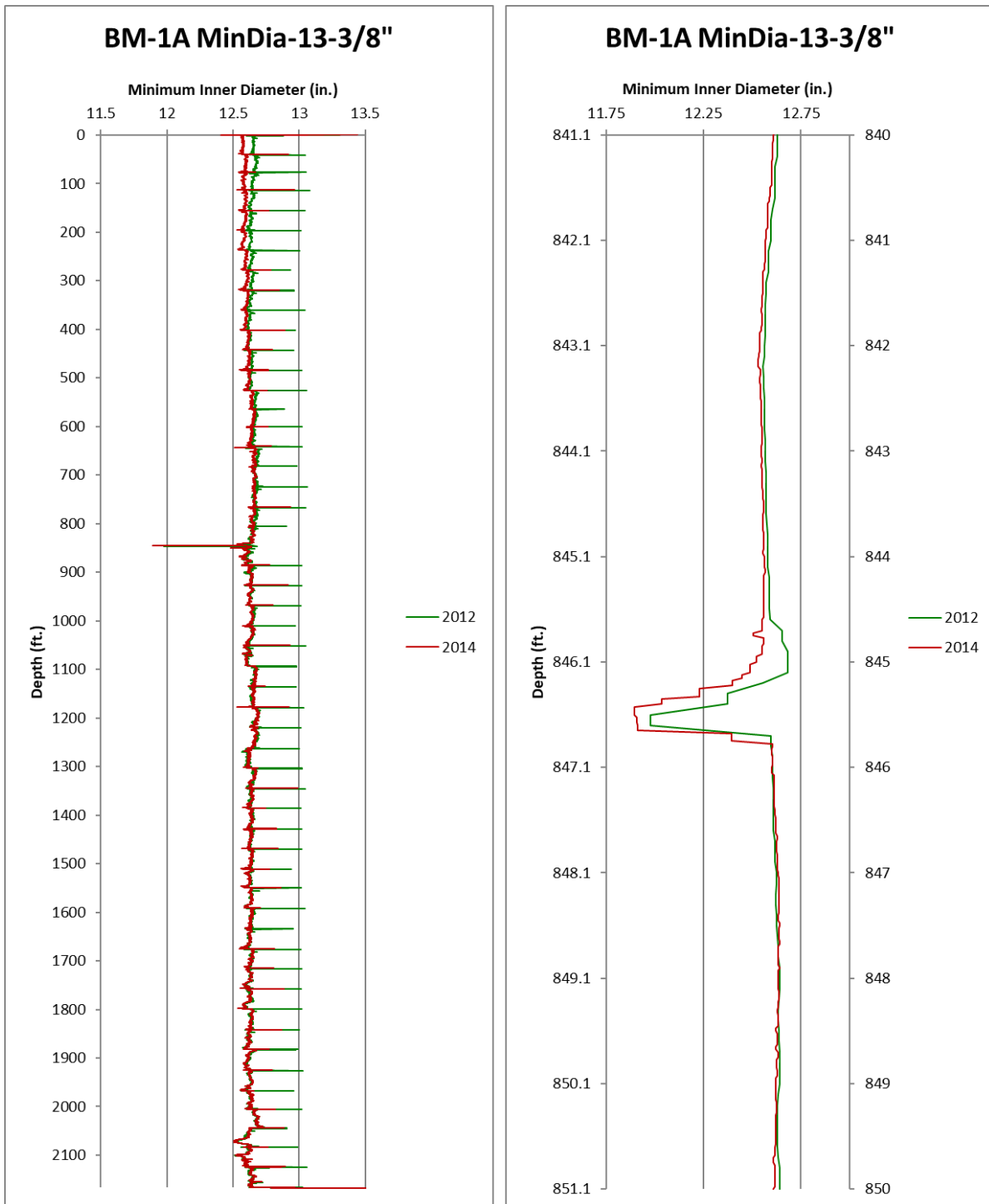


Figure 3-5. BM-1A Minimum diameter curves from 2012 and 2014 MAC data

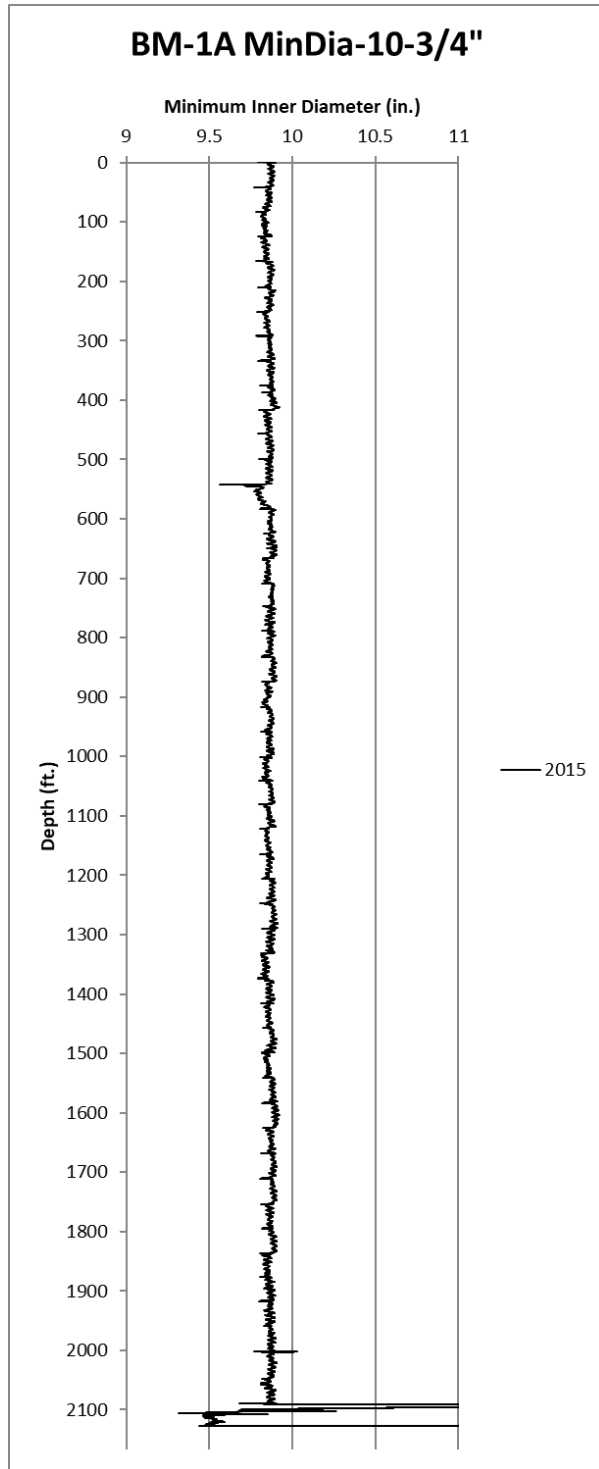


Figure 3-6. BM-1A Minimum diameter curve from 2015 MAC data

Figure 3-7 shows an overlay of the 2012, 2014, and 2015 MAC data at the bottom of the well. As shown below, during the installation of the 10 3/4" liner, some cement was left over just below the end of the liner and is leading to a reduction in the diameter of the 13 3/8" casing around 2095' – 2130'. Although there is a reduction in the minimum diameter at this depth, it is not currently a cause for concern.

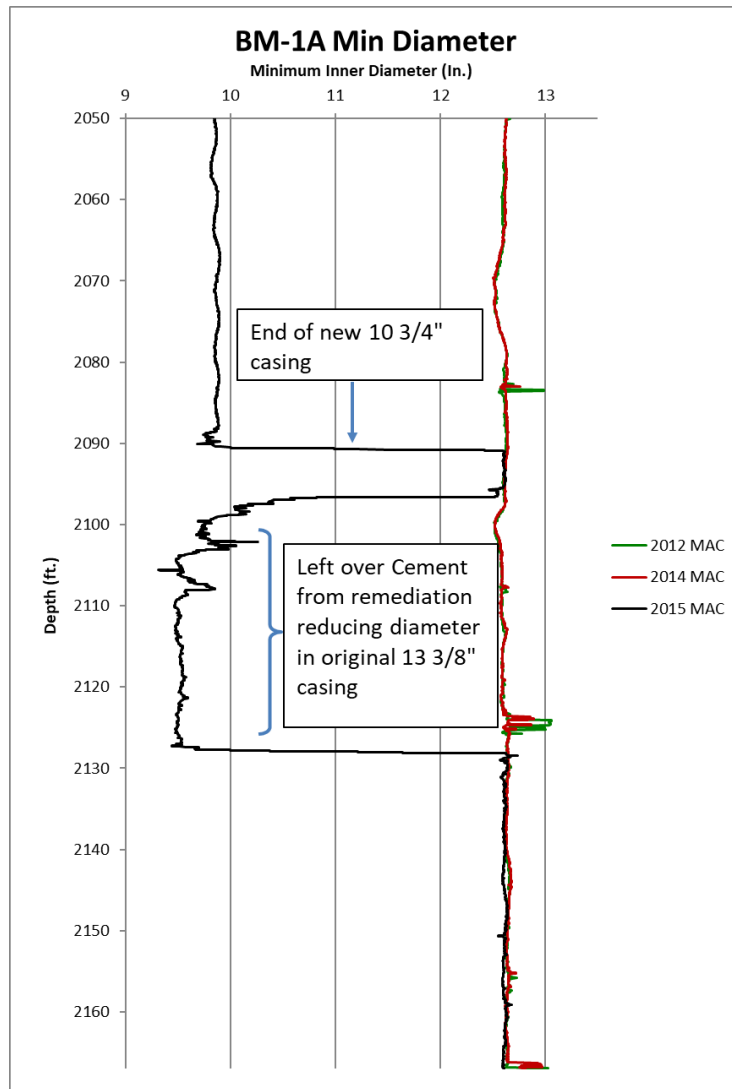


Figure 3-7. BM-1A Minimum diameter curve at the end of 10 3/4" casing

The 2012 and 2014 MAC data showed a casing restriction as a result of well deformation at 845.5' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-8 shows cross sections at two different depths, taken from the radial arm data collected in the 2014 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a uniform decrease in the inner diameter at the deformation depth.

The minimum diameter at 845.5' is 11.89", which is notably lower than the minimum diameter of 12.54" at 843'. Figure 3-9 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed. Although the well has been lined since the 2014 MAC, the deformation observed around 845.5' is likely ongoing and the well should continue to be monitored. Some moderate deformation has also been noted around the salt-caprock interface.

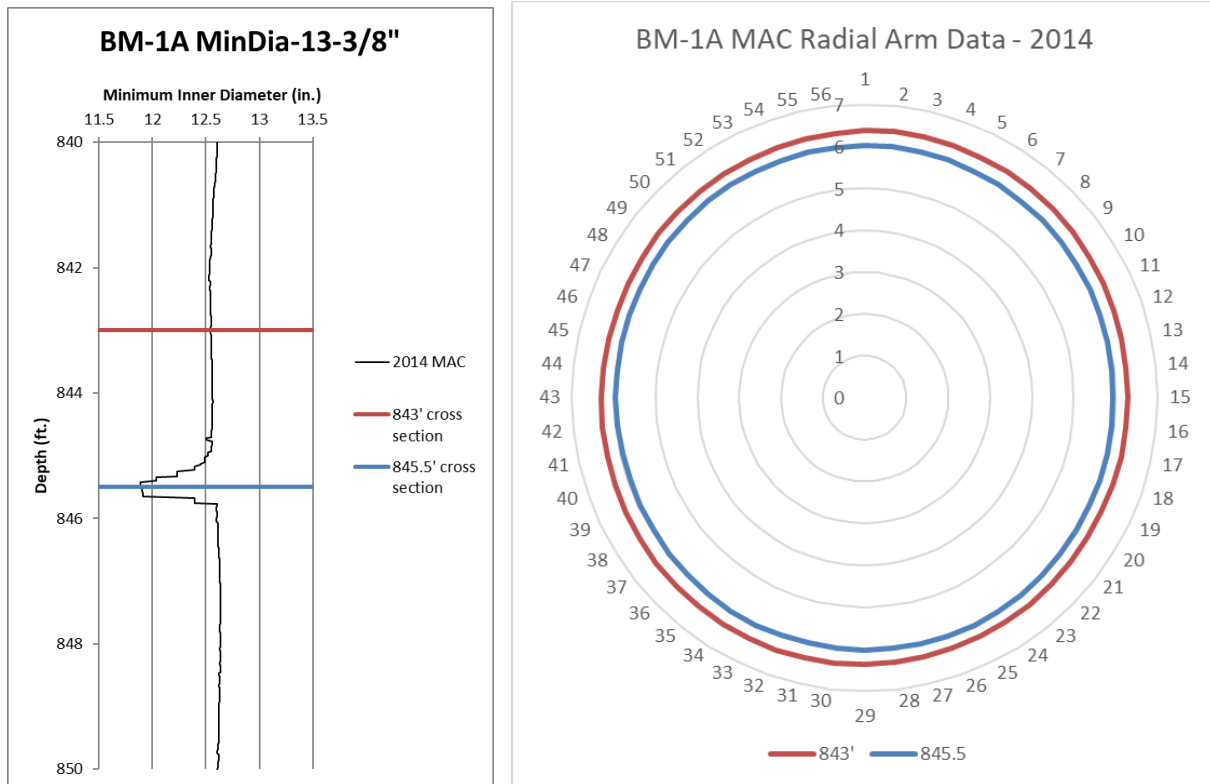


Figure 3-8. Cross sections of BM-1A 2014 MAC data at the depth of casing restriction (blue) and above the restriction (red).

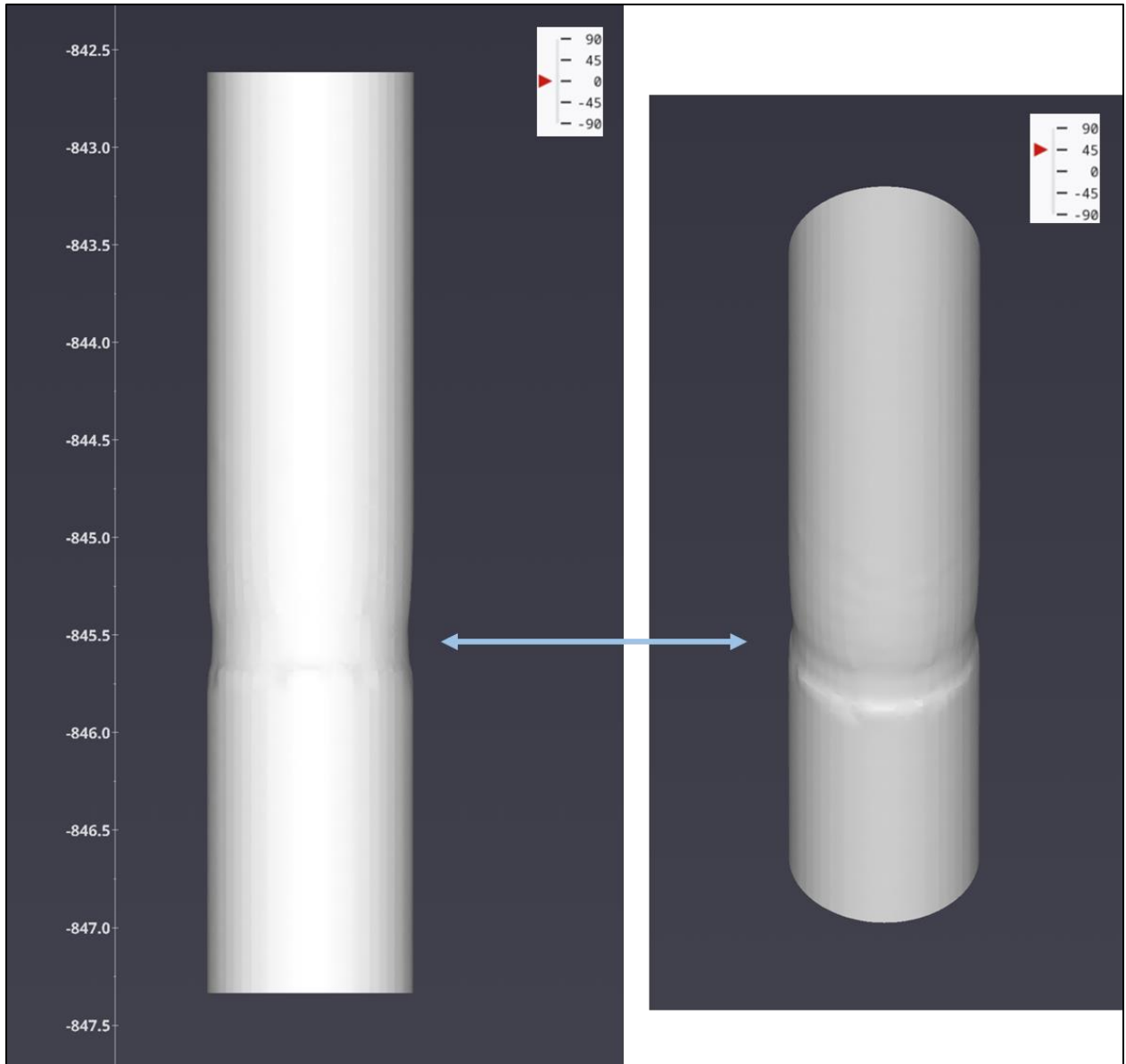


Figure 3-9. 3D visual of BM-1A 2014 MAC radial arm data at the casing restriction

3.3.2. BM-2

BM-2 has a total of two MAC logs from 2009 and 2014 taken on the 8 5/8" casing. The 2009 log was not included in this analysis as it had incomplete data. Figure 3-10 shows the minimum diameter curve for the 8-5/8" casing which was calculated from the 2014 MAC log. Although there are no major restrictions at the casing collars, there is a decrease in the minimum diameter between collar locations around 784.85'.

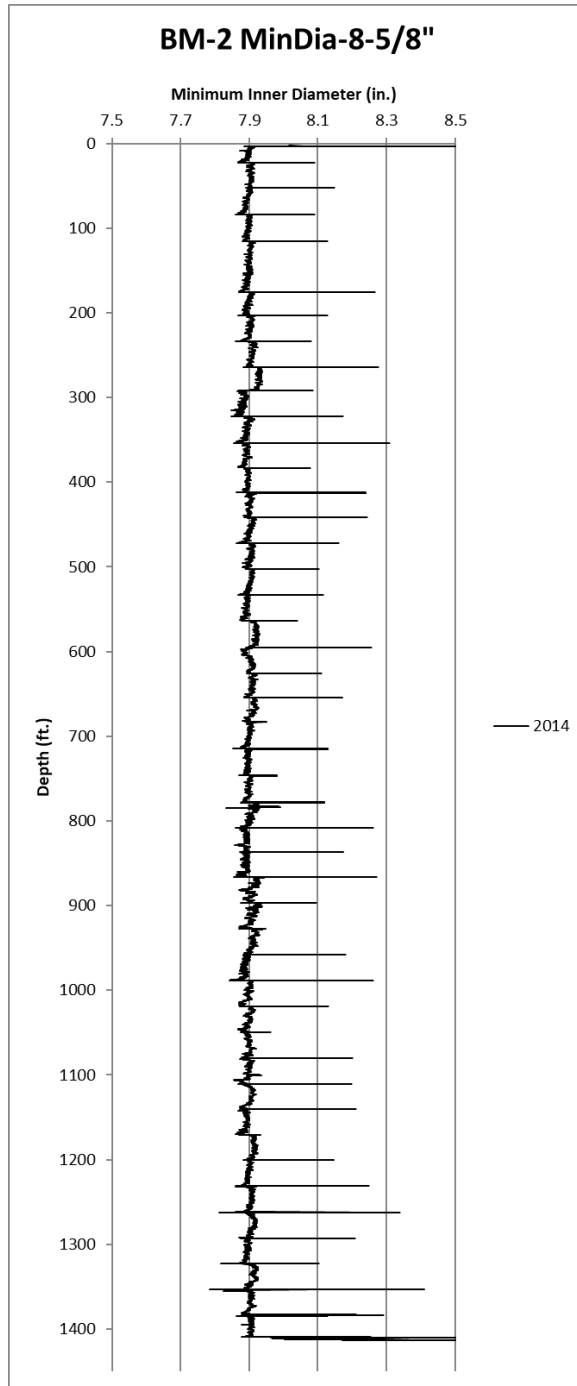


Figure 3-10. BM-2 Minimum diameter curves from the 2014 MAC data

Figure 3-11 shows cross sections taken at and below the depth of interest at 784.85'. An ovality in the casing can be observed at this depth as seen in the figure below. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the ovality seen at a depth of 784.85'. This is different than the collar compression typically observed at the Bryan Mound site. The 2014 MAC does not show the deformation at this depth to be severe, however it should be noted as an area to monitor going forward, especially in light of recent events at BM-116A, where extreme deformation occurred in-between casing collars.

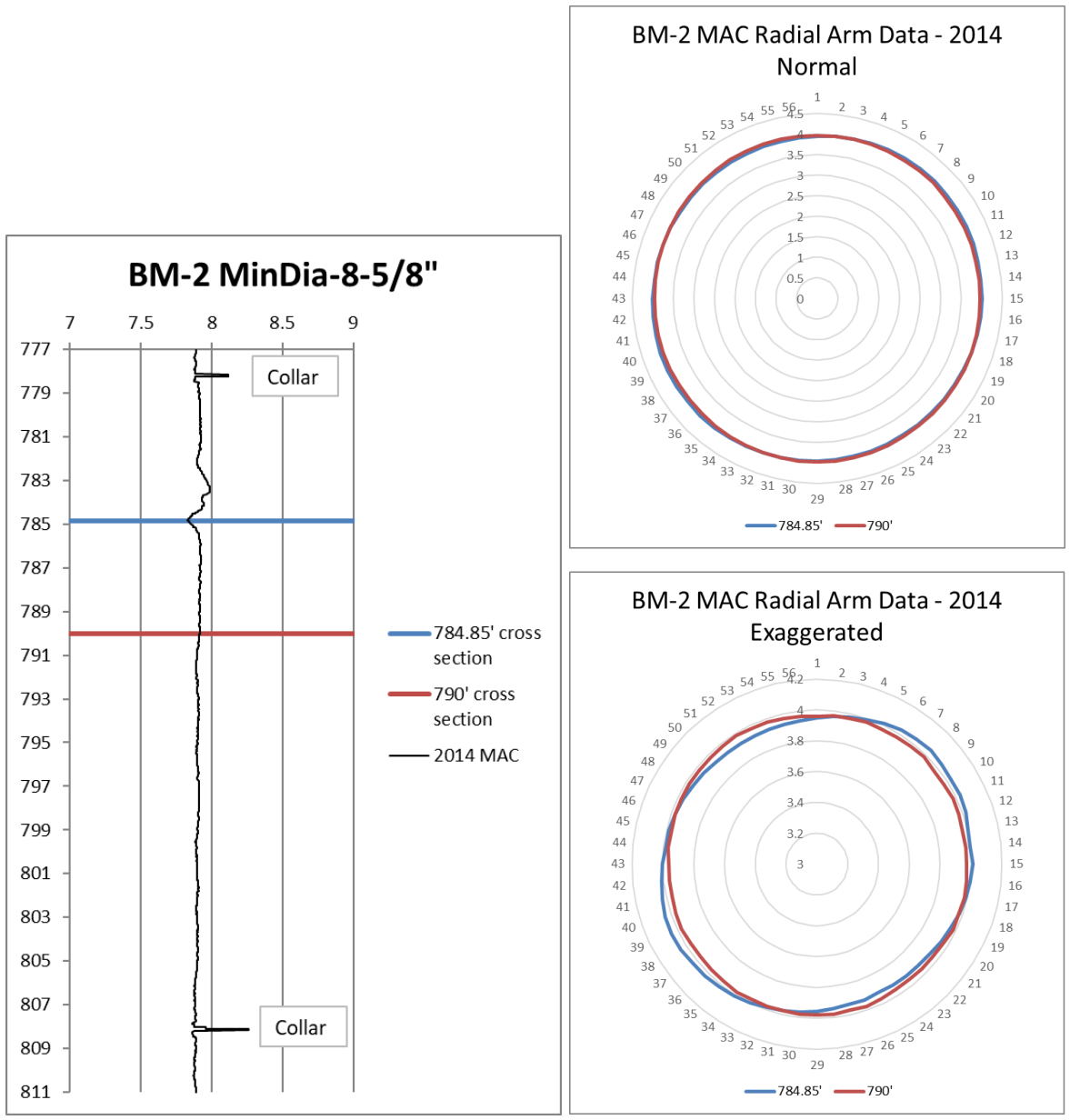


Figure 3-11. Cross sections of BM-2 2014 MAC data at the depth of casing ovality (blue) and below the ovality (red).

3.3.3. BM-2A

BM-2A has one MAC log from 2012, which was taken on the 13 3/8” casing. Figure 3-12 shows the minimum diameter curve for the 13-3/8” casing which was calculated from the 2012 MAC log. Although there are no major restrictions at the casing collars, there is a slight decrease in the minimum diameter between collar locations around 851.8’.

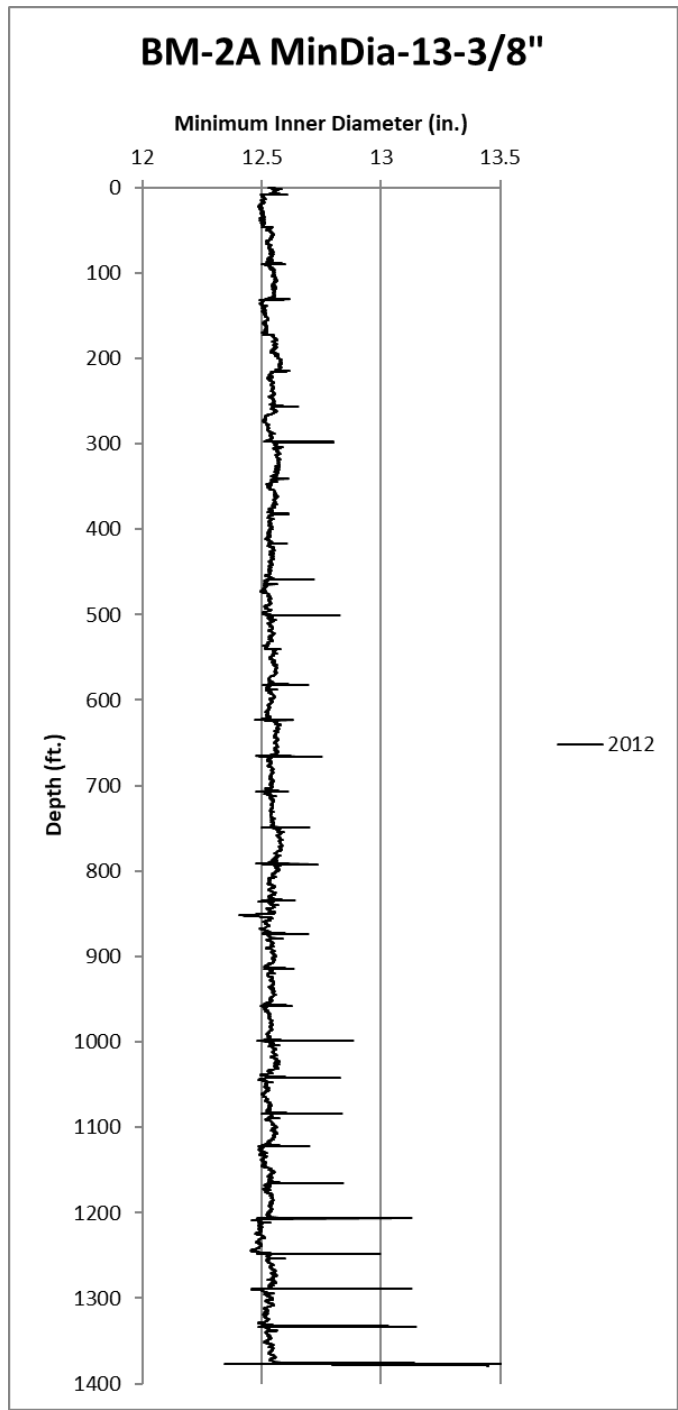


Figure 3-12. BM-2A minimum diameter curve from 2012 MAC data

Figure 3-13 shows cross sections taken at and below the depth of interest at 851.8'. An ovality in the casing can be observed at this depth as seen in the figure below. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the ovality seen at a depth of 851.8'. The 2012 MAC does not show the deformation at this depth to be severe, however it should be noted as an area to monitor going forward, especially in light of recent events at BM-116A, where extreme deformation occurred in-between casing collars.

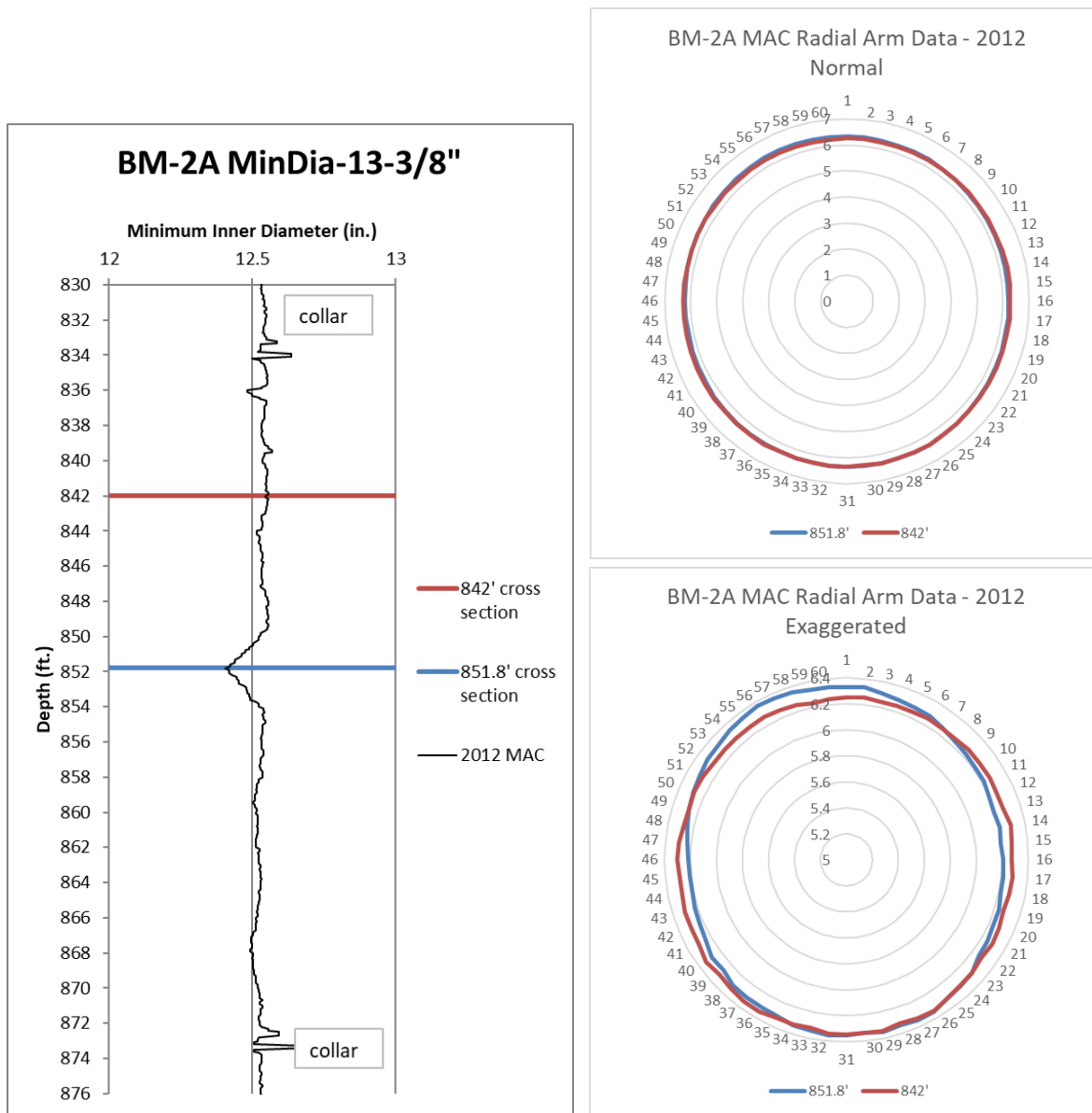


Figure 3-13. Cross sections of BM-2A 2012 MAC data at the depth of casing ovality (blue) and below the ovality (red).

3.3.4. BM-4A

BM-4A has a total of two MAC logs from 2009 and 2019. Both logs were taken on the 13 3/8" casing. Figure 3-14 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2009 and 2019 MAC logs. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. There is some minimal deformation observed around the salt caprock interface which does not appear to be rapidly worsening that should be noted but it is not a major cause for concern at this time.

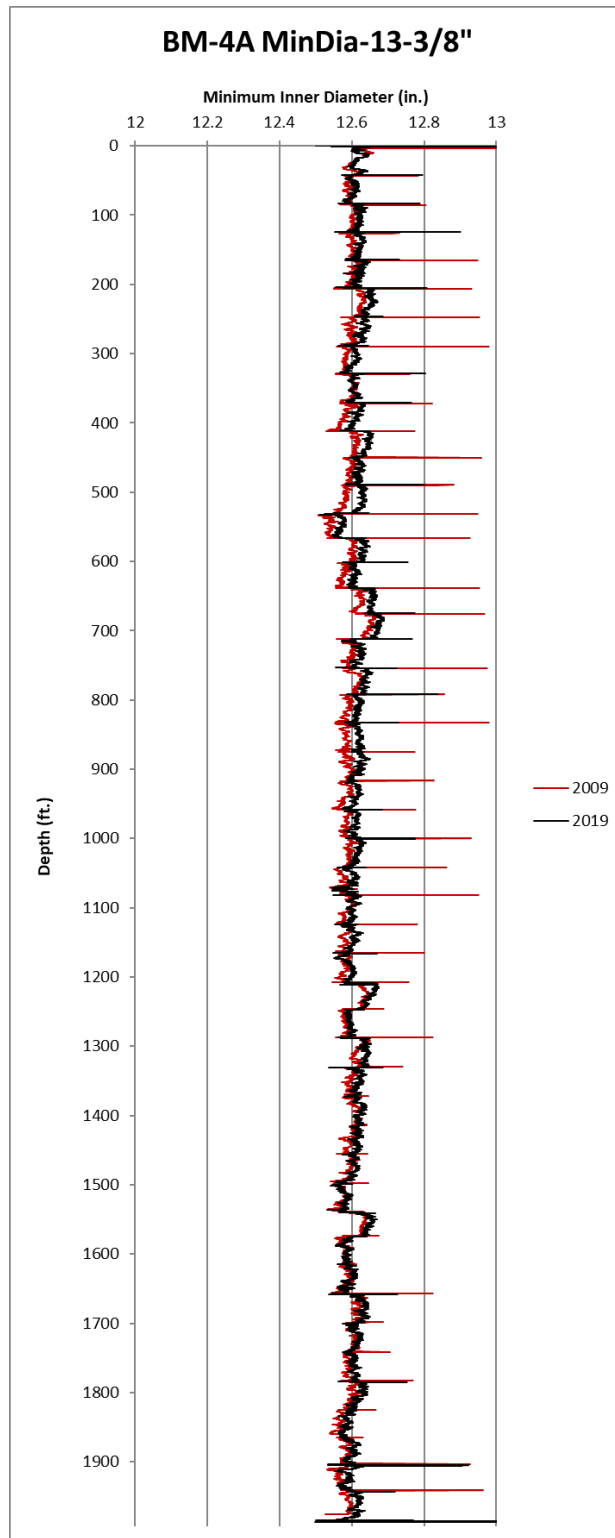


Figure 3-14. BM-4A minimum diameter curves from 2009 and 2019 MAC data

3.3.5. BM-4B

BM-4B has a total of three MAC logs from March 2014, May 2014, and 2019. The March 2014 MAC was taken on the 13 3/8" casing. The well was then lined, and the May 2014 and 2015 MACs were taken down the 10 3/4" liner. Figure 3-15 shows the minimum diameter curve for the 13-3/8" casing which was calculated from the March 2014 MAC log. From this dataset, a casing restriction was identified at 878', and a decrease in the minimum diameter curve can be observed at this depth. Figure 3-16 shows the minimum and average diameter curves for the 10 3/4" liner, which was calculated from May 2014 and 2019 MAC logs. There are no observed casing restrictions on the 10 3/4" casing at this time. There is an unexpected decrease in the 10 3/4" liner minimum diameter curve around 1210 feet in the 2019 MAC log, however this is the result of a single radial arm reading and does not show up in the average diameter curve for the liner. There are no other areas of notable deformation in this well.

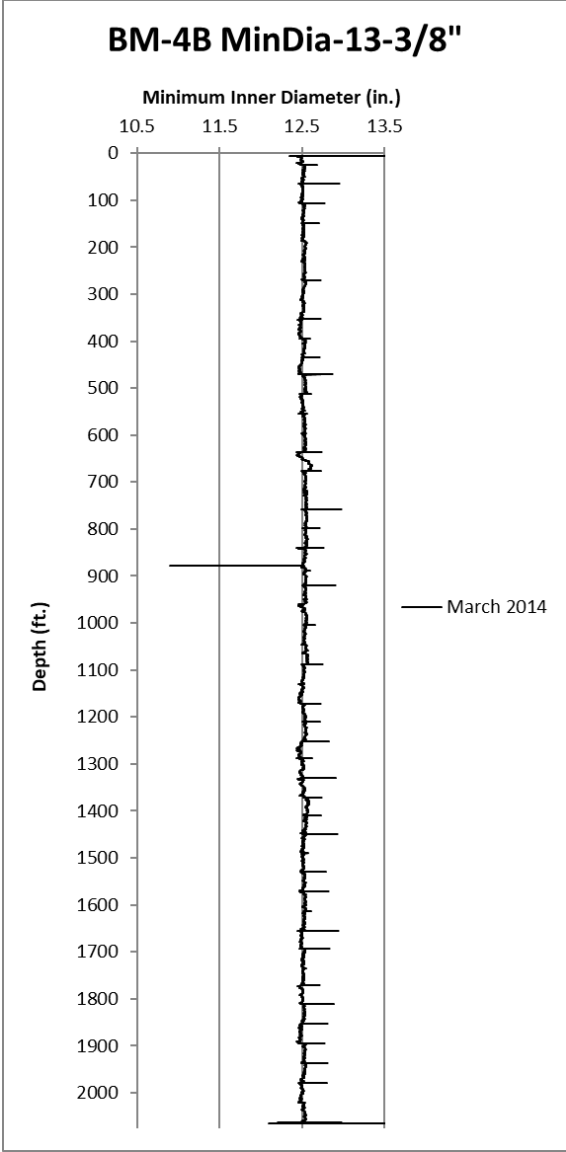


Figure 3-15. BM-4B minimum diameter curve from March 2014 MAC data

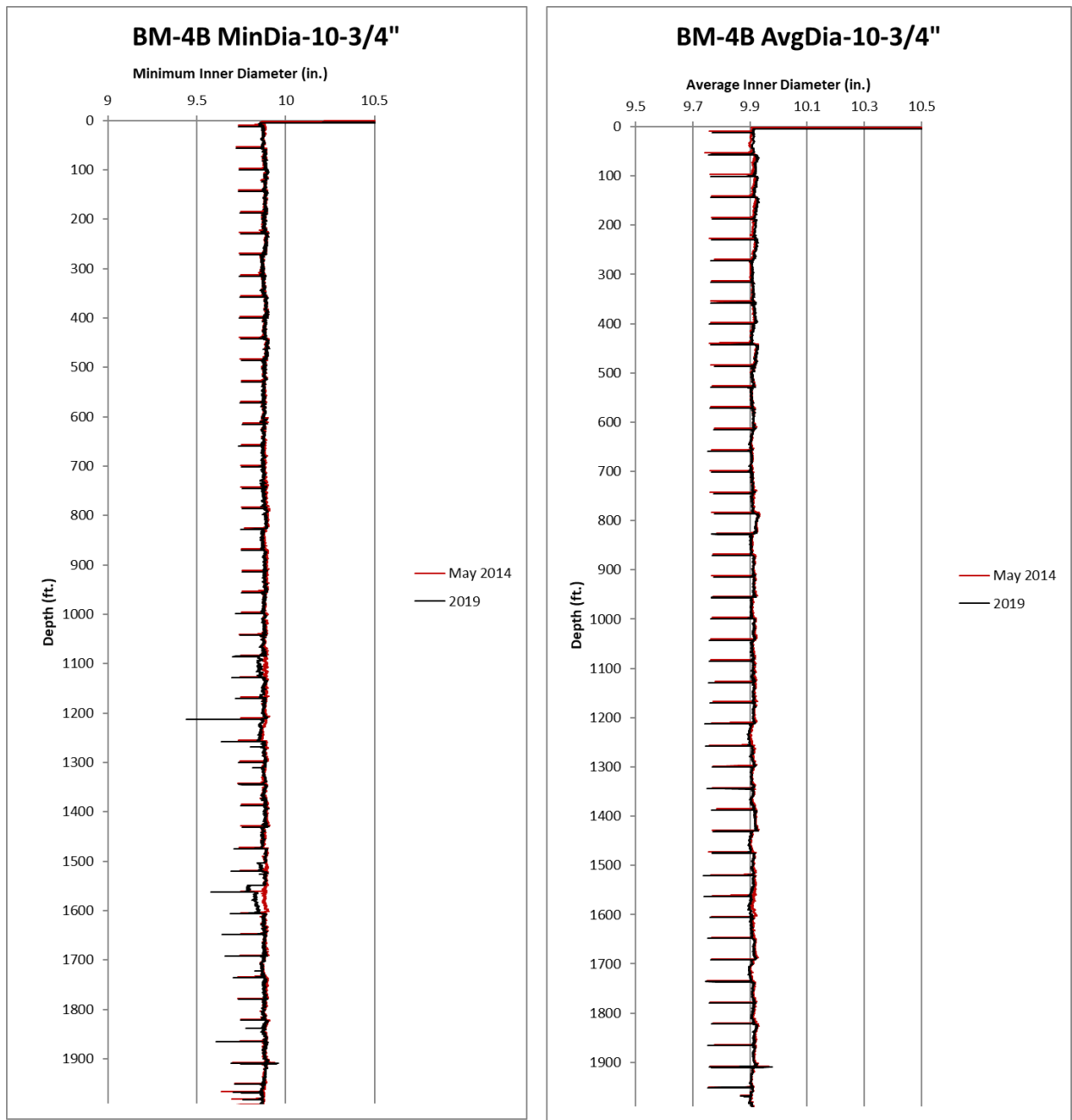


Figure 3-16. BM-4B minimum and average diameter curves from May 2014 and 2019 MAC data

The March 2014 MAC data showed a casing restriction as a result of well deformation at 878.1' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-17 shows cross sections at two different depths, taken from the radial arm data collected in the March 2014 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth. The deformation is not uniform and appears to be worse around arms 21-27. The minimum diameter at 878.1' is 10.90", which is notably lower than the minimum diameter of

12.51" at 875'. Figure 3-18 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 878'. There also appears to be some deformation around 877.5', which is likely a result of casing compression as well. Although the well has been lined since the March 2014 MAC, the deformation observed in the 13 3/8" casing around 878' is likely ongoing and the well should continue to be monitored.

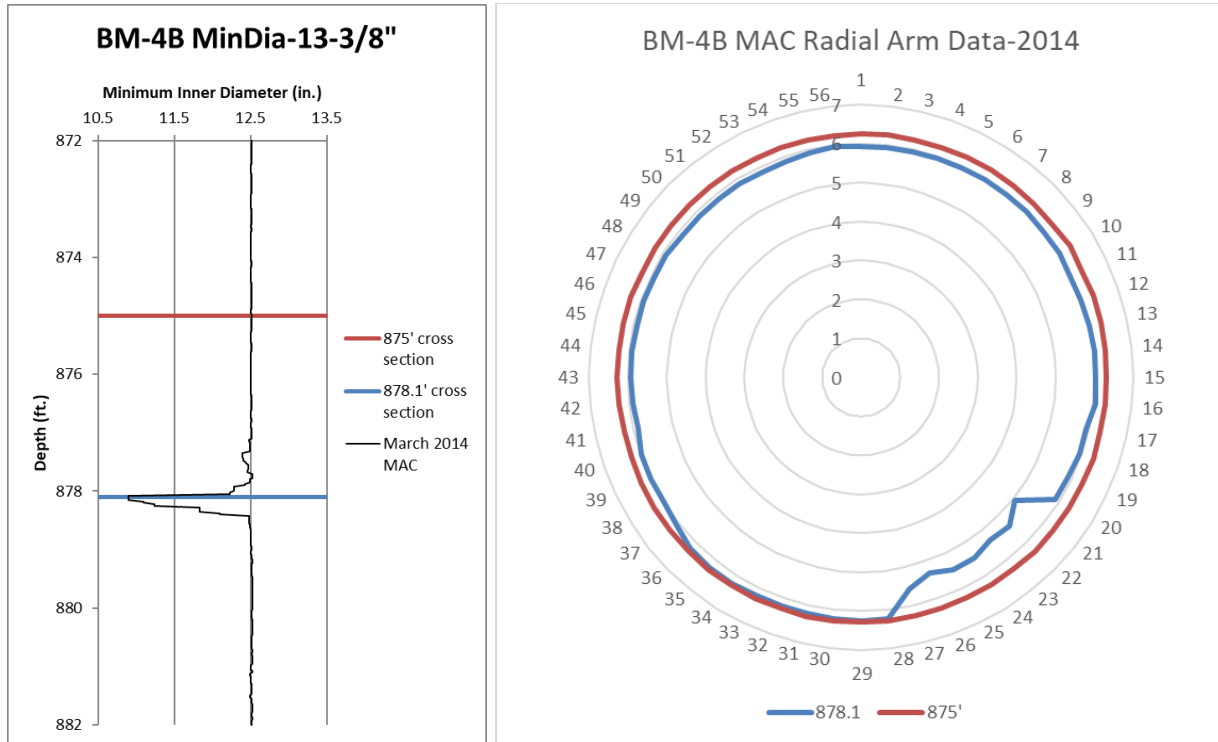


Figure 3-17. Cross sections of BM-4B March 2014 MAC data at the depth of casing restriction (blue) and above the restriction (red).

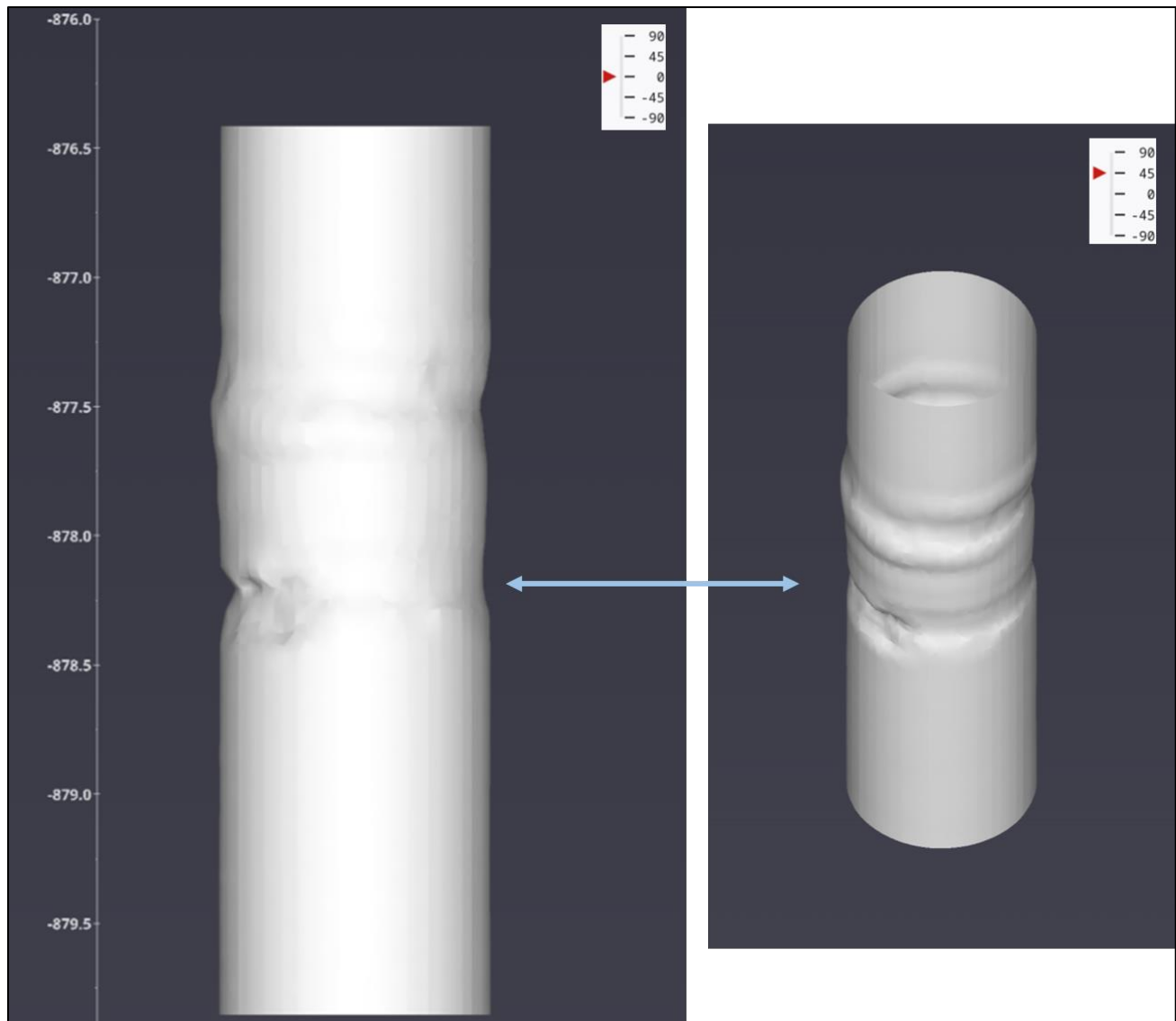


Figure 3-18. 3D visual of BM-4B March 2014 radial arm data at the casing restriction

3.3.6. BM-4C

BM-4C has a total of three MAC logs from 2008, 2014, and 2019, which were all taken on the 13 3/8" casing. Figure 3-19 shows the minimum diameter curve for the 13-3/8" casing which were calculated from the 2008, 2014, and 2019 MAC logs. With the exception of some slight deformation below the salt-caprock interface around 1100'-1200' which does not appear to be rapidly worsening, there are no substantial casing restrictions or areas of notable deformation to cause concern from the available MAC data at this time.

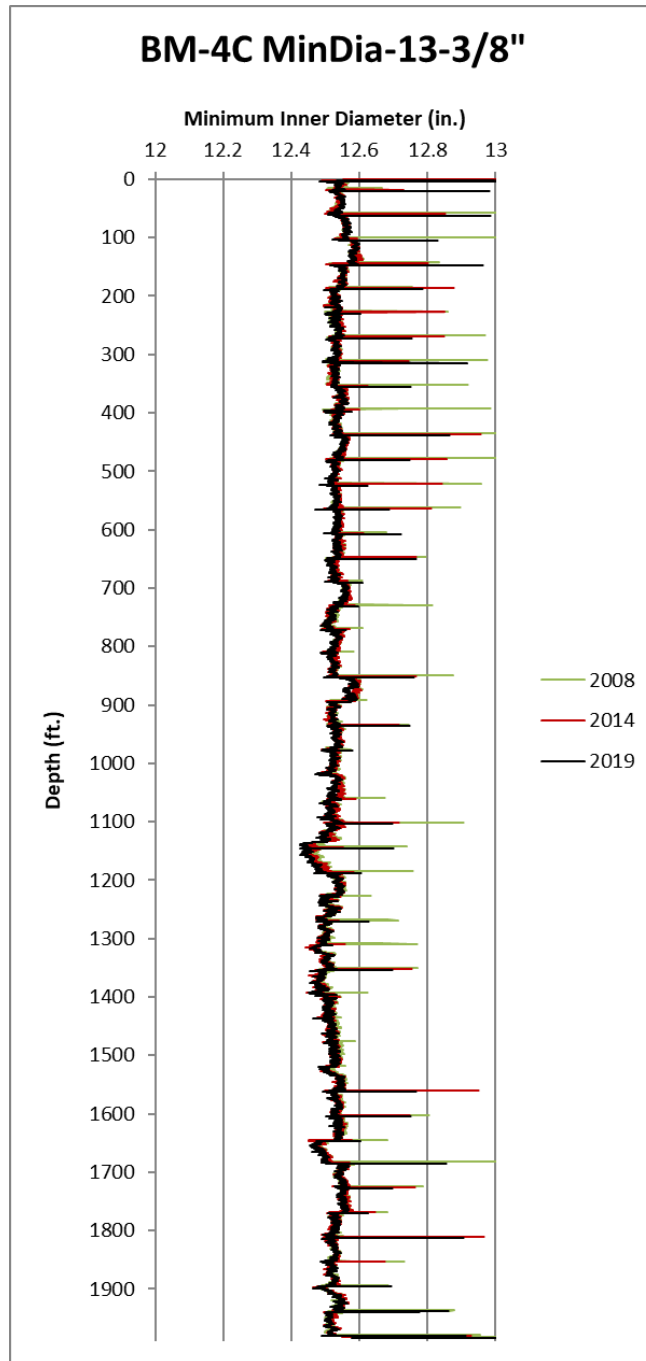


Figure 3-19. BM-4C minimum diameter curves from 2014 and 2019 MAC data

3.3.7. BM-5

BM-5 has two MAC logs from 2013 and 2018, which were both taken on the 13 3/8" casing. At this time, Sandia only has a PDF copy of the report and the curve traces for the 2018 MAC log and does not have the LAS file containing the radial arm data measurements. Therefore, only the 2013 log has been displayed in the analysis below. Figure 3-20 shows the minimum diameter curve for the 13-3/8" casing which was calculated from the 2013 MAC log. From this dataset, a casing restriction

was identified at 797', and a decrease in the minimum diameter curve can be observed at this depth. Although the LAS data is not available for the 2018 MAC, the PDF containing the curve files does show a decrease in diameter across all radial arm measurements and a note of possible collar collapse around 802'.

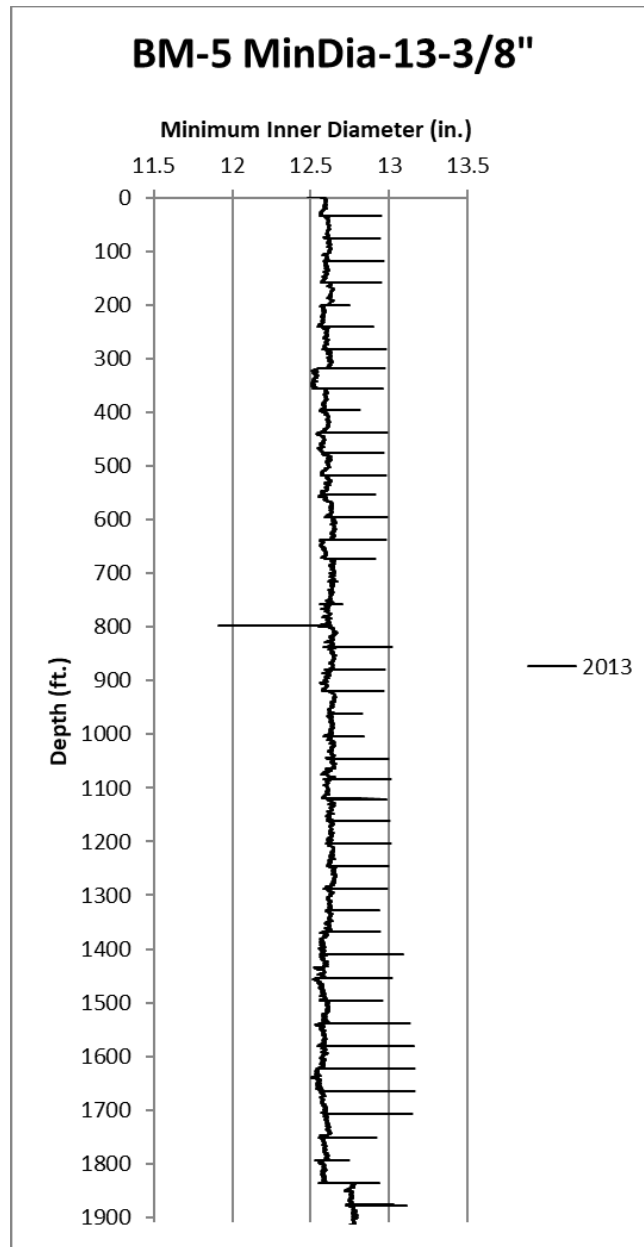


Figure 3-20. BM-5 minimum diameter curve from the 2013 MAC data

The 2013 MAC data showed a casing restriction as a result of well deformation at 797' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-21 shows cross sections at two different depths, taken from the radial arm data collected in the 2013 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a

nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a uniform decrease in the inner diameter at the deformation depth. The minimum diameter at 797' is 11.91", which is notably lower than the minimum diameter of 12.61" at 794'. Figure 3-22 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 797'.

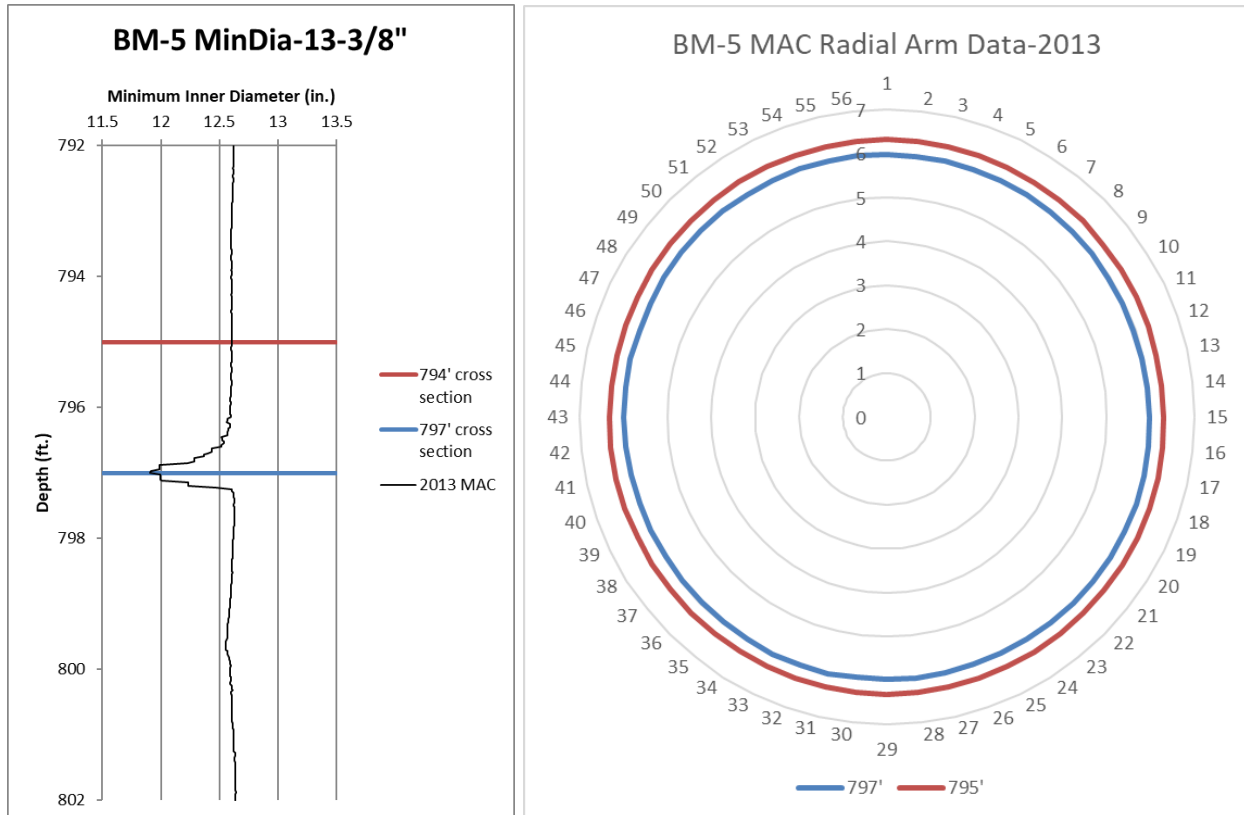


Figure 3-21. Cross sections of BM-5 2013 MAC data at the depth of casing restriction (blue) and above the restriction (red).

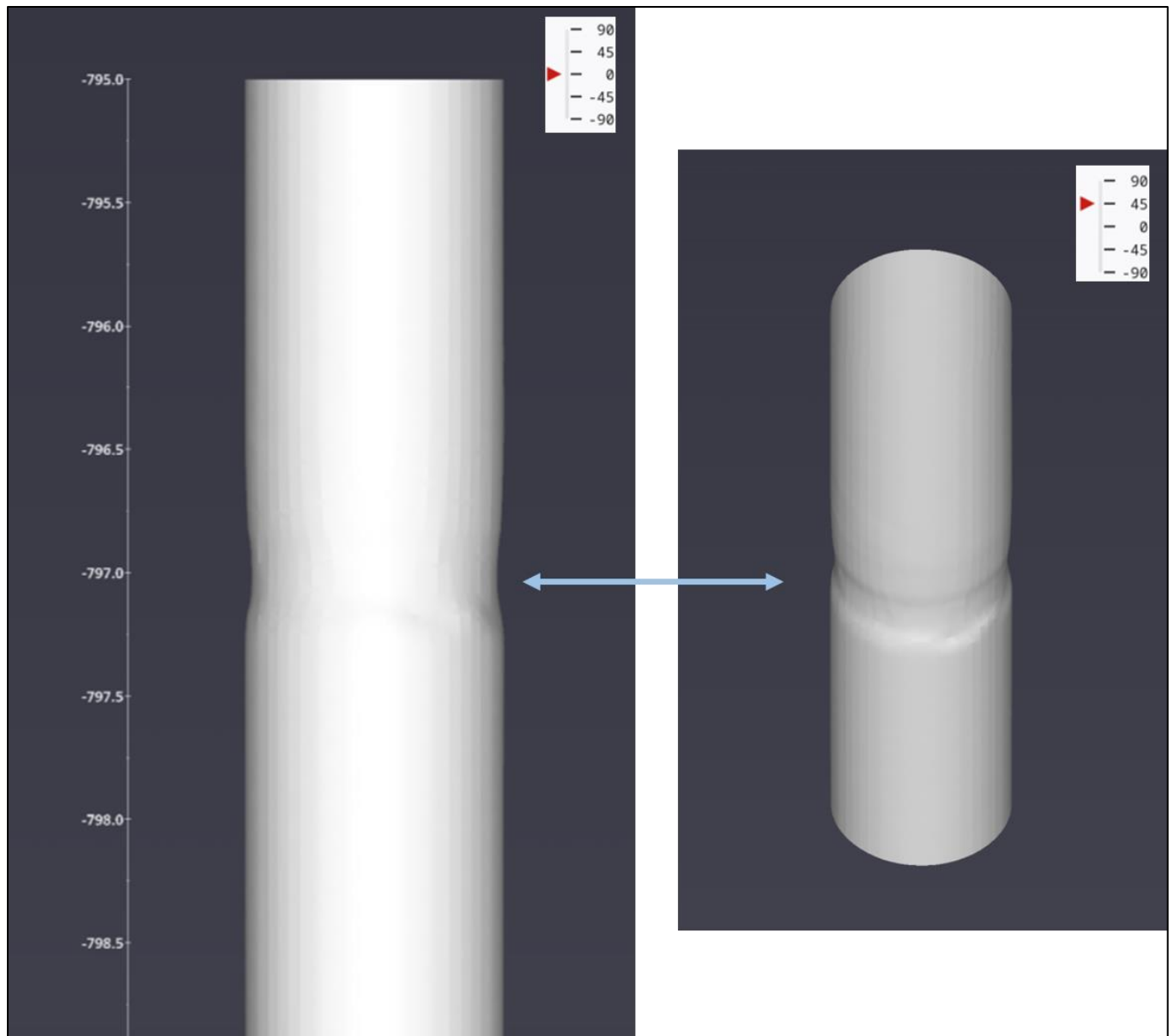


Figure 3-22. 3D visual of BM-5 2013 MAC radial arm data at the casing restriction

3.3.8. BM-5A

BM-5A has a total of three MAC logs from 2009, 2014, and 2019, which were all taken on the 13 3/8" casing. The 2009 log was excluded from this analysis as it had incomplete data. Figure 3-23 shows the minimum and average diameter curves for the 13-3/8" casing which were calculated from the 2014 and 2019 MAC logs. From this dataset, a casing restriction was identified at 750', and a decrease in the minimum diameter curve can be observed at this depth. Figure 3-24 shows the minimum diameter curves from the 2014 and 2019 logs around the deformation depth at 750', which shows a clear progression as the restriction appears to be worsening with time. There is also deformation observed around 1482', which is present in both the 2014 and 2019 logs. The deformation at this depth does not appear to be increasing with time and only effects a small radial

section at 1482', and it does not show up in the average diameter curve. In a classic case of collar restriction, the diameter would experience a relatively uniform decrease in diameter and most or all radial arm measurements would show a decrease in diameter, which could be observed from the average diameter measurement. It should be noted that non-circular deformation may not always show up in the average diameter curve, however it can be a helpful tool for identifying more classic cases of collar compression which are the focus of this report.

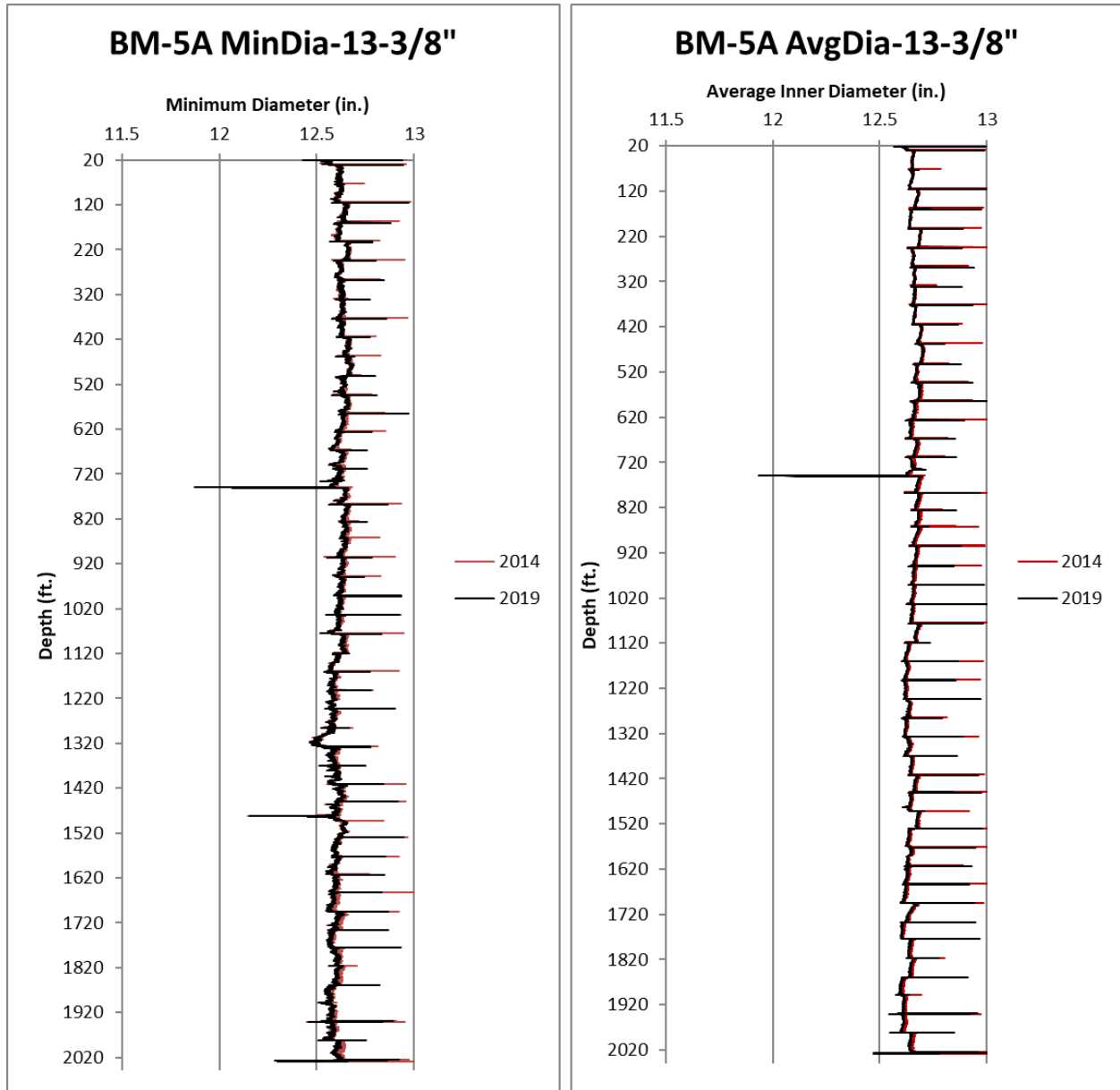


Figure 3-23. BM-5A minimum and average diameter curves from 2014 and 2019 MAC data

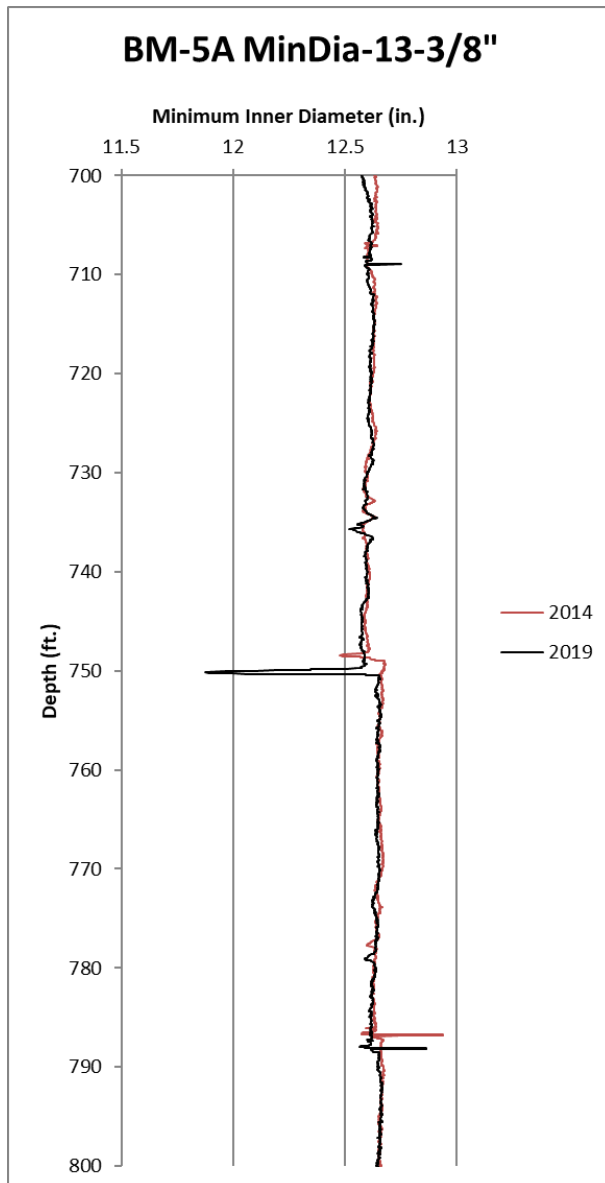


Figure 3-24. BM-5A minimum diameter curves from 2014 and 2019 MAC data at casing restriction depth

Figure 3-25 shows cross sections from the 2014 and 2019 MAC radial arm data at the lower deformation depth. Again, this deformation does not appear to be worsening with time and is only affecting the area near arms 49-56. Although it should be noted, this is not an area of major concern at the moment.

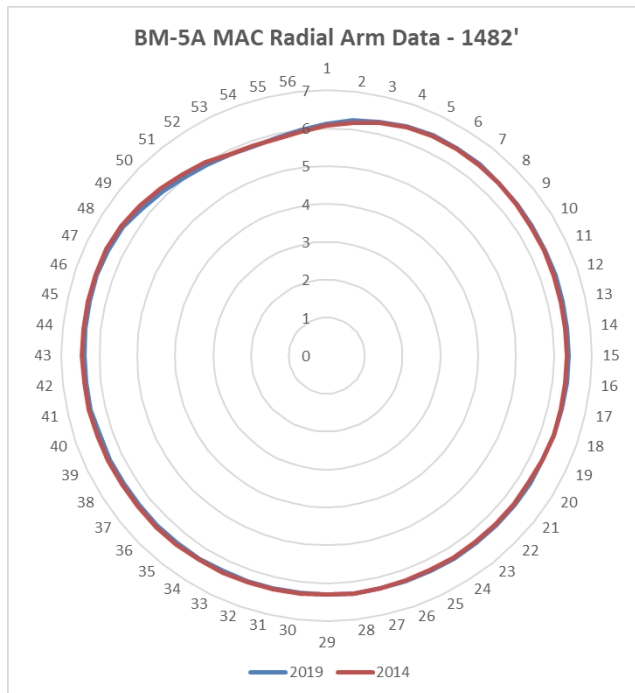


Figure 3-25. Cross sections of BM-5A 2019 MAC data at 1482'

The 2014 and 2019 MAC data showed well deformation as the result of a casing restriction at 750.1' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-26 shows cross sections at two different depths, taken from the radial arm data collected in the 2019 MAC log. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a uniform decrease in the inner diameter at the deformation depth. The minimum diameter at 750.1' is 11.88" which is notably lower than the minimum diameter of 12.57" at 746'. Figure 3-27 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed. The deformation observed around 750.1' is likely ongoing and the well should continue to be monitored.

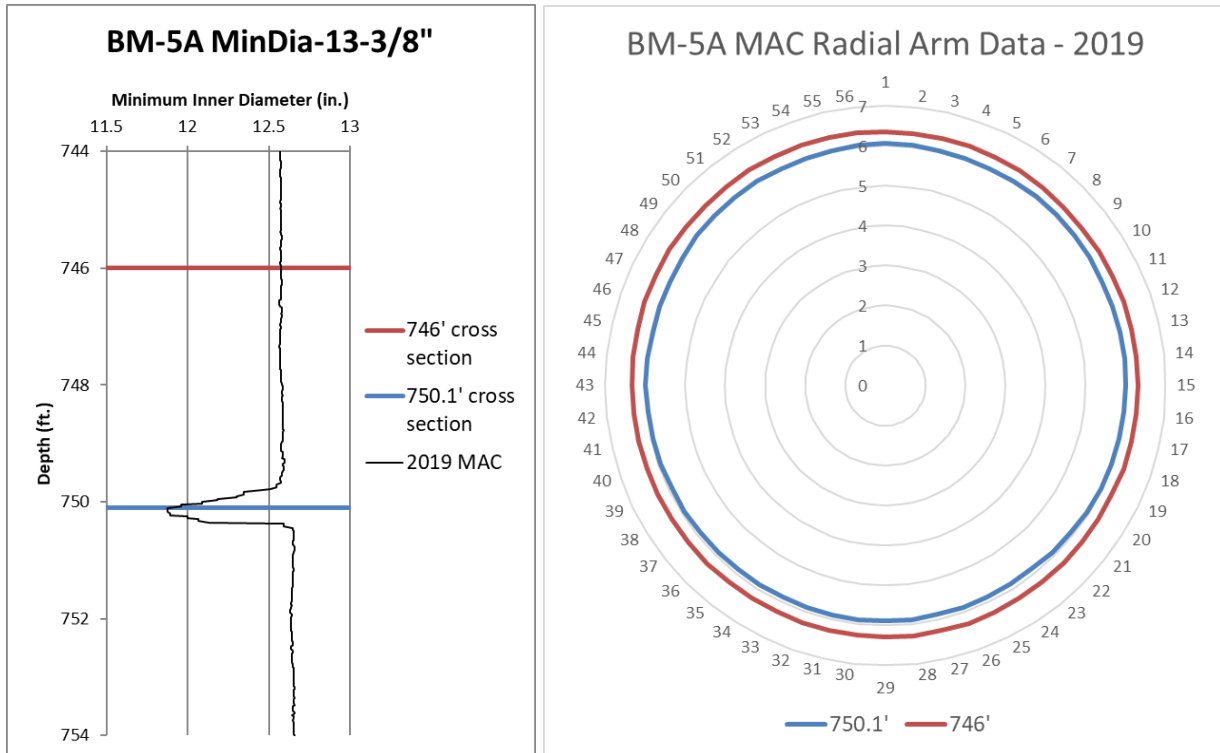


Figure 3-26. Cross sections of BM-5A 2019 MAC data at the depth of casing restriction (blue) and above the restriction (red).

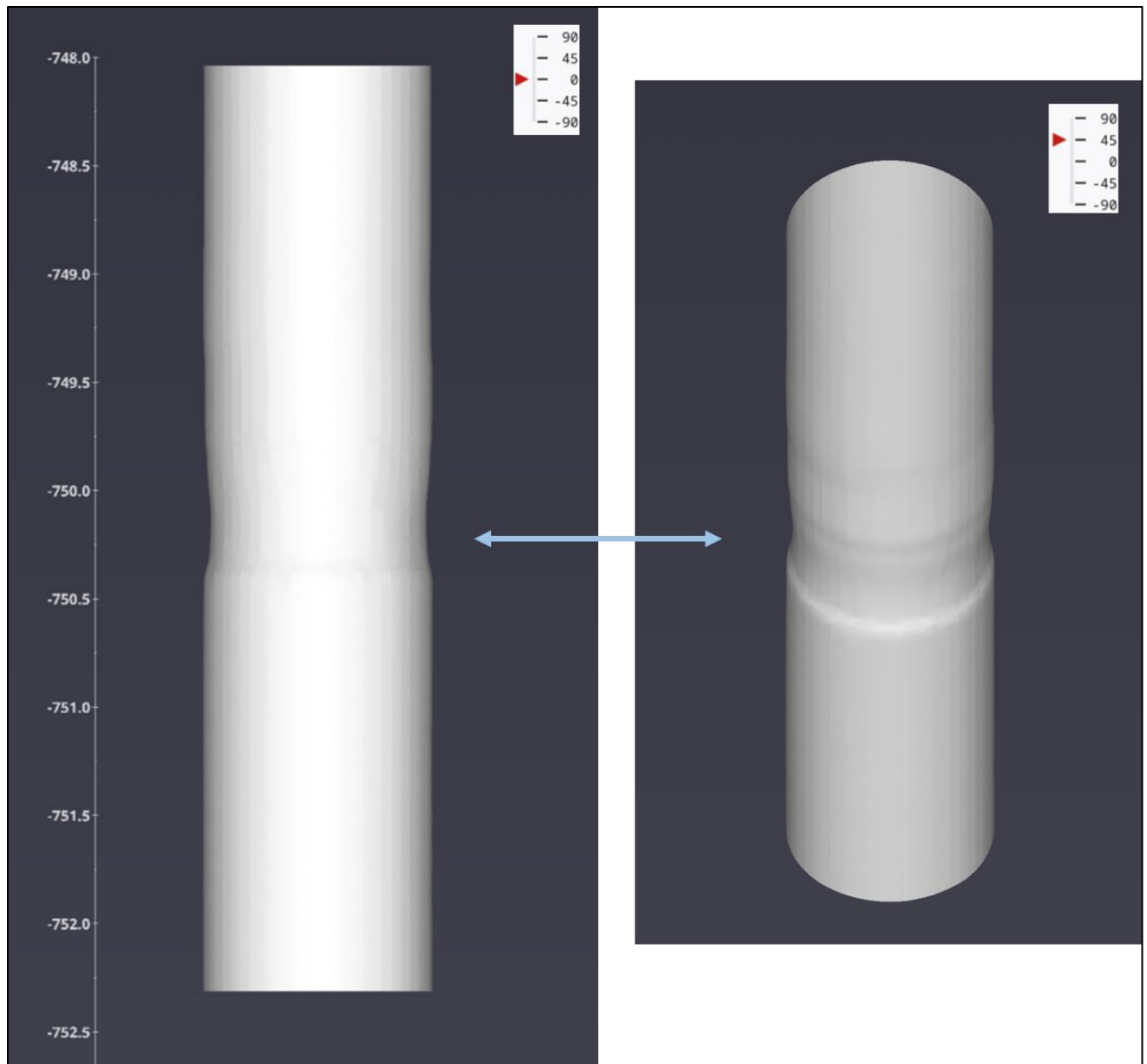


Figure 3-27. 3D visual of BM-5A 2019 MAC radial arm data at the casing restriction

3.3.9. BM-5C

BM-5C has a total of two MAC logs from 2007 and 2017, which were both taken on the 13 3/8" casing. Figure 3-28 shows the minimum and average diameter curves for the 13-3/8" casing which were calculated from the 2007 and 2017 MAC logs. The decrease in the minimum diameter seen around 942.8' in the 2017 MAC was the result of a single radial arm reading and is not reflected in the average diameter curve. Figure 3-29 shows cross sections of the 2017 MAC radial arm data taken above, below, and at the depth of the tool error. The tool error occurs in arm 11 and is not reflected in the nearby cross sections taken at 942.75' and 942.875', showing that this is a localized issue both in terms of tool error depths and the number of radial arm measurements affected. No substantial

casing restrictions or areas of notable deformation to cause concern from the available MAC data at this time.

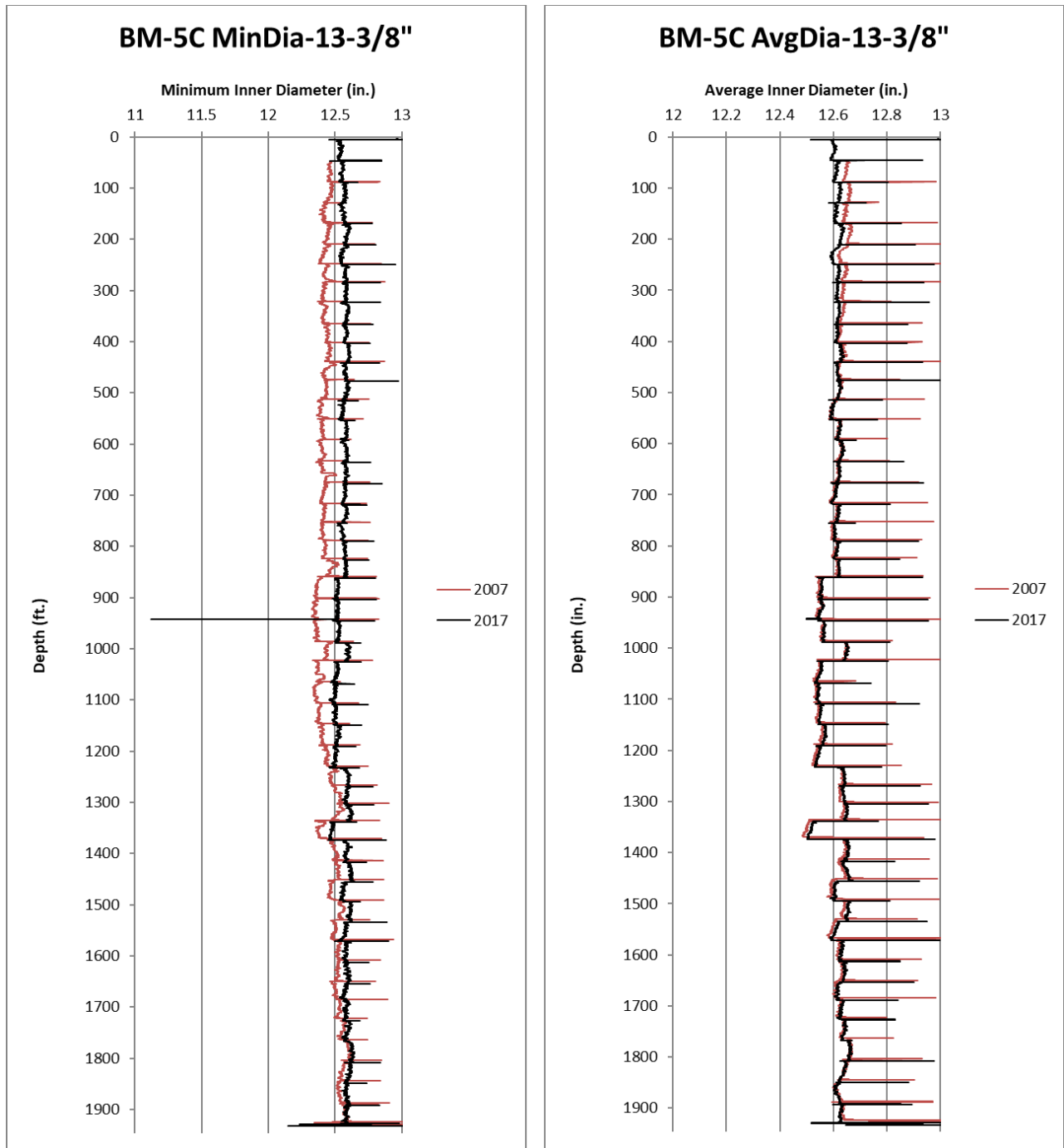


Figure 3-28. BM-5C minimum and average diameter curves from 2007 and 2017 MAC data

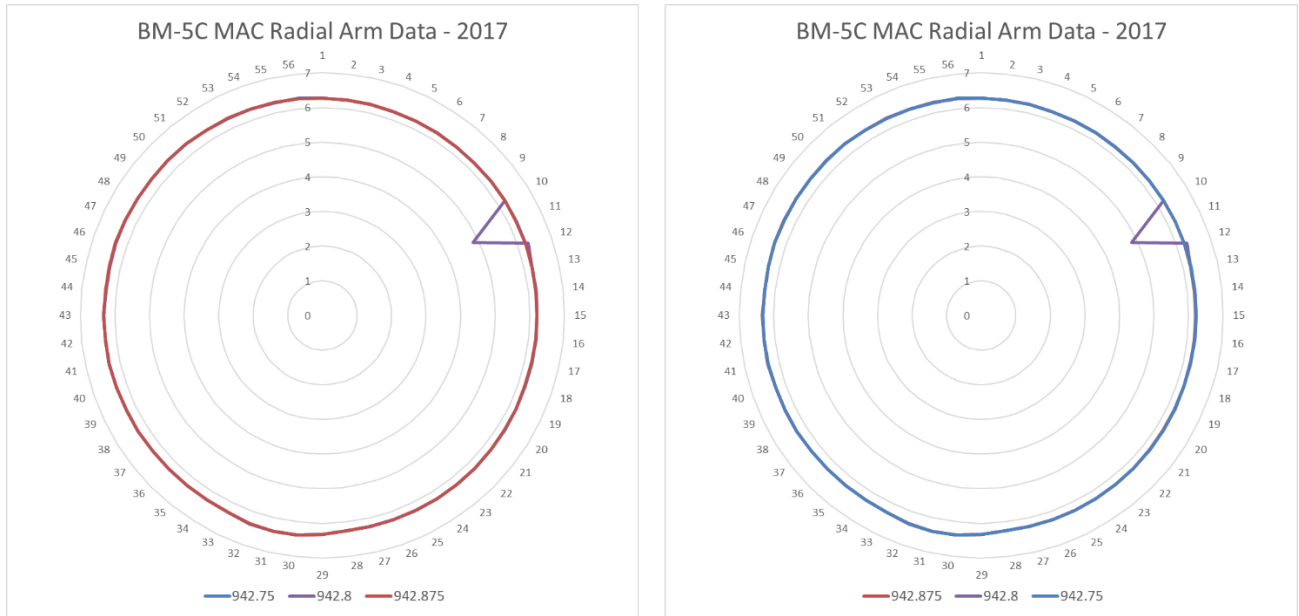


Figure 3-29. Cross sections of BM-5C 2017 MAC data near the depth of tool error

3.3.10. BM-101A

BM-101A has a total of four MAC logs from 2011, 2017, 2020, and 2021. The 2011, 2017, and 2020 logs were all taken on the 16” casing. The 2021 log was taken on the 13 3/8” liner after it was installed. Figure 3-30 shows the minimum diameter curves for the 16” casing which were calculated from the 2011, 2017, and 2020 MAC logs. From this dataset, a casing restriction was identified at 898.7’, and a decrease in the minimum diameter curve can be observed at this depth. The restriction does not appear to be substantially worsening in the time between the 2011 – 2020 MAC logs. There is also a decrease in the minimum diameter around 1015’ for the 2011 MAC, however this is the result of a single radial arm reading and does not show up in the average diameter curve. Minimal deformation has also been noted around 920’-930’ and 1970’-1988’ however it does not appear to be worsening with time. Figure 3-31 shows the minimum diameter curve for the 13 3/8” liner which was calculated from the 2021 MAC and does not show any issues at this time.

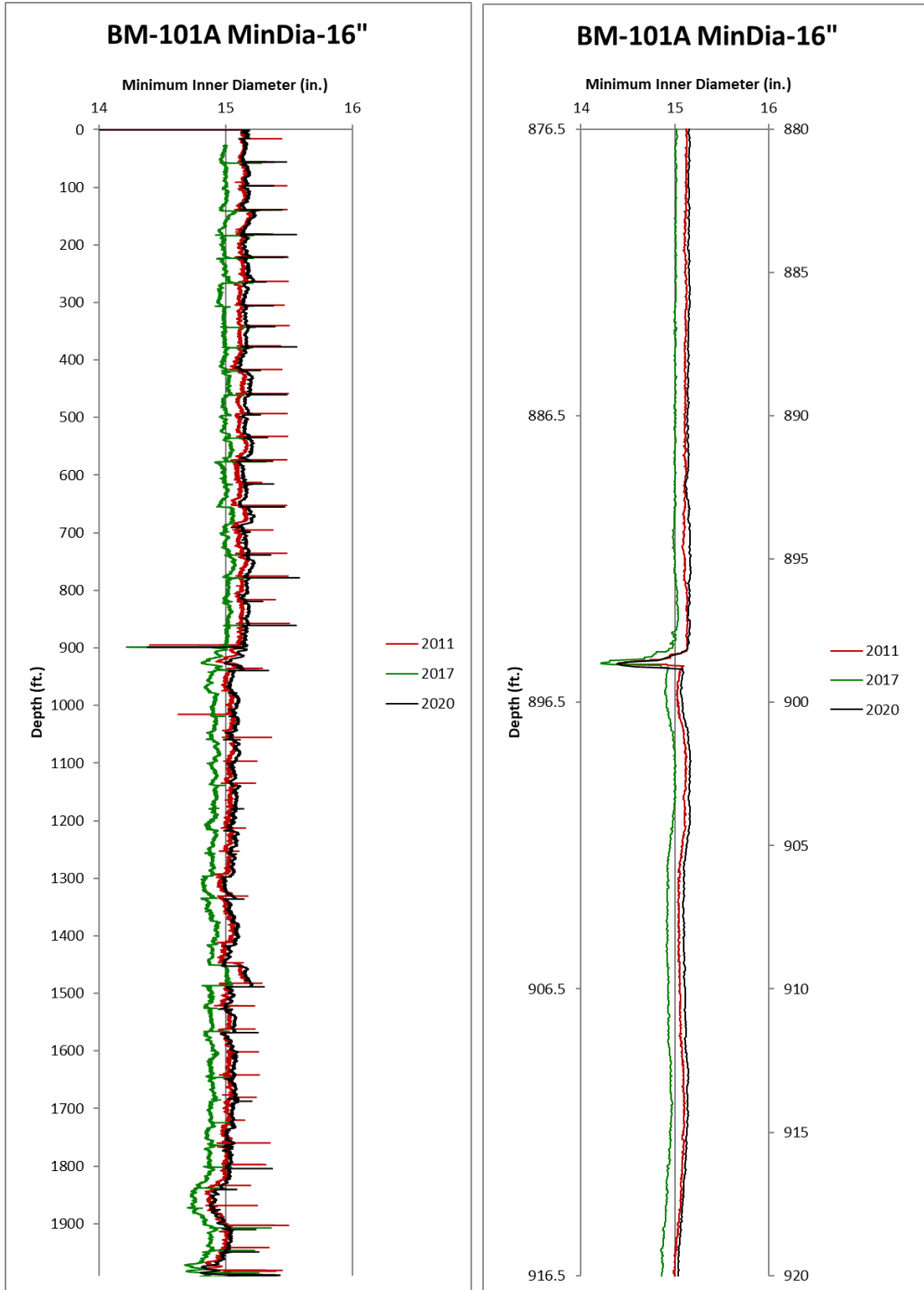


Figure 3-30. BM-101A minimum diameter curves from 2011, 2017 and 2020 MAC data

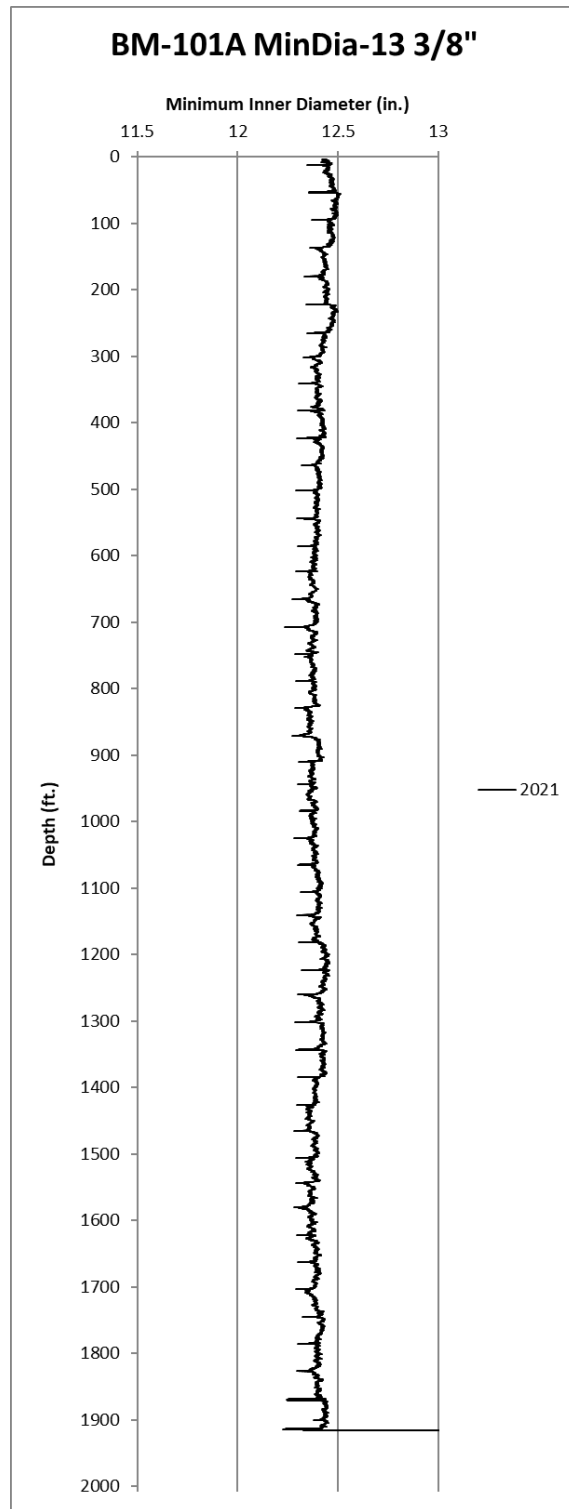


Figure 3-31. BM-101A minimum diameter curve from 2021 MAC data

The 2011, 2017, and 2020 MAC logs showed a casing restriction as a result of well deformation at 898.65' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-32 shows cross sections at two different depths, taken from

the radial arm data collected in the 2020 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth, with the deformation occurring in a fairly uniform pattern. The minimum diameter at 898.65' is 14.38", which is notably lower than the minimum diameter of 15.15" at 896'. Figure 3-33 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 898.65'. Although the well has been lined since the 2020 MAC, the deformation observed in the 16" casing around 898.65' is likely ongoing and the well should continue to be monitored.

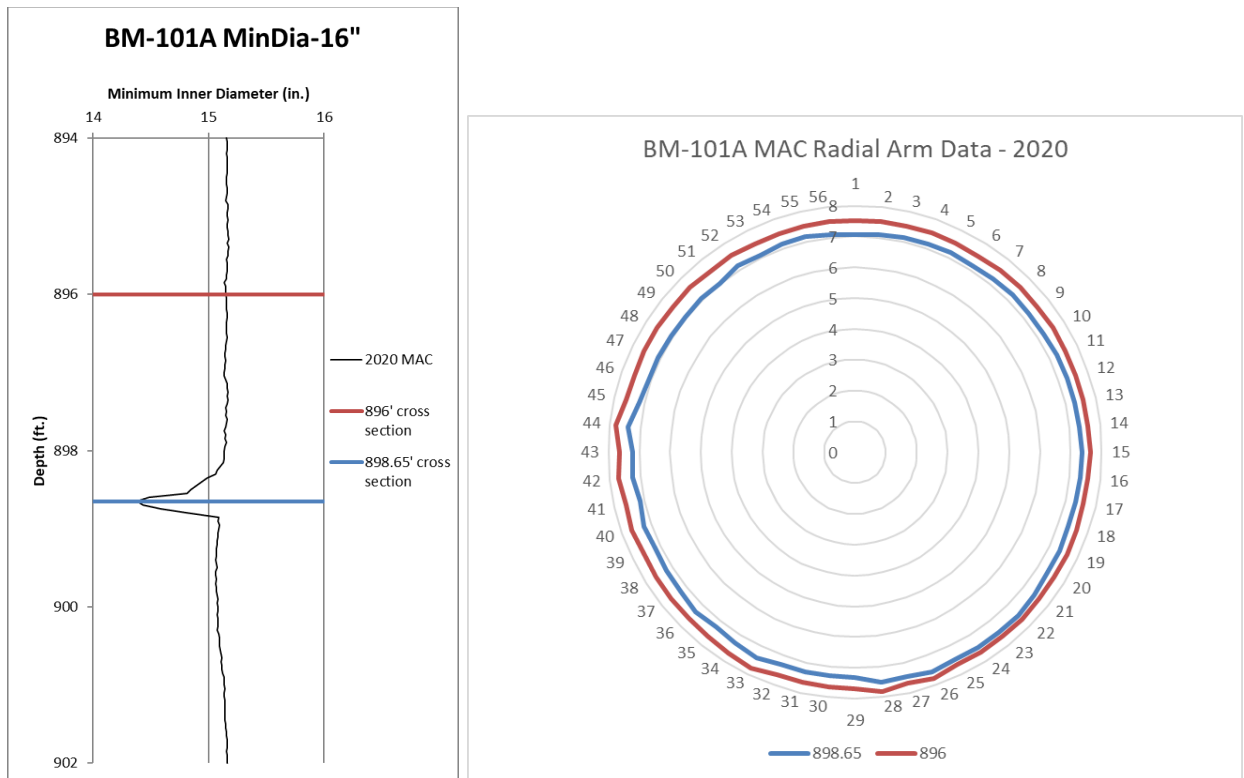


Figure 3-32. Cross sections of BM-101A 2020 MAC data at the depth of casing restriction (blue) and above the restriction (red).

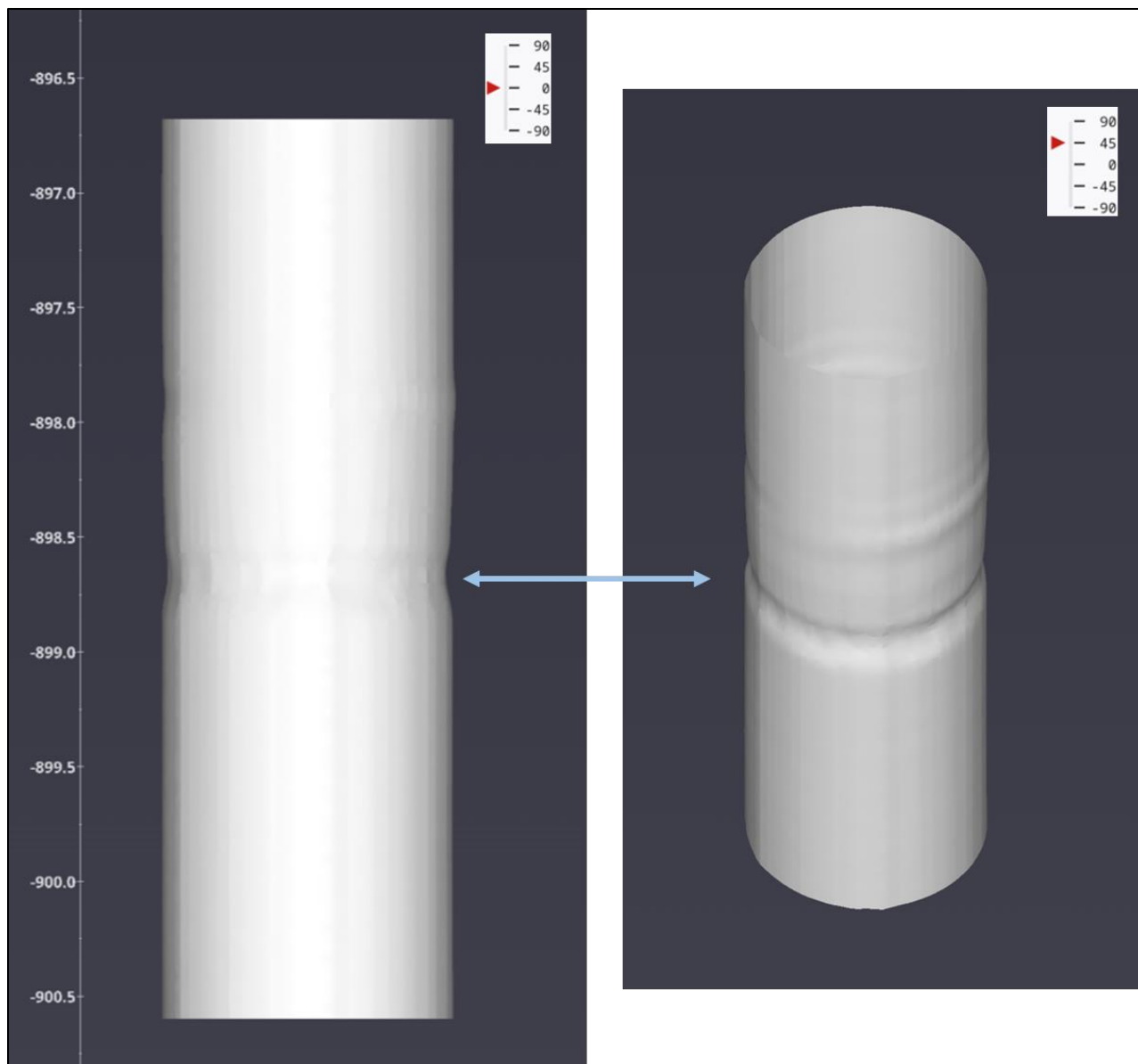


Figure 3-33. 3D visual of BM-101A 2020 MAC radial arm data at the casing restriction

3.3.11. BM-101C

BM-101C has a total of four MAC logs from 2012, September 2014, October 2014, and 2016. The 2012 and September 2014 logs were taken on the 16" casing. The well was then lined with a 13 3/8" casing which was surveyed in the October 2014 MAC. The 2016 MAC was run down the 10 3/4" hanging string. Figure 3-34 shows the minimum diameter curves for the logs taken on the 16" casing. In the 2012 and September 2014 logs a casing restriction for this well was identified at a depth of 902.7' and appears to have significantly worsened between the two logs. Figure 3-35 shows the minimum diameter curves for the logs taken on the 13 3/8" and 10 3/4" casings, which do not show any signs of a casing restriction.

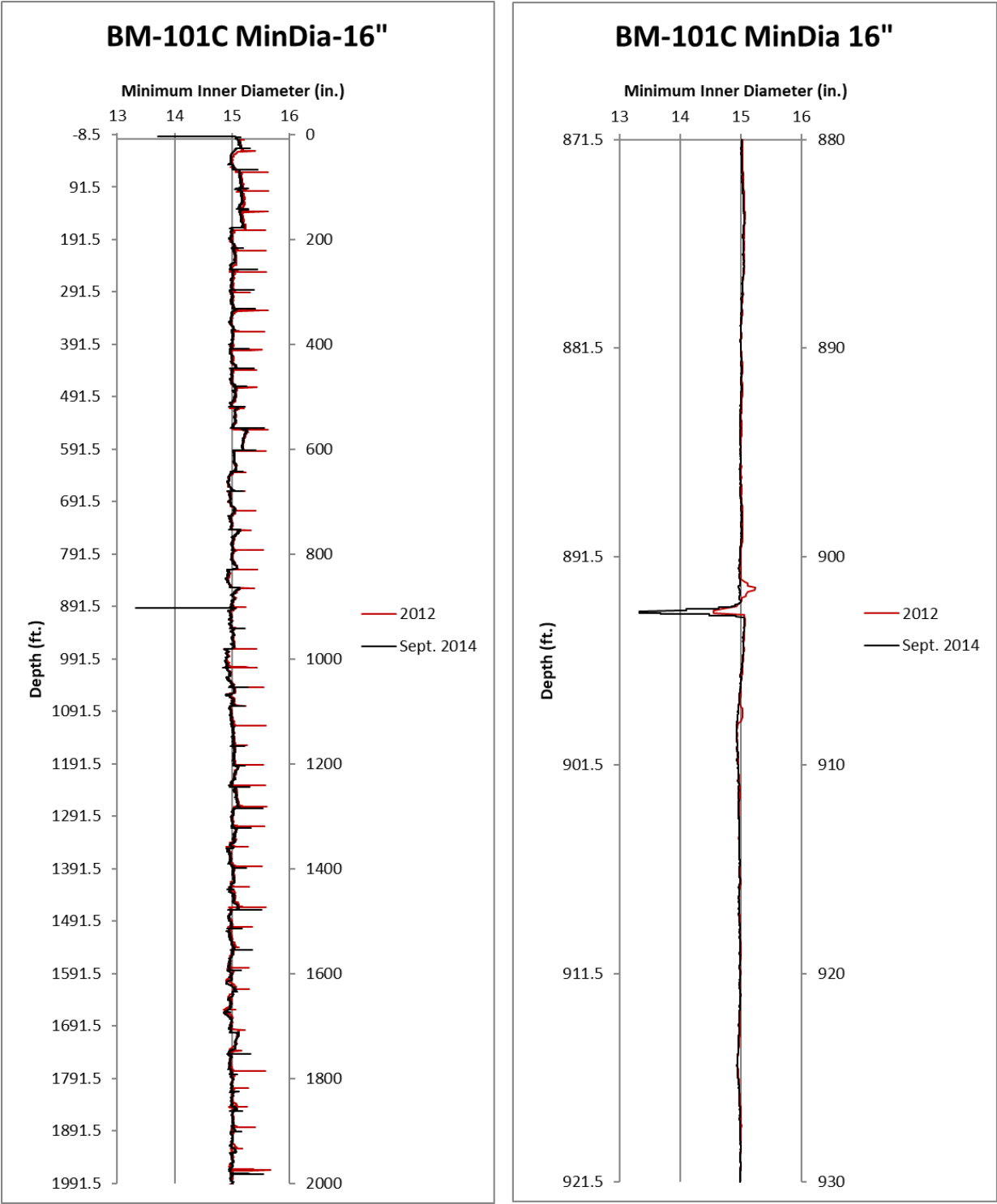


Figure 3-34. BM-101C minimum diameter curves from 2012 and September 2014 MAC data

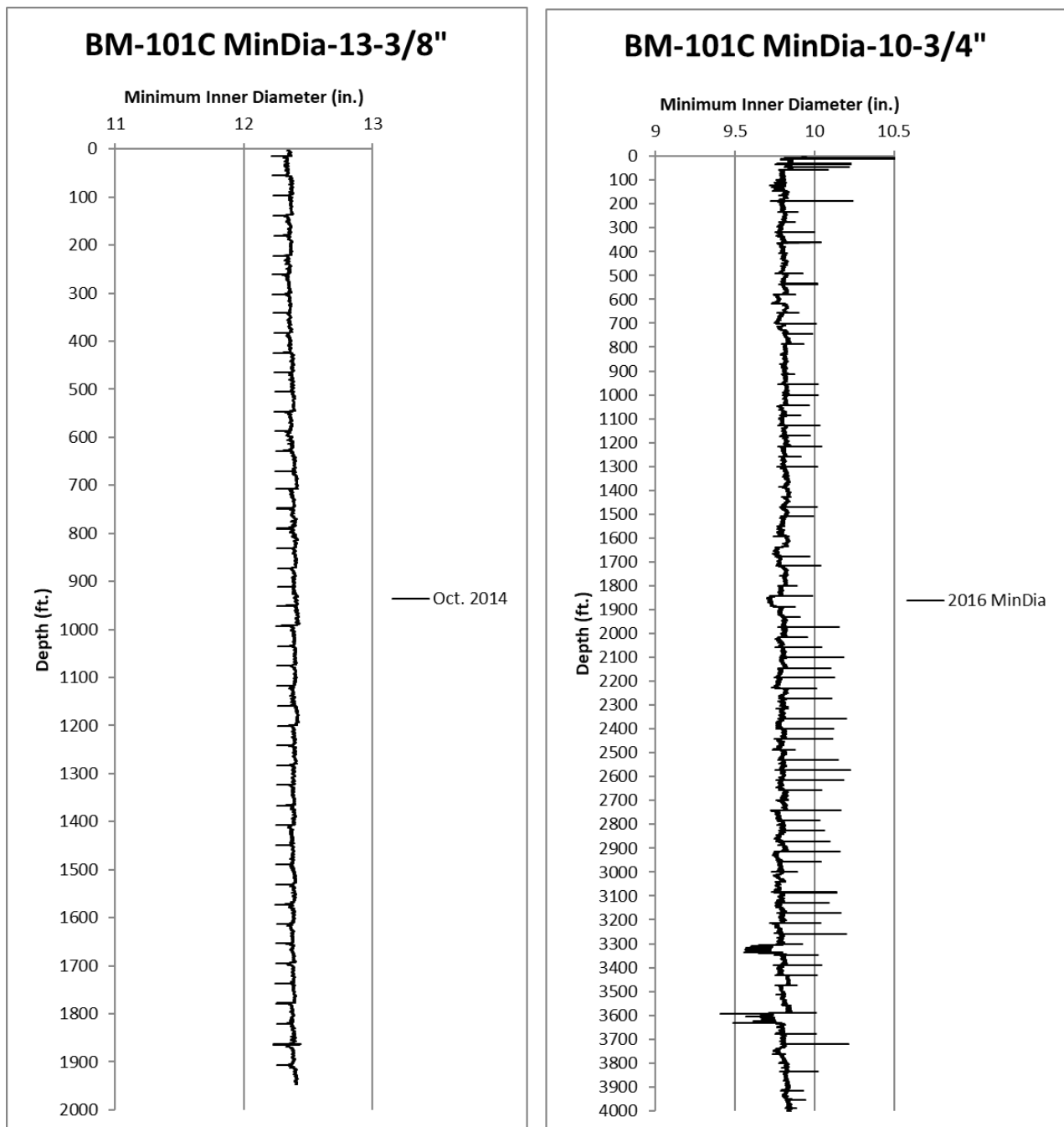


Figure 3-35. BM-101C minimum diameter curves from October 2014 and 2016 MAC data

The two MAC surveys on the 16" casing showed a casing restriction as a result of well deformation at 902.7'. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-36 shows cross sections taken from the September 2014 MAC radial arm measurements. A cross section taken at the depth of deformation is plotted against a second cross section that is not currently experiencing well deformation for comparison. From the radial arm

cross sections, it is apparent that the well is experiencing an overall decrease in the minimum diameter at the identified deformation depth. The minimum diameter at 902.63' is 13.33", which is notably lower than the minimum diameter of 14.99" at 900'. Figure 3-37 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed. It should also be noted that the decrease in diameter does not follow a uniform pattern as seen in both the radial cross section and 3D visual of the MAC data from September 2014. Although the well has been lined since the 2014 MAC, the deformation observed around 902.7 is likely ongoing and the well should continue to be monitored.

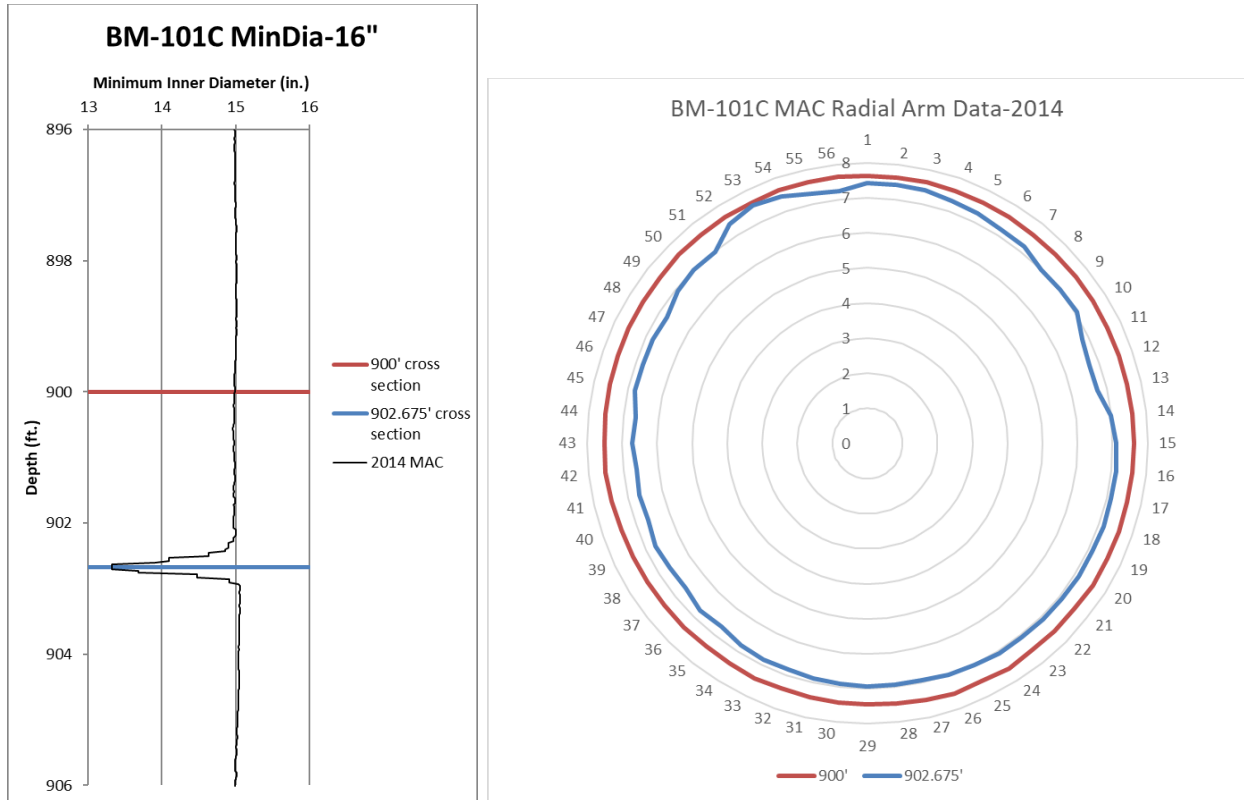


Figure 3-36. Cross sections of BM-101C September 2014 MAC data at the depth of casing restriction (blue) and above the restriction (red).

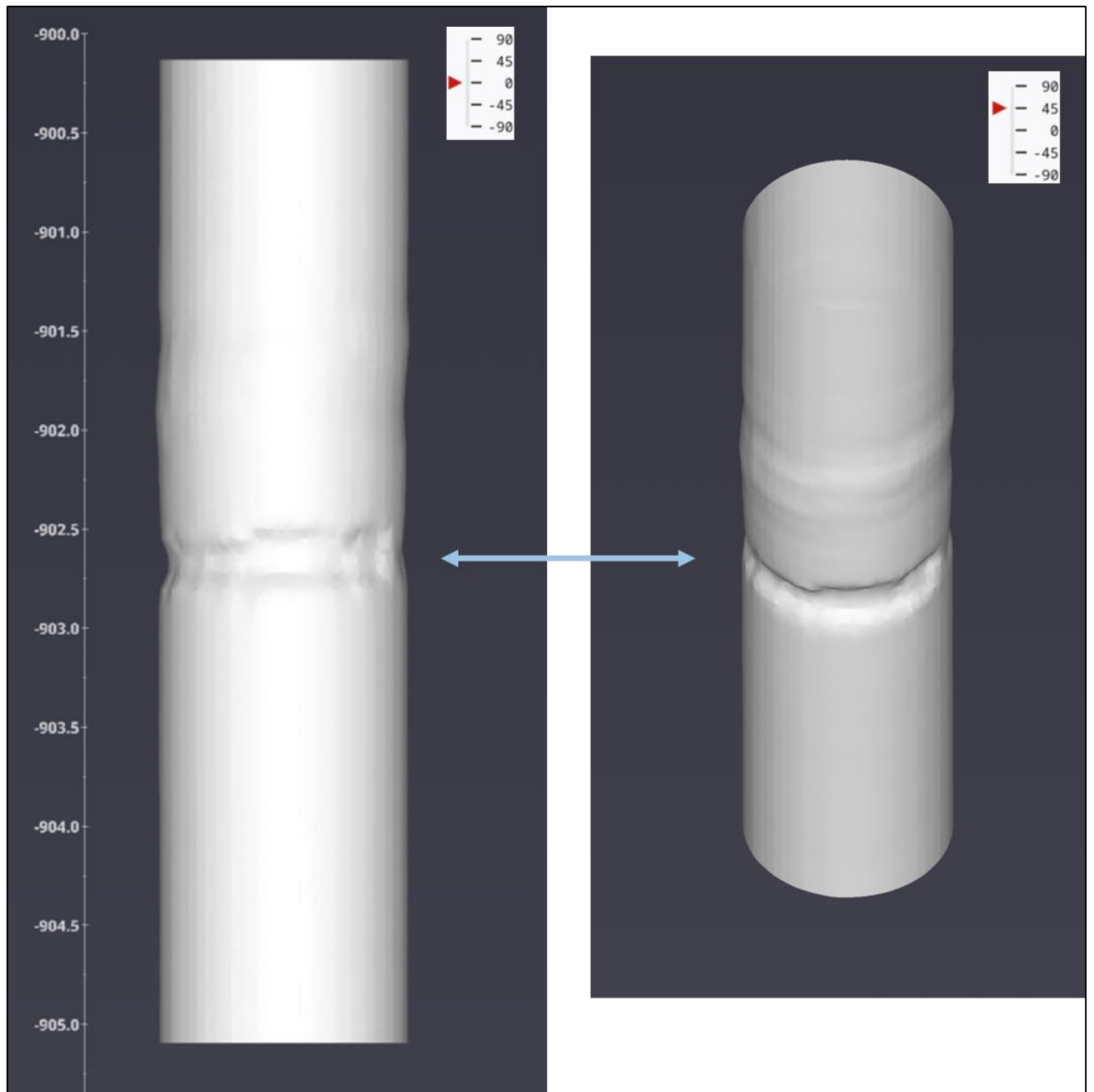


Figure 3-37. 3D visual of BM-101C September 2014 MAC data at casing restriction.

3.3.12. *BM-102B*

BM-102B has a total of two MAC logs from 2012 and 2021. The 2012 log was taken on the 16" casing. The well was then lined and the 2021 log was taken down the 13 3/8" casing. Figure 3-38 shows the minimum diameter curves for the 16" and 13-3/8" casing which were calculated from the

2012 and 2021 MAC logs. From this dataset, a casing restriction was identified at 867.6' in the 2012 MAC log, and a decrease in the minimum diameter curve can be observed at this depth.

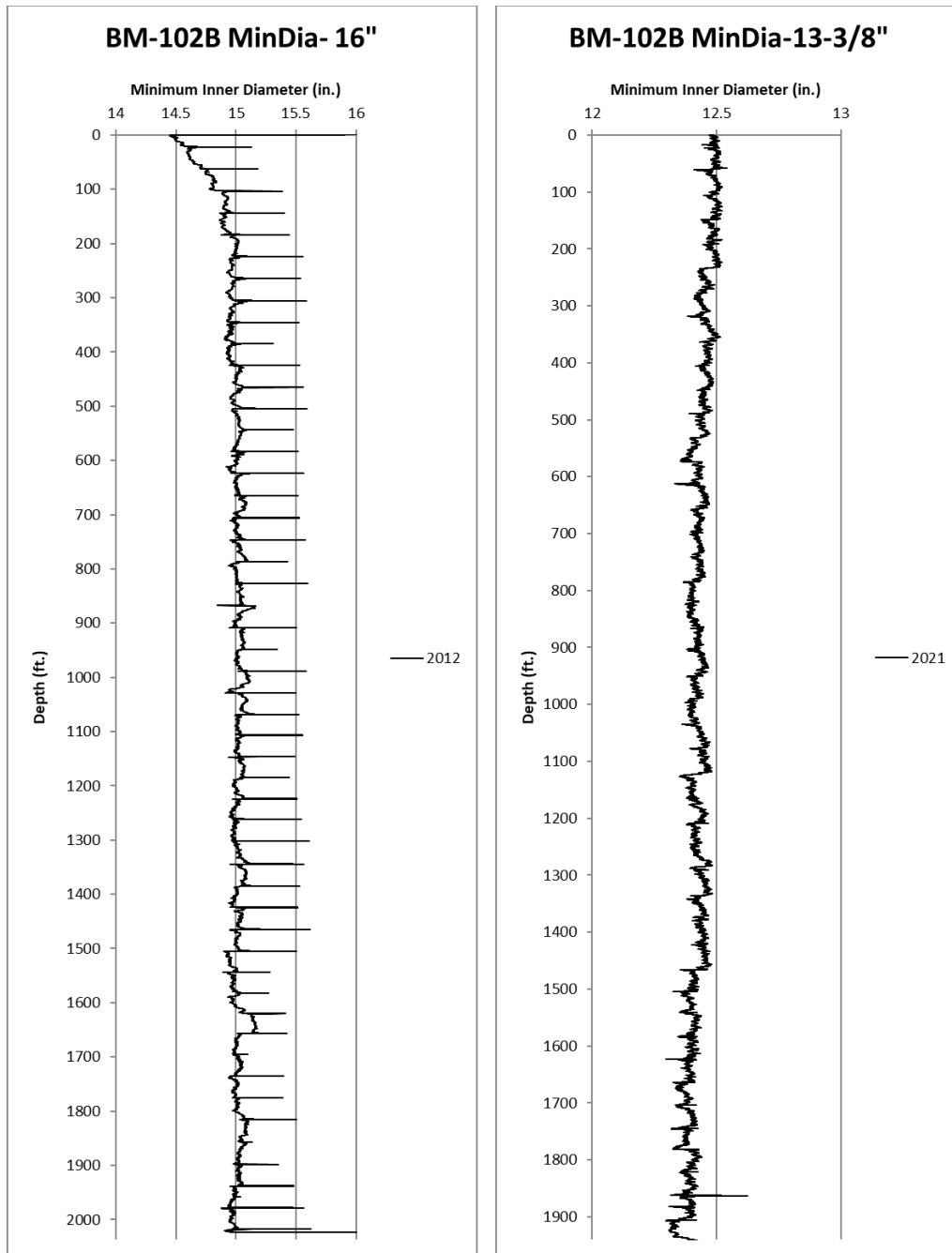


Figure 3-38. BM-102B minimum diameter curves from 2012 and 2021 MAC data

The 2012 MAC data showed a casing restriction as a result of well deformation at 867.6' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-39 shows cross sections at two different depths, taken from the radial arm data collected in the 2012 MAC data. An initial cross section was taken at the minimum diameter

measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the deformation seen at the collar. From the radial arm data, it is clear that the well is experiencing a decrease in the inner diameter at the deformation depth. The minimum diameter at 867.6' is 14.85", which is lower than the minimum diameter of 15.05" at 866'. Figure 3-40 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed around 867.6'. Although the well has been lined since the 2012 MAC and there is no evidence of deformation in the liner, the deformation observed in the 16" casing around 868' is likely ongoing and the well should continue to be monitored.

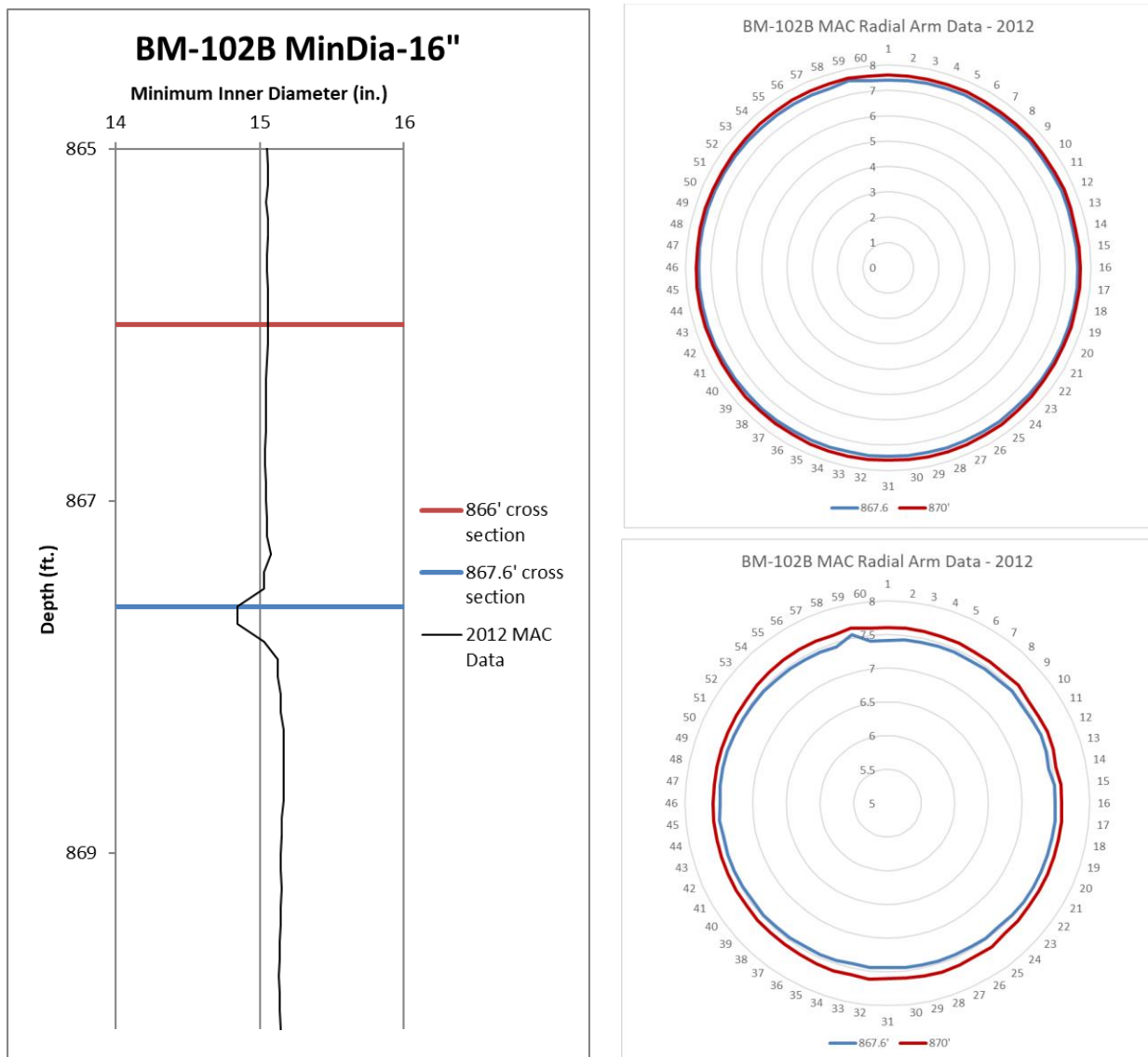


Figure 3-39. Cross sections of BM-102B 2012 MAC data at the depth of casing restriction (blue) and above the restriction (red).

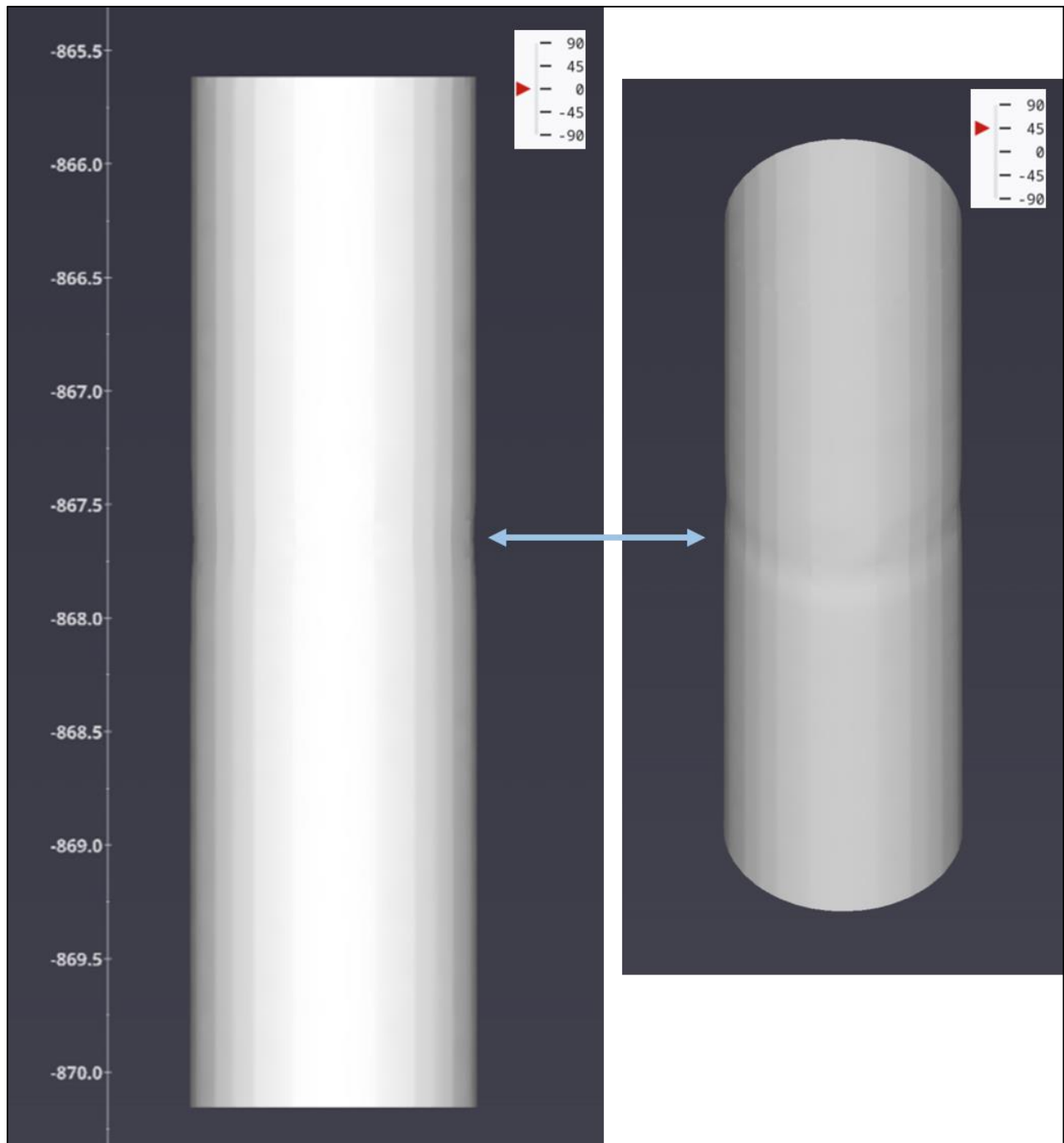


Figure 3-40. 3D visual of BM-102B 2012 radial arm data at the casing restriction

3.3.13. *BM-102C*

BM-102C has a total of two MAC logs from 2012 and 2022. The 2012 log was taken on the 16" casing. The well was then lined and the 2022 log was taken down the 13 3/8" casing. Figure 3-41 shows the minimum diameter curves for the 16" and 13-3/8" casing which were calculated from the 2012 and 2022 MAC logs. From this dataset, a casing restriction was identified at 907.4', and a

decrease in the minimum diameter curve can be observed at this depth in the 2012 MAC log. The 13 3/8" casing does not show any significant signs of deformation as of the 2022 MAC log.

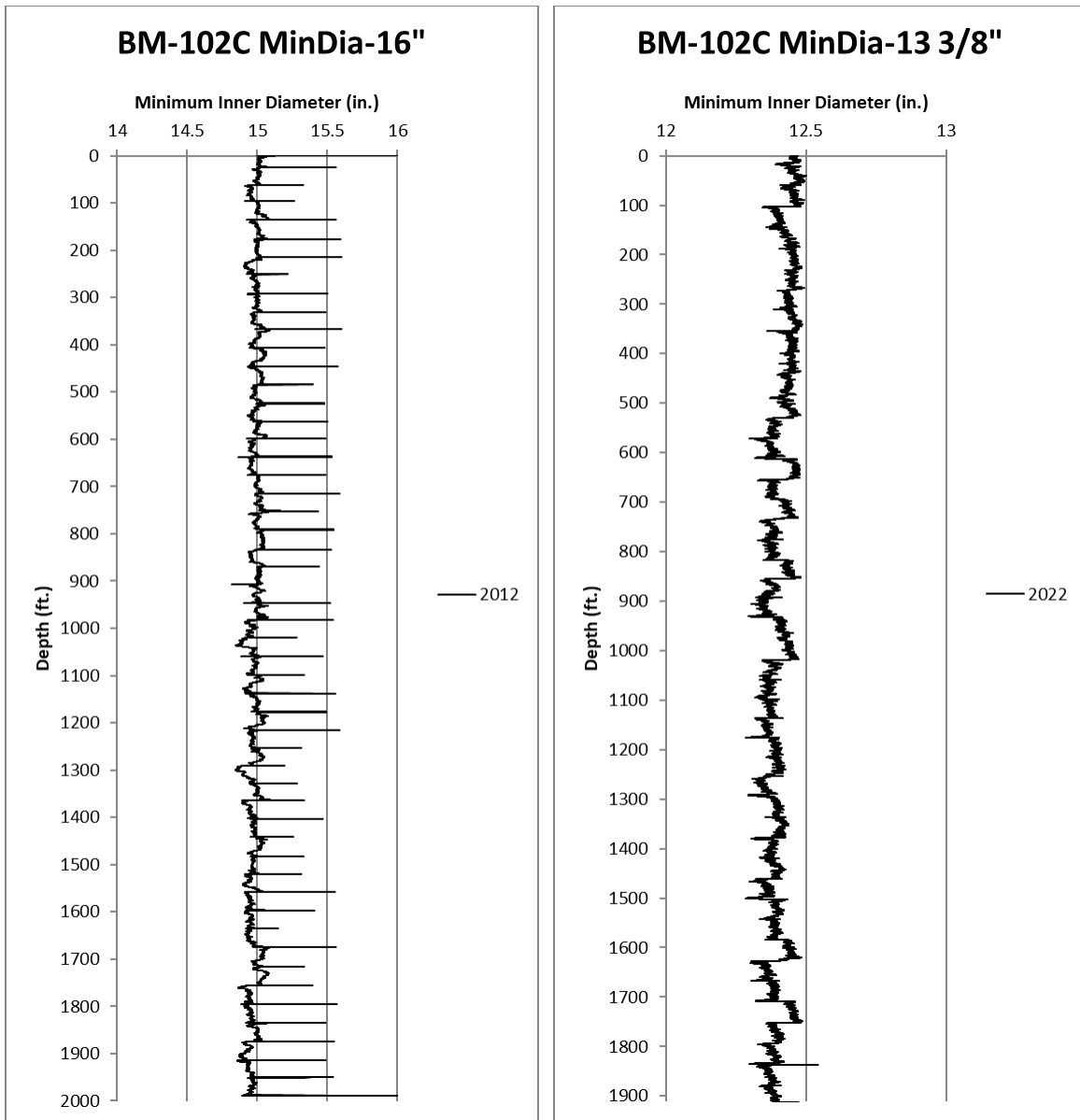


Figure 3-41. BM-102C minimum diameter curves from 2012 and 2022 MAC data

The 2012 MAC data showed a casing restriction as a result of well deformation at 907.4' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-42 shows cross sections at two different depths, taken from the radial arm data collected in the 2012 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the deformation seen at the collar. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner

diameter at the deformation depth. The minimum diameter at 907.4' is 14.82", which is lower than the minimum diameter of 15.03" at 905'. Figure 3-43 displays a 3D visual of the MAC radial arm data at the depth of interest, where a slight restriction in the casing can be observed around 907.4'. Although the well has been lined since the 2012 MAC, the deformation observed in the 16" casing around 907.4' is likely ongoing and the well should continue to be monitored.

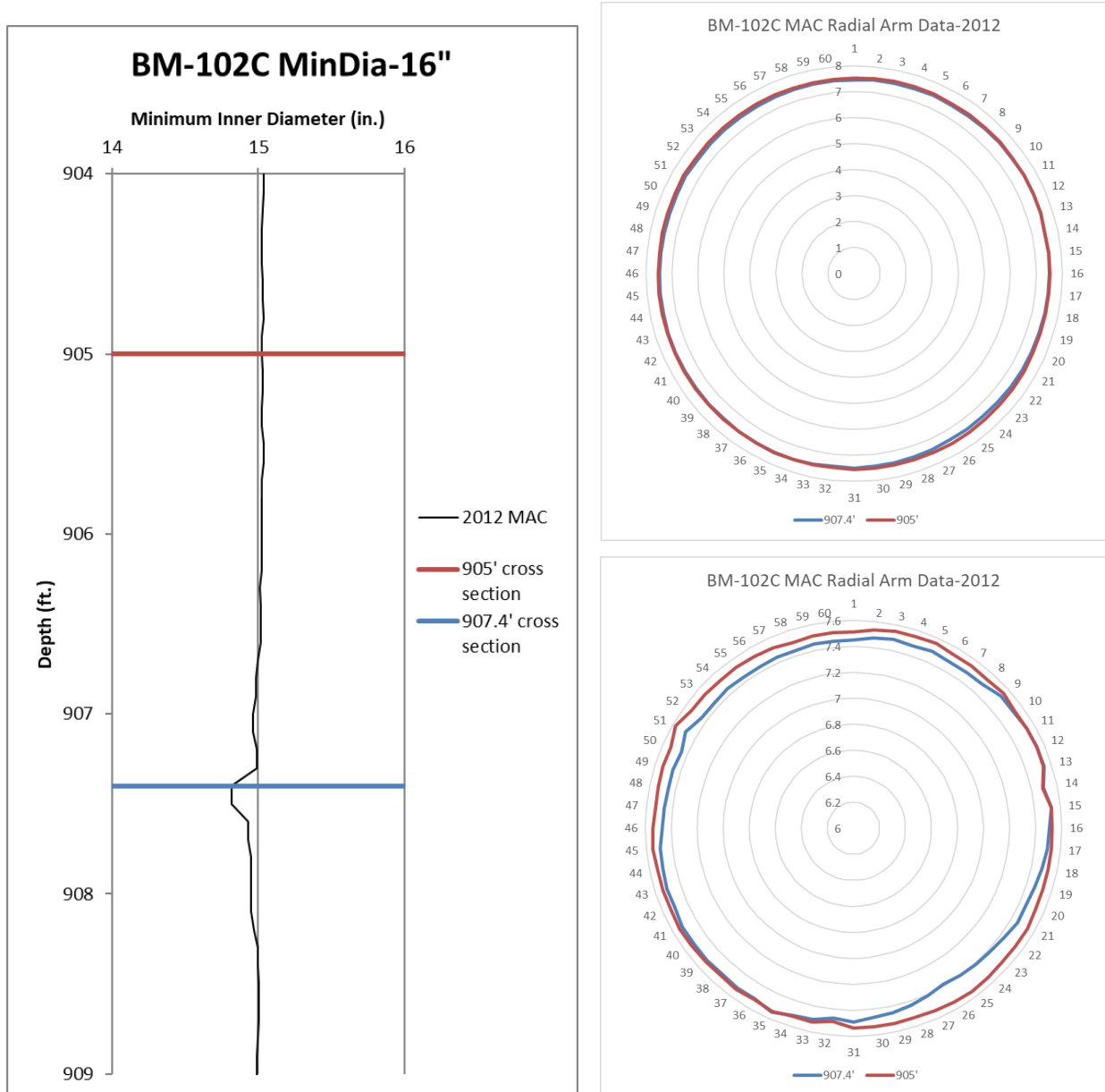


Figure 3-42. Cross sections of BM-102C 2012 MAC data at the depth of casing restriction (blue) and above the restriction (red).

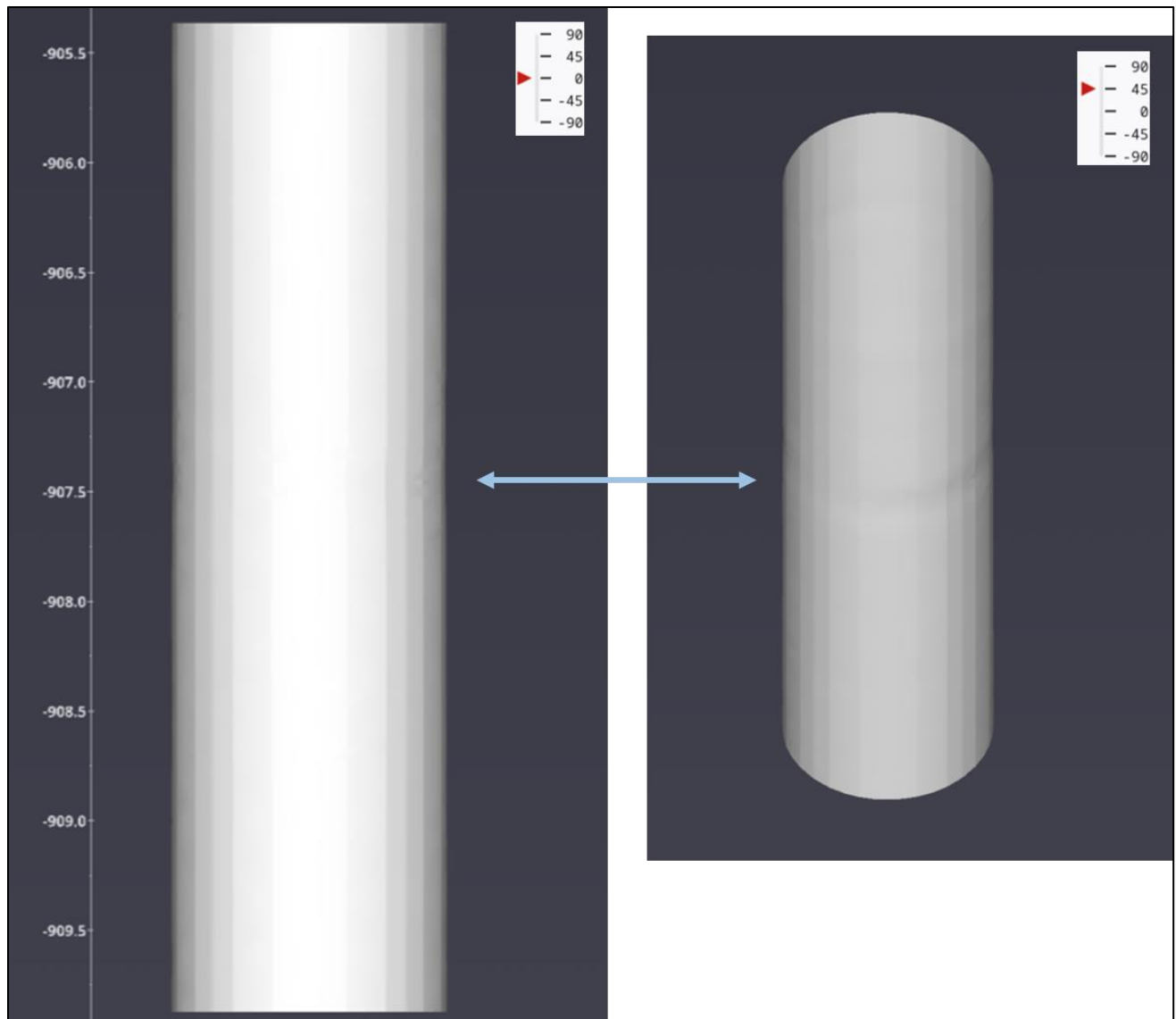


Figure 3-43. 3D visual of BM-102C 2012 radial arm data at the casing restriction

3.3.14. *BM-103B*

BM-103B has a total of three MAC logs from 2011, August 2015, and December 2015. The 2011 and August 2015 logs were taken on the 16" casing. The well was then lined and the December 2015 log was taken on the 13 3/8" casing. Figure 3-44 shows the minimum diameter curves for the 16" casing which were calculated from the 2011 and August 2015 MAC logs. From this dataset, a casing restriction was identified at 999.5' in the 16" casing, and a decrease in the minimum diameter curve can be observed at this depth. The casing restriction in the 16" casing does not appear to have worsened between the 2011 and August 2015 logs. Minor deformation has also been noted around the salt-caprock interface around 1063' and lower in the well around 1455', which does not appear to be rapidly worsening. Figure 3-45 shows the minimum diameter curve for the 13 3/8" casing which was calculated for the December 2015 log and does not show any indications of deformation.

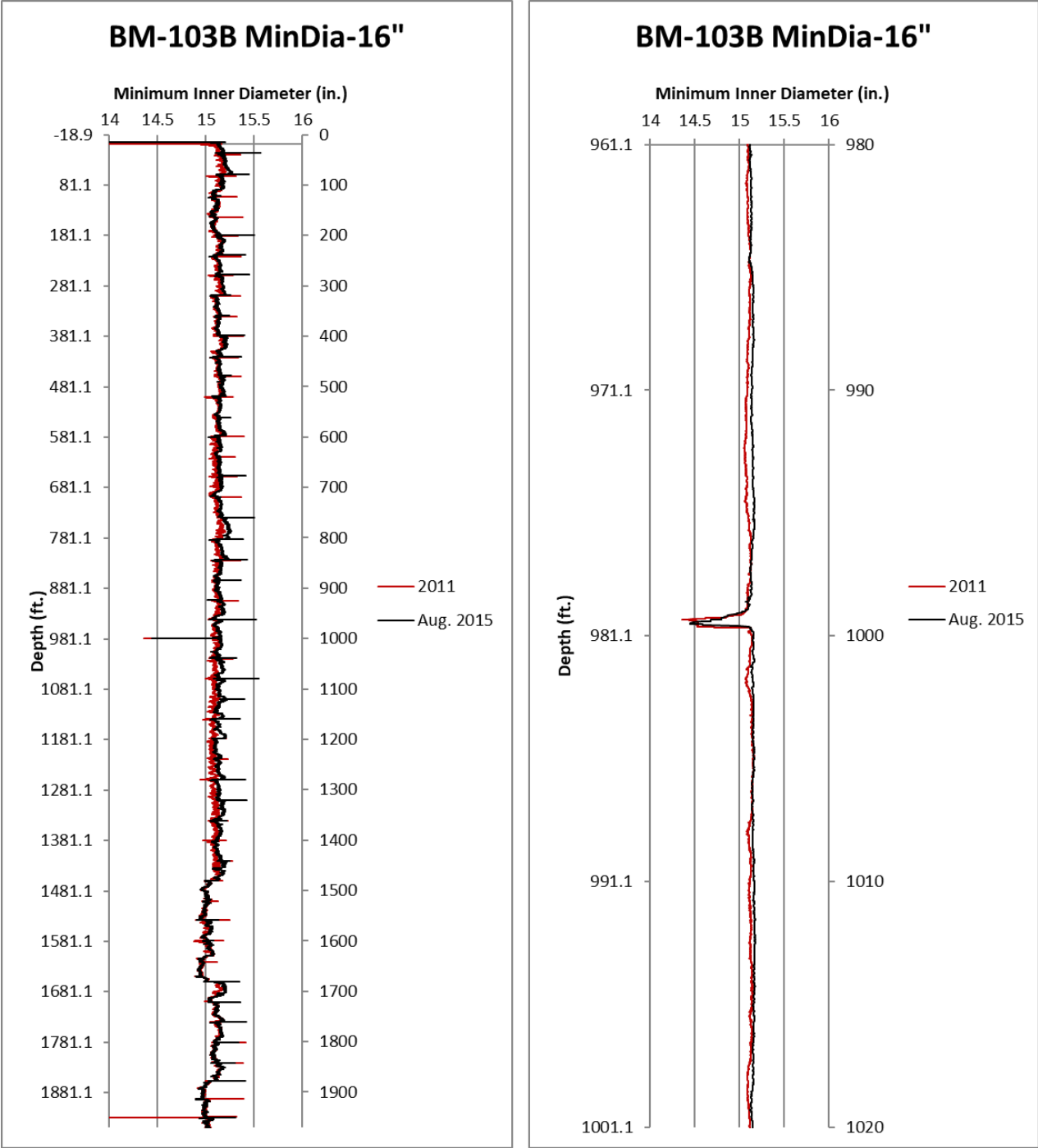


Figure 3-44. BM-103B minimum diameter curves from 2011 and August 2015 MAC data

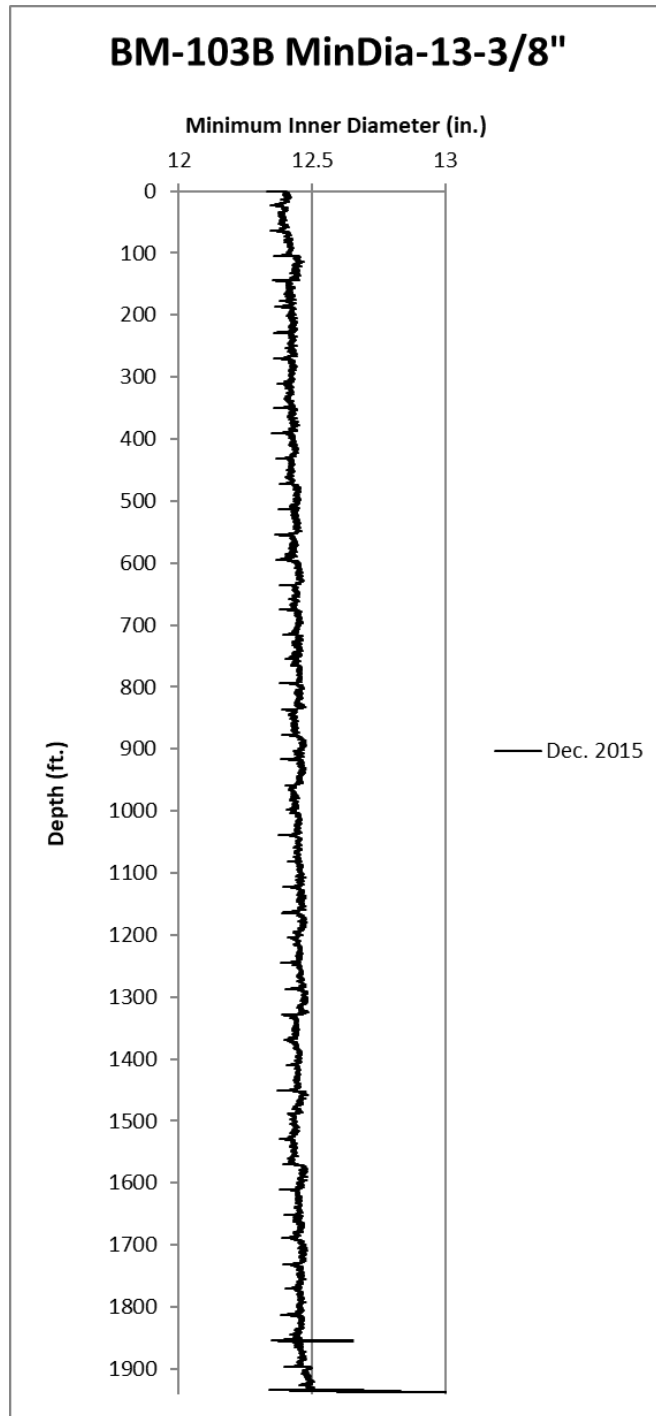


Figure 3-45. BM-103B minimum diameter curve from December 2015 MAC data

The 2011 and August 2015 MAC data showed a casing restriction as a result of well deformation at 999.5' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-46 shows cross sections at two different depths, taken from the radial arm data collected in the September 2015 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second

cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth, with the deformation occurring in a fairly uniform pattern. The minimum diameter at 999.5' is 14.44", which is notably lower than the minimum diameter of 15.15" at 996'. Figure 3-47 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed around 999.5'. There also appears to be some deformation above the restriction, which is likely a result of casing compression as well. Although the well has been lined since the August 2015 MAC, the deformation observed in the 16" casing around 999.5' is likely ongoing and the well should continue to be monitored.

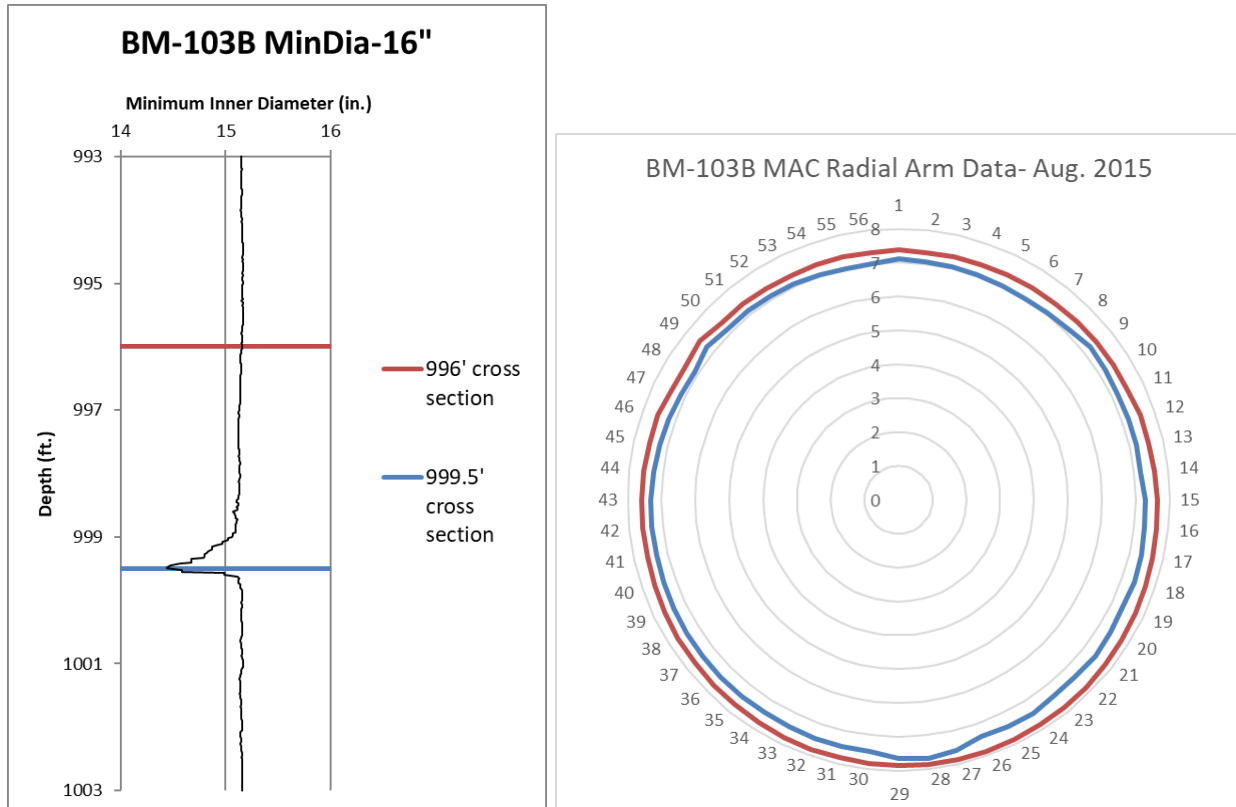


Figure 3-46. Cross sections of BM-103B August 2015 MAC data at the depth of casing restriction (blue) and above the restriction (red).

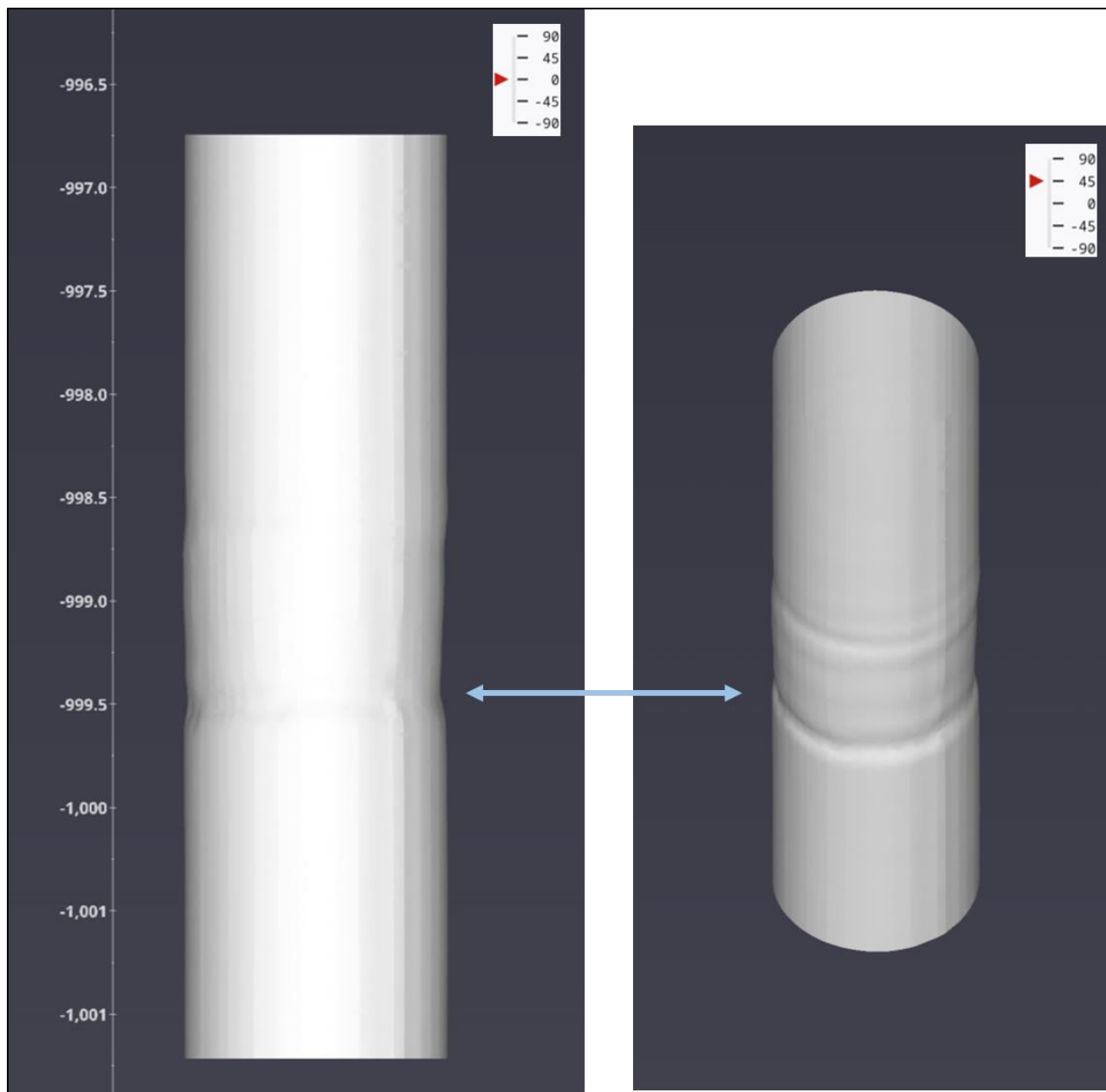


Figure 3-47. 3D visual of BM-103B August 2015 MAC radial arm data at the casing restriction

3.3.15. *BM-103C*

BM-103C has a total of three MAC logs from 2011, July 2014, and August 2014. The 2011 and July 2014 logs were taken on the 16" casing. The well was then lined, and the August 2014 log was taken on the 13 3/8" casing. Figure 3-48 shows the minimum diameter curves for the 16" and 13-3/8" casing which were calculated from the 2011, July 2014, and August 2014 MAC logs. There are no substantial casing restrictions or areas of notable deformation to cause concern from the available MAC data.

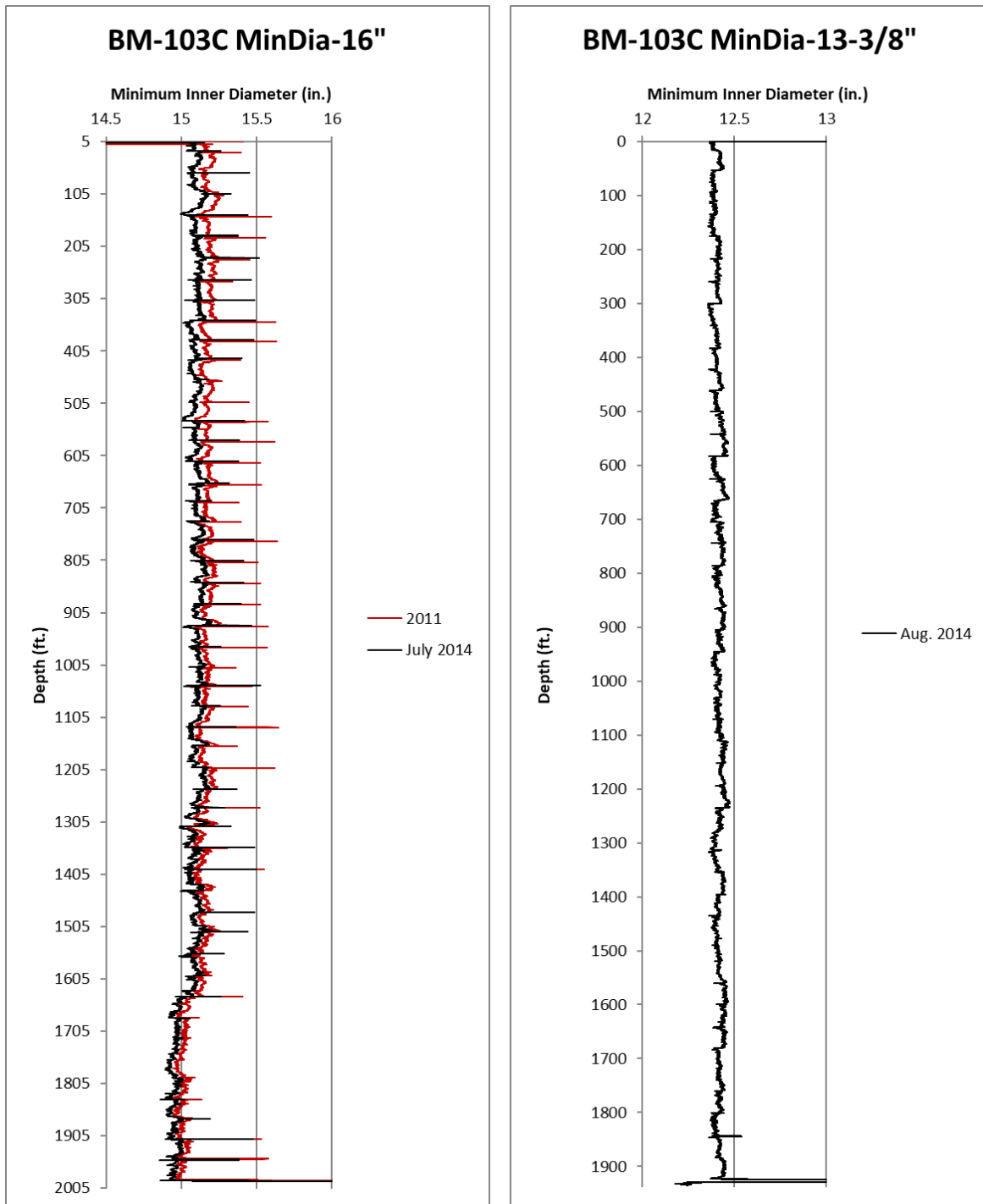


Figure 3-48. BM-103C minimum diameter curves from 2011, July 2014, and August 2014 MAC data

3.3.16. BM-104A

BM-104A has a total of three MAC logs from 2010, 2015, and 2020. All three logs were taken on the 13 3/8" casing. Figure 3-49 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2010, 2015, and 2020 MAC logs. From this dataset, casing restrictions were identified at 905.9' and 942.8', and a decrease in the minimum diameter curve can be observed at these depths. Because there are slight offsets in the baseline data for each MAC (likely the result of differences in tool calibration), it is hard to determine whether the deformation is actually getting worse over time for the casing restriction at 942.8'. However, the casing restriction at 905' shows a clear progression from the 2010 log which shows an increase in minimum diameter at the collar (as expected at a casing collar joint) to the 2020 log where there is a decrease in the minimum diameter at the casing collar. Moderate deformation has also been noted at non-collar locations from 940'-1060' which does not appear to be rapidly worsening.

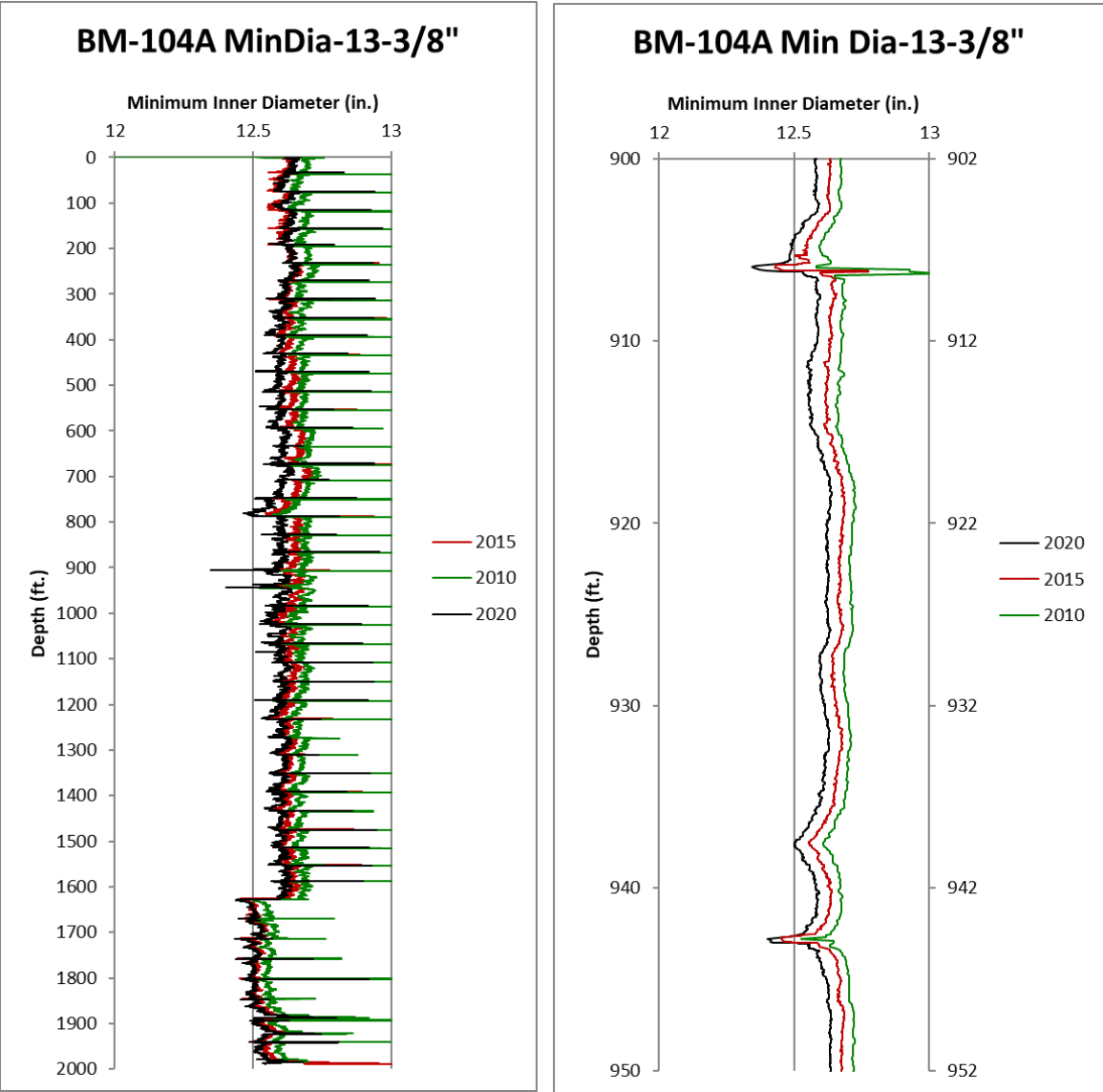


Figure 3-49. BM-104A minimum diameter curves from 2010, 2015, and 2020 MAC data

The BM-104A MAC data showed casing restrictions as a result of well deformation on the 13 3/8" casing at 905.9' and 942.8'. This deformation occurs at two consecutive collar locations and is resulting in a decrease in the inner-casing diameter. Figure 3-50 shows cross sections from the upper casing restriction location. Cross sections for each figure were taken from the radial arm data collected in the 2020 MAC data at two different depths. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the restriction seen at a depth of 905.9'. From the radial arm data, it is clear that the well is experiencing a small decrease in the inner diameter at both deformation depths. The minimum diameter at 905.9' is 12.47", which is slightly lower than the minimum diameter of 12.58" at 901'. Although the restriction at this depth is not severe, it can still be observed in Figure 3-51 which displays a 3D visual of the MAC radial arm data at the depth of interest.

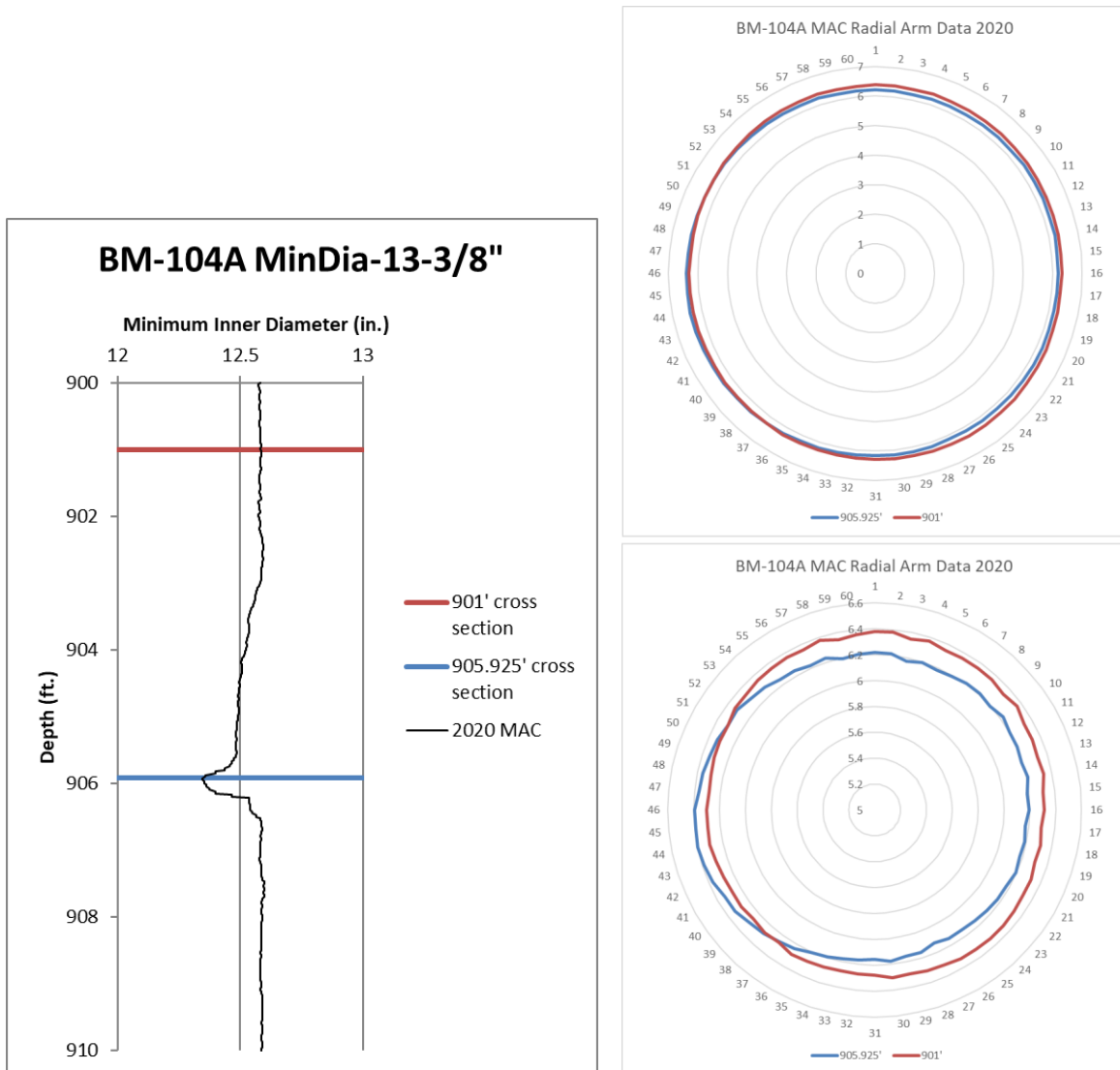


Figure 3-50. Cross sections of BM-104A 2020 MAC data at the depth of 905.9' casing restriction (blue) and above the restriction (red).

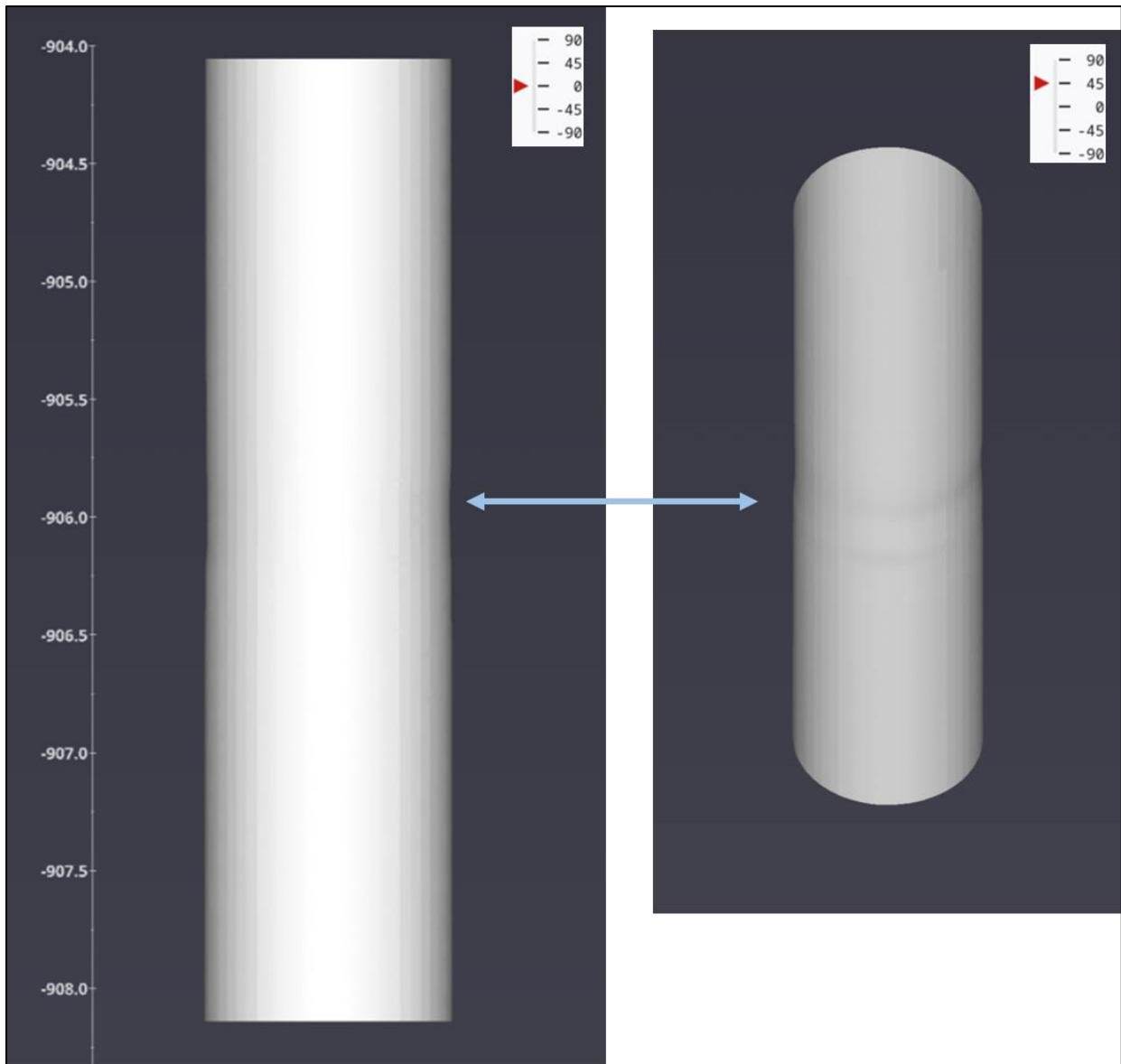


Figure 3-51. 3D visual of BM-104A 2020 MAC radial arm data at the upper casing restriction

Figure 3-52 shows cross sections from the lower casing restriction location. From the radial arm data, it is clear that the well is experiencing a decrease in the inner diameter at both deformation depths. The minimum diameter at 942.8' is 12.40", which is slightly lower than the minimum diameter of 12.63" at 922'. Although the restriction at this depth is not severe, it can still be observed in Figure 3-53 which displays a 3D visual of the MAC radial arm data at the depth of interest.

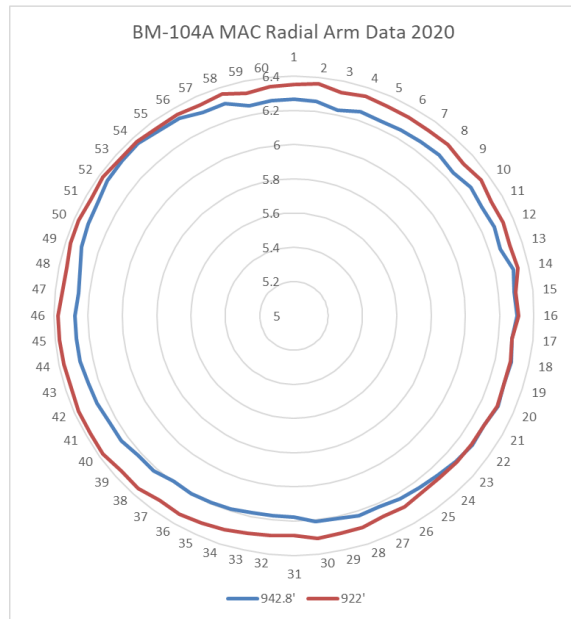
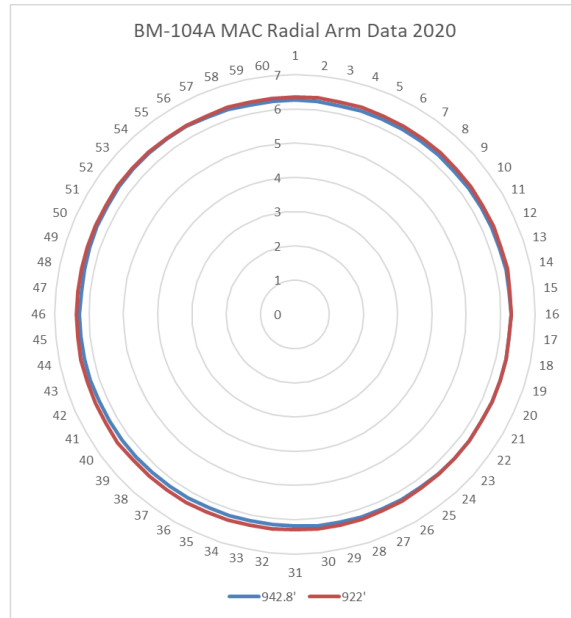
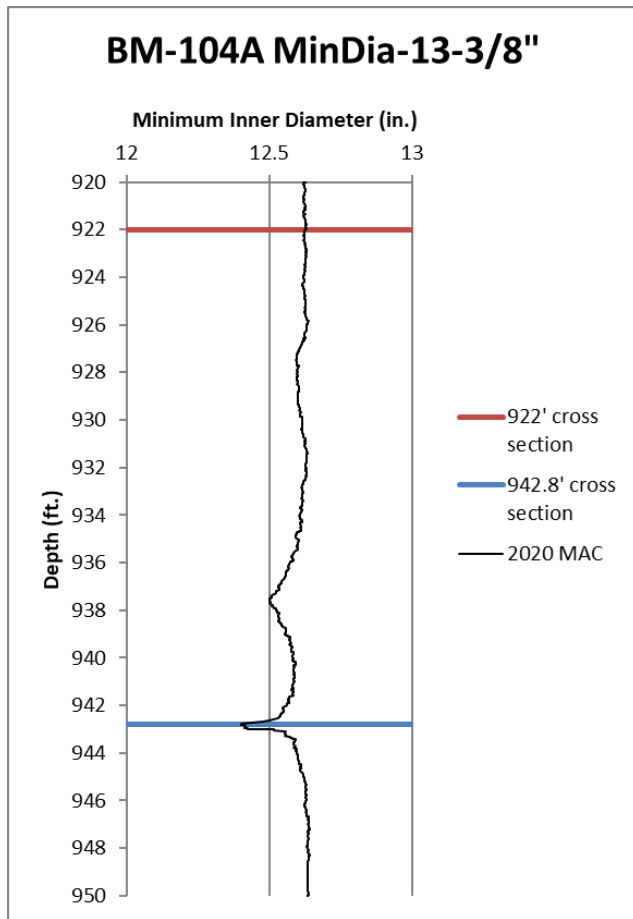


Figure 3-52. Cross sections of BM-104A 2020 MAC data at the depth of 942.8' casing restriction (blue) and above the restriction (red).

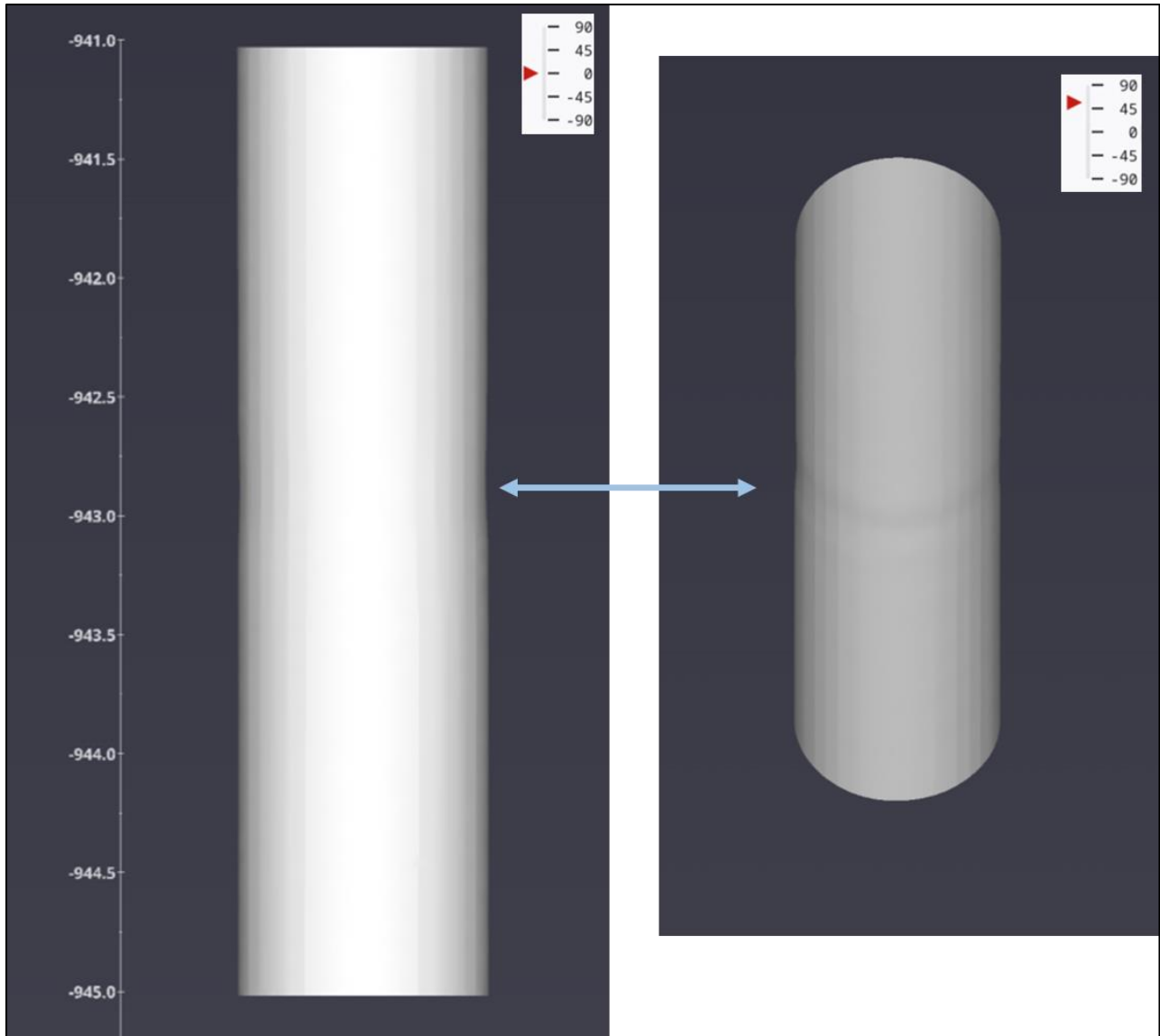


Figure 3-53. 3D visual of BM-104A 2020 MAC radial arm data at the lower casing restriction

3.3.17. BM-104B

BM-104B has a total of two MAC logs from 2009, and 2018. Both logs were taken on the 13 3/8" casing. Figure 3-54 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2009 and 2018 MAC logs. From this dataset, a casing restriction was identified at 881.6', and a decrease in the minimum diameter curve can be observed at this depth. The deformation at 881.6' appears to be worsening with time. Some moderate deformation near the salt-caprock interface has also been noted which does not appear to be rapidly worsening.

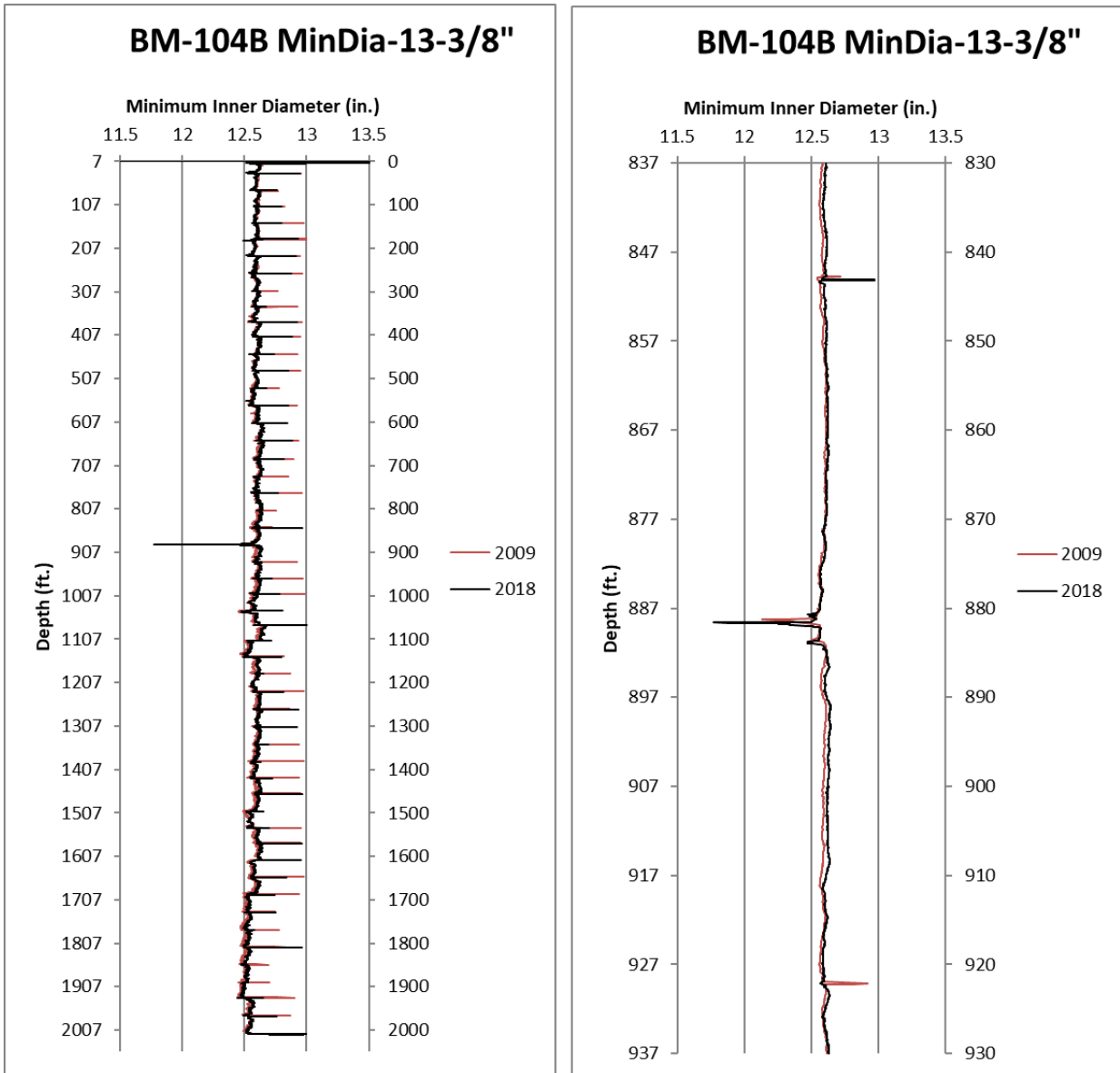


Figure 3-54. BM-104B minimum diameter curves from 2009 and 2018 MAC data

The 2009 and 2018 MAC data showed a casing restriction as a result of well deformation at 881.6’ on the 13 3/8” casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-55 shows cross sections at two different depths, taken from the radial arm data collected in the 2018 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth, and the deformation is not uniform. The minimum diameter at 881.6’ is 11.77”, which is notably lower than the minimum diameter of 12.57” at 876’. Figure 3-56 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at

881.6'. The deformation observed in the 13 3/8" casing around 882' is likely ongoing and the well should continue to be monitored.

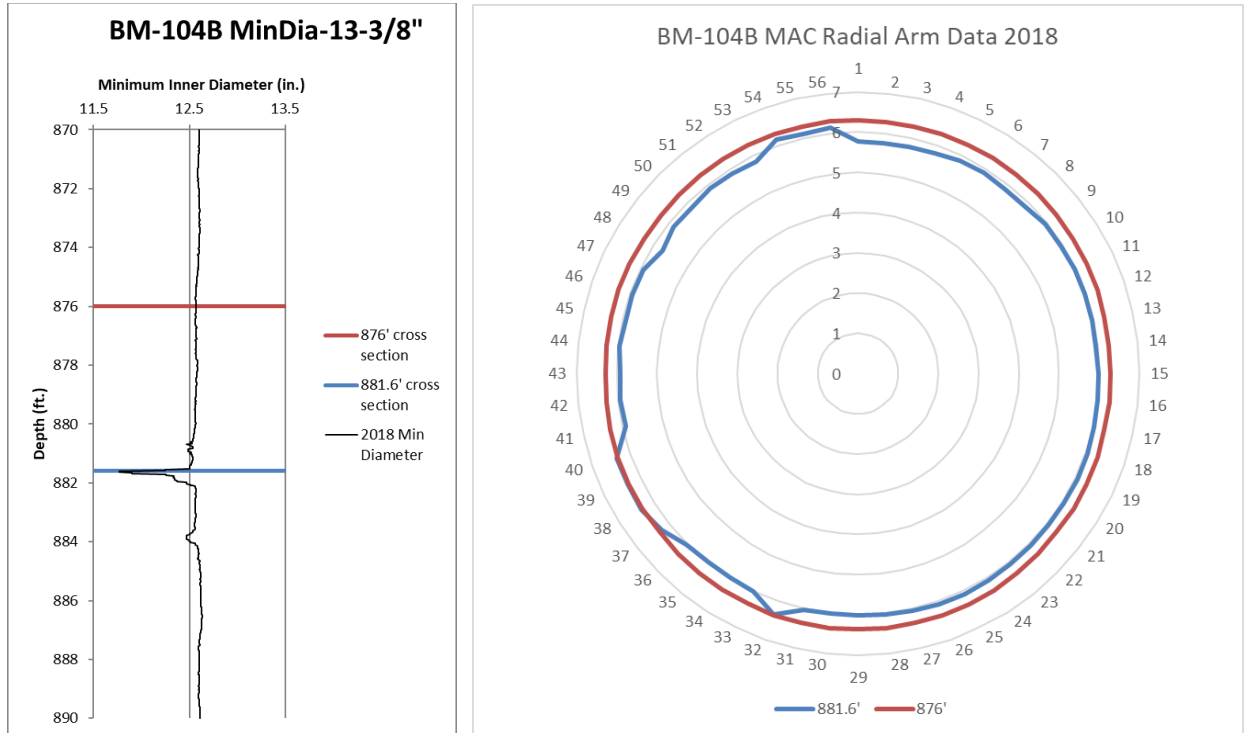


Figure 3-55. Cross sections of BM-104B 2018 MAC data at the depth of casing restriction (blue) and above the restriction (red).

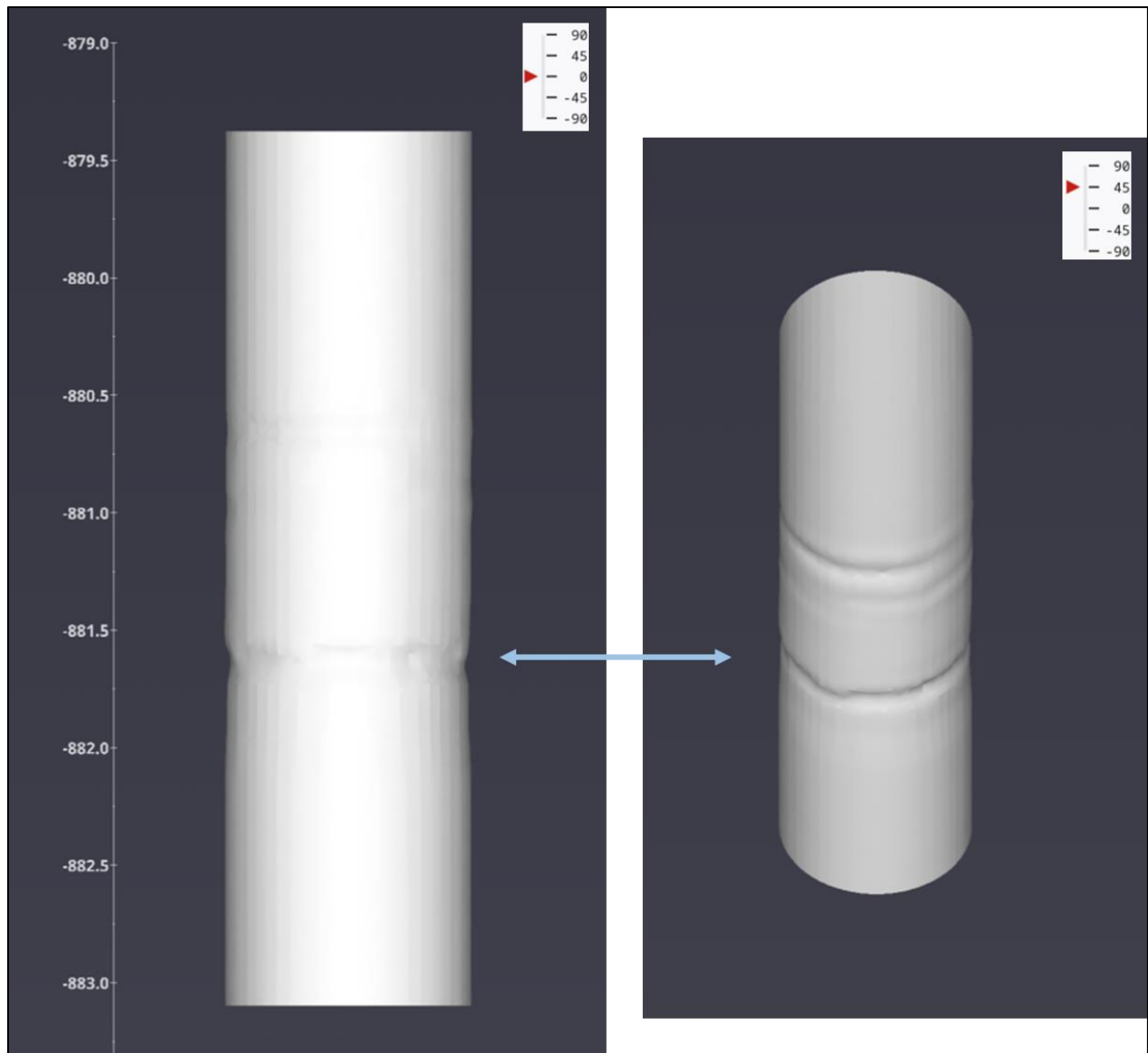


Figure 3-56. 3D visual of BM-104B 2018 MAC radial arm data at the casing restriction

3.3.18. BM-104C

BM-104C has a total of three MAC logs from 2010, 2015, and 2020. All three logs were taken on the 13 3/8" casing. Figure 3-57 shows the minimum and average diameter curves for the 13-3/8" casing which were calculated from the 2010, 2015, and 2020 MAC logs. From this dataset, two casing restrictions were identified at 804.7' and 885.3', and a decrease in the minimum diameter curve can be observed at these depths. Because there are slight offsets in the baseline data for each MAC (likely the result of differences in tool calibration), it is hard to determine whether this deformation is actually getting worse over time for the casing restriction at 804.7'. However, the casing restriction at 885.3' does seem to be getting worse over time at the minimum diameter point, even after taking into account the baseline offset in the MAC data. Very minor deformation near the salt-caprock

interface has been noted around 1030', which does not appear to be rapidly worsening and is not a cause for concern at the moment.

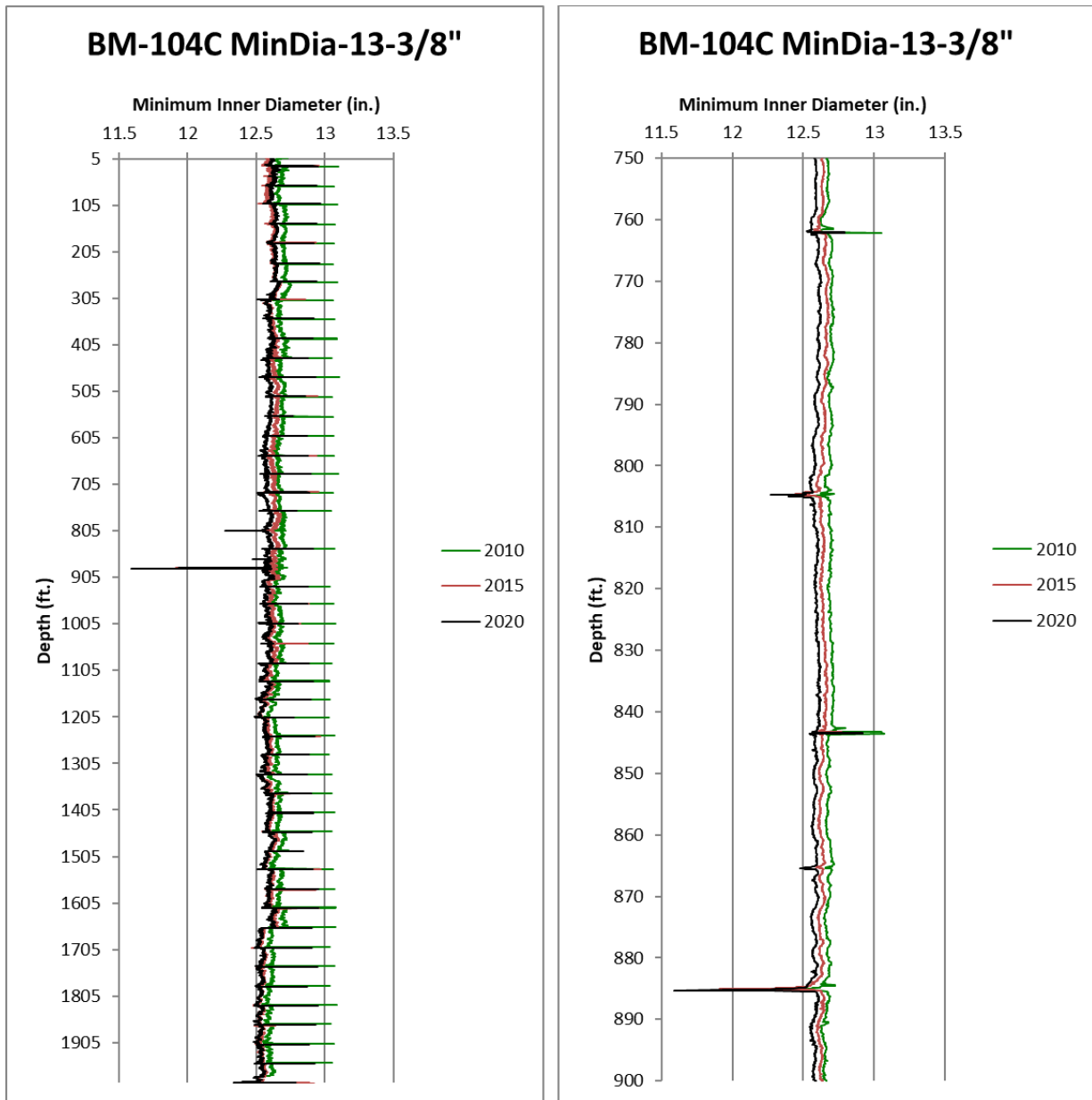


Figure 3-57. BM-104C minimum diameter curves from 2010, 2015, and 2020 MAC data

The BM-104C MAC data showed casing restrictions as a result of well deformation on the 13 3/8" casing at 804.7' and 885.3'. This deformation occurs at two consecutive collar locations and is resulting in a decrease in the inner-casing diameter. Figure 3-58 shows cross sections from the upper casing restriction location. Cross section for each figure were taken from the radial arm data collected in the 2020 MAC data at two different depths. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second

cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the restriction seen at a depth of 804.7'. From the radial arm data, it is clear that the well is experiencing a decrease in the inner diameter at the deformation depth. The minimum diameter at 804.7' is 12.27", which is slightly lower than the minimum diameter of 12.58" at 799'. Although the restriction at this depth is not severe, it can still be observed in Figure 3-59 which displays a 3D visual of the MAC radial arm data at the depth of interest.

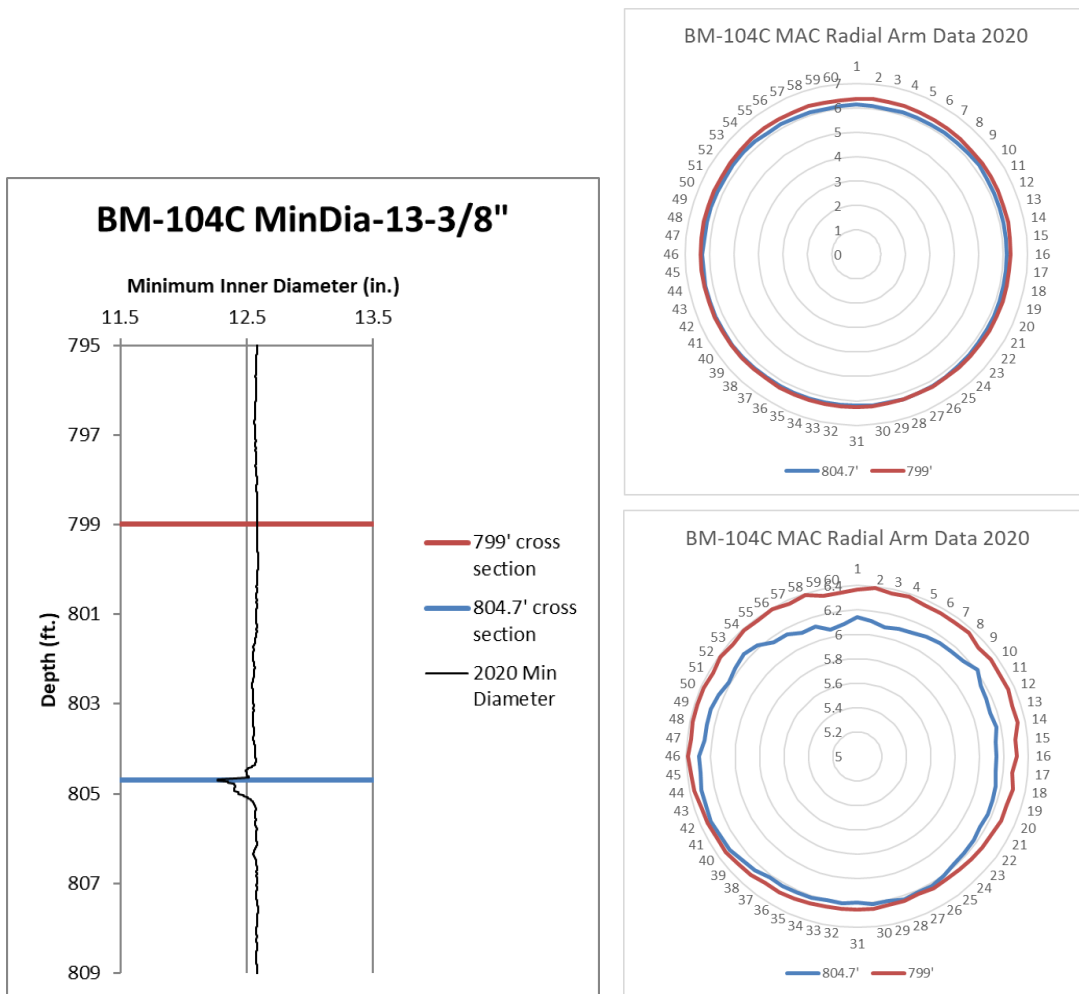


Figure 3-58. Cross sections of BM-104C 2020 MAC data at the depth of the 804.7' casing restriction (blue) and above the restriction (red).

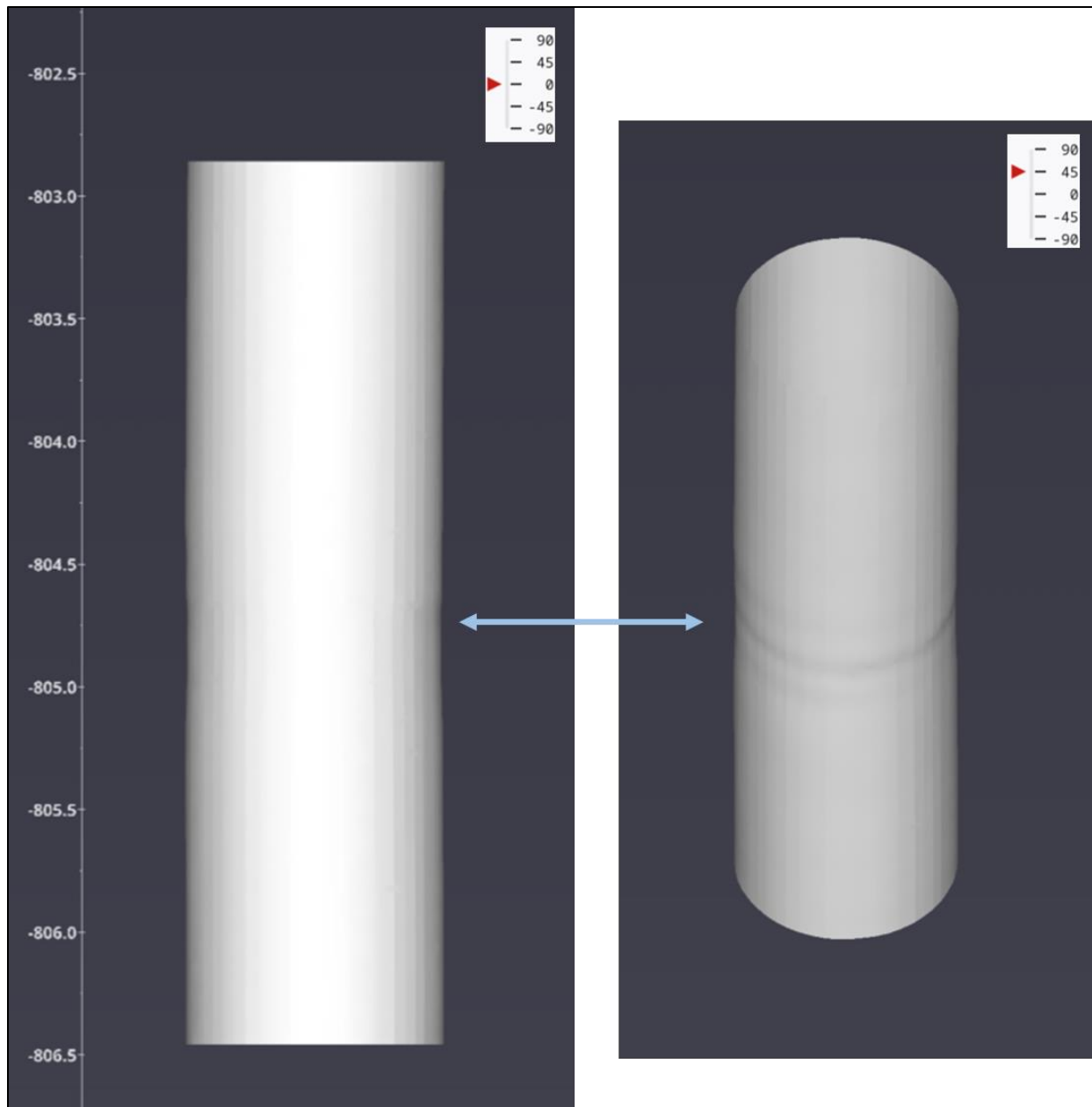


Figure 3-59. 3D visual of BM-104C 2020 MAC radial arm data at the upper casing restriction

Figure 3-60 shows cross sections from the lower casing restriction location at 885.3'. From the radial arm data, it is clear that the well is experiencing an overall decrease in the inner diameter at this depth. The minimum diameter at 885.3' is 11.59", which is notably lower than the minimum diameter of 12.57" at 879'. Figure 3-61 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 885.3'.

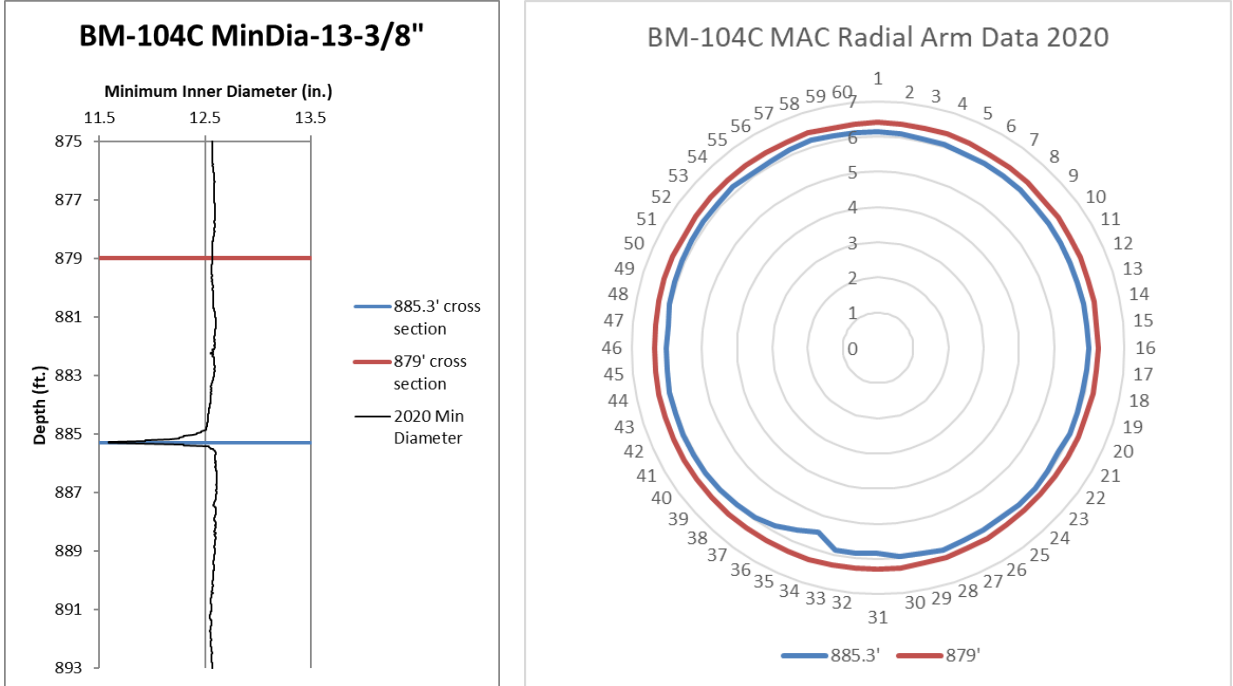


Figure 3-60. Cross sections of BM-104C 2020 MAC data at the depth of 885.3' casing restriction (blue) and above the restriction (red).

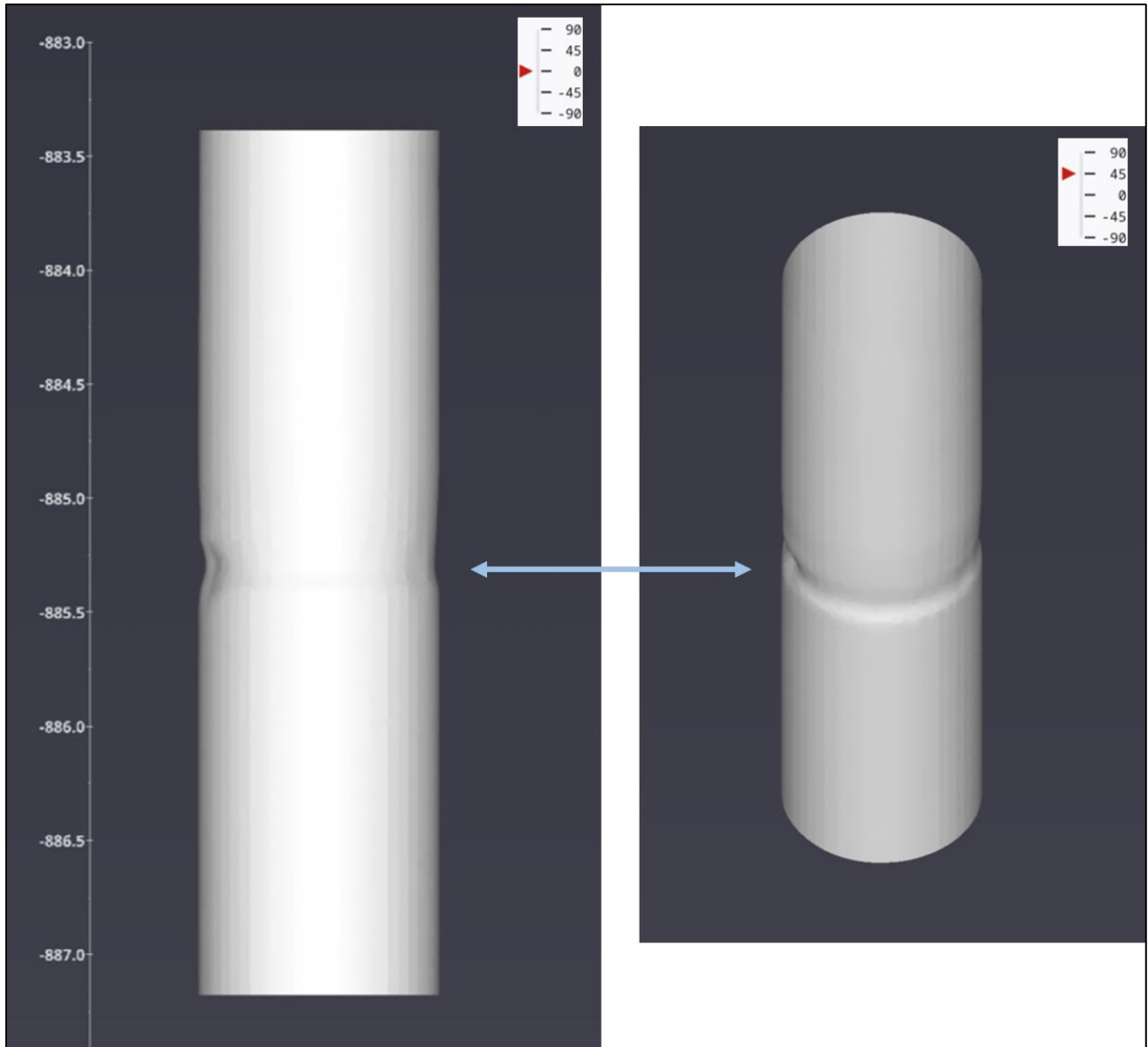


Figure 3-61. 3D visual of BM-104B 2020 MAC radial arm data at the lower casing restriction

3.3.19. *BM-105B*

BM-105B has a total of three MAC logs from 2011, 2016, and 2021. All three logs were taken on the 16" casing. Figure 3-62 shows the minimum diameter curves for the 16" casing which were calculated from the 2011, 2016, and 2021 MAC logs. From this dataset, a casing restriction was identified at 810.8', and a decrease in the minimum diameter curve can be observed at this depth. Between 2016 and 2021 the restriction observed in the minimum diameter does not appear to be worsening. Some additional non-collar related deformation has also been noted around 1115' which does not appear to be rapidly worsening.

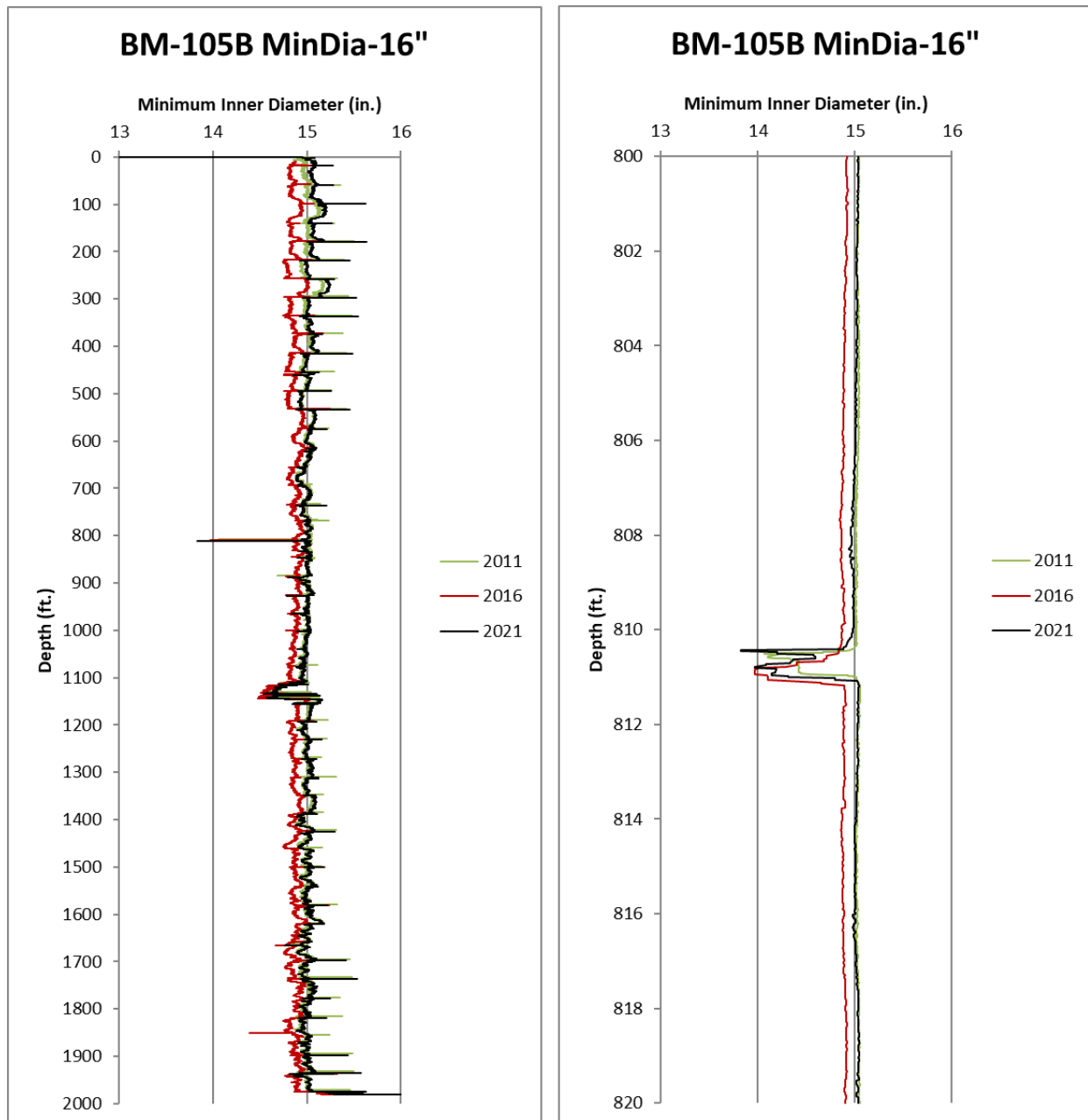


Figure 3-62. BM-105B minimum diameter curves from 2011, 2016, and 2021 MAC data

The 2011, 2016, and 2021 MAC data showed a casing restriction as a result of well deformation at 810.775' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-63 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken near the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The true minimum

diameter measurement in the area is seen at 810.45' however this is the result of one radial arm measurement, so a slightly lower depth of 810.775' was used. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth, with a fairly uniform radial distribution. The minimum diameter at 810.775' is 13.97", which is notably lower than the minimum diameter of 15.02" at 804'. Figure 3-64 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 810.775'.

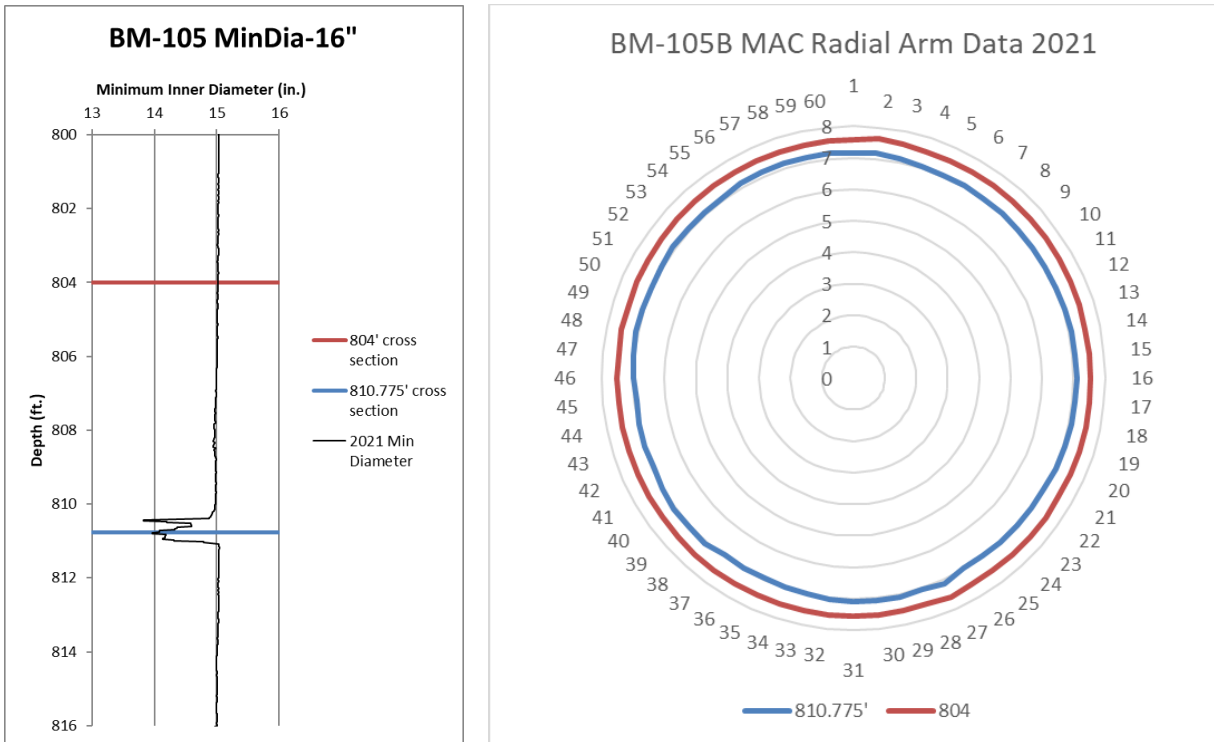


Figure 3-63. Cross sections of BM-105B 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

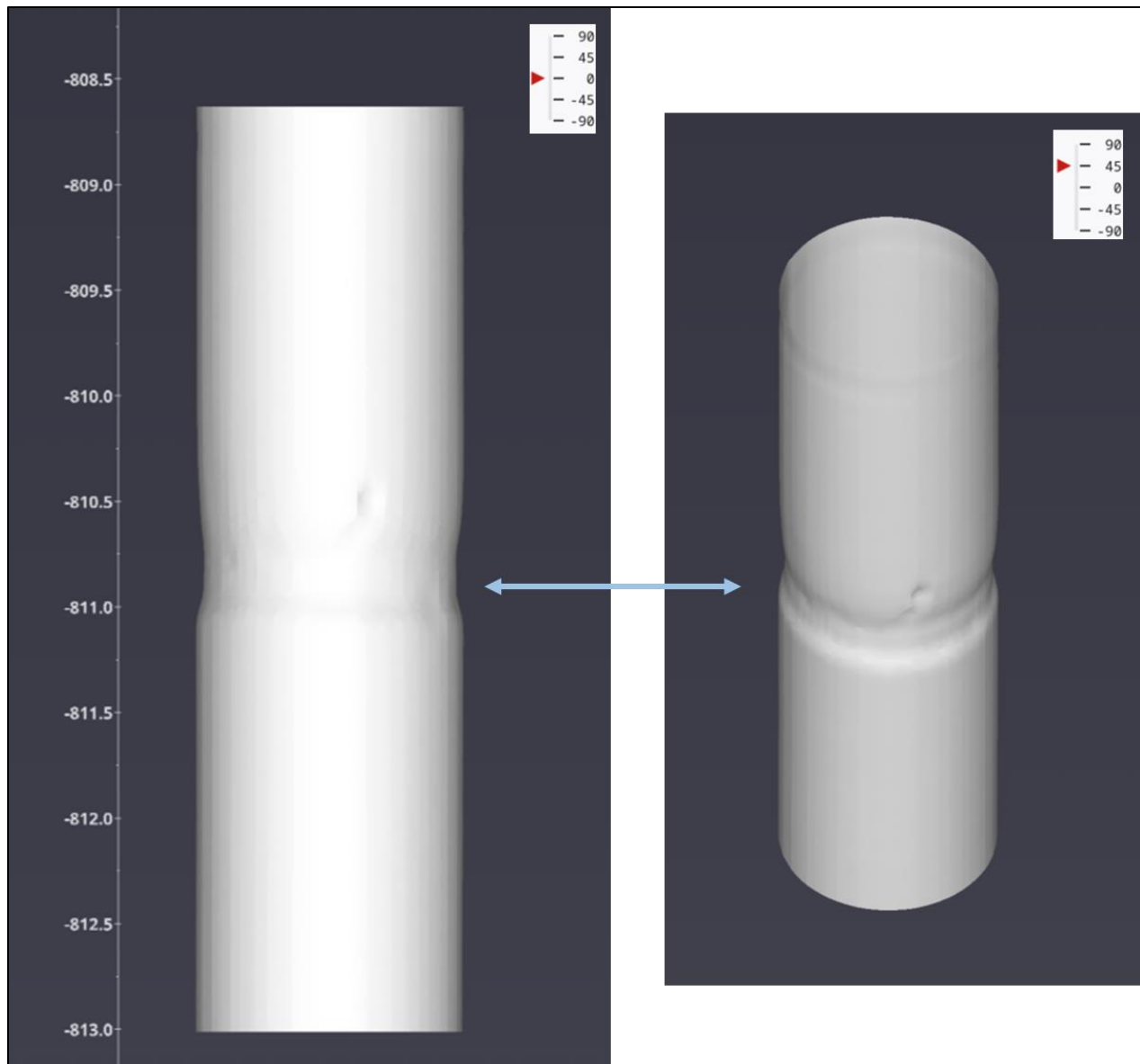


Figure 3-64. 3D visual of BM-105B 2021 MAC radial arm data at the lower casing restriction

3.3.20. BM-105C

BM-105C has a total of two MAC logs from 2012 and 2021, which were both taken on the 16" casing. The 2012 log was excluded from this analysis as the data file did not include individual radial arm measurements. Figure 3-65 shows the minimum and average diameter curves for the 16" casing which was calculated from the 2021 MAC log. From this dataset, a casing restriction was identified at 206.95', and a decrease in the minimum diameter curve can be observed at this depth. Although there is a notable decrease in diameter at the depth of interest, this does not appear to be a typical case of collar compression as seen at many of the other BM wells and is likely the result of some debris in the casing.

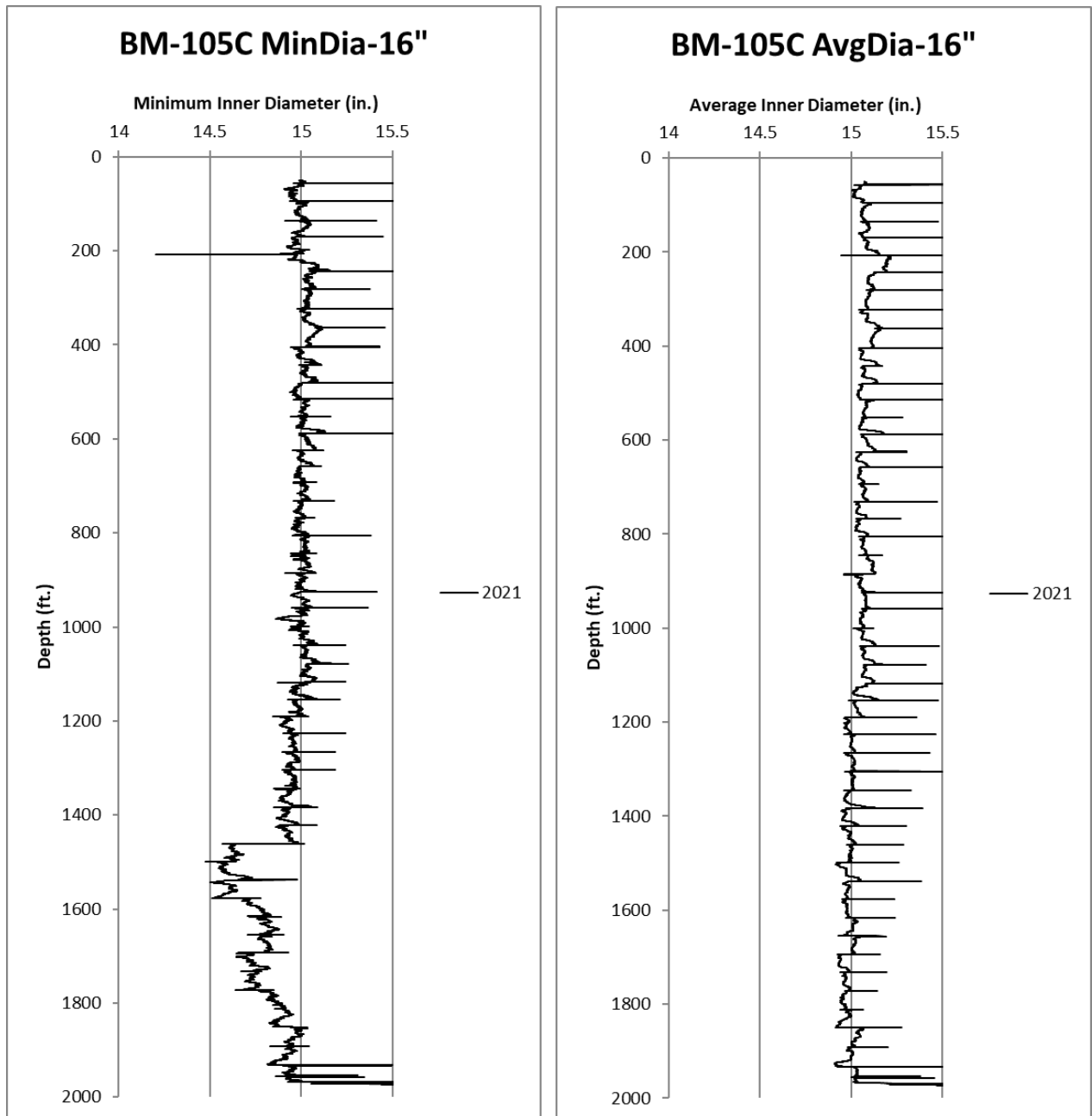


Figure 3-65. BM-105C minimum and average diameter curves from 2021 MAC data

Figure 3-66 displays a 3D visual of the MAC radial arm data at the depth of interest. Although there is visible deformation occurring near a casing collar, it is limited to one side of the casing. Additionally, a normal collar kick can be observed in the remainder of this region, which is the opposite of what would typically be observed in cases of collar compression at Bryan Mound. While there is a true decrease in minimum diameter around this depth, it does not appear to be a result of geology and is not a major concern at this time. This case also serves as a good example of a situation where a decrease in the minimum diameter might not always be indicative of uniform radial deformation. To get a full picture of what is going on at a specific depth it is important to look at the radial arm data from that region.

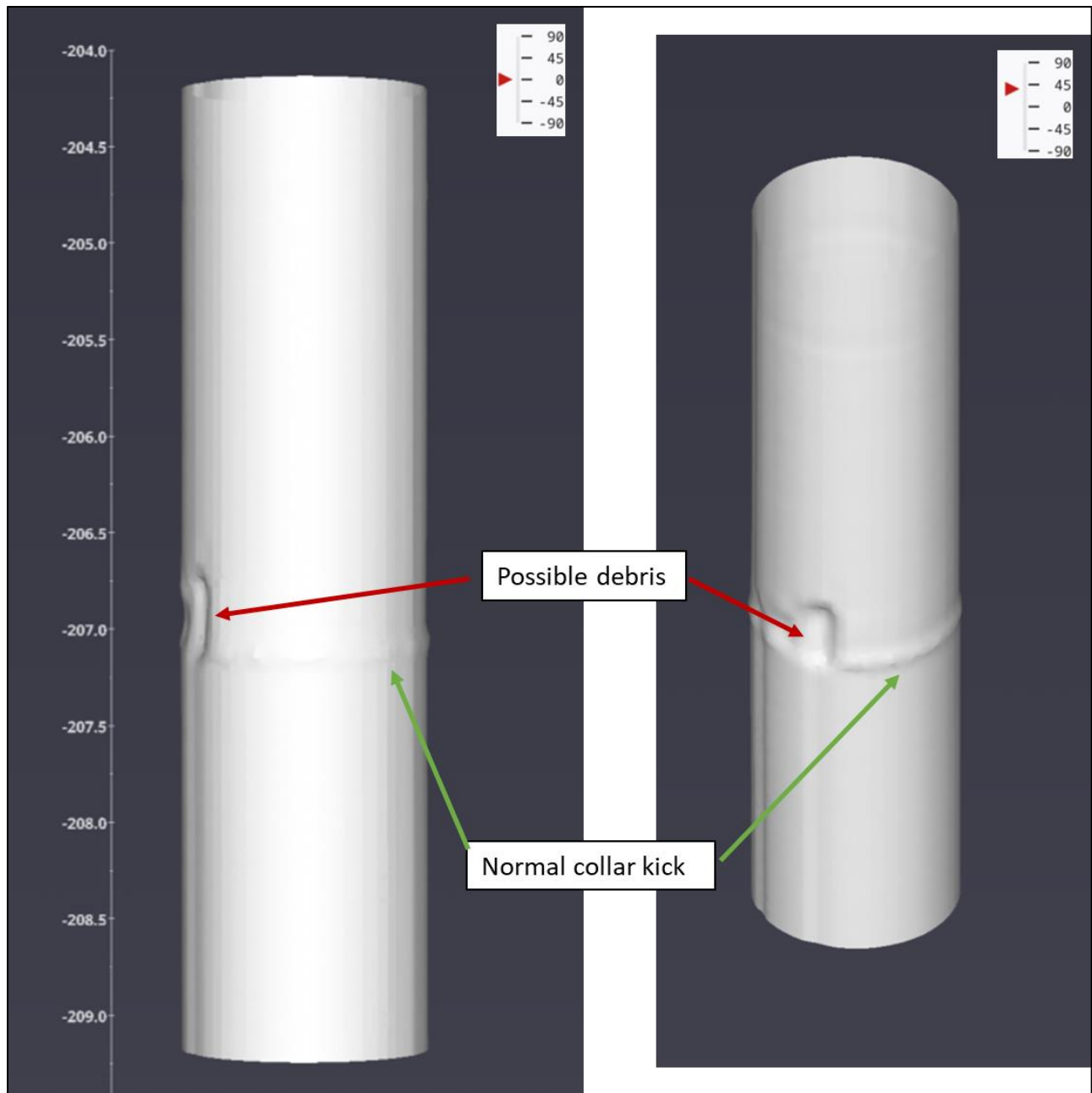


Figure 3-66. 3D visual of BM-105B 2021 MAC radial arm data near 207'

3.3.21. BM-106A

BM-106A has a total of three MAC logs from 2009, 2011, and 2020. The 2009 and 2011 logs were taken on the 13 3/8" casing. The well was then lined and the 2020 log was taken on the 10 3/4" liner. Figure 3-67 shows the minimum diameter curves for the 13-3/8" casings which were calculated from the 2009 and 2011 MAC logs. From this dataset, a casing restriction in the 13 3/8" casing was identified at 881.9', and a decrease in the minimum diameter curve can be observed at this depth, however it does not appear to be worsening between the 2009 and 2011 logs. Figure 3-68

shows the minimum diameter curve which was calculated from the 2020 MAC log, which appears to be in good condition.

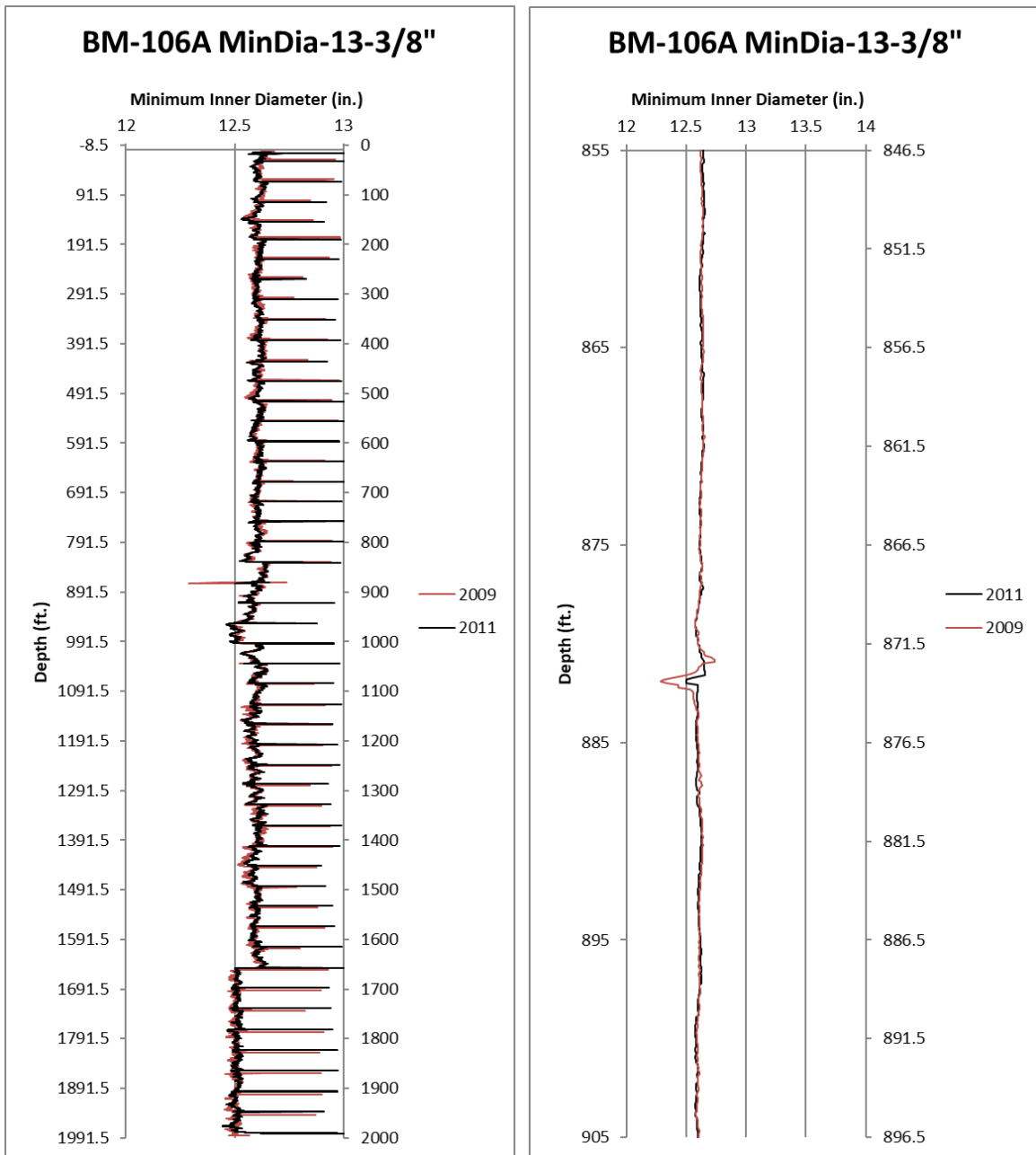


Figure 3-67. BM-106A minimum diameter curves from 2009 and 2011 MAC data

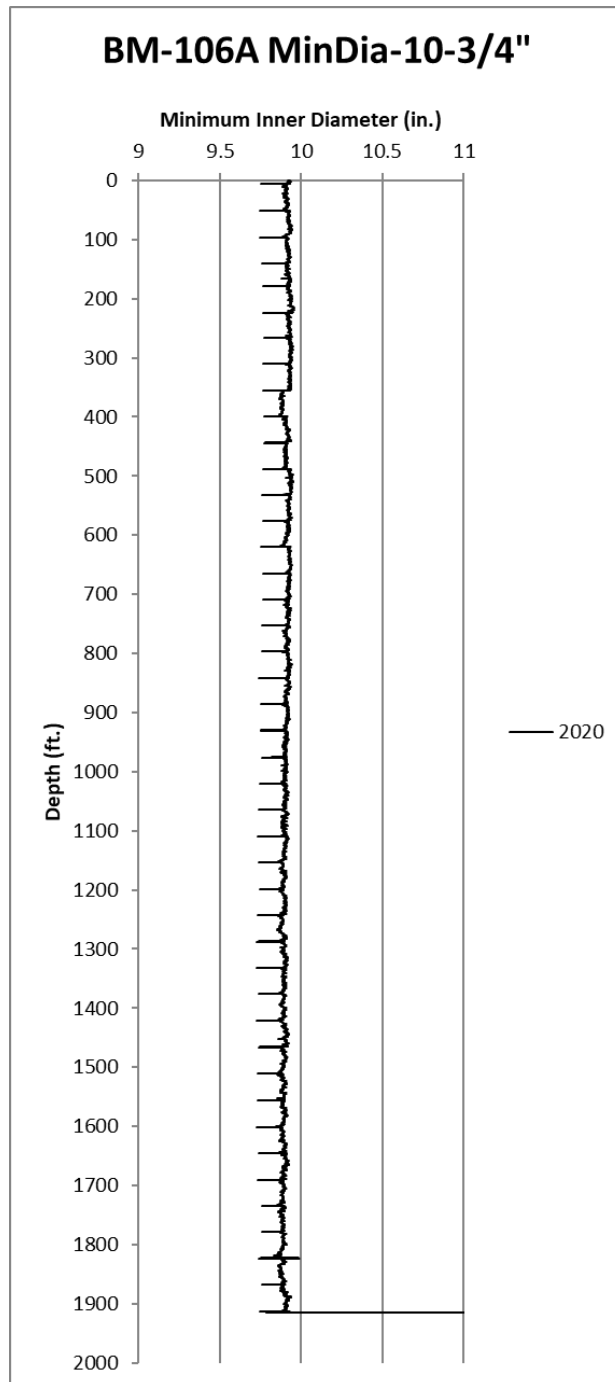


Figure 3-68. BM-106A minimum diameter curve from 2020 MAC data

The 2009 and 2011 MAC data showed a casing restriction as a result of well deformation at 881.9' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-69 shows cross sections at two different depths, taken from the radial arm data collected in the 2011 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the casing restriction

seen at 881.9'. From the radial arm data, it is clear that the well is experiencing a small decrease in the inner diameter at the deformation depth. The minimum diameter at 881.9' is 12.50", which is slightly lower than the minimum diameter of 12.72" at 875'. Figure 3-70 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 881.9'. Although the well has been lined since the March 2011, the deformation observed in the 13 3/8" casing around 882' is likely ongoing and the well should continue to be monitored.

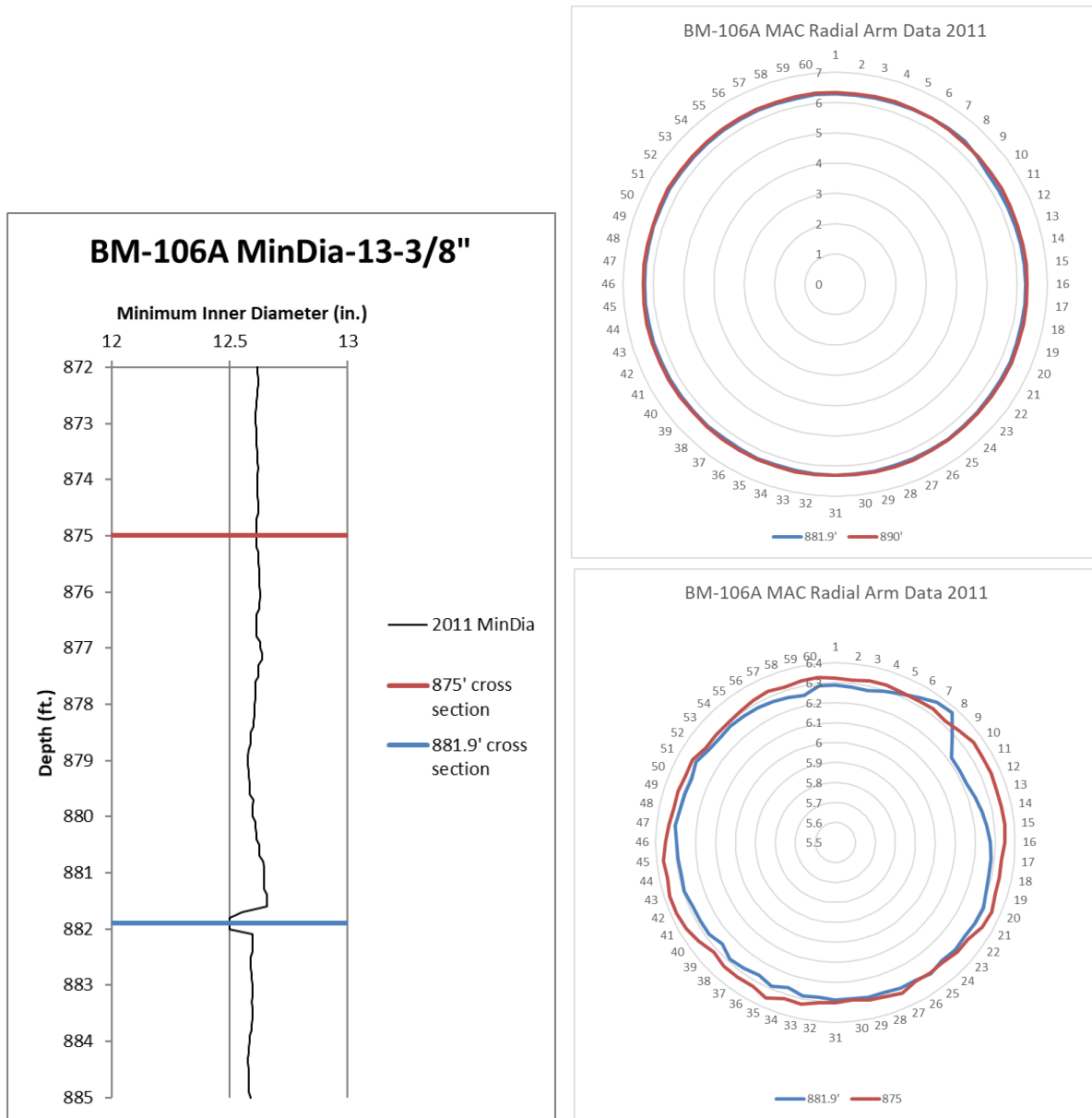


Figure 3-69. Cross sections of BM-106A 2011 MAC data at the depth of casing restriction (blue) and above the restriction (red).

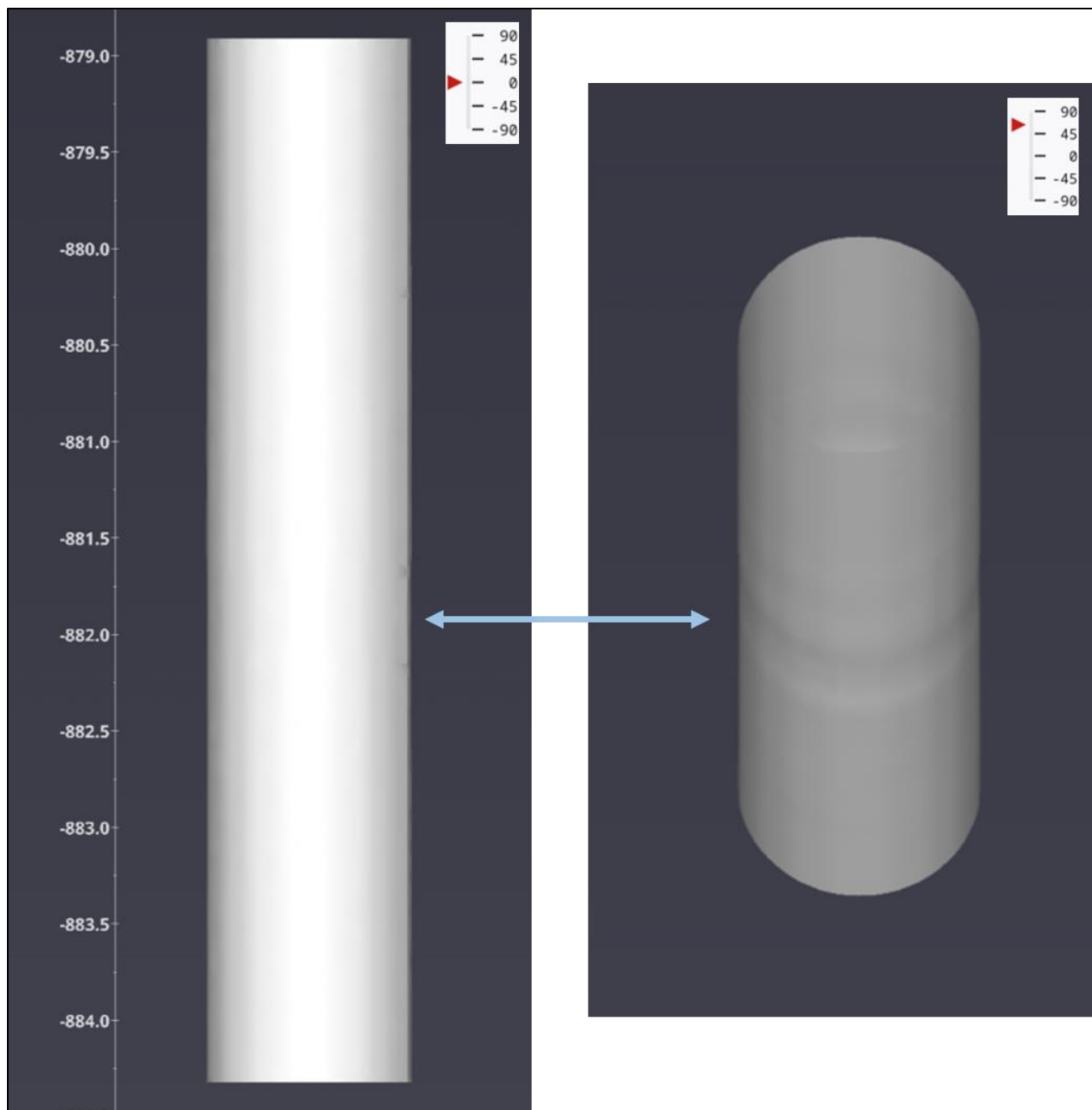


Figure 3-70. 3D visual of BM-106A 2011 MAC radial arm data at the lower casing restriction

3.3.22. *BM-106B*

BM-106B has a total of three MAC logs from October 2011, November 2011, and 2021. The October 2011 log was taken on the 13 3/8" casing. The well was then lined and the November 2011 and 2021 logs were taken on the 10 3/4" liner. Figure 3-71 shows the minimum diameter curves for the 13-3/8" and 10 3/4" casing which were calculated from the October 2011, November 2011, and 2021 MAC logs. From this dataset, a casing restriction was identified in the 13 3/8" casing at 834.2', and a decrease in the minimum diameter curve can be observed at this depth. Although there is

some discrepancy in the baseline values for the November 2011 and 2021 MAC logs, there does not appear to be any casing deformation in the liner as of the 2021 MAC.

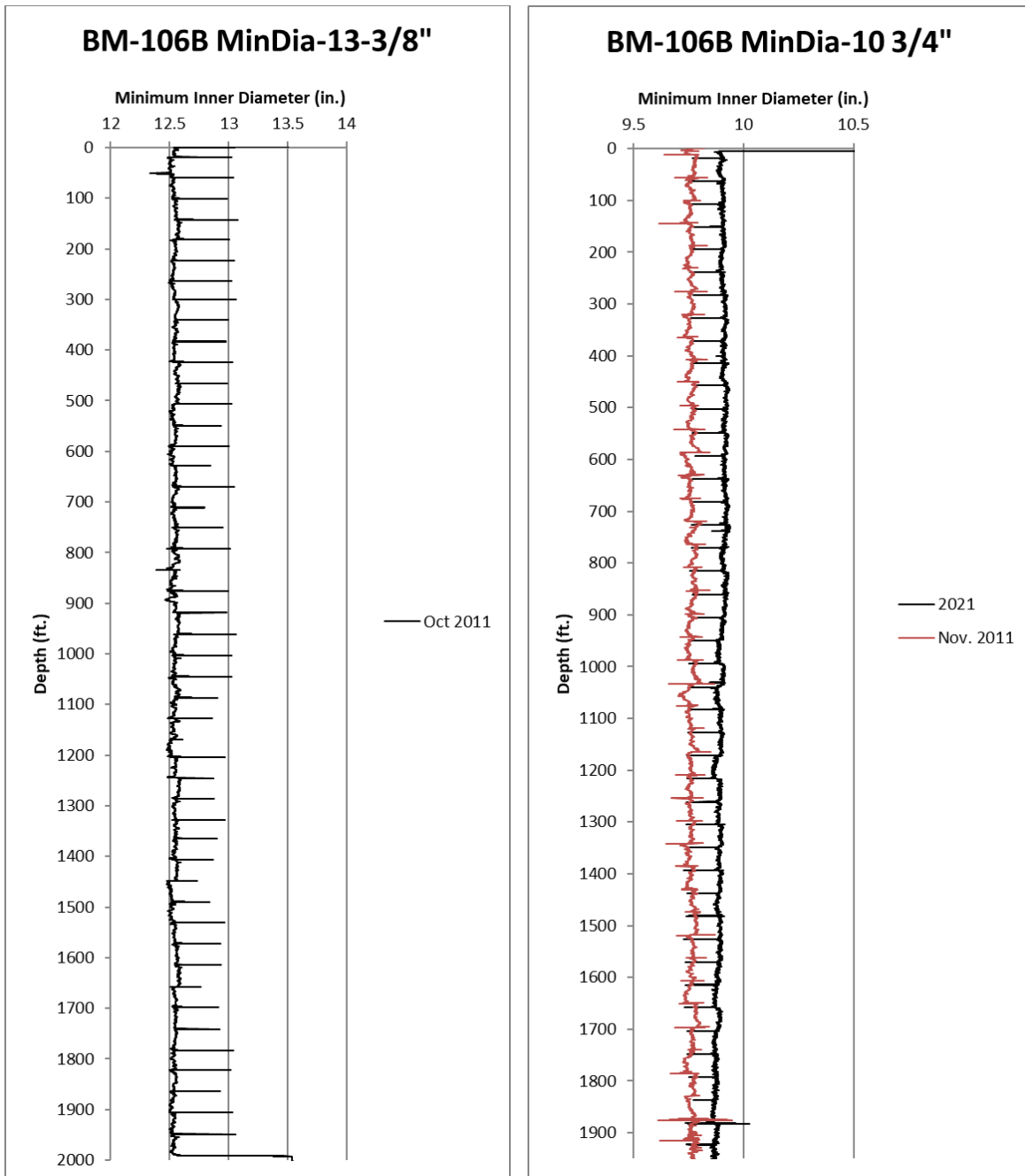


Figure 3-71. BM-106B minimum diameter curves from October 2011, November 2011, and 2021 MAC data

The October 2011 MAC data showed a casing restriction as a result of well deformation at 834.2' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the

inner-casing diameter. Figure 3-72 shows cross sections at two different depths, taken from the radial arm data collected in the October 2011 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth. The minimum diameter at 834.2' is 12.39", which is notably lower than the minimum diameter of 12.53" at 828'. Figure 3-73 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 834.2'. Although the well has been lined since the October 2011 MAC, the deformation observed in the 13 3/8" casing is likely ongoing, and the well should continue to be monitored.

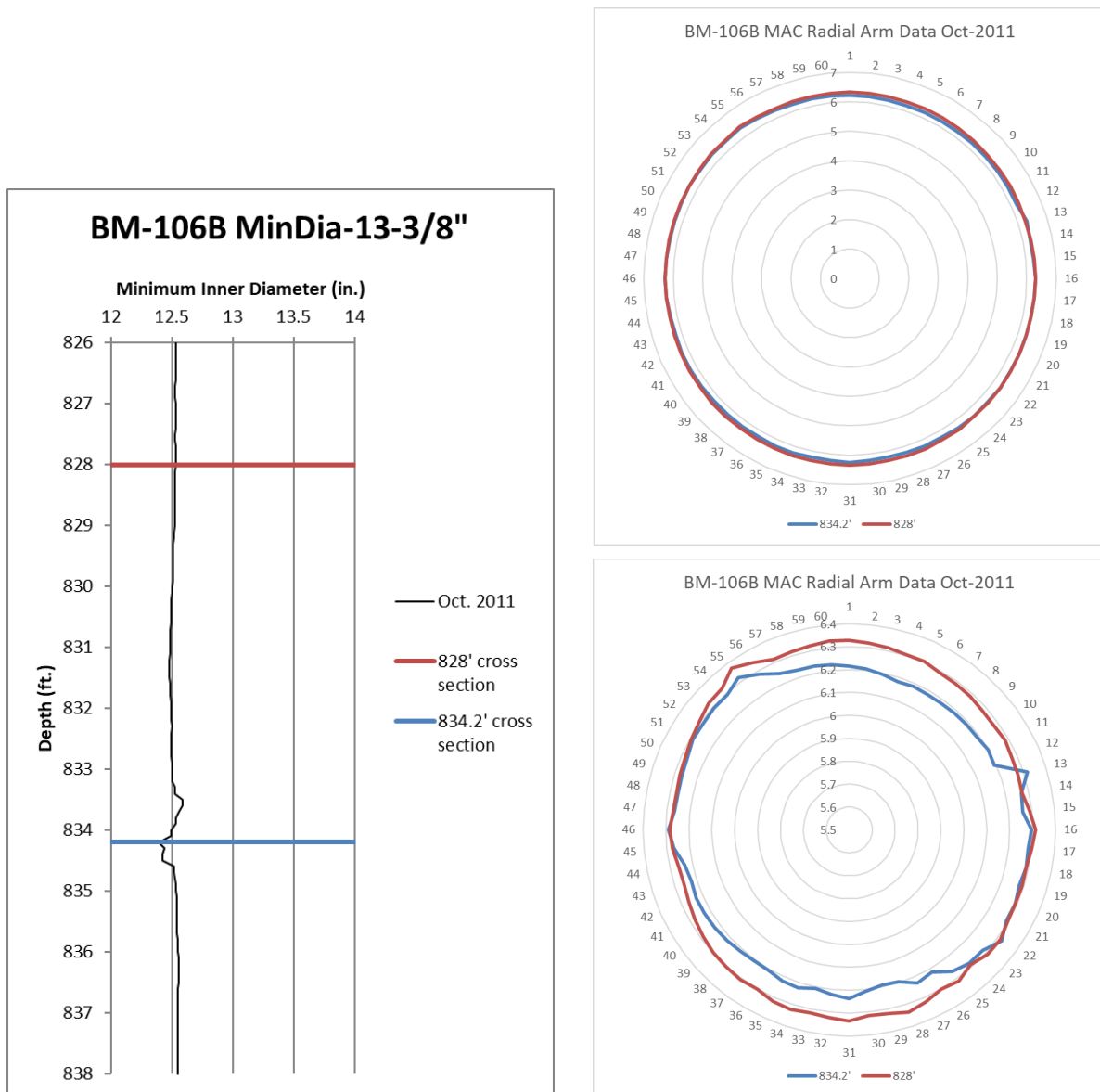


Figure 3-72. Cross sections of BM-106B 2011 MAC data at the depth of casing restriction (blue) and above the restriction (red).

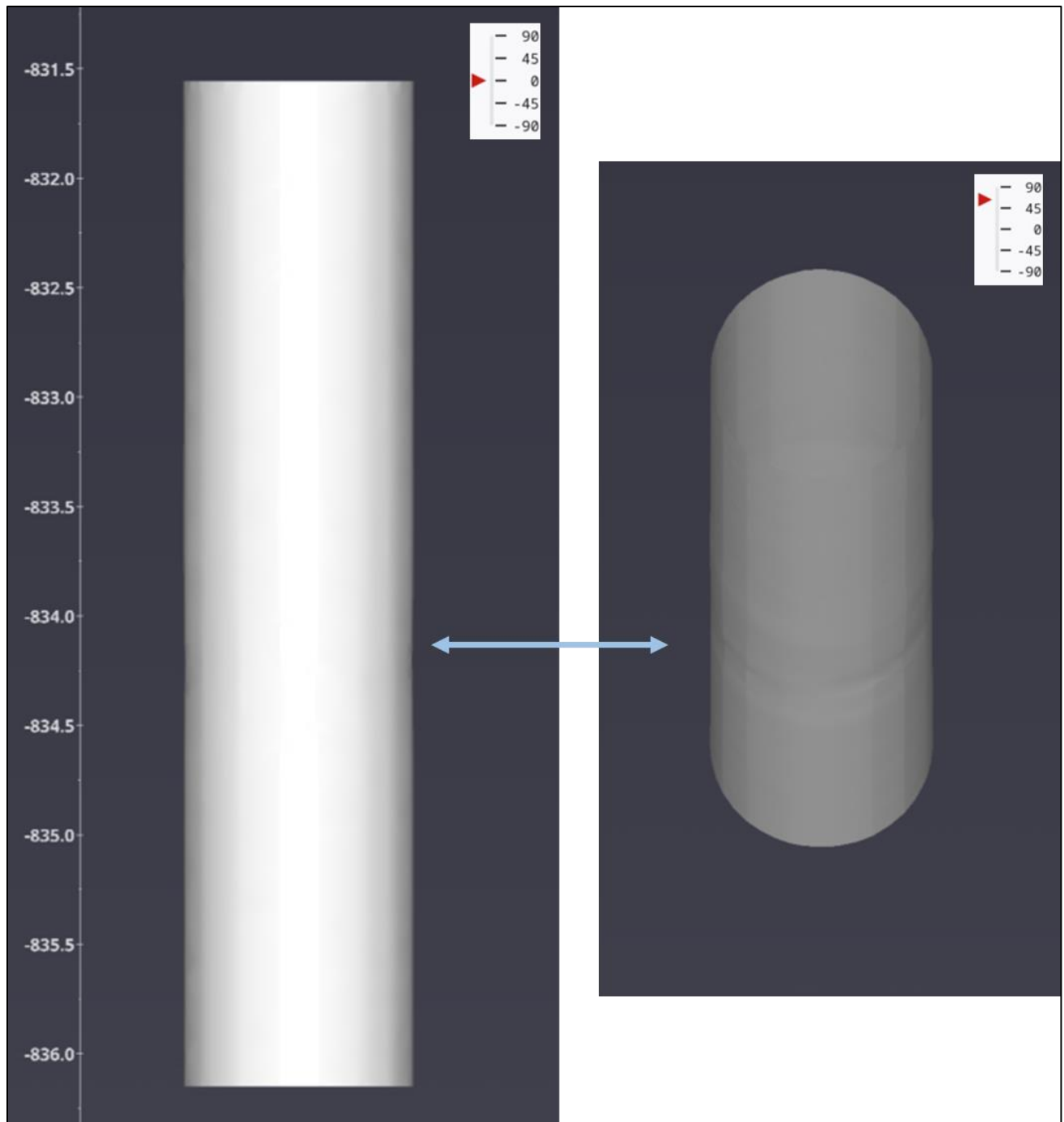


Figure 3-73. 3D visual of BM-106B 2011 MAC radial arm data at the lower casing restriction

3.3.23. BM-106C

BM-106C has a total of four MAC logs from 2011, 2017 (February 3 and February 8), and 2021. All four logs were taken on the 13 3/8" casing. Figure 3-74 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2011, 2017, and 2021 MAC logs. From this dataset, a casing restriction was identified at 848.25', and a decrease in the minimum diameter curve can be observed at this depth. The deformation at 848.25' appears to be worsening with time.

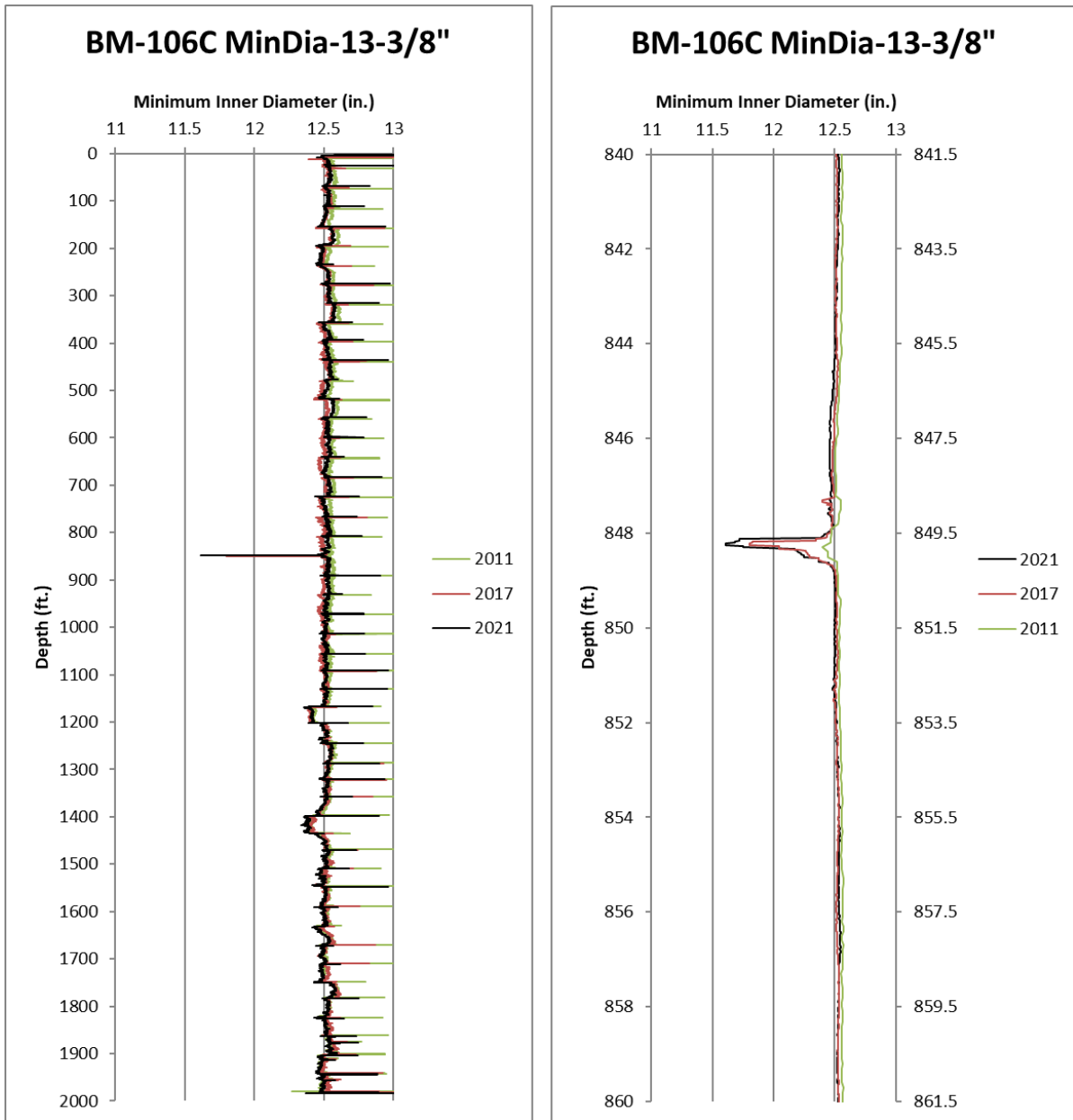


Figure 3-74. BM-106C minimum diameter curves from 2011, 2017, and 2021 MAC data

The 2011, 2017, and 2021 MAC data showed a casing restriction as a result of well deformation at 848.25' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-75 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial

arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth. The minimum diameter at 848.25' is 11.61", which is notably lower than the minimum diameter of 12.51" at 844'. Figure 3-76 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 848.25'.

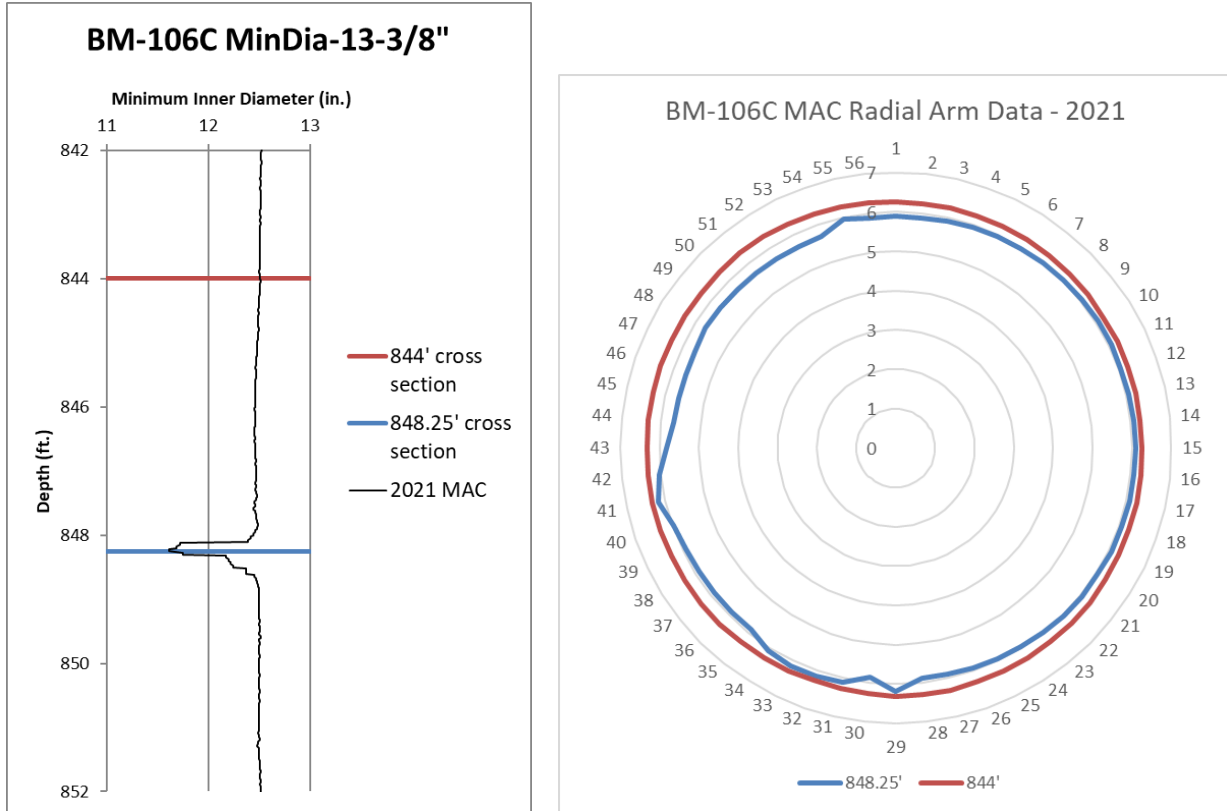


Figure 3-75. Cross sections of BM-106C 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

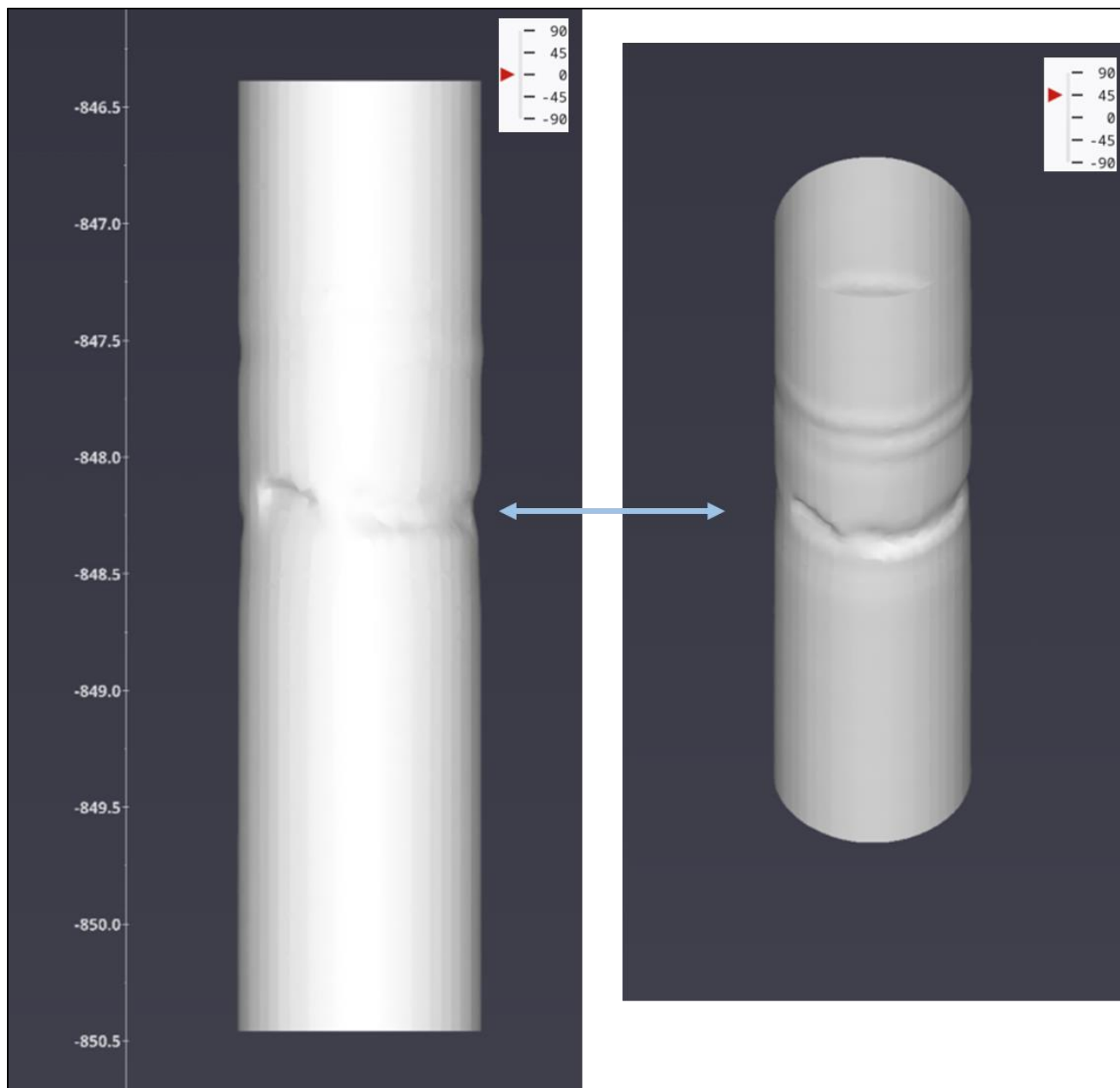


Figure 3-76. 3D visual of BM-106C 2021 MAC radial arm data at the lower casing restriction

3.3.24. BM-107A

BM-107A has a total of four MAC logs from 2010, 2015, 2016, and 2019. All four logs were taken on the 13 3/8" casing. Figure 3-77 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2010, 2015, 2016, and 2019 MAC logs. There are currently no notable signs of collar compression in this well. There has been some minimal deformation noted near the salt-caprock interface around 1073' -1080'. There has also been deformation noted around 1326'-1359' in the salt, which does not seem to be worsening over time.

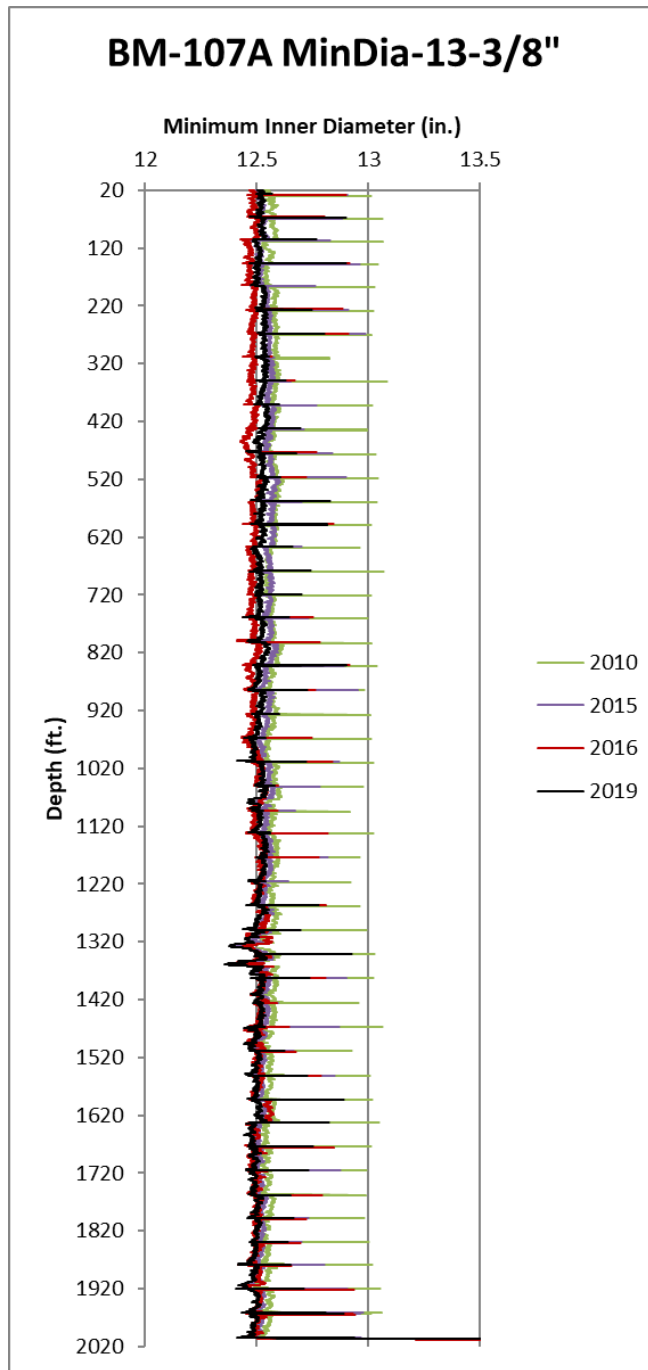


Figure 3-77. BM-107A minimum diameter curves from 2010, 2015, 2016, and 2019 MAC data.

3.3.25. BM-107B

BM-107B has a total of three MAC logs from 2010, 2015, and 2020. All three logs were taken on the 13 3/8" casing. Figure 3-78 shows the minimum and average diameter curves for the 13-3/8" casing which were calculated from the 2010, 2015, and 2020 MAC logs. Some deformation has been noted between 1950' and 2008', likely the result of cement remnants from drilling. A slight decrease in the

minimum casing diameter is also seen around 810.2', which occurs near but not at a collar connection, and does not seem to be getting worse over time and so is not a concern at this time.

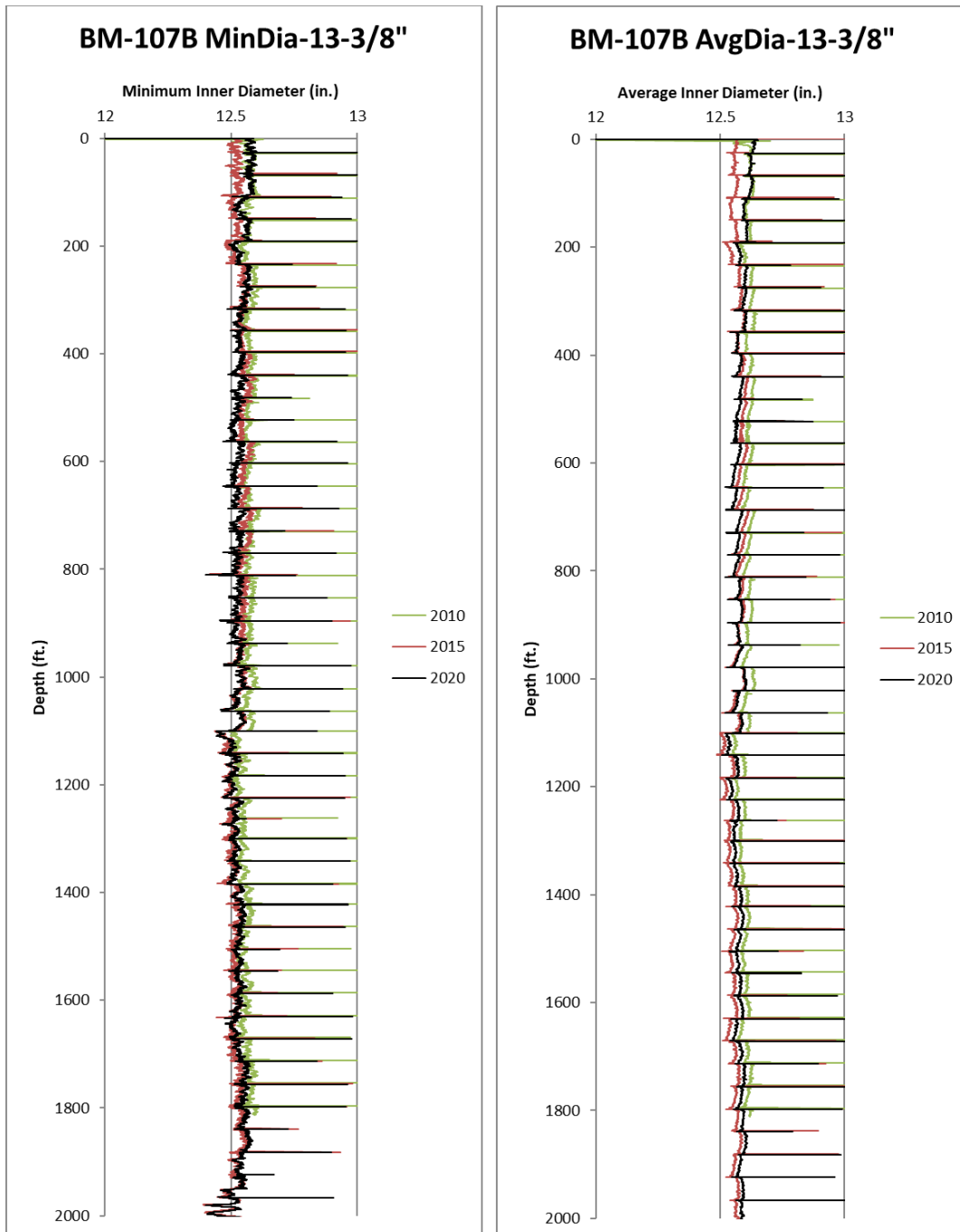


Figure 3-78. BM-107B minimum and average diameter curves from 2010, 2015, and 2020 MAC data.

3.3.26. BM-107C

BM-107C has a total of four MAC logs from 2011, 2016, March 2021, and June 2021. The 2011, 2016, and March 2021 logs were taken on the 13 3/8" casing. The well was then lined and the June

2021 log was taken on the 10 3/4" liner. Figure 3-79 shows the minimum diameter curves for the 13-3/8" casings which were calculated from the 2011, 2016, and March 2021 MAC logs. From this dataset, a casing restriction was identified at 835.85', and a decrease in the minimum diameter curve can be observed at this depth. The deformation in the 13 3/8" casing appears to be worsening with time. Figure 3-80 shows the minimum diameter curve for the 10 3/4" liner, which does not show any signs of a casing restriction.

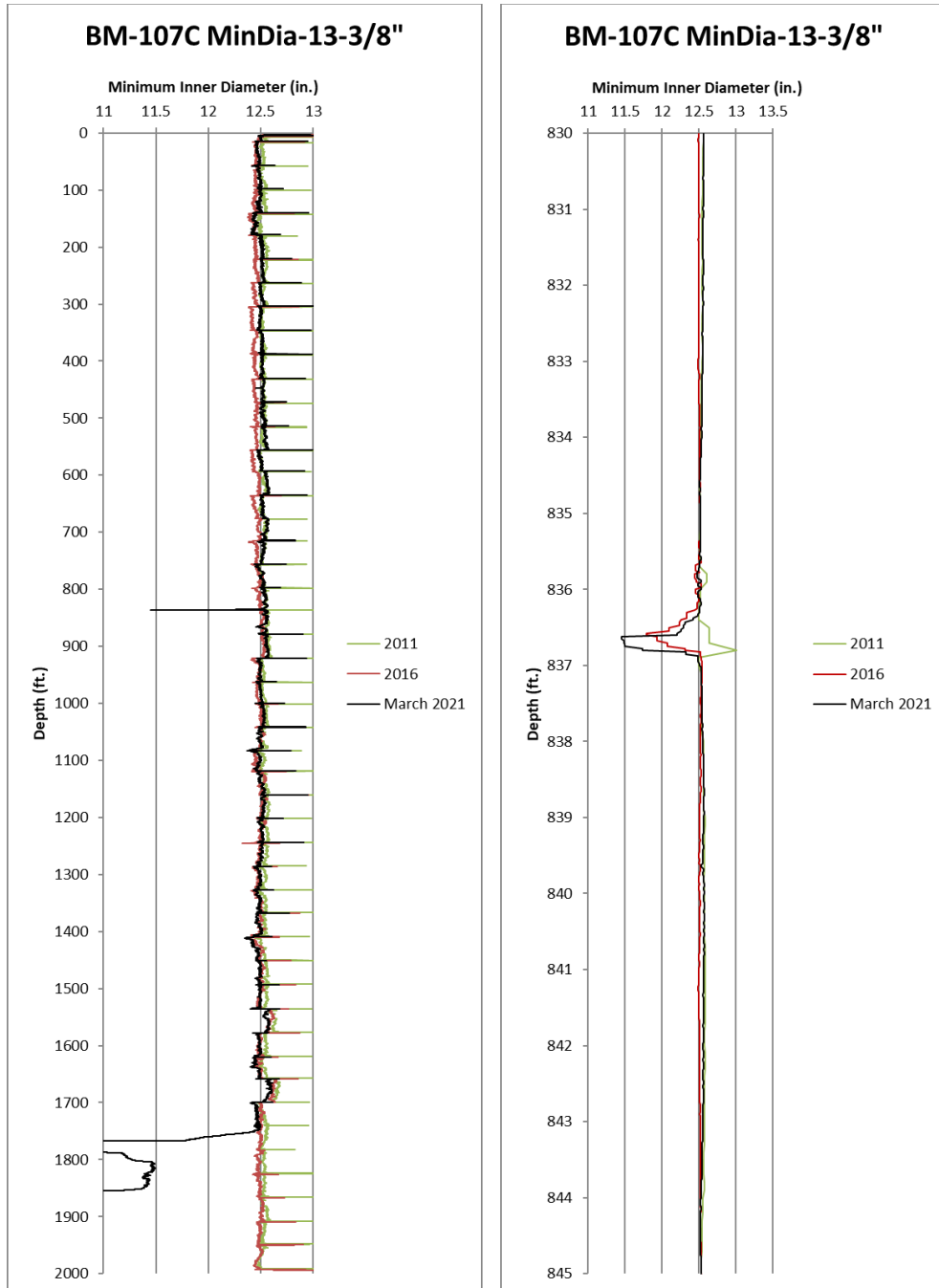


Figure 3-79. BM-107C minimum diameter curves from 2011, 2016 and March 2021 MAC data.

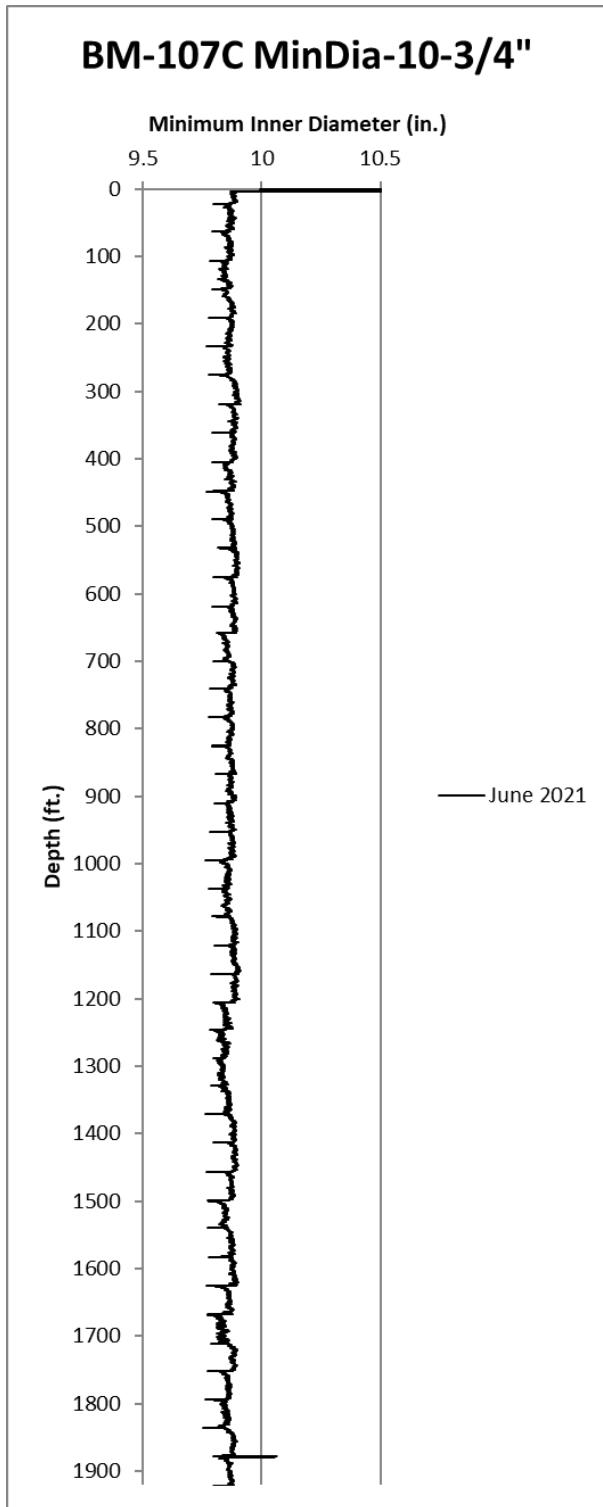


Figure 3-80. BM-107C minimum diameter curves from June 2021 MAC data.

The 2016 and March 2021 MAC data showed a casing restriction as a result of well deformation at 835.85' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a

decrease in the inner-casing diameter. Figure 3-81 shows cross sections at two different depths, taken from the radial arm data collected in the March 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a notable decrease in the inner diameter at the deformation depth. The minimum diameter at 835.85' is 11.45", which is notably lower than the minimum diameter of 12.55" at 832'. Figure 3-82 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed at 835.85'. There also appears to be some deformation around 835', which is likely a result of casing compression as well. Although the well has been lined since the March 2021 MAC, the deformation observed in the 13 3/8" casing around 834' is likely ongoing and the well should continue to be monitored.

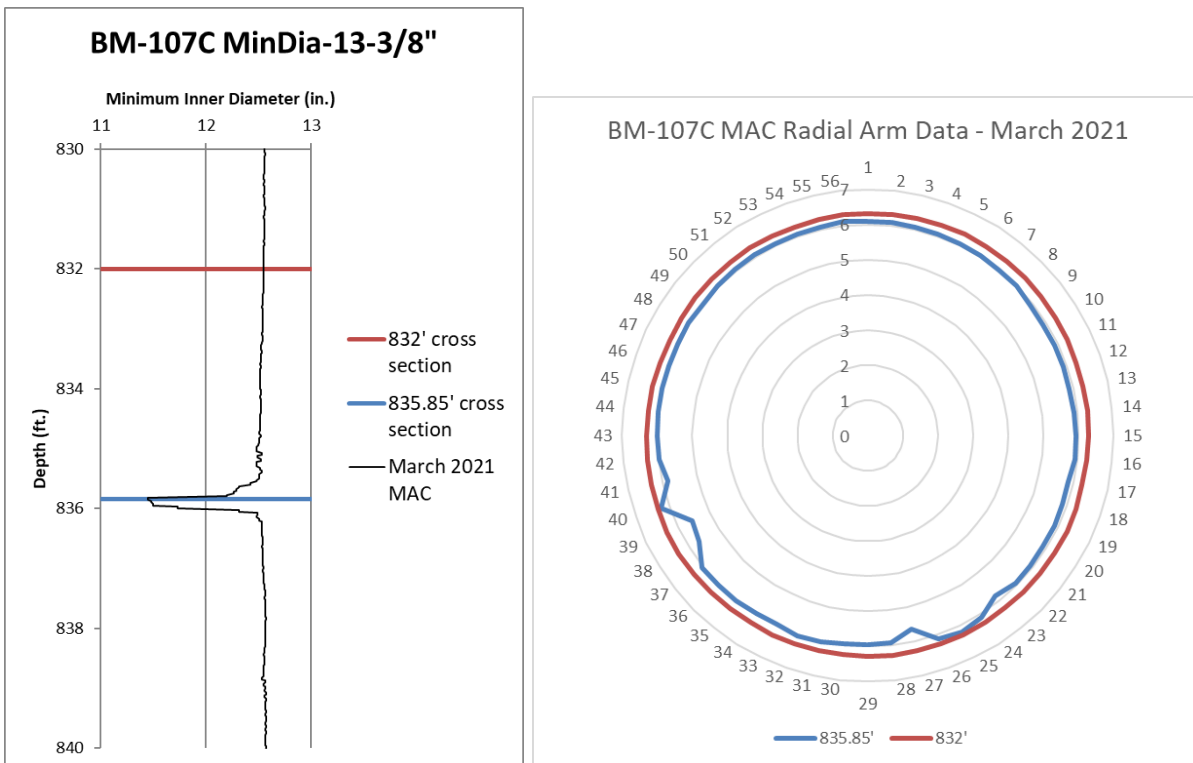


Figure 3-81. Cross sections of BM-107C 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

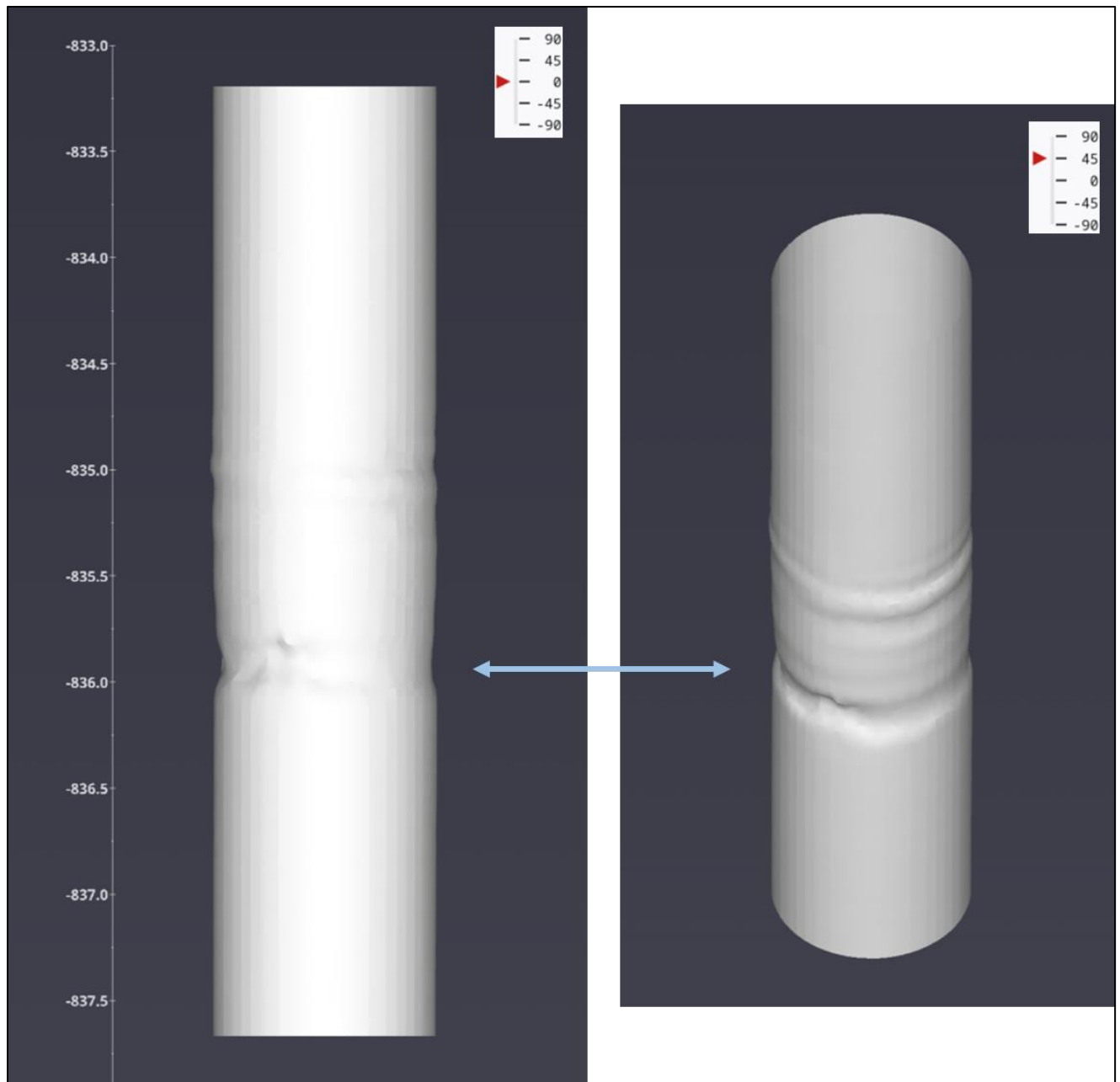


Figure 3-82. 3D visual of BM-107C March 2021 MAC radial arm data at the lower casing restriction

3.3.27. *BM-108A*

BM-108A has a total of two MAC logs from 2010 and 2020. Both logs were taken on the 13 3/8" casing. Figure 3-83 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2010 and 2020 MAC logs. From this dataset, a casing restriction was identified at 865.3', and a decrease in the minimum diameter curve can be observed at this depth. Although there appears to be a slight progression in the casing restriction between the 2010 and 2020 MACs, it is difficult to say whether this a true worsening of the restriction or is a result of normal variation

between the two logs. Some deformation mid-casing has also been noted near the salt-caprock interface around 1040'-1060' which does appear to be moderately increasing over time.

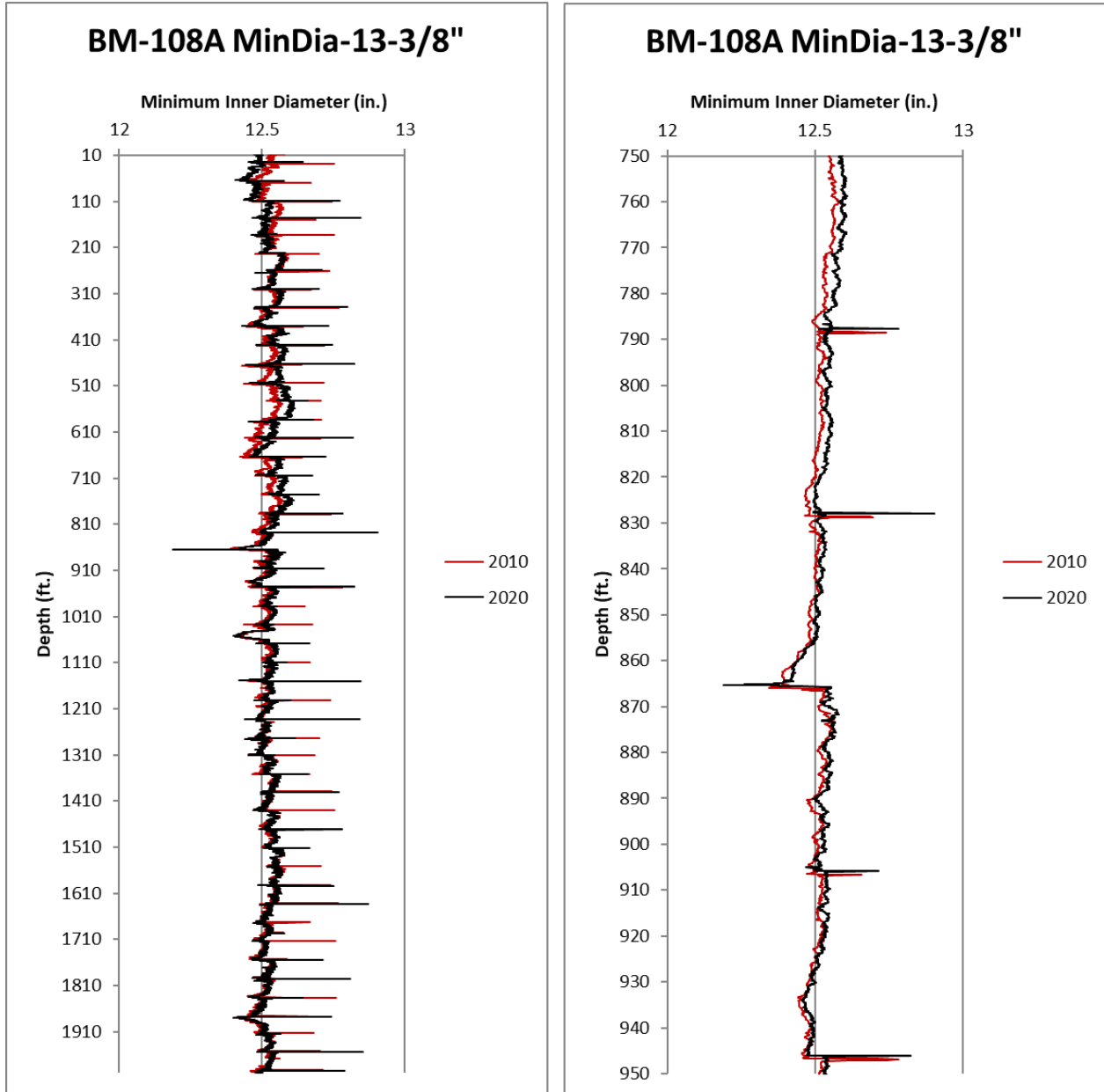


Figure 3-83. BM-108A minimum diameter curves from 2010 and 2020 MAC data.

The 2010 and 2020 MAC data showed a casing restriction as a result of well deformation at 865.3' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-84 shows cross sections at two different depths, taken from the radial arm data collected in the 2020 MAC data. An initial cross section was taken at the minimum

diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 865.3' is 12.19", which is slightly lower than the minimum diameter of 12.43" at 862'. Figure 3-85 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 865.3'.

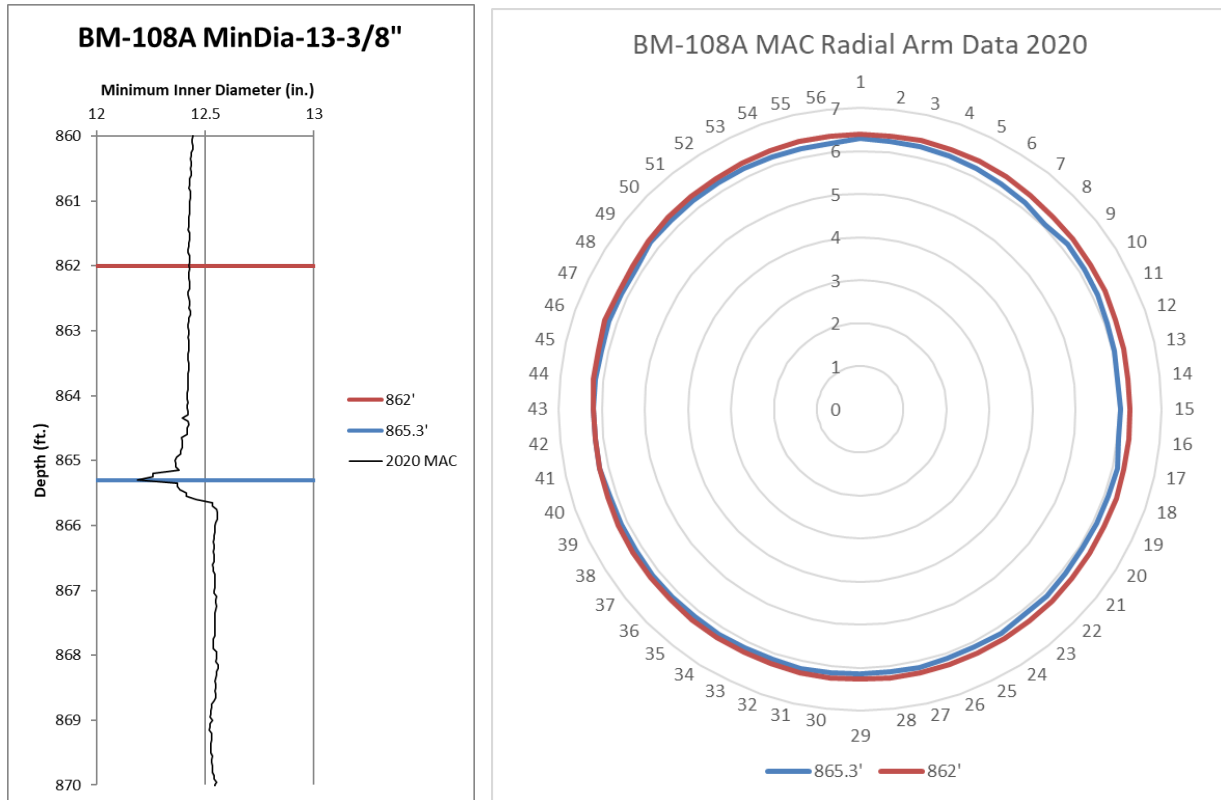


Figure 3-84. Cross sections of BM-108A 2020 MAC data at the depth of casing restriction (blue) and above the restriction (red).

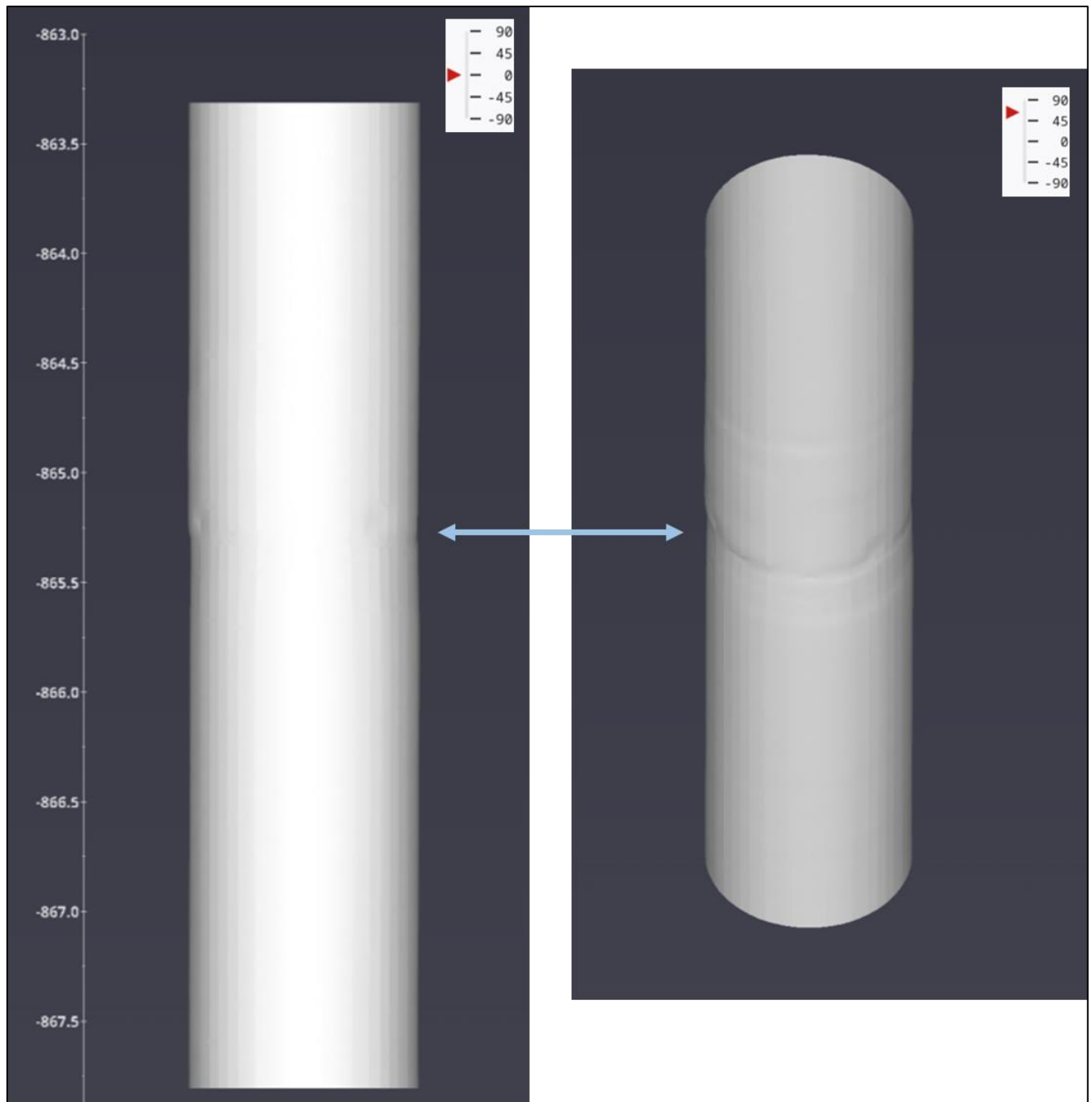


Figure 3-85. 3D visual of BM-108A 2020 radial arm data at the casing restriction

3.3.28. BM-108B

BM-108B has a total of two MAC logs from 2011 and 2021. Both logs were taken on the 13 3/8" casing. Figure 3-86 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2011 and 2021 MAC logs. From this dataset, a casing restriction was identified at 873.9', and a decrease in the minimum diameter curve can be observed at this depth. From the minimum diameter curve, a clear decrease can be observed between the 2011 and 2021 logs as the

minimum diameter progresses from a typical collar kick signature to showing evidence of a casing restriction.

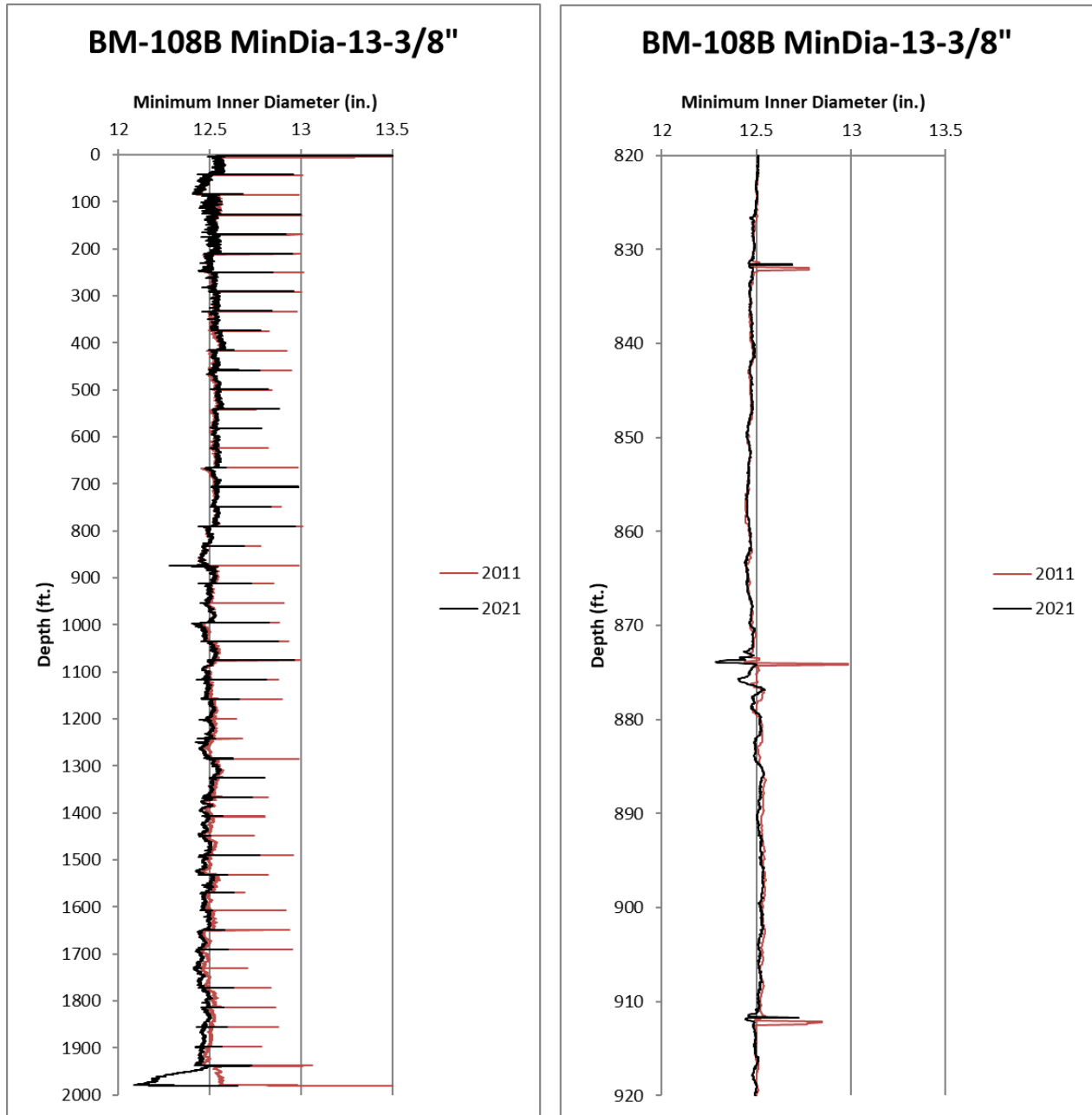


Figure 3-86. BM-108B minimum diameter curves from 2011 and 2021 MAC data.

The 2021 MAC data showed a casing restriction as a result of well deformation at 873.9' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-87 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a

nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the casing restriction seen at 873.9'. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 873.9' is 12.28", which is slightly lower than the minimum diameter of 12.48" at 871'. Figure 3-87 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 873.9'.

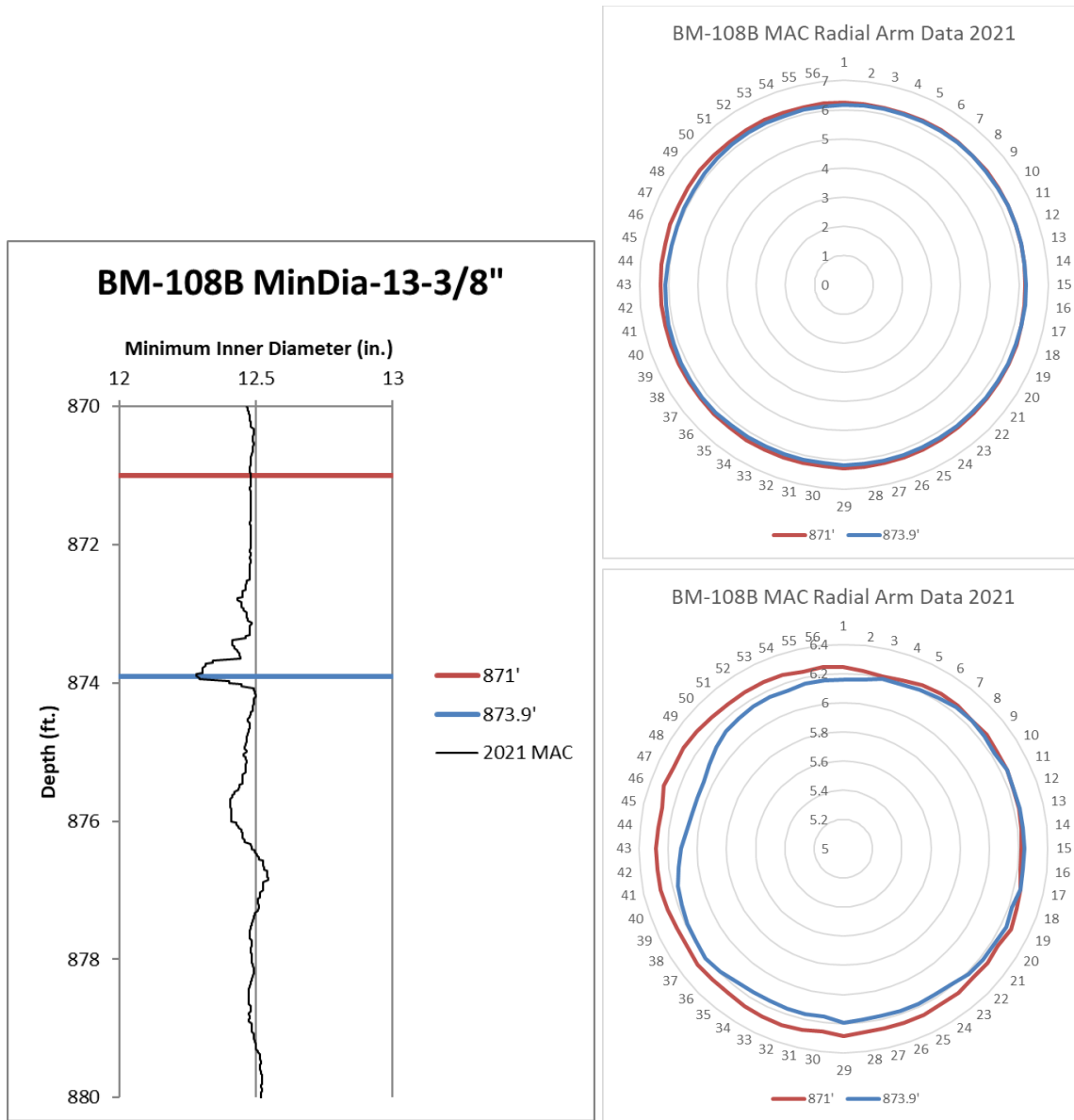


Figure 3-87. Cross sections of BM-108B 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

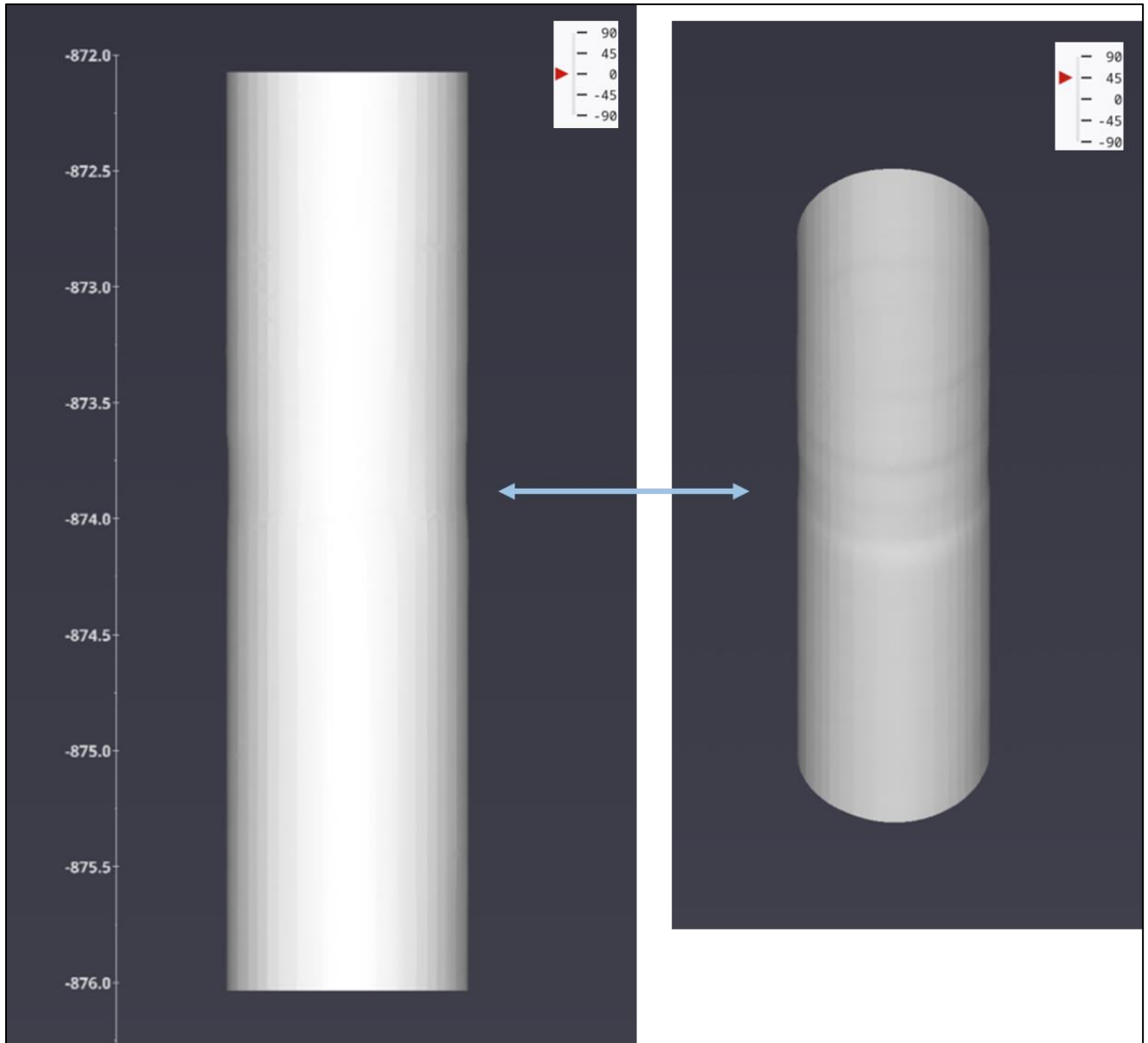


Figure 3-88. 3D visual of BM-108B 2021 MAC radial arm data at the casing restriction

3.3.29. *BM-108C*

BM-108C has two MAC logs from 2011 and 2020 which were both taken on the 9 5/8" casing. Figure 3-89 shows the minimum diameter curves for the 9-5/8" casing which were calculated from the 2011 and 2020 MAC data. It should be noted that the baseline curves are offset, likely the result of differences in tool calibration between the two MAC surveys. Despite the variation in the data, as of the most recent MAC, there are no major deformation locations or collar restrictions observed at this well.

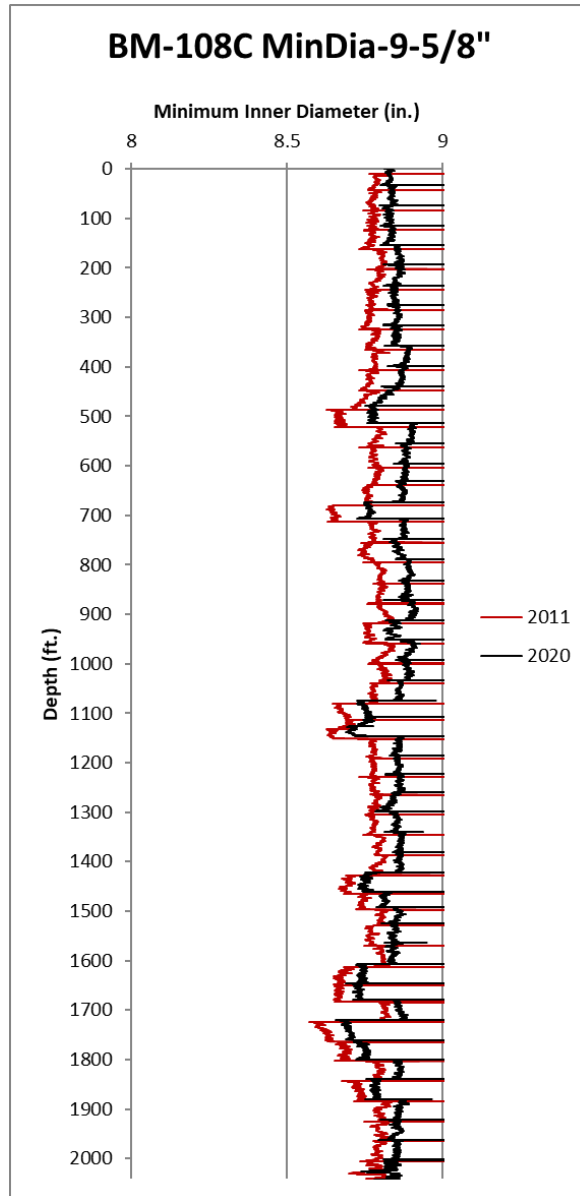


Figure 3-89. BM-108C minimum diameter curves from 2011 and 2020 MAC data.

3.3.30. BM-109A

BM-109A has a total of three MAC logs from 2012, 2016, and 2021. All three logs were taken on the 13 3/8” casing. Figure 3-90 shows the minimum diameter curves for the 13-3/8” casing which were calculated from the 2012, 2016, and 2021 MAC logs. From this dataset, a casing restriction was identified at 828.8’, and a decrease in the minimum diameter curve can be observed at this depth. A clear progression can be observed at the deformation location between the 2012 and 2021 logs as the minimum diameter curve goes from a typical collar kick signature to showing evidence of a casing restriction. Some deformation has also been noted at the salt-caprock interface around 1070’, which has shown a notable increase between MAC logs.

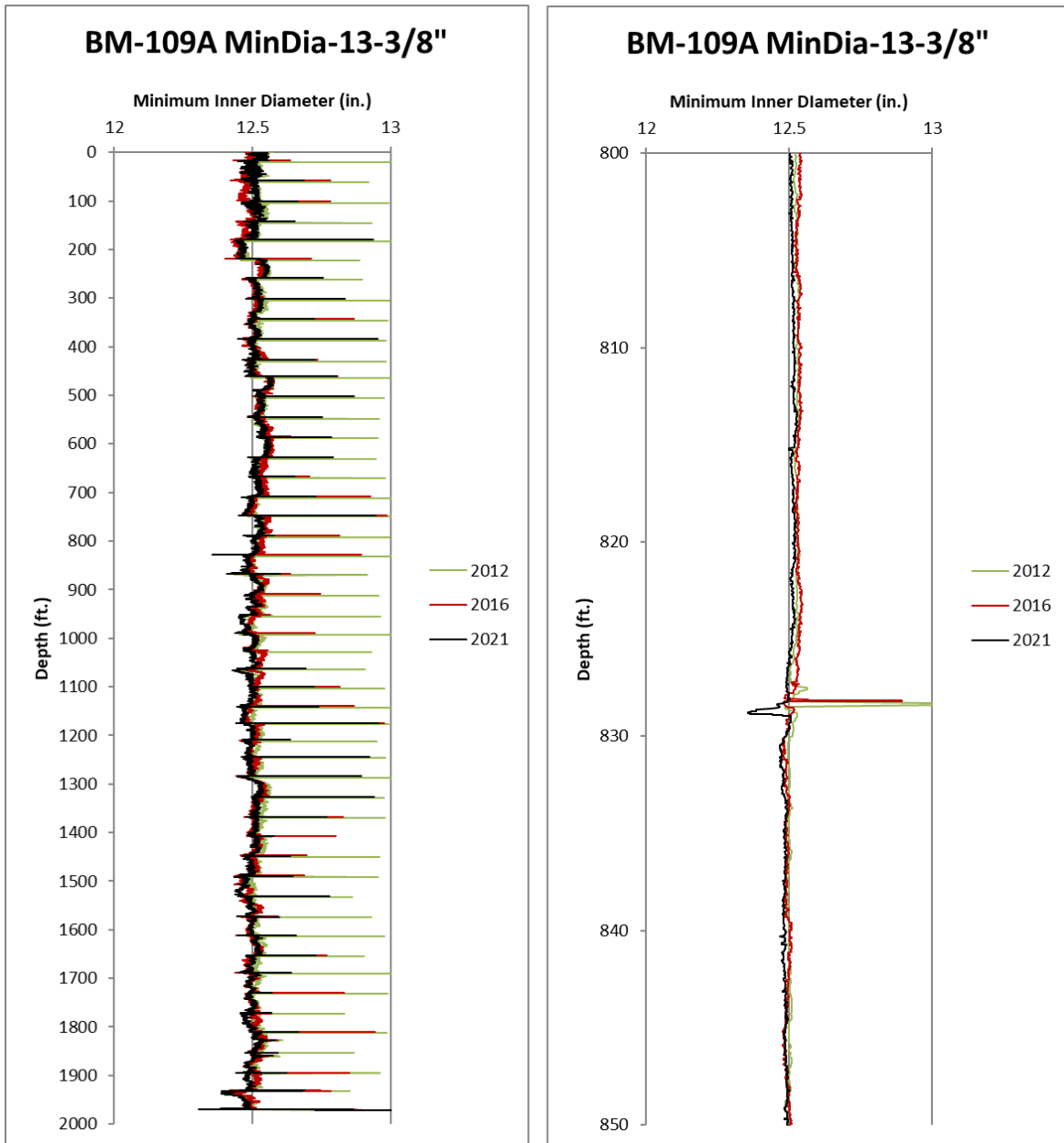


Figure 3-90. BM-109A minimum diameter curves from 2012, 2016, and 2021 MAC data.

The 2021 MAC data showed a casing restriction as a result of well deformation at 828.8' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-91 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the casing restriction seen at 828.8'. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 828.8' is 12.35", which is slightly

lower than the minimum diameter of 12.50" at 826'. Figure 3-92 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 828.8'.

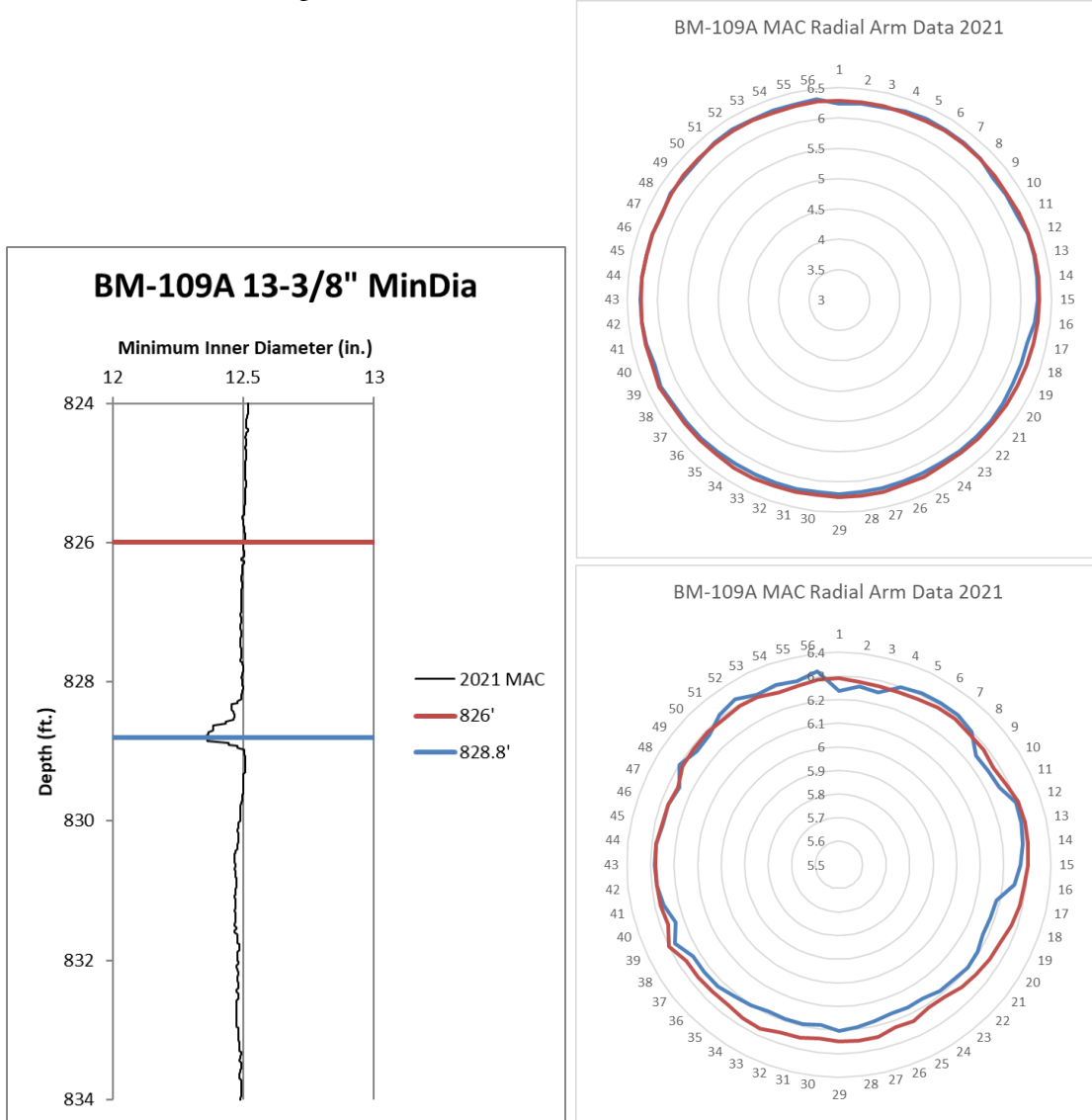


Figure 3-91. Cross sections of BM-109A 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

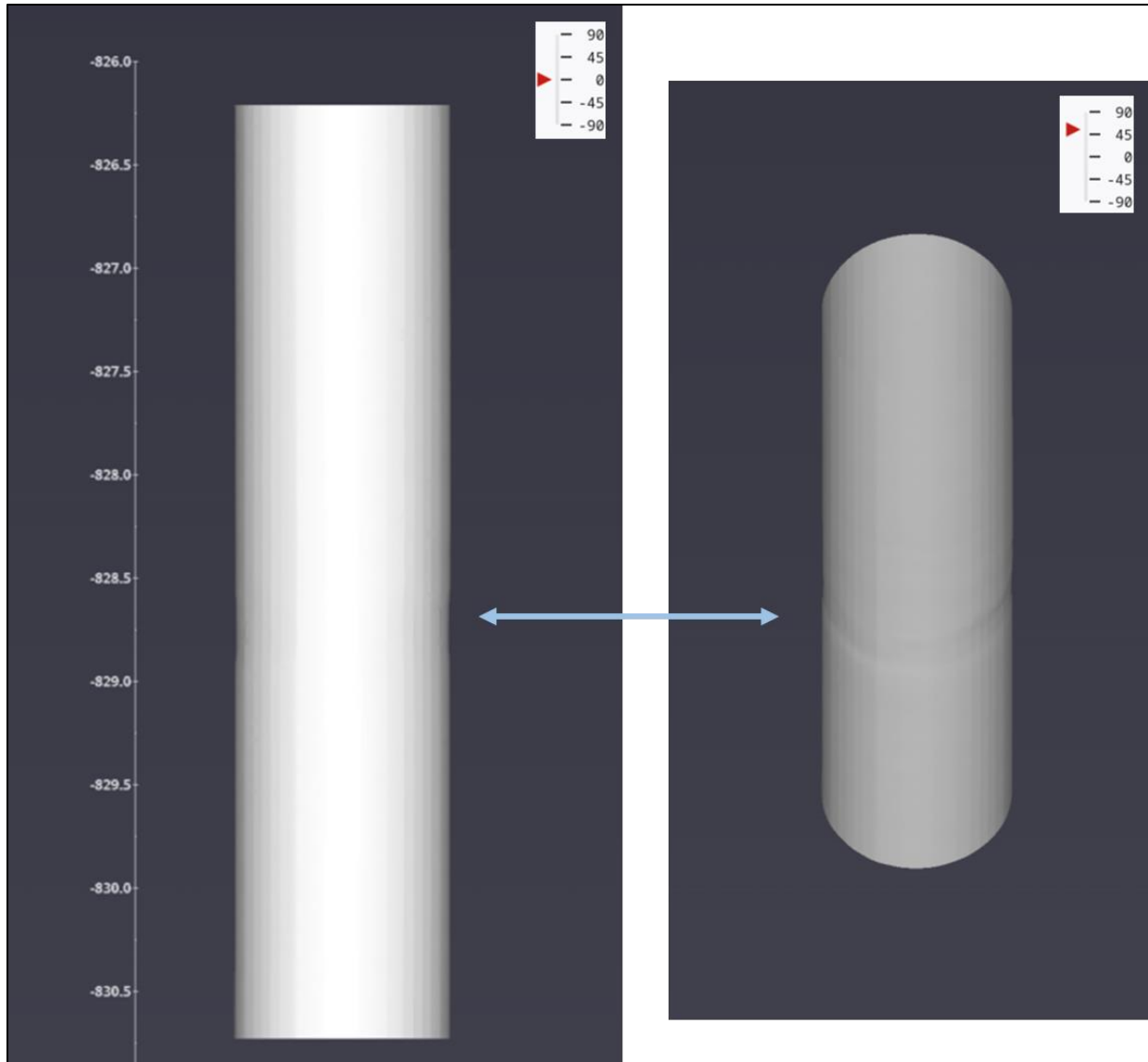


Figure 3-92. 3D visual of BM-109A 2021 radial arm data at the casing restriction

3.3.31. BM-109B

BM-109B has a total of three MAC logs from 2011, 2016, and 2021. All three logs were taken on the 13 3/8" casing. Figure 3-93 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2011, 2016, and 2021 MAC logs. From this dataset, a casing restriction was identified at 825.9', and a decrease in the minimum diameter curve can be observed at this depth. It does not appear to be significantly worsening with time between the 2011 and 2021 logs. Some mid-casing deformation has also been identified around 1215', which does not appear to be rapidly worsening.

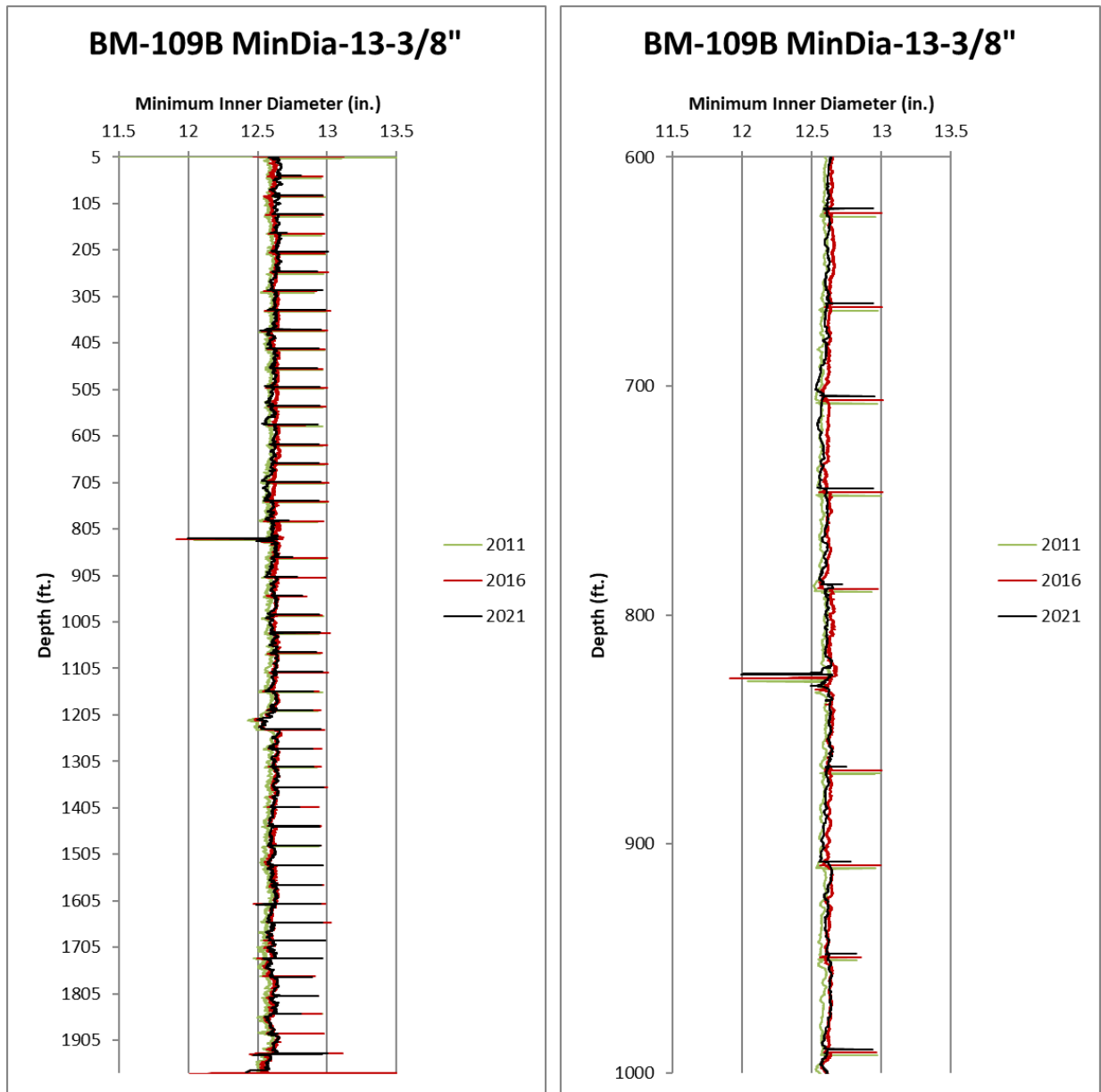


Figure 3-93. BM-109B minimum diameter curves from 2011, 2016, and 2021 MAC data.

The 2011, 2016, and 2021 MAC data showed a casing restriction as a result of well deformation at 825.9' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-94 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 825.9' is 12.00", which is notably lower than the minimum diameter of 12.64" at 821'. Figure 3-95 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 825.9'.

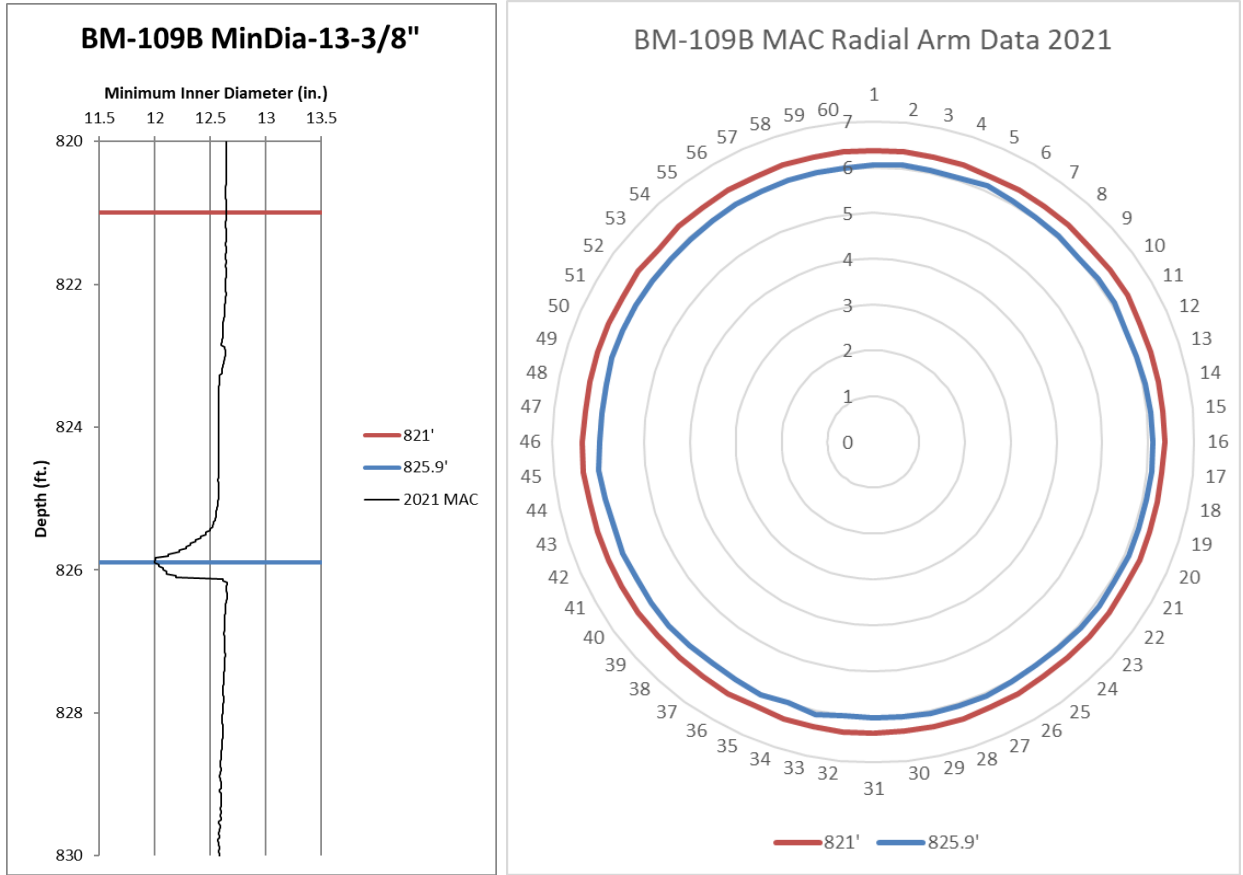


Figure 3-94. Cross sections of BM-109B 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

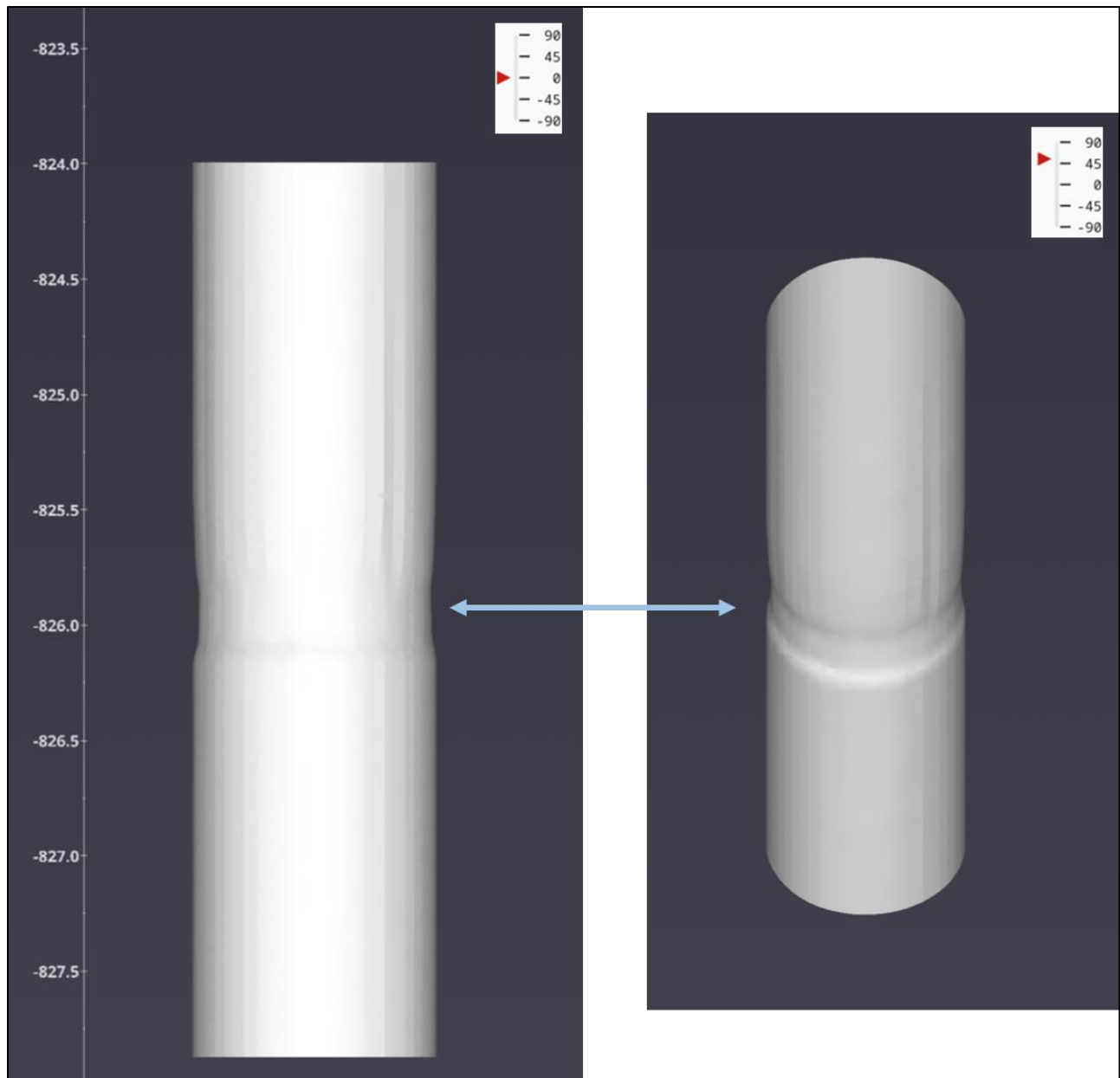


Figure 3-95. 3D visual of BM-109B 2021 radial arm data at the casing restriction

3.3.32. *BM-109C*

BM-109C has a total of two MAC logs from 2009 and 2019. Both logs were taken on the 13 3/8" casing. Figure 3-96 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2009 and 2019 MAC logs. While some deformation has been noted near the salt-caprock interface around 1028' that appears to be moderately increasing, there are no collar restrictions observed in the well at this time.

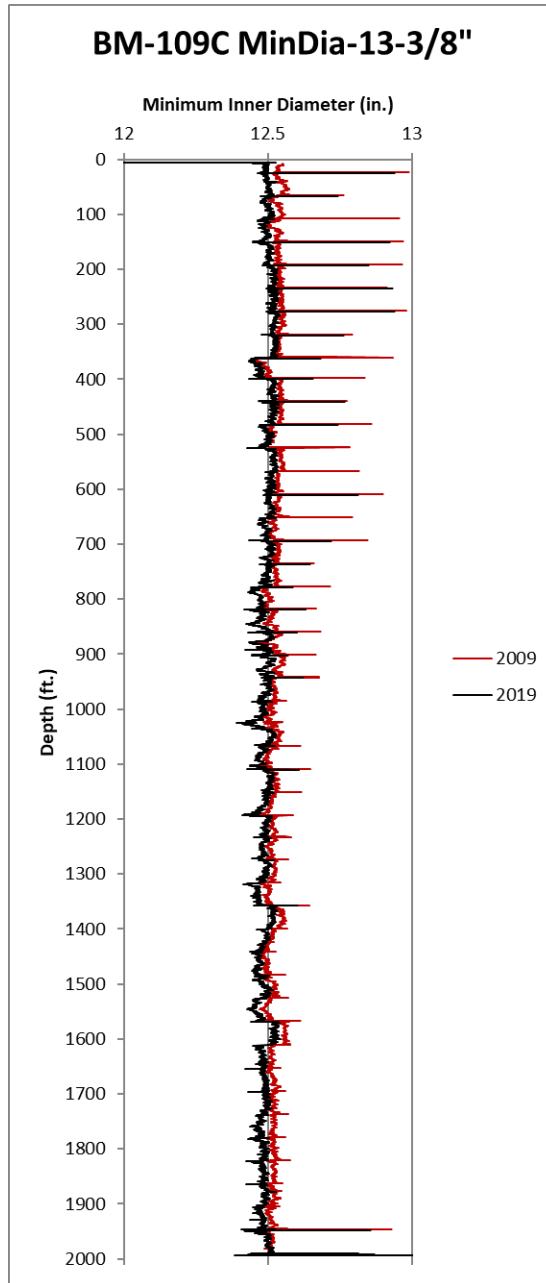


Figure 3-96. BM-109C minimum diameter curves from 2009 and 2019 MAC data.

3.3.33. BM-110A

BM-110A has a total of four MAC logs from 2011, 2016 (May 20 and May 25), and 2021. All four logs were taken on the 13 3/8" casing. Figure 3-97 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2011, 2016 (May 20 and May 25), and 2021 MAC logs. From this dataset, a casing restriction was identified at 844.65', and a decrease in the minimum diameter curve can be observed at this depth. This deformation appears to be worsening with time. Some additional mid-casing deformation has also been identified around 990' which does show signs of a potential increase in deformation.

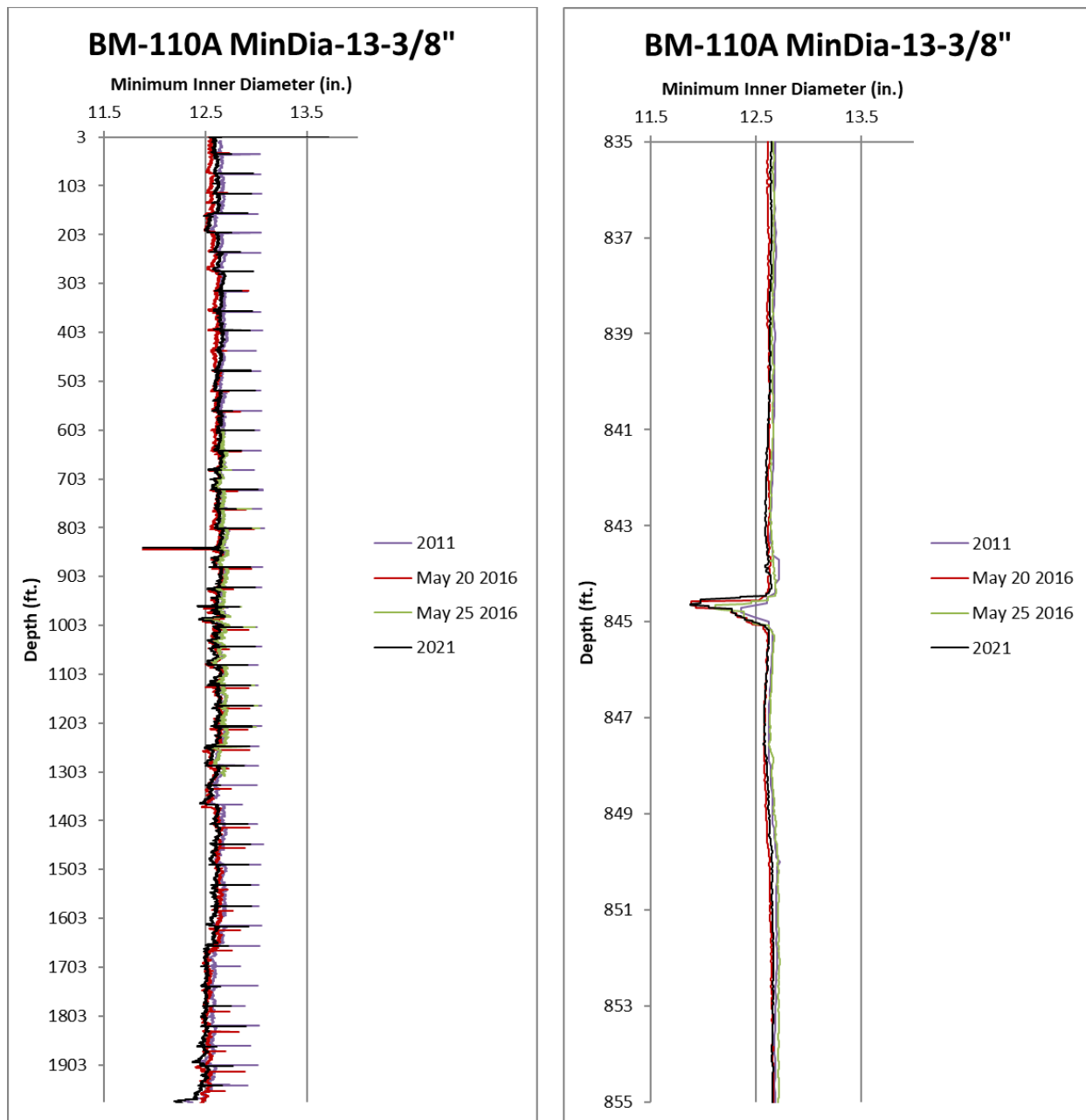


Figure 3-97. BM-110A minimum diameter curves from 2011, 2016, and 2021 MAC data.

The 2011, 2016 (5/20 and 5/25), and 2021 MAC data showed a casing restriction as a result of well deformation at 844.65' on the 13 3/8" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-98 shows cross sections at two different depths, taken from the radial arm data collected in the 2021 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 844.65' is 11.88", which is notably lower than the

minimum diameter of 12.62" at 841'. Figure 3-99 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 844.65'.

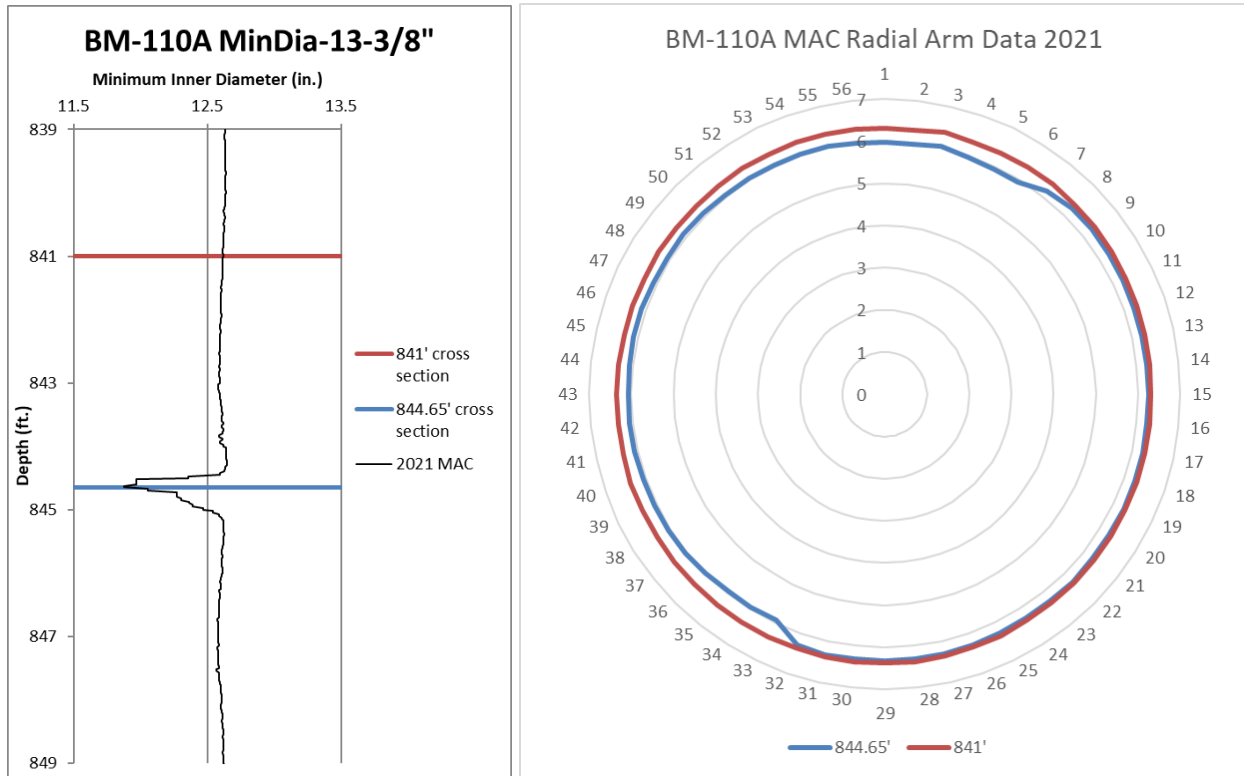


Figure 3-98. Cross sections of BM-110A 2021 MAC data at the depth of casing restriction (blue) and above the restriction (red).

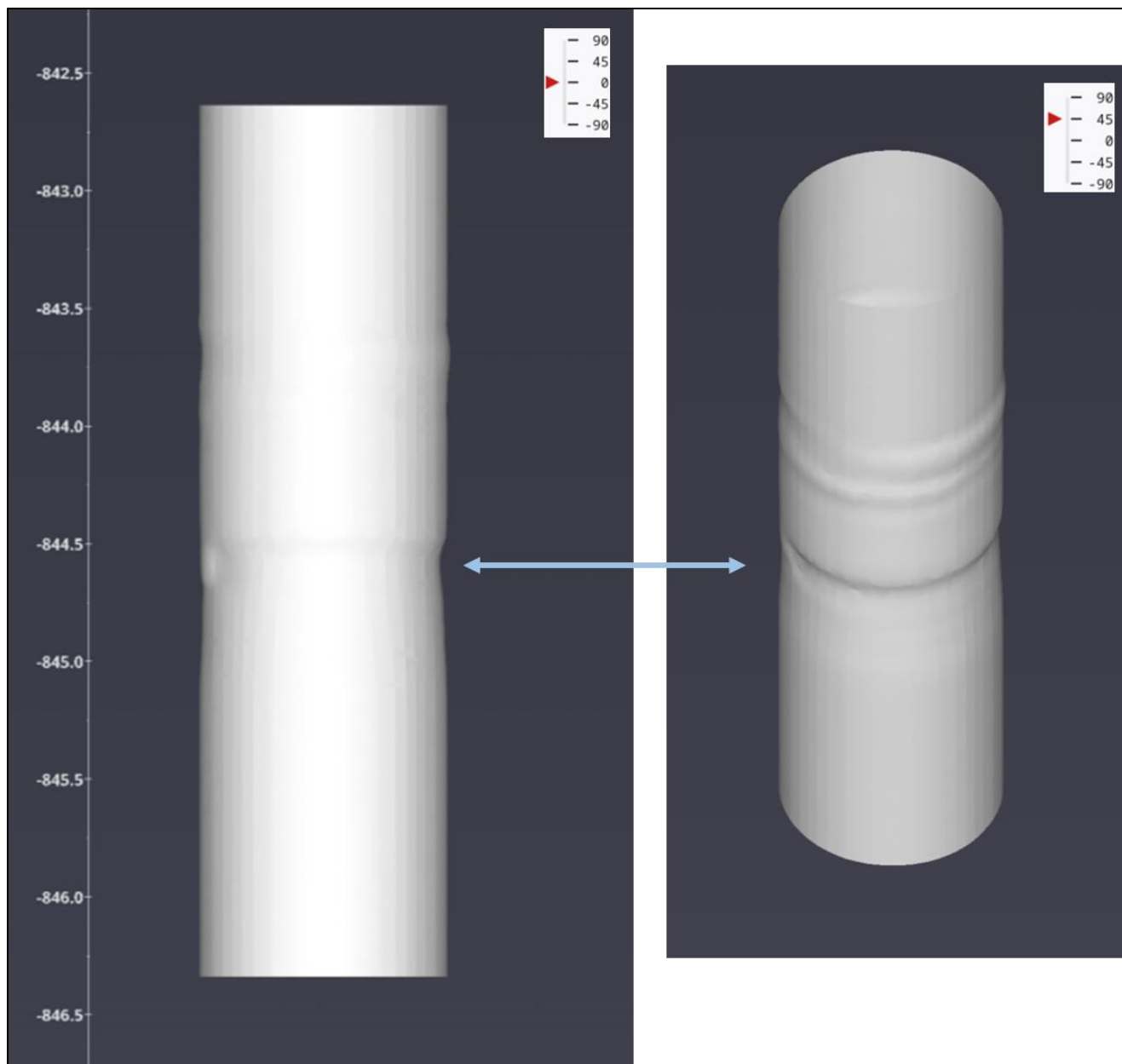


Figure 3-99. 3D visual of BM-110A 2021 radial arm data at the casing restriction

3.3.34. *BM-110B*

BM-110B has a total of three MAC logs from 2011, 2016, and 2021. All three logs were taken on the 13 3/8" casing. Figure 3-100 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2011, 2016, and 2021 MAC data. There are currently no collar restrictions observed at this well. There is some minor radial deformation throughout the well, however there are no significant concerns at this time.

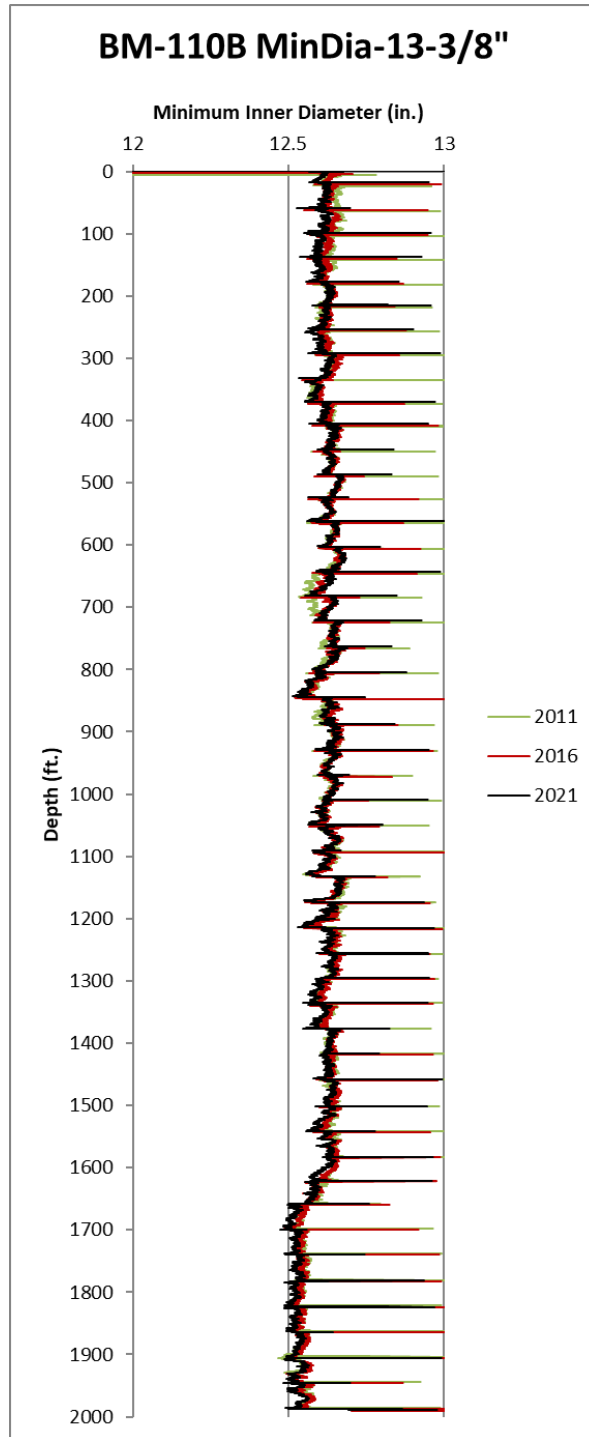


Figure 3-100. BM-110B minimum diameter curves from 2011, 2016, and 2021 MAC data.

3.3.35. *BM-110C*

BM-110C has a total of three MAC logs from 2009, 2014, and 2020. All three logs were taken on the 13 3/8” casing. Figure 3-101 shows the minimum diameter curves for the 13-3/8” casing which were calculated from the 2009, 2014, and 2020 MAC logs. There are no substantial casing

restrictions as a result of collar compression observed in the MAC data for this well. There is some minimal decreases in diameter seen throughout the well however they do not appear to be worsening with time and are likely a result of the initial well installation.

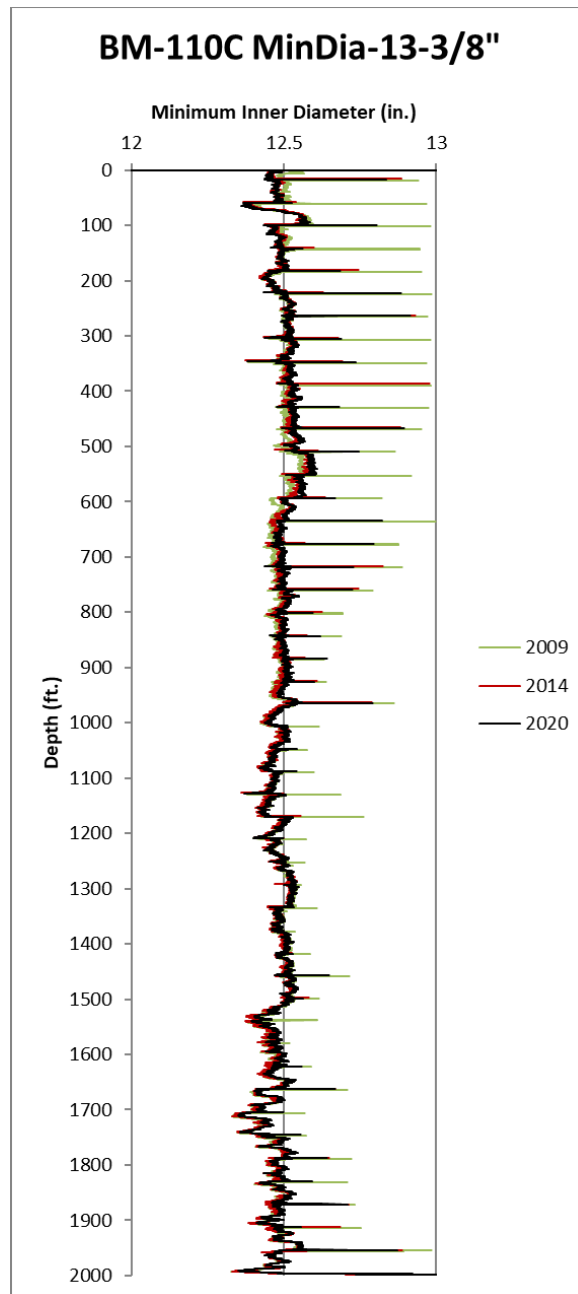


Figure 3-101. BM-110C minimum diameter curves from 2009, 2014, and 2020 MAC data.

3.3.36. BM-111A

BM-111A has a total of two MAC logs from 2011 and 2021. Both logs were taken on the 16" casing. Figure 3-102 shows the minimum and average diameter curves for the 16" casing which were calculated from the 2011 and 2021 MAC data. There are no substantial casing restrictions as a result

of collar compression observed in the MAC data for this well. There are several areas where the minimum diameter decreases, however these spikes are not present when looking at the average diameter curve and so likely do not represent collar compression. For example, the mid-casing restriction seen around 894' is the result of 3-4 arm readings at that depth and does not seem to be caused by external geological forces. Although these isolated instances of decreases in the minimum diameter should be noted, they are not of major concern at this time.

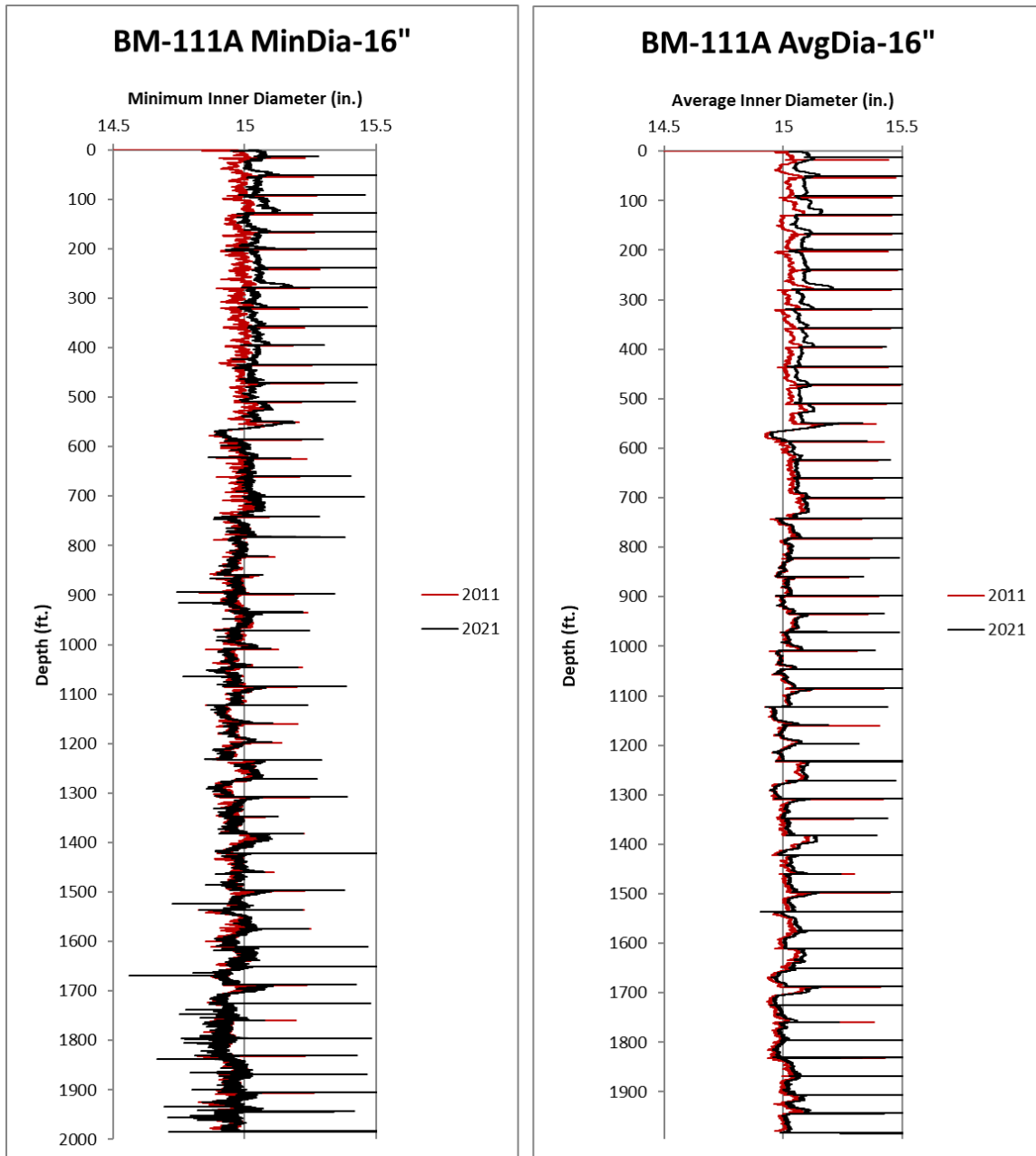


Figure 3-102. BM-111A minimum diameter curves from 2011 and 2021 MAC data.

3.3.37. BM-111B

BM-111B has a total of two MAC logs from 2011 and 2021. Both logs were taken on the 16” casing. Figure 3-103 shows the minimum and average diameter curves for the 16” casing which were calculated from the 2011 and 2021 MAC data. Although there are some isolated decreases in minimum diameter values for the 2021 log, they are not present in the average diameter curves and do not occur at a casing collar. There they are not of major concern at the moment.

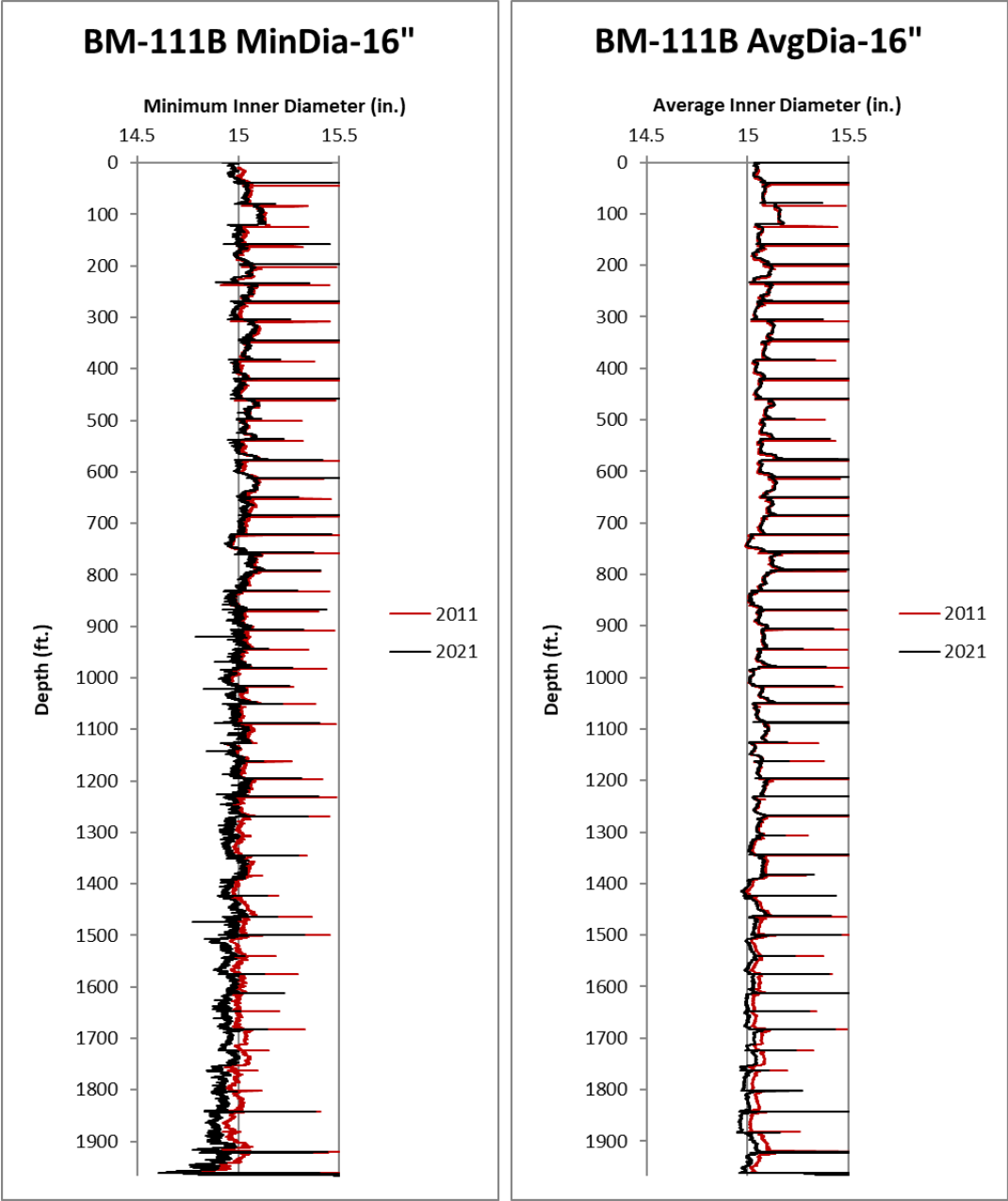


Figure 3-103. BM-111B minimum and average diameter curves from 2011 and 2021 MAC data.

3.3.38. BM-112A

BM-112A has a total of two MAC logs from 2011 and 2015. Both logs were taken on the 16” casing. Figure 3-104 shows the minimum diameter curves for the 16” casing which were calculated from the 2011 and 2015 MAC logs. From this dataset, a casing restriction was identified at 887.3’, and a decrease in the minimum diameter curve can be observed at this depth, which has significantly worsened between the two logs.

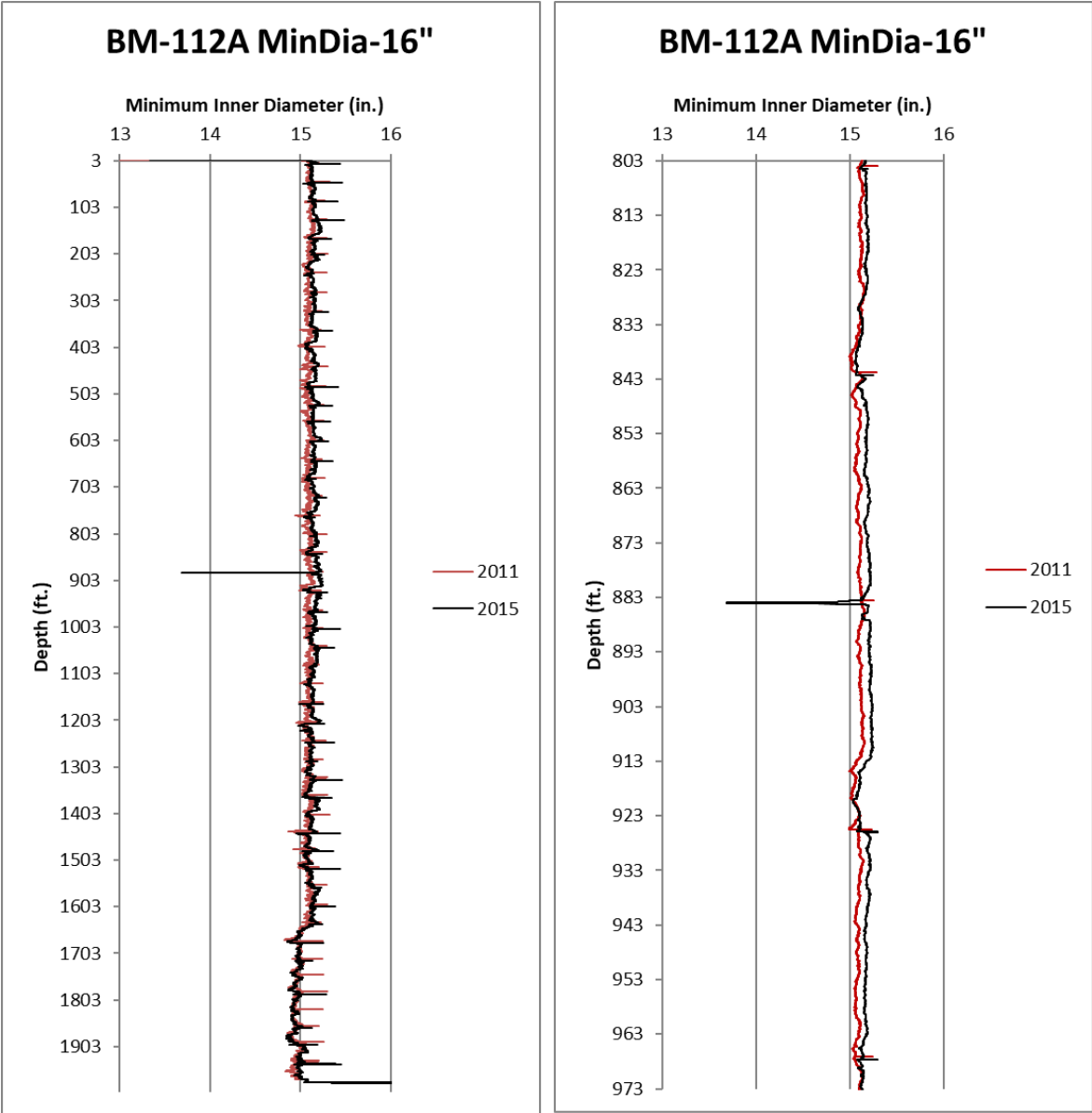


Figure 3-104. BM-112A minimum diameter curves from 2011 and 2015 MAC data.

The 2015 MAC data showed a casing restriction as a result of well deformation at 887.3' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-105 shows cross sections at two different depths, taken from the radial arm data collected in the 2015 MAC data. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section from a nearby depth that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a slight decrease in the inner diameter at the deformation depth. The minimum diameter at 887.3' is 13.67", which is notably lower than the minimum diameter of 15.22" at 883'. Figure 3-106 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be observed at 887.3'.

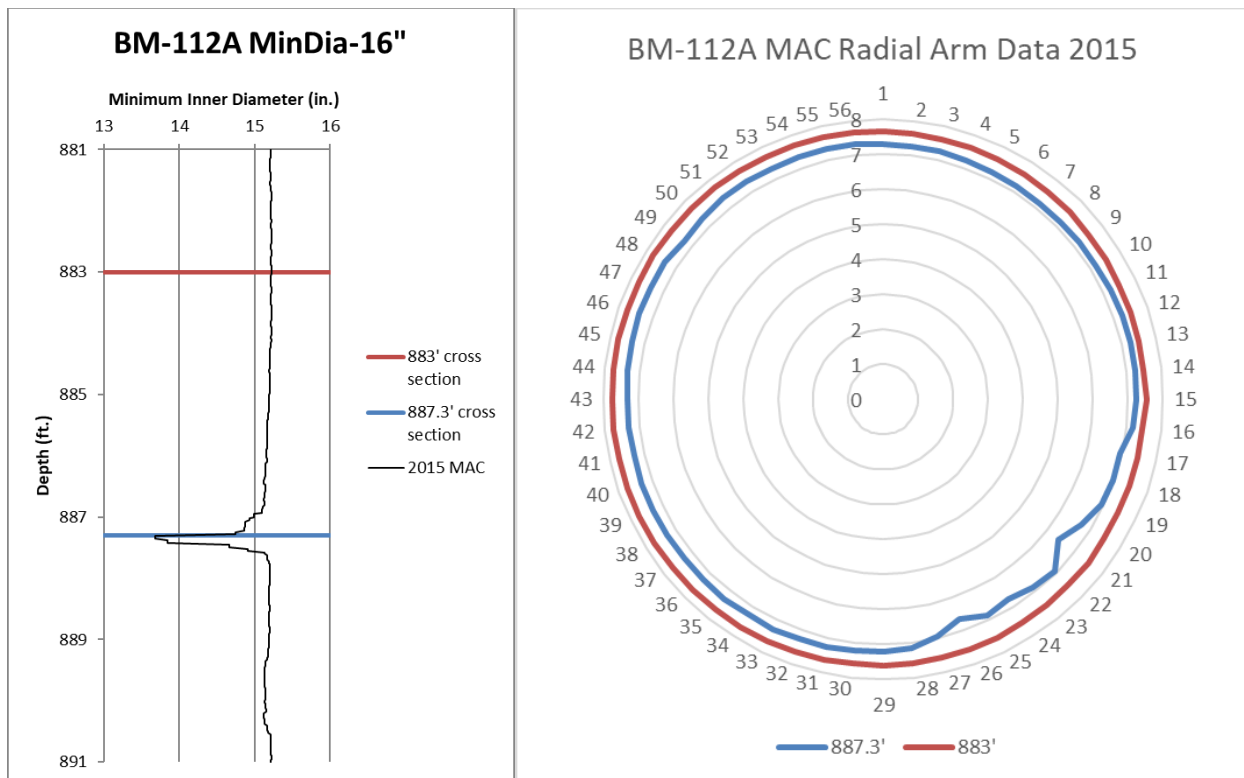


Figure 3-105. Cross sections of BM-112A 2015 MAC data at the depth of casing restriction (blue) and above the restriction (red).

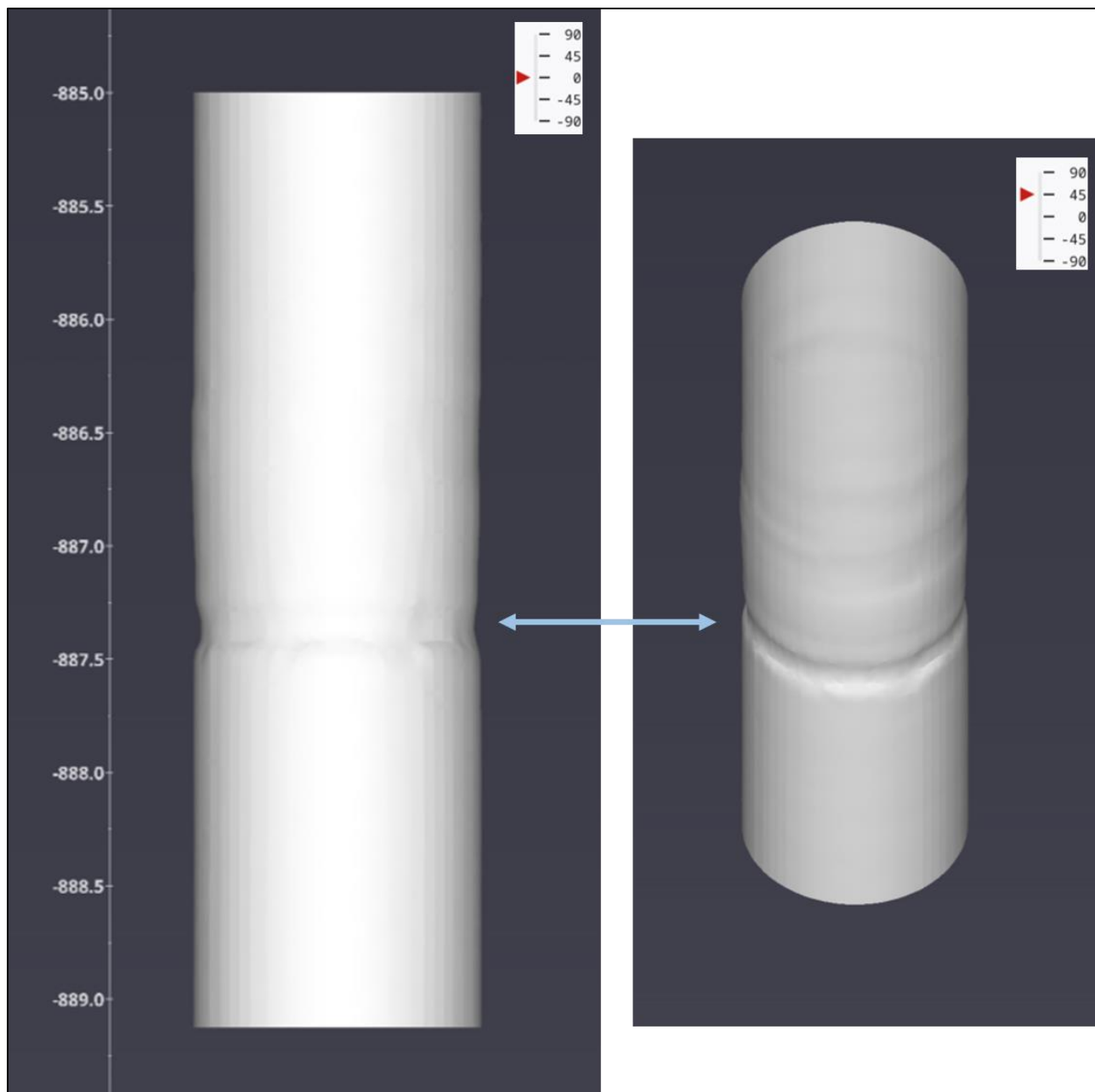


Figure 3-106. 3D visual of BM-112A 2015 radial arm data at the casing restriction

3.3.39. *BM-112C*

BM-112C has a total of three MAC logs from 2011, July 2014, and October 2014. The 2011 and July 2014 logs were taken on the 16" casing. The well was then lined, and the October 2014 log was taken on the 13 3/8" casing. Figure 3-107 shows the minimum diameter curves for the 16" casing which were calculated from the 2011 and July 2014 MAC logs. From this dataset, a casing restriction was identified at 873.6', and a decrease in the minimum diameter curve can be observed at this depth. Although there appears to be a slight progression in the minimum diameter between the 2011 and July 2014 MACs, it is difficult to say whether this a true worsening of the restriction, or is a result of normal variation between the two logs, as there also seem to be some other baseline offset issues between the two logs. Figure 3-108 shows the minimum diameter curve for the 13 3/8"

casing which was calculated from the October 2014 MAC and does not show any signs of a casing restriction.

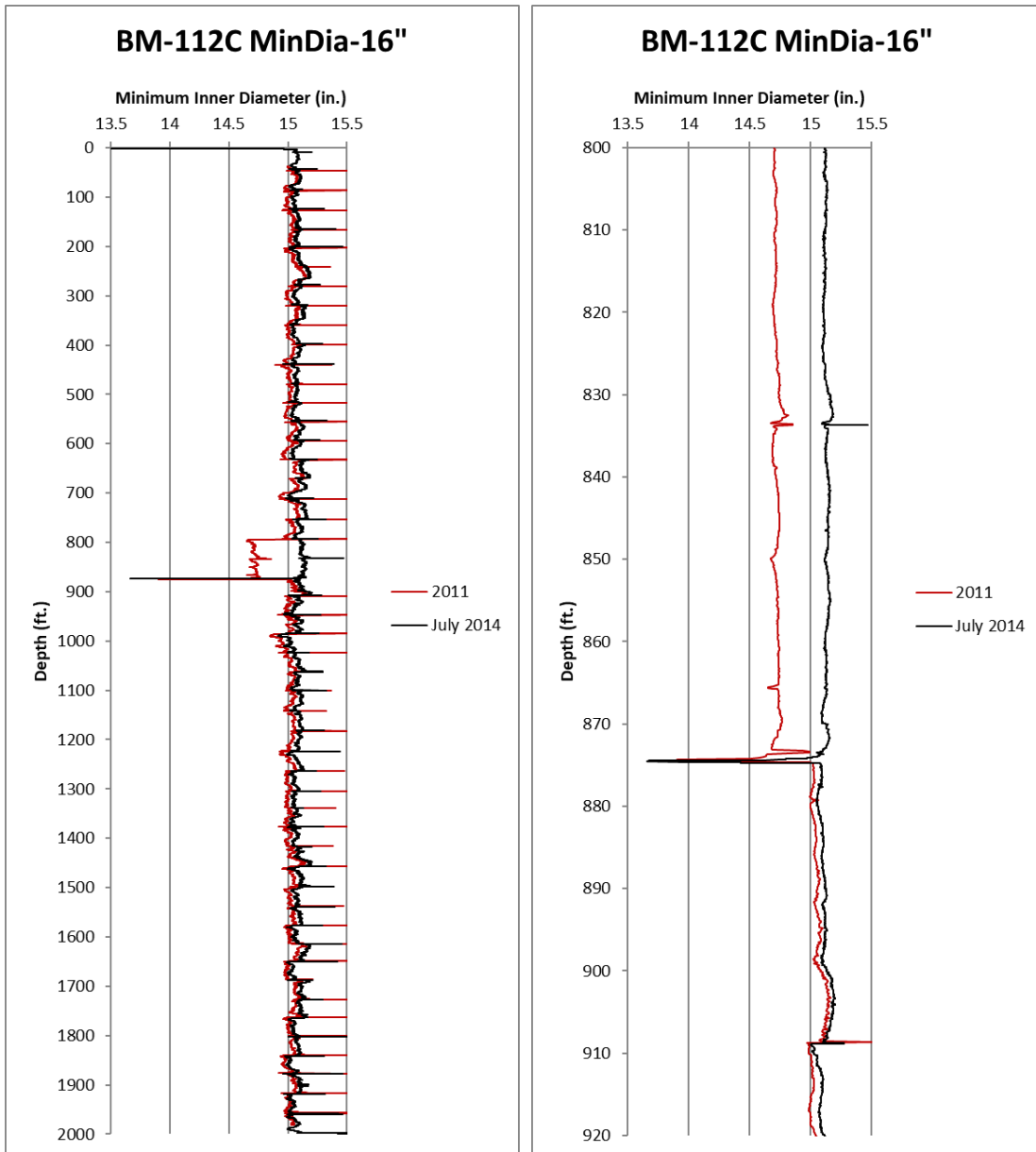


Figure 3-107. BM-112C minimum diameter curves from 2011 and July 2014 MAC data.

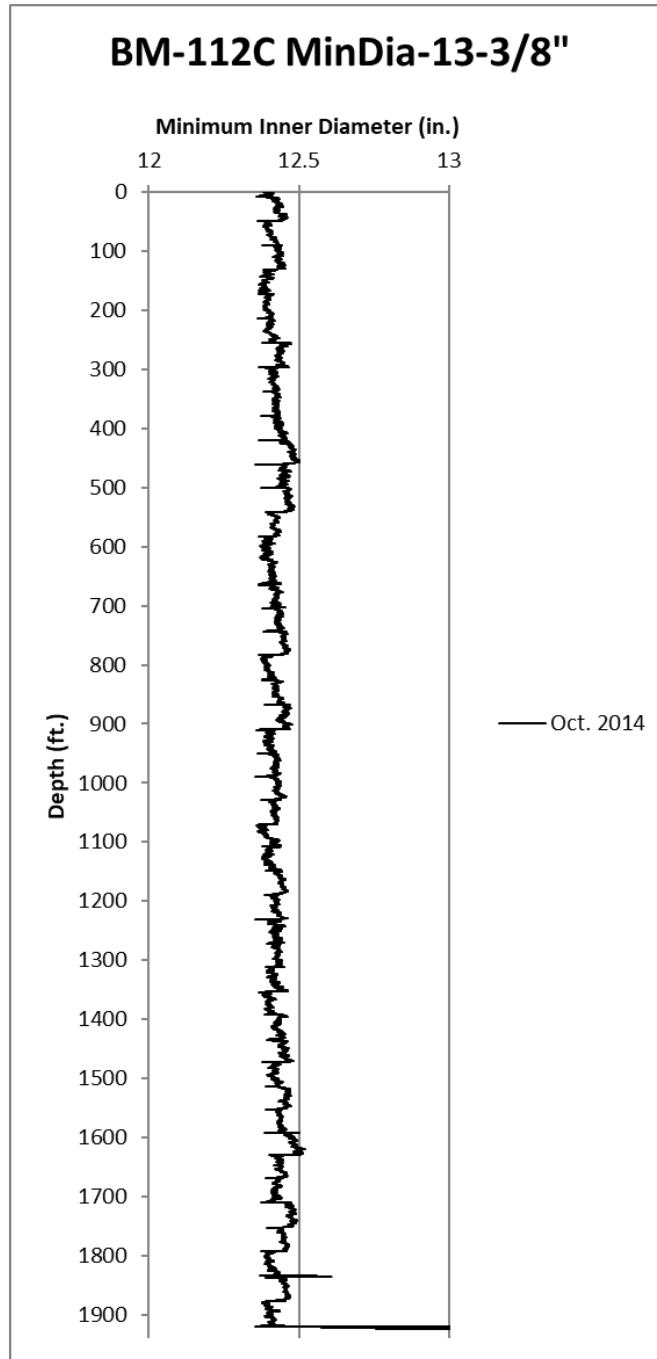


Figure 3-108. BM-112C minimum diameter curve from October 2014 MAC data.

The 2011 and July 2014 MAC data showed well deformation as the result of a casing restriction at 873.55' on the 16" casing. This deformation occurs at a collar location and is resulting in a decrease in the inner-casing diameter. Figure 3-109 shows cross sections at two different depths, taken from the radial arm data collected in the 2014 MAC log. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section that is not currently experiencing deformation. From the radial arm data, it is clear that the well is experiencing a decrease in the inner diameter at the deformation depth. The minimum

diameter at 873.55' is 13.66" which is notably lower than the minimum diameter of 15.14" at 870'. Figure 3-110 displays a 3D visual of the MAC radial arm data at the depth of interest, where a restriction in the casing can be clearly observed. The deformation observed around 873.55' is likely ongoing and the well should continue to be monitored.

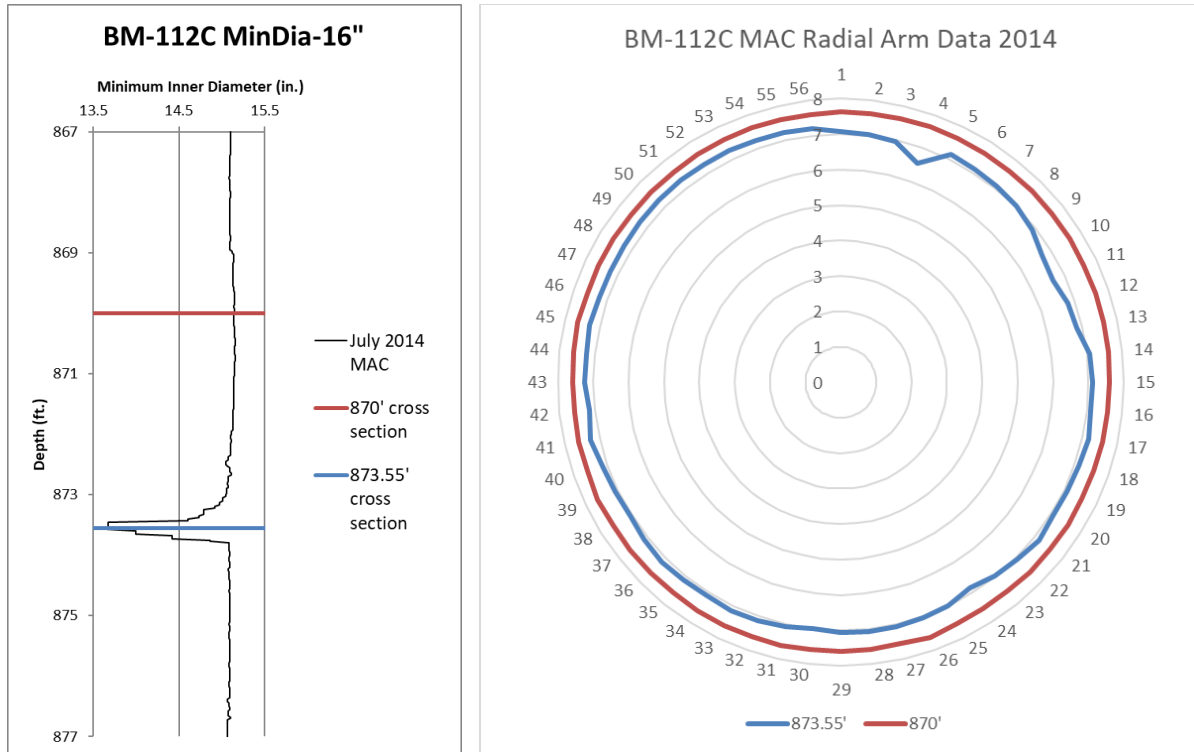


Figure 3-109. Cross sections of BM-112C 2014 MAC data at the depth of casing restriction (blue) and above the restriction (red).

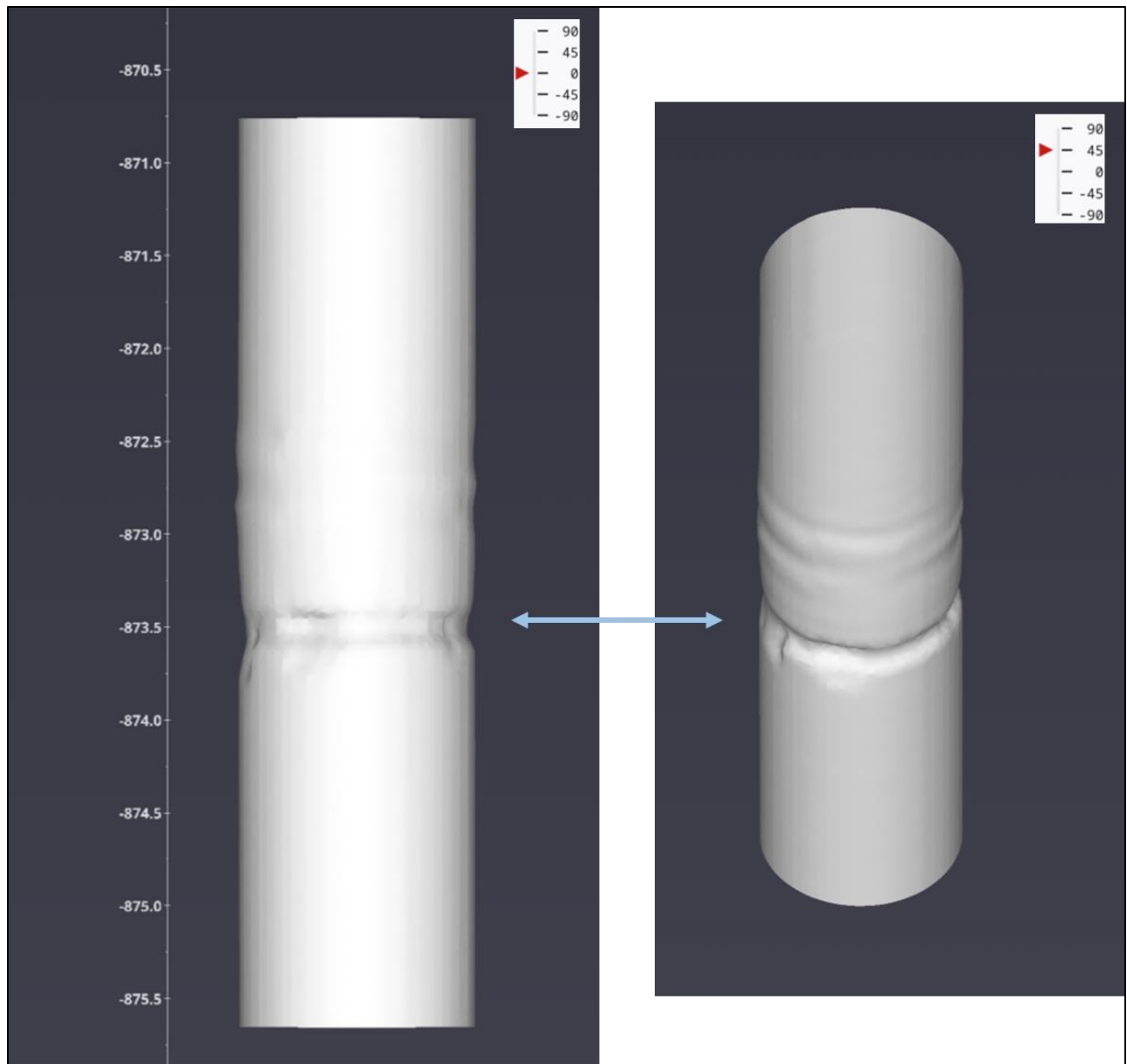


Figure 3-110. 3D visual of BM-112C 2014 radial arm data at the casing restriction

3.3.40. *BM-113A*

BM-113A has a total of two MAC logs from 2011 and 2020. Both logs were taken on the 13 3/8" casing. Figure 3-111 shows the minimum and average diameter curves for the 13 3/8" casing which were calculated from the 2011 and 2020 MAC data. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. Although there are no major restrictions at the casing collars, there is a decrease in the minimum diameter between collar locations around 882.4', which can be observed in Figure 3-112. Although there appears to be a slight progression in the minimum diameter between the 2011 and 2020 MACs, it is difficult to say

whether this a true worsening of the restriction or is a result of normal variation between the two logs.

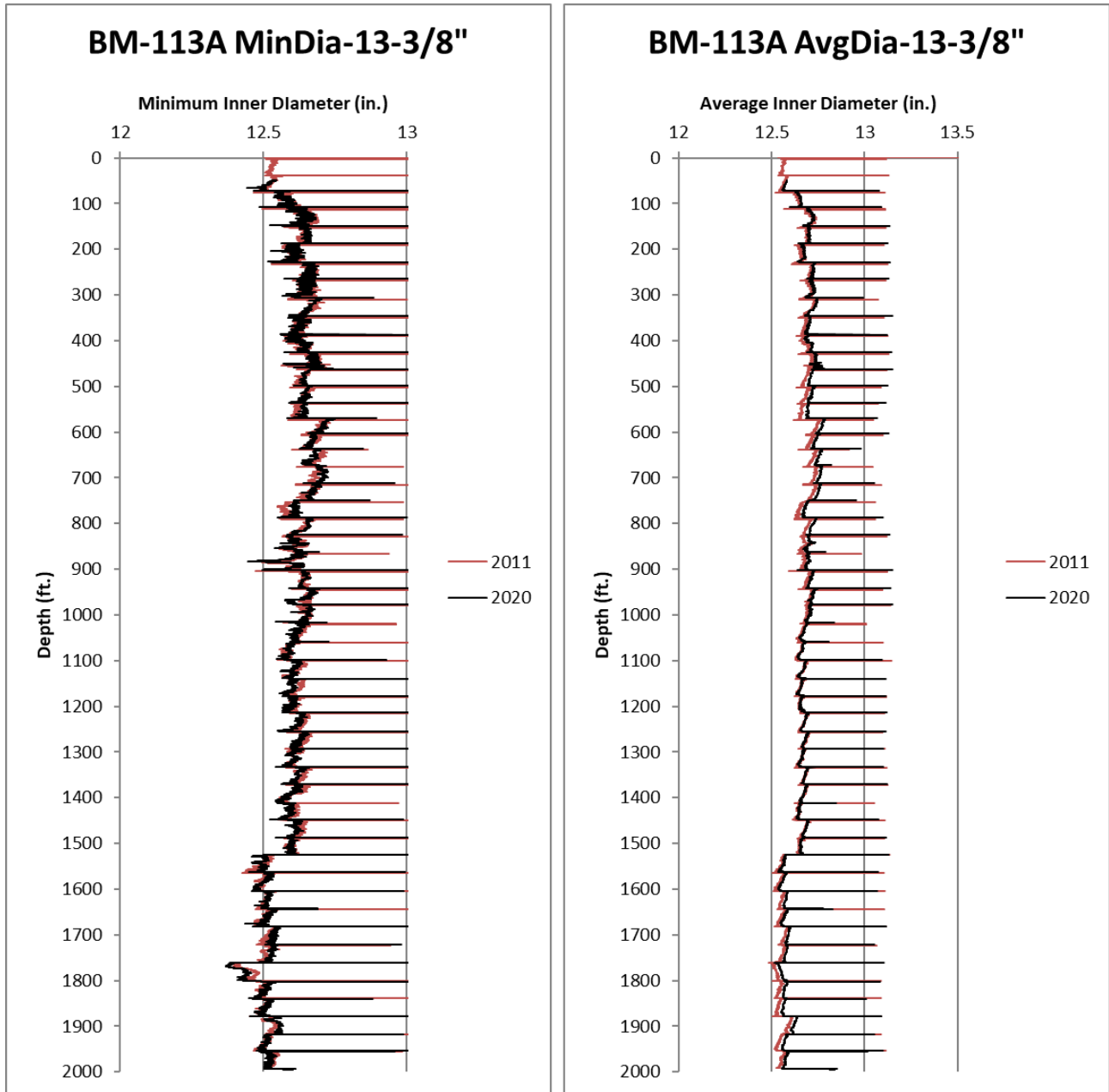


Figure 3-111. BM-113A minimum and average diameter curves from 2011 and 2020 MAC data.

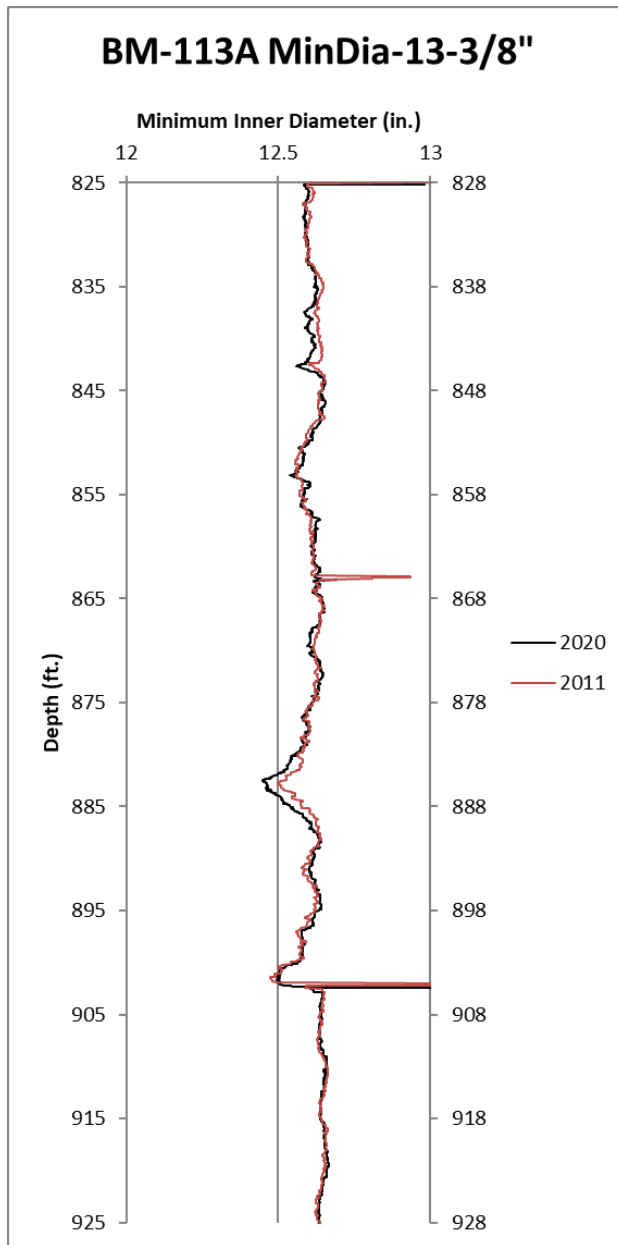


Figure 3-112. BM-113A minimum diameter curves from 2011 and 2020 MAC data at restriction depth

Figure 3-113 shows cross sections taken at and above the depth of interest at 882.425'. An ovality in the casing can be observed at this depth as seen in the figure below. The two radial arm plots show the same data, with the scale in the lower plot being exaggerated to highlight the ovality seen at a depth of 882.425'. This is different than the collar compression typically observed at the Bryan Mound site. The 2020 MAC does not show the deformation at this depth to be severe, however it should be noted as an area to monitor going forward, especially in light of recent events at BM-116A, where extreme deformation occurred in-between casing collars.

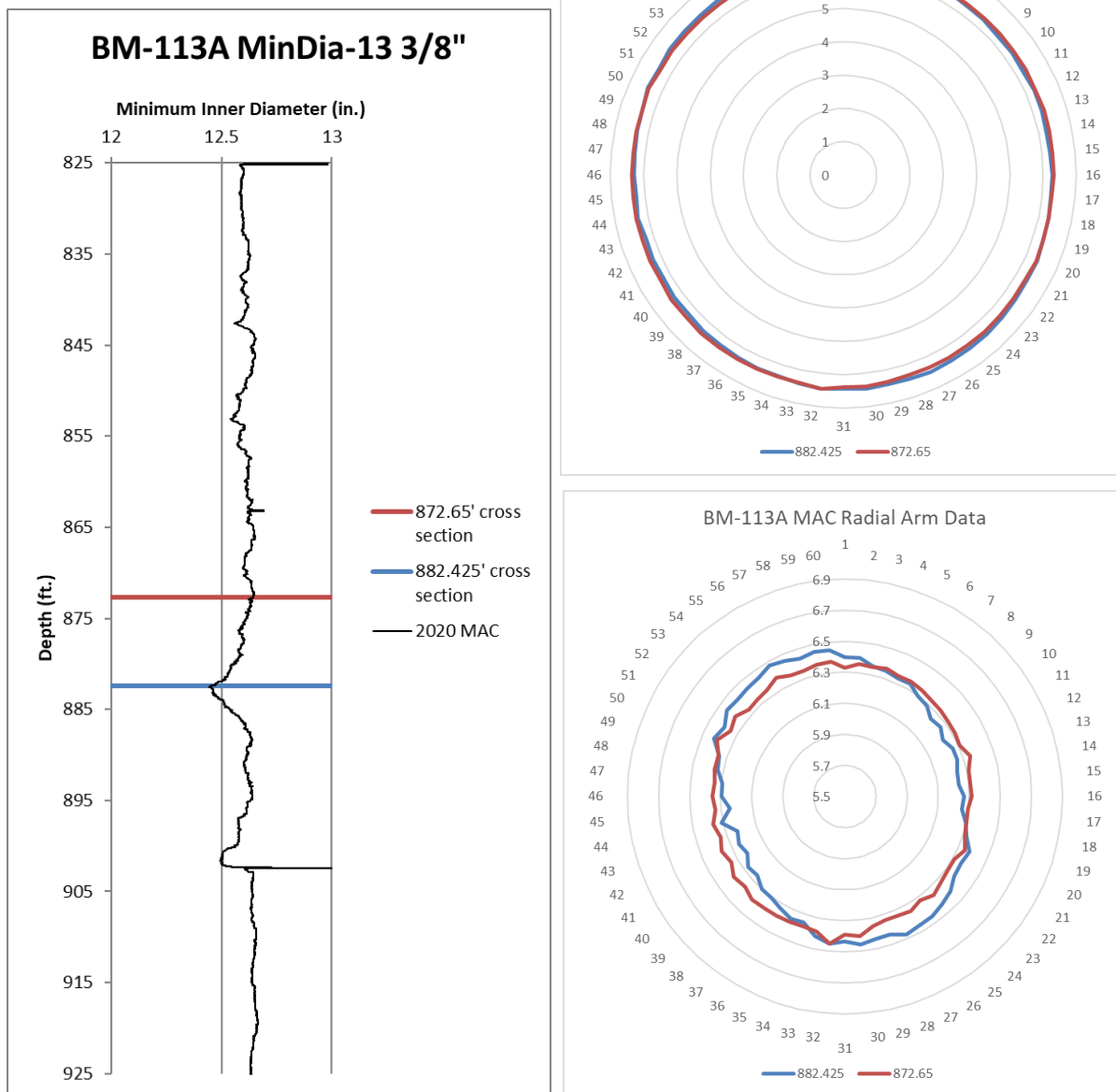


Figure 3-113. Cross sections of BM-113A 2020 MAC data at the depth of casing ovality (blue) and above the ovality (red).

3.3.41. BM-113B

BM-113B has a total of three MAC logs taken in 2008, 2011, and 2020. All three logs were taken on the 13 3/8” casing. Due to a smoothing issue with the most recent data file, the 2020 log has not been included in this analysis. Figure 3-114 shows the minimum diameter curves for the 13-3/8” casings which were calculated from the 2008 and 2011 MAC logs. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. Some minimal

deformation can be observed near the salt-caprock interface around 1067' however it does not appear to be worsening with time. Although there are no major concerns as of the 2011 MAC, the well should be re-evaluated if a non-smoothed data file is obtained for the 2020 MAC data.

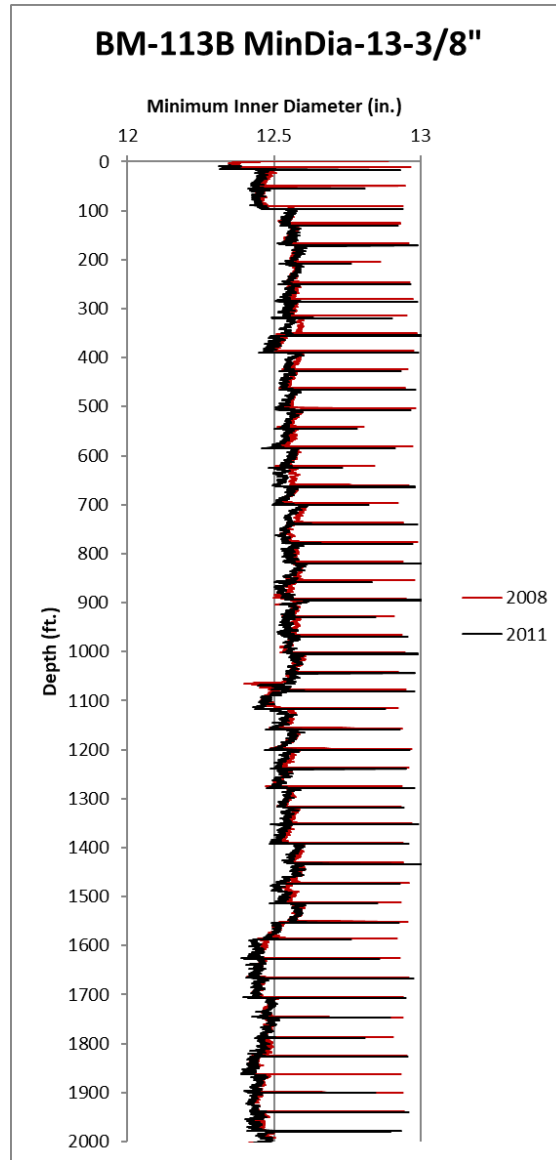


Figure 3-114. BM-113B minimum diameter curves from 2008 and 2011 MAC data.

3.3.42. BM-114A

BM-114A has a total of two MAC logs from 2010 and 2020. Both logs were taken on the 13 3/8" casing. Figure 3-115 shows the minimum diameter curves for the 13-3/8" casing which were calculated from the 2010 and 2020 MAC logs. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. There is some minimal deformation near the salt-caprock interface around 1075', however the deformation does not appear to be increasing and is not a major cause for concern at the moment.

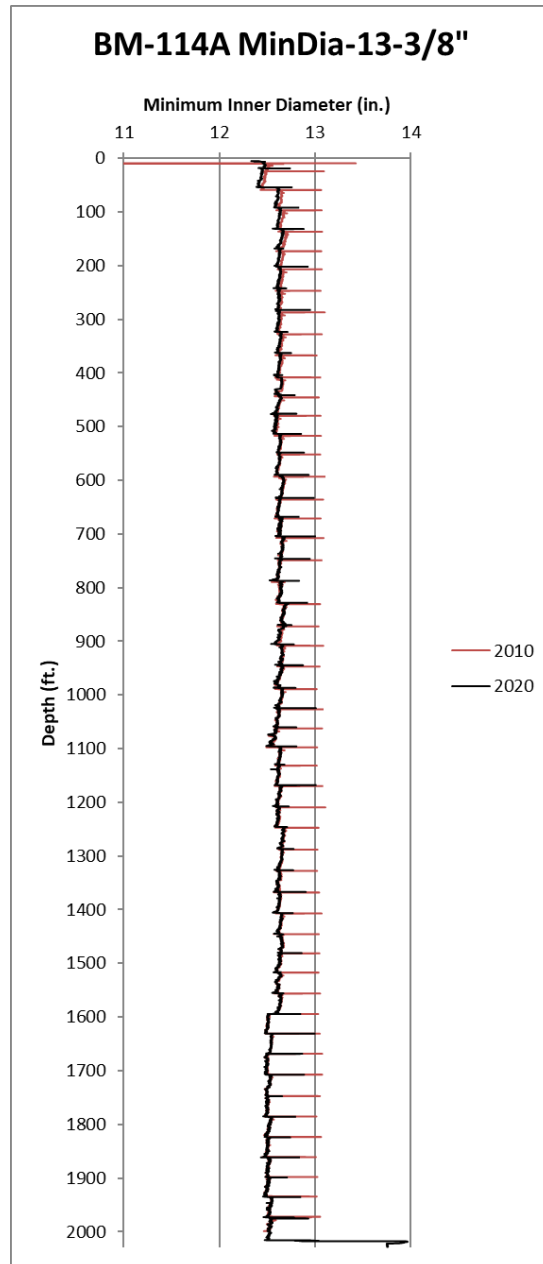


Figure 3-115. BM-114A minimum diameter curves from 2010 and 2020 MAC data.

3.3.43. *BM-114B*

BM-114B has a total of two MAC logs from 2010 and 2019. Both logs were taken on the 13 3/8” casing. Figure 3-116 shows the minimum diameter curves for the 13 3/8” casing which was calculated from the 2010 and 2019 MAC logs. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. There is some minimal deformation observed around the salt caprock interface that should be noted but does not appear to be rapidly worsening and is not a major cause for concern at this time.

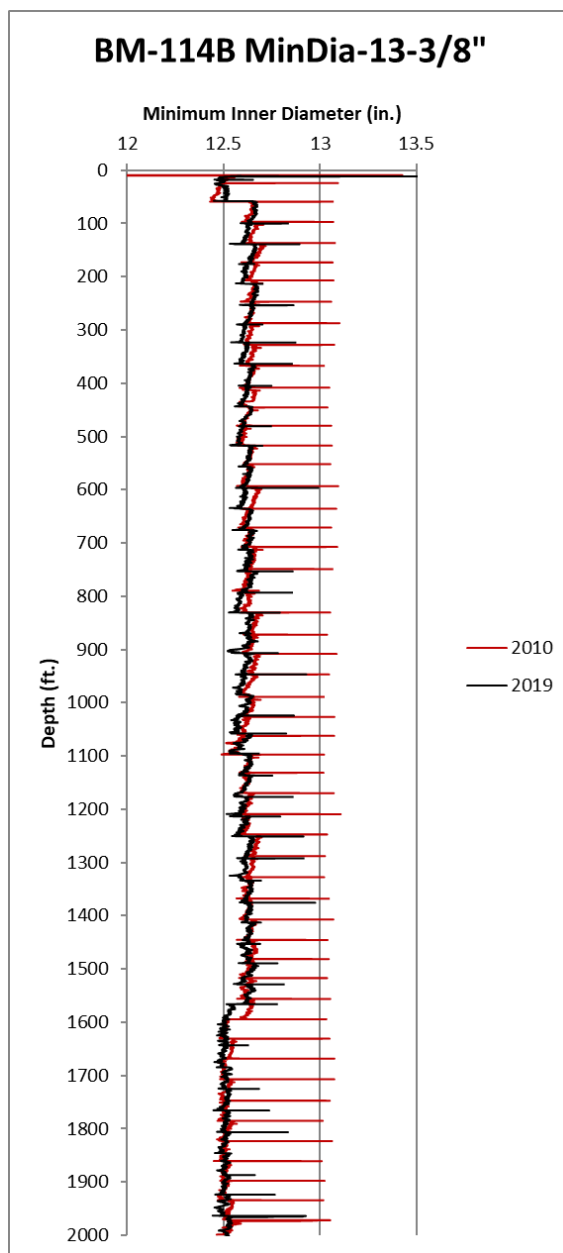


Figure 3-116. BM-114B minimum diameter curves from 2010 and 2019 MAC data.

3.3.44. BM-115A

BM-115A has a total of three MAC logs from 2011, 2020, and 2024. All three logs were taken on the 13 3/8" casing. Figure 3-117 shows the minimum diameter curves for the 13 3/8" casing which was calculated from the 2011, 2020, and 2024 MAC data. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. Some moderate deformation has been noted around 960'-1040' which does not appear to be rapidly worsening and is not a major cause for concern at this time.

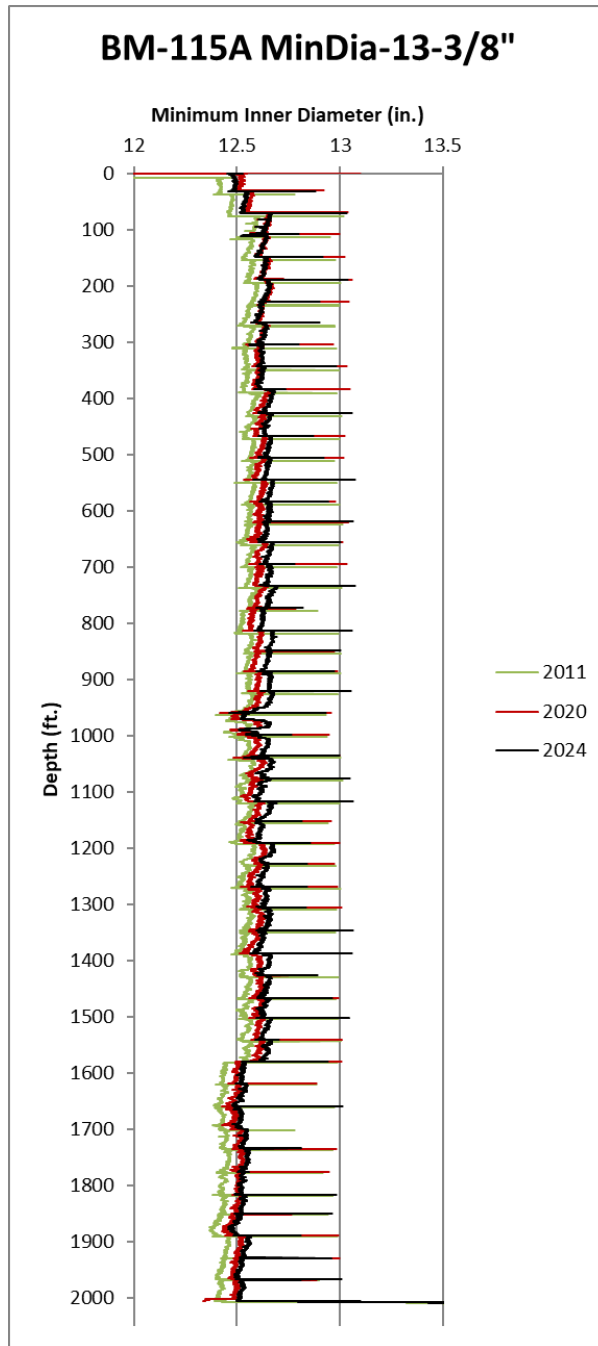


Figure 3-117. BM-115A minimum diameter curves from 2011, 2020 and 2024 MAC data.

3.3.45. BM-115B

BM-115B has a total of two MAC logs from 2012 and 2020. Both logs were taken on the 13 3/8” casing. Figure 3-118 shows the minimum diameter curves for the 13 3/8” casing which was calculated from the 2012 and 2020 MAC data. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. Some minimal deformation has been noted around the salt-caprock interface from 1070’-1085’ which does not appear to be rapidly worsening and is not a major cause for concern at this time.

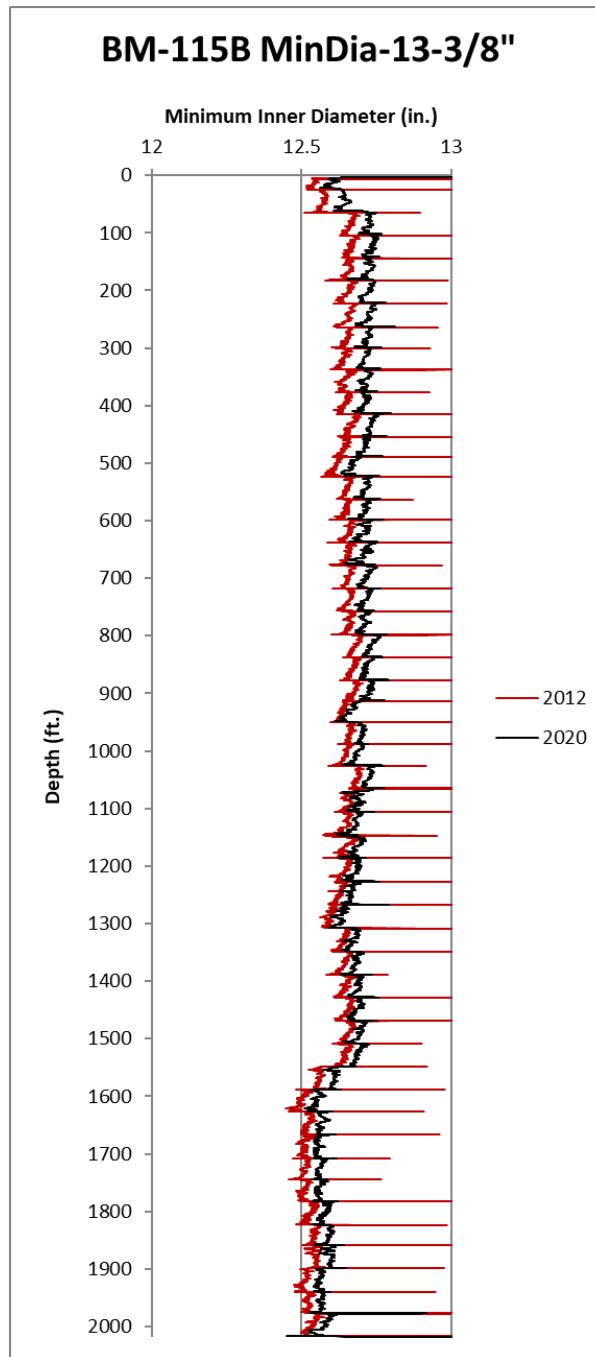


Figure 3-118. BM-115B minimum diameter curves from 2012 and 2020 MAC data.

3.3.46. BM-116A

Prior to the May 2024 well failure, BM-116A had two MAC logs from 2009 and 2019. Both logs were taken on the 13 3/8" casing. The 2009 log was excluded due to incomplete data. Neither of the previous logs had shown any major indications that there was deformation occurring that was cause for concern. After the BM-116A well failure, a high-resolution ultrasonic imaging tool was used to evaluate the well. It was determined that the well failure occurred around 983'. Figure 3-119 shows

the minimum diameter curves for the 13 3/8" casing as calculated from the 2019 MAC and the 2024 ultrasonic imaging data. An extreme mid-casing restriction is observed at the well failure depth, as expected.

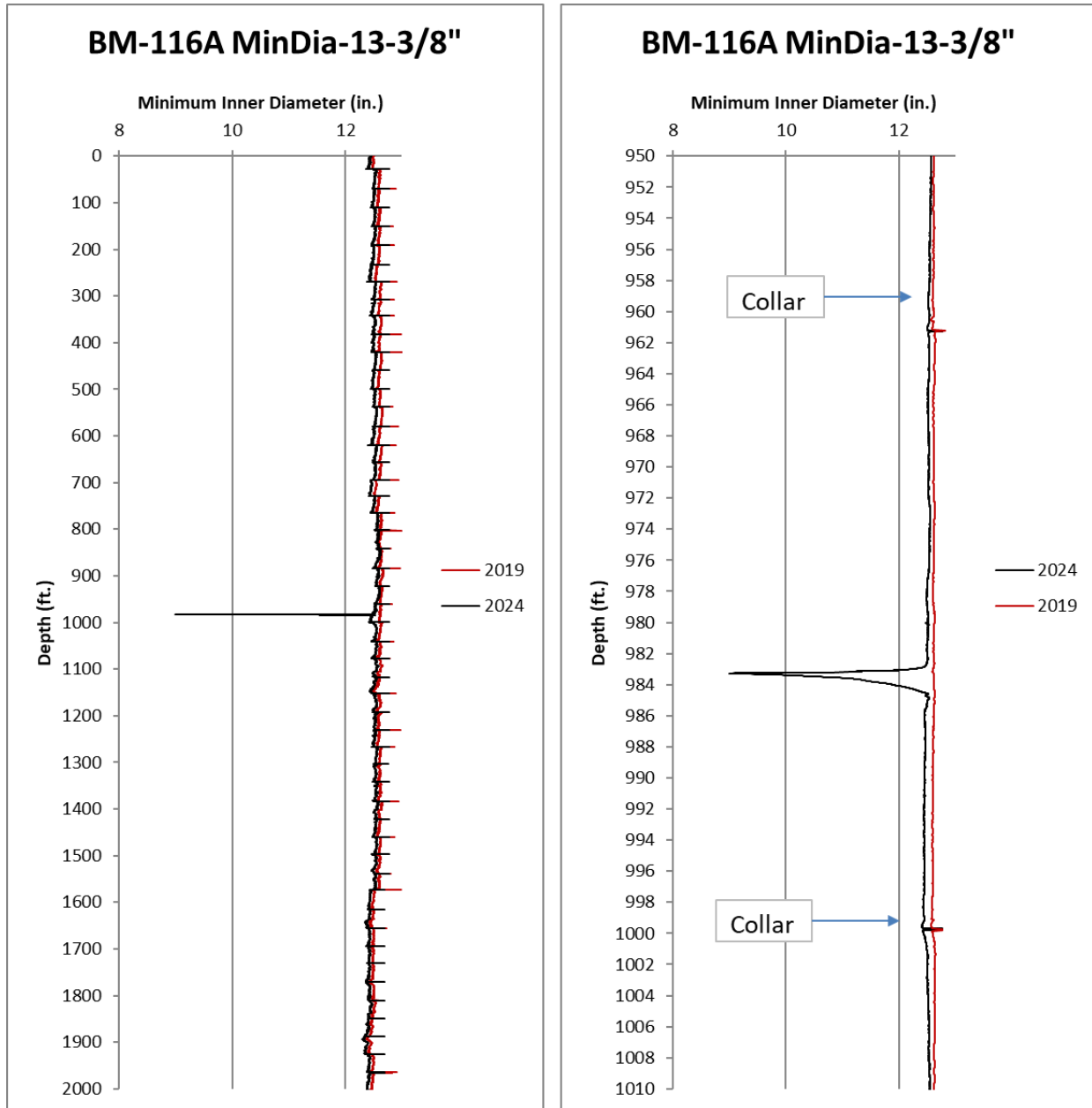


Figure 3-119. BM-116A minimum diameter curves from 2019 and 2024 MAC data.

Figure 3-120 shows cross sections at two different depths, taken from the radial arm data collected in the 2024 ultrasonic imaging log. As seen in the figure, this tool had much higher resolution than a typical MAC log would. An initial cross section was taken at the minimum diameter measurement for the deformation region and was compared against a second cross section that is not currently

experiencing deformation. The cross-sectional data shows extreme deformation of the casing at the minimum diameter depth, which was expected given that there was a failure of integrity in the well.

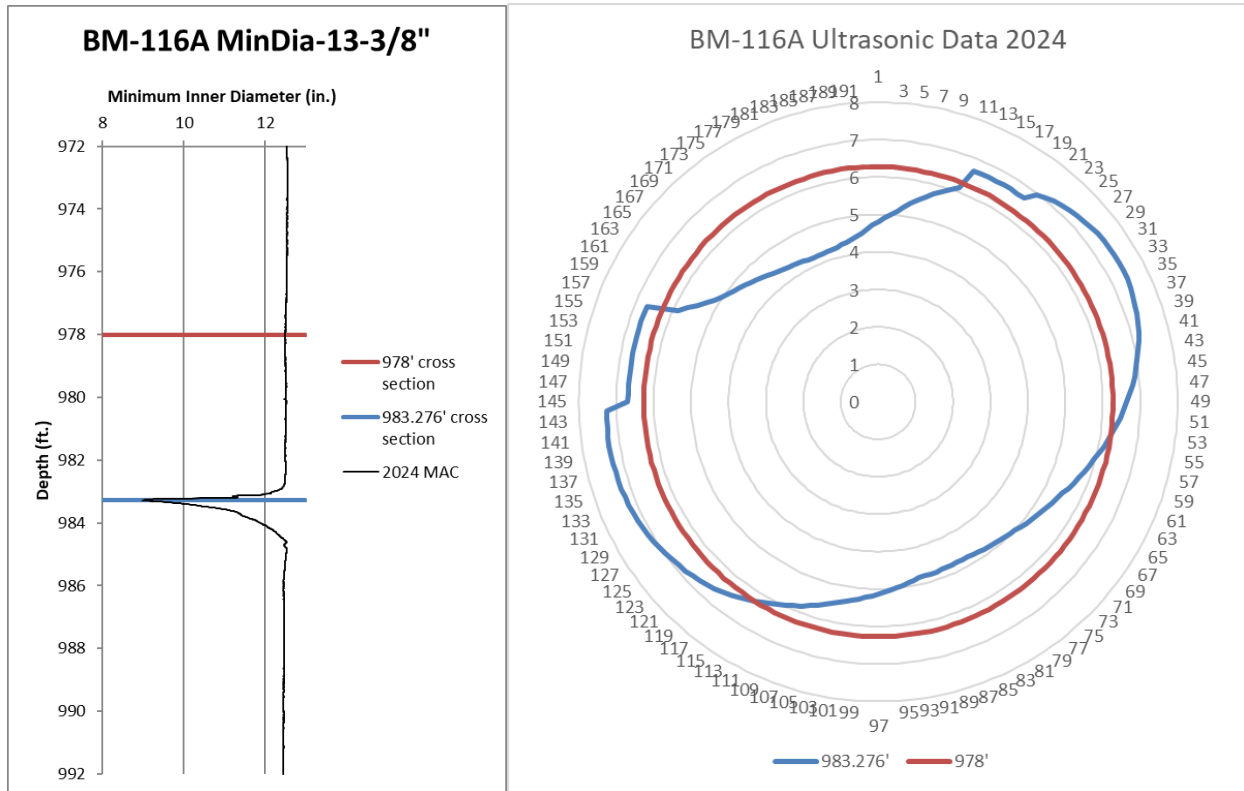


Figure 3-120. Cross sections of BM-116A 2024 ultrasonic imaging data at the depth of casing failure (blue) and above the restriction (red).

Figure 3-121 shows a 3D visual of 2024 BM-116A radial arm data, taken from the ultrasonic imaging data. Although the deformation occurred mid-casing, and not at a collar location as is typically seen at other Bryan Mound wells, based on the 3D imaging, it appears to be a result of a similar axial compression force. The well failure at BM-116A is especially concerning considering that there were no previous indications in the MAC data that any issues or areas of concern were present within the well. The failure also occurred mid-casing, whereas historically the most extreme casing restrictions at Bryan Mound have typically been observed at collar locations.

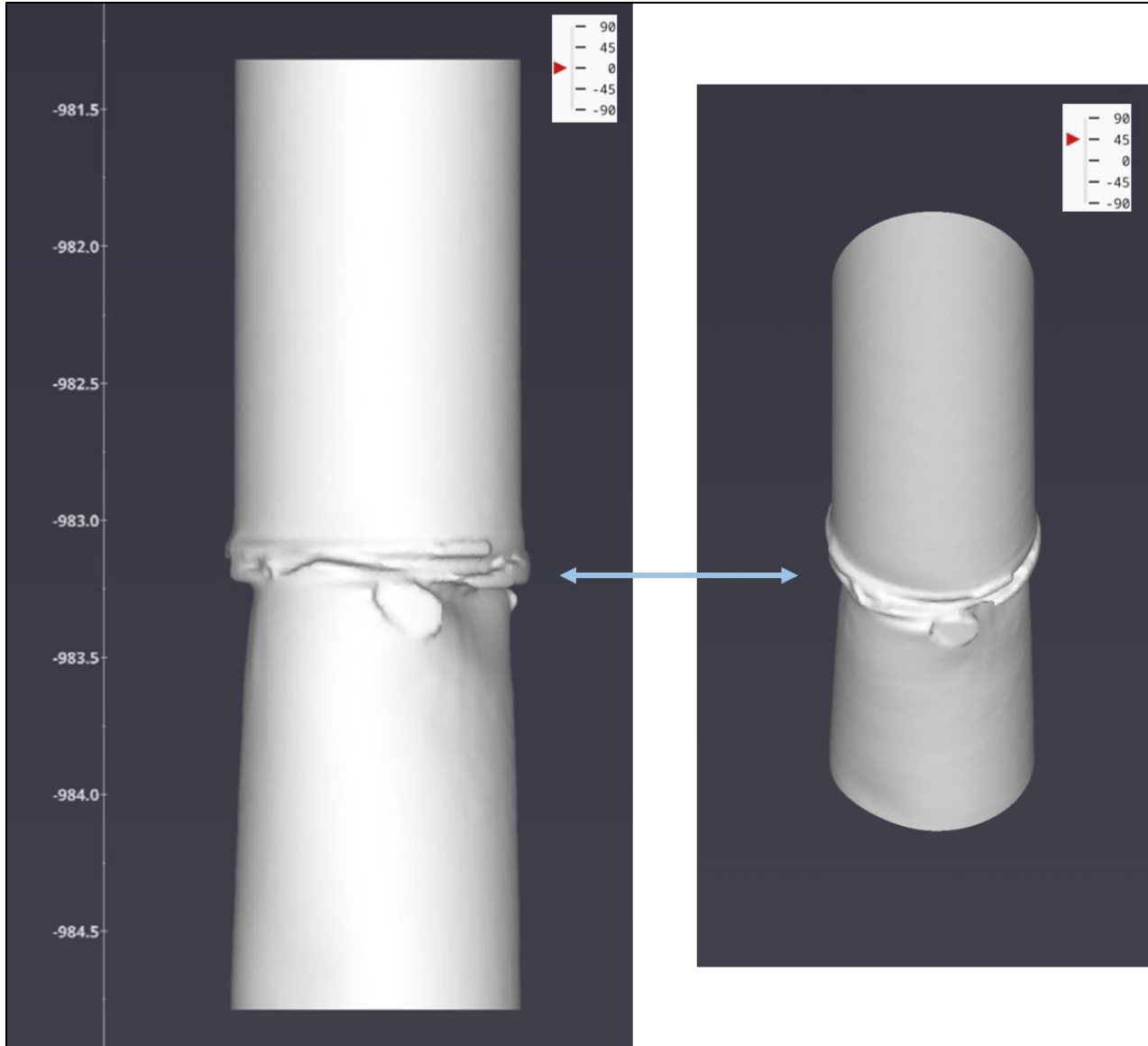


Figure 3-121. 3D visual of BM-116A 2024 radial arm data at the casing failure

3.3.47. BM-116B

BM-116B has a total of two MAC logs from 2012 and 2020. Both logs were taken on the 13 3/8" casing. Figure 3-122 shows the minimum diameter curves for the 13 3/8" casing which was calculated from the 2012 and 2020 MAC data. There are no substantial casing restrictions as a result of collar compression observed in the MAC data for this well. Some minor deformation has been noted near the salt-caprock interface around 1000' which does show a slight increase between MAC logs.

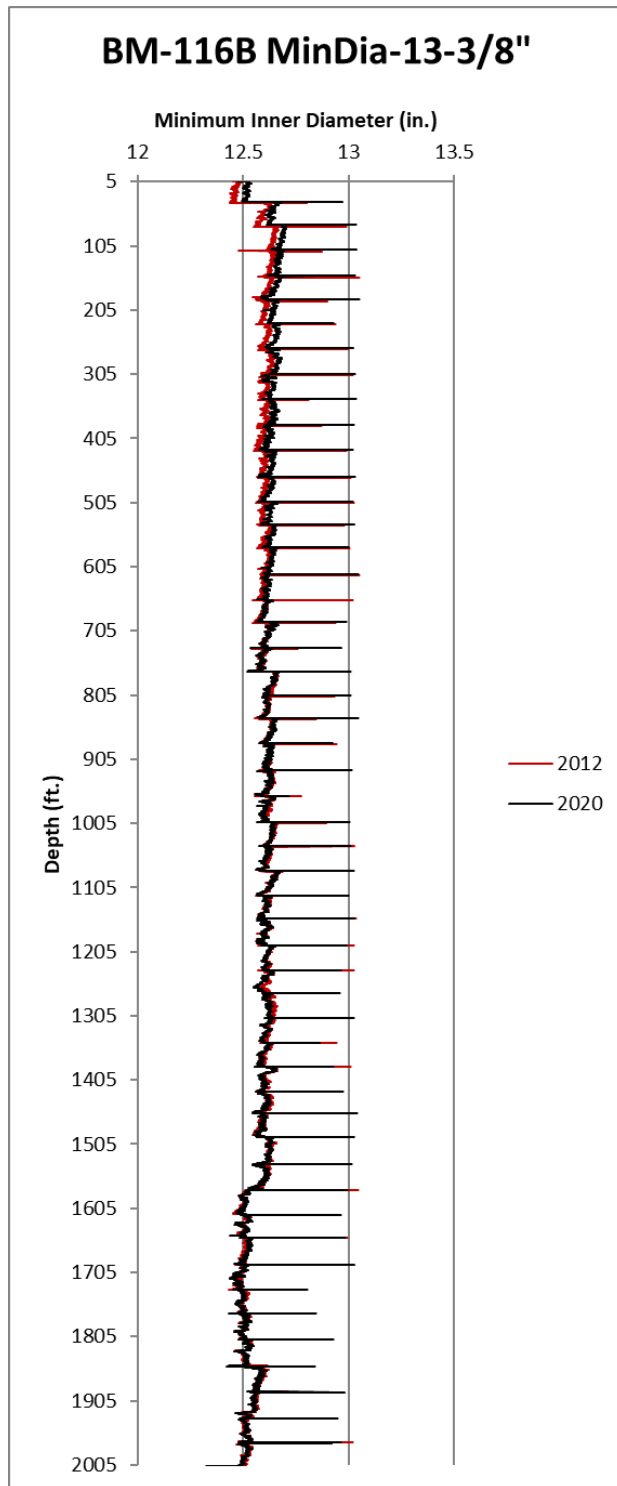


Figure 3-122. BM-116B minimum diameter curves from 2012 and 2020 MAC data.

3.4. Summary of Bryan Mound MAC Data

A summary of the Bryan Mound MAC data can be seen below in Table 3-2. The focus of this analysis was to identify casing restrictions as a result of collar compression; however other relevant concerns have also been noted.

Table 3-2. Summary of BM MAC collar compression analysis

| Well | collar restriction depth (ft. rel. BHF) | collar restriction depth (ft. rel. MSL) | well lined since collar restriction last noted? | additional comments: |
|---------|---|---|---|---|
| BM-001A | 845.5 | 834.1 | yes | none |
| BM-002 | | | | decrease in min diameter between collars around 784.85' |
| BM-002A | | | | decrease in min diameter between collars around 851.8' |
| BM-004A | | | | minimal deformation around SCRIF |
| BM-004B | 878.1 | 864.3 | yes | none |
| BM-004C | | | | minimal deformation around 1100'-1200' |
| BM-005 | 797.0 | 789.8 | no | none |
| BM-005A | 750.1 | 742.9 | no | minimal deformation around 1482' |
| BM-005C | | | | none |
| BM-101A | 898.7 | 892.4 | yes | minimal deformation around 920'-930' and 1970'-1988' |
| BM-101C | 902.6 | 896.3 | yes | none |
| BM-102B | 867.6 | 862.7 | yes | none |
| BM-102C | 907.4 | 901.5 | yes | none |
| BM-103B | 999.5 | 993.7 | yes | minimal deformation around SCRIF and 1455' |
| BM-103C | | | | none |
| BM-104A | 905.9, 942.8 | 896.1, 933.0 | no | moderate deformation from 1040'-1060' |
| BM-104B | 881.6 | 871.9 | no | moderate deformation at SCRIF |
| BM-104C | 804.7, 885.3 | 795, 875.6 | no | minimal deformation around SCRIF |
| BM-105B | 810.8 | 797.7 | no | moderate deformation around 1115' |
| BM-105C | | | | possible debris, causing restriction around 207' |
| BM-106A | 881.9 | 866.4 | yes | none |
| BM-106B | 834.2 | 818.5 | yes | none |
| BM-106C | 848.3 | 832.0 | no | none |
| BM-107A | | | | deformation around 1326'-1359' |
| BM-107B | | | | Decrease in min diameter near collar around 810.2'. Deformation around 1950'-2008', possible cement |
| BM-107C | 835.9 | 820.9 | yes | none |
| BM-108A | 865.3 | 849.3 | no | moderate deformation around 1040'-1060' |
| BM-108B | 873.9 | 858.6 | no | none |
| BM-108C | | | | none |
| BM-109A | 828.8 | 812.8 | no | minimal deformation around SCRIF |
| BM-109B | 825.9 | 810.3 | no | minimal deformation around 1215' |
| BM-109C | | | | minimal deformation around SCRIF |
| BM-110A | 844.7 | 829.2 | no | decrease in min diameter between collars around 990' |
| BM-110B | | | | none |
| BM-110C | | | | none |
| BM-111A | | | | isolated instances of min diameter decreases, results of 1-4 radial arm measurements |
| BM-111B | | | | none |
| BM-112A | 887.3 | 876.3 | no | none |
| BM-112C | 873.6 | 862.6 | yes | none |
| BM-113A | | | | decrease in min diameter between collars around 882.4' |
| BM-113B | | | | none |
| BM-114A | | | | minimal deformation around SCRIF |
| BM-114B | | | | minimal deformation around SCRIF |
| BM-115A | | | | moderate deformation from 960'-1040' |
| BM-115B | | | | minimal deformation around SCRIF |
| BM-116A | | | | well failure at 983.276' |
| BM-116B | | | | minimal deformation around SCRIF |

From the MAC data available at the time of this report, 24 of the 47 wells at Bryan Mound are experiencing deformation at a casing collar. These collar restrictions have been noted in BM-1A, BM-4A, BM-5, BM-5A, BM-101A, BM-101C, BM-102B, BM-102C, BM-103B, BM-104A, BM-104B, BM-104C, BM-105B, BM-106A, BM-106B, BM-106C, BM-107C, BM-108A, BM-108B, BM-109A, BM-109B, BM-110A, BM-112A, and BM-112C. With the exception of BM-103B, all collar restriction depths occurred between 700'-950'.

Additionally, BM-2, BM-2A and BM-113A all have mid-casing restrictions as a result of casing ovality observed between 700'-950'. Historically these instances have not been a major concern, as the most severe casing deformation was typically seen at collar locations. However, in light of the recent mid-casing well failure that took place at BM-116A, the restrictions seen in BM-2, BM-2A, and BM-113A have all been noted and highlighted in the above analysis section of the report for each cavern.

4. ADDITIONAL DATA ANALYSIS

Following the Bryan Mound MAC analysis outlined in Section 3, several additional datasets were explored to see if they offered any possible correlations or explanations for the well deformation observed at the Bryan Mound site. Temperature logging data, pulsed eddy current logs, and sulphur mining well locations were all identified as datasets worth looking into. The results of each analysis are provided below.

4.1. General Spatial Analysis

Figure 4-1 shows a spatial representation of the BM wells with collar compression across the dome. The wells experiencing collar compression have been marked in red, wells not experiencing collar compression are marked in green, and well BM-116A has been marked in yellow. In general, the collar restrictions seem to be fairly evenly spread across the dome. None of the wells in the southwest corner have shown signs of collar compression, however that is the same region where the BM-116A mid-casing well failure took place, making it an area of increased concern. There are also several caverns where some wells are experiencing collar compression while others are not. There does not seem to be any general directional pattern to explain why this is happening. At this time, no conclusive correlations with the collar compression can be drawn from the spatial analysis presented below.

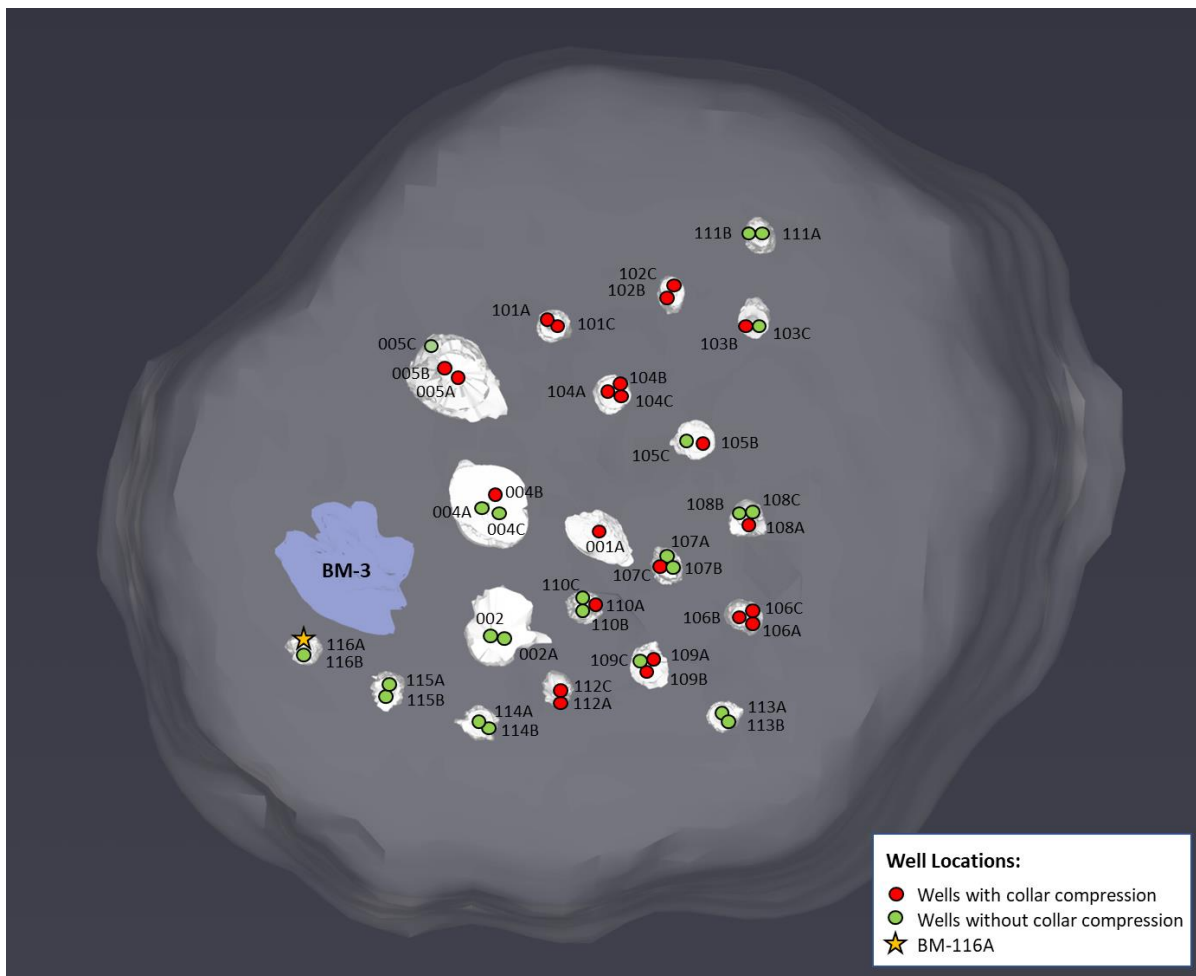


Figure 4-1. Well collar compression locations at the Bryan Mound salt dome.

4.2. BM Well Temperature Logging Data

Bryan Mound temperature logging data has historically shown a unique temperature profile in comparison with the other three SPR sites. Temperature logs at Bryan Mound show a notable increase in temperature in the caprock often reaching maximum temperatures of 130-159 degrees Fahrenheit, which cannot be explained by the normal geothermal gradient. The concentration of higher temperatures in the caprock is a result of the sulphur mining that took place at the BM dome. As discussed earlier, this sulphur mining process relied on injecting extremely hot water into the caprock to retrieve the sulphur, which affected the temperature profile in the mining region and as a result is still observed in recent temperature logs taken at the site.

Temperature logging data was available for each of the 47 Bryan Mound wells included in this report. A summary of the temperature data used in the following analysis can be seen in Table 4-1 below. If multiple temperature logs were available for a given well, the most recent non-MIT log was selected for analysis. Although temperature logs taken during Mechanical Integrity Testing should not be significantly affected by the process, if an acceptable non-MIT log was available for a well it was used in an effort to reduce potential bias in the data. If a well only had MIT temperature logging data available, it was included in the analysis and those cases have been noted in this report.

An initial analysis of the temperature data shows an average maximum temperature of approximately 148.4 degrees Fahrenheit. Although the average maximum temperature for wells with observed collar restrictions is higher than the overall average, the difference is small and is not significant enough to draw a conclusive correlation between higher than average temperatures and the presence of collar restrictions.

Table 4-1. Summary of BM temperature analysis data

| Well | Log date | Vertical resolution (ft.) | MIT? | max temp (°F) | max temp depth (ft. rel. MSL) | collar compression depth (ft. rel. MSL) |
|---------|------------|---------------------------|------|---|-------------------------------|---|
| BM-001A | 2/14/2022 | 0.25 | no | 149.502 | -797.95 | -834.1 |
| BM-002 | 4/29/2013 | 0.05 | yes | 144.1531 | -846.15 | |
| BM-002A | 1/31/2008 | 1 | no | 155.3311 | -806.8 | |
| BM-004A | 12/8/2022 | 0.25 | yes | 149.9243 | -740.05 | |
| BM-004B | 12/8/2022 | 0.25 | yes | 152.7042 | -752.9 | -864.3 |
| BM-004C | 12/8/2022 | 0.25 | yes | 152.0853 | -755.15 | |
| BM-005 | 3/29/2023 | 0.25 | yes | 149.0729 | -752.1 | -789.8 |
| BM-005A | 3/31/2021 | 0.25 | no | 151.1239 | -784.6 | -742.9 |
| BM-005C | 3/29/2023 | 0.25 | yes | 147.6757 | -815.45 | |
| BM-101A | 6/10/2021 | 0.25 | no | 147.2405 | -814.9 | -892.35 |
| BM-101C | 10/1/2021 | 0.25 | yes | 148.4173 | -807.15 | -896.325 |
| BM-102B | 12/21/2021 | 0.25 | yes | 145.7089 | -848.2 | -862.7 |
| BM-102C | 5/8/2019 | 0.5 | no | 147.7476 | -853.7 | -901.5 |
| BM-103B | 5/26/2021 | 0.25 | no | 148.1543 | -886.9 | -993.7 |
| BM-103C | 3/17/2023 | 0.25 | yes | 146.5325 | -871.95 | |
| BM-104A | 11/8/2022 | 0.05 | no | 146.8047 | -749.4 | -896.125, -933 |
| BM-104B | 11/9/2022 | 0.25 | yes | 148.8255 | -768.35 | -871.9 |
| BM-104C | 11/8/2022 | 0.25 | yes | 148.0275 | -786.85 | -795, -875.6 |
| BM-105B | 3/31/2021 | 0.25 | no | 147.918 | -799.8 | -797.675 |
| BM-105C | 1/10/2008 | 1 | no | 147.3691 | -762.4 | |
| BM-106A | 9/29/2020 | 0.25 | no | 159.0449 | -690.75 | -866.4 |
| BM-106B | 7/29/2020 | 0.25 | no | 146.2861 | -725.1 | -818.5 |
| BM-106C | 11/4/2020 | 0.25 | yes | 155.1587 | -706.9 | -831.95 |
| BM-107A | 9/1/2020 | 0.25 | no | 154.7868 | -727.75 | |
| BM-107B | 5/10/2018 | 0.5 | yes | 155.405 | -717 | |
| BM-107C | 8/5/2021 | 0.25 | yes | 152.3331 | -731.75 | -820.85 |
| BM-108A | 5/25/2021 | 0.25 | no | 151.273 | -727.75 | -849.3 |
| BM-108B | 7/25/2019 | 0.25 | yes | 154.4394 | -738.9 | -858.6 |
| BM-108C | 7/25/2019 | 0.25 | yes | 150.1437 | -754.3 | |
| BM-109A | 1/28/2016 | 0.25 | yes | 158.6361 | -708.25 | -812.8 |
| BM-109B | 2/1/2016 | 0.25 | yes | 152.8976 | -744.8 | -810.3 |
| BM-109C | 4/18/2018 | 0.5 | no | 157.9626 | -724.2 | |
| BM-110A | 3/1/2022 | 0.25 | yes | 150.9729 | -581.75 | -829.15 |
| BM-110B | 3/2/2022 | 0.25 | yes | 152.7991 | -717.45 | |
| BM-110C | 7/9/2019 | 0.5 | no | 158.7654 | -745.7 | |
| BM-111A | 8/5/2020 | 0.25 | yes | 137.0328 | -982.05 | |
| BM-111B | 8/5/2020 | 0.25 | yes | 138.88 | -965.1 | |
| BM-112A | 2/14/2022 | 0.25 | yes | 150.1285 | -790.75 | -876.3 |
| BM-112C | 5/16/2019 | 0.25 | yes | 152.6566 | -768.5 | -862.55 |
| BM-113A | 7/27/2022 | 1 | no | 151.16 | -731 | |
| BM-113B | 2/11/2021 | 0.25 | yes | 151.9053 | -724.45 | |
| BM-114A | 5/13/2021 | 0.25 | no | 135.1885 | -824.75 | |
| BM-114B | 9/25/2017 | 0.25 | yes | 132.8096 | -855.25 | |
| BM-115A | 7/8/2019 | 0.5 | no | 134.6624 | -952 | |
| BM-115B | 12/3/2021 | 0.25 | yes | 132.9009 | -875.65 | |
| BM-116A | 4/12/2021 | 0.25 | no | 136.5686 | -856.05 | |
| BM-116B | 4/22/2019 | 0.5 | no | 136.595 | -890 | |
| | | | | min | 132.8096 | |
| | | | | average (all wells) | 148.41938 | |
| | | | | average (w/ collar restriction) | 150.62809 | |
| | | | | average (without collar restriction) | 146.11464 | |
| | | | | max | 159.0449 | |

Figure 4-2 displays a visualization of the temperature data for each Bryan Mound well that has been created using the Earth Volumetric Studio (EVS) software. The wells have been color coded to match the temperature measurements taken along each well. The BM salt-dome and caprock models have also been included for reference and the temperature peaks can clearly be identified near the caprock region.

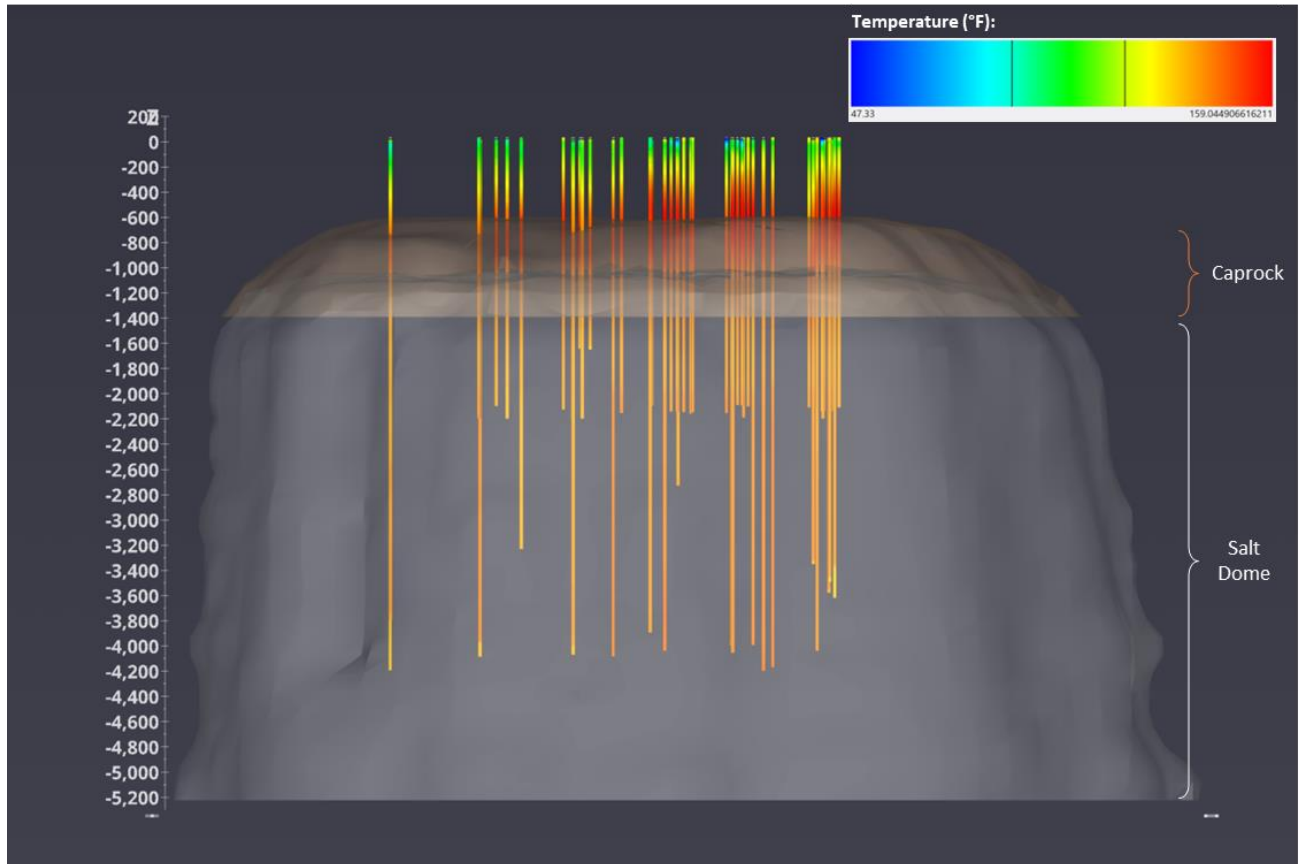
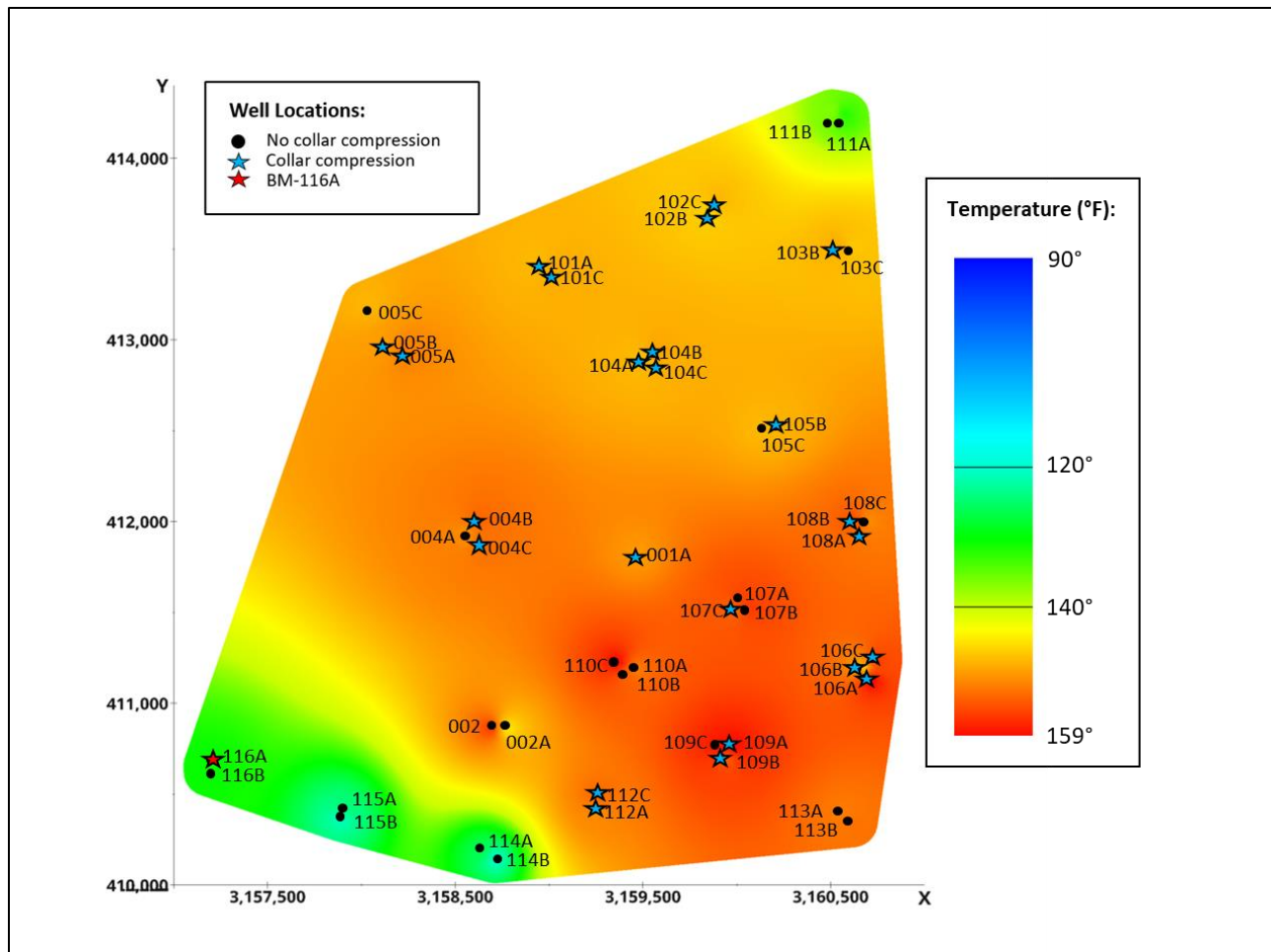


Figure 4-2. EVS visualization of BM well temperature data with caprock (orange) and salt dome (white) models included for reference

A sitewide temperature gradient model was created using the temperature logging data shown above. The first calculation was a 2D temperature estimation using the maximum temperature values from each well across the site. The model was created in EVS using the Franke/Neilson inverse distance weighting formula and is shown below in Figure 4-3. It should be noted that because the maximum temperature depths used in the interpolation calculation were each recorded at different depths, this model is not accurate at any specific downhole depth and should only be used as a general picture of maximum temperature distribution across the site. Wells with collar compression have been marked in blue stars on the map. From this figure it does appear that the wells with noticeable lower maximum temperatures in the northwest and southwest corners (BM-111A, BM-111B, BM-114A, BM-114B, BM-115A, BM-115B, BM-116A, BM-116B) are also not experiencing collar compression. However, the recent well failure at BM-116A does serve as a reminder that wells in these areas are not immune to deformation concerns, and should still be closely monitored. Outside of the northeast and southwest corners there does not appear to be any discernable pattern or explanation

as to why some of those wells are experiencing collar compression and others are not based on the maximum temperature gradient.



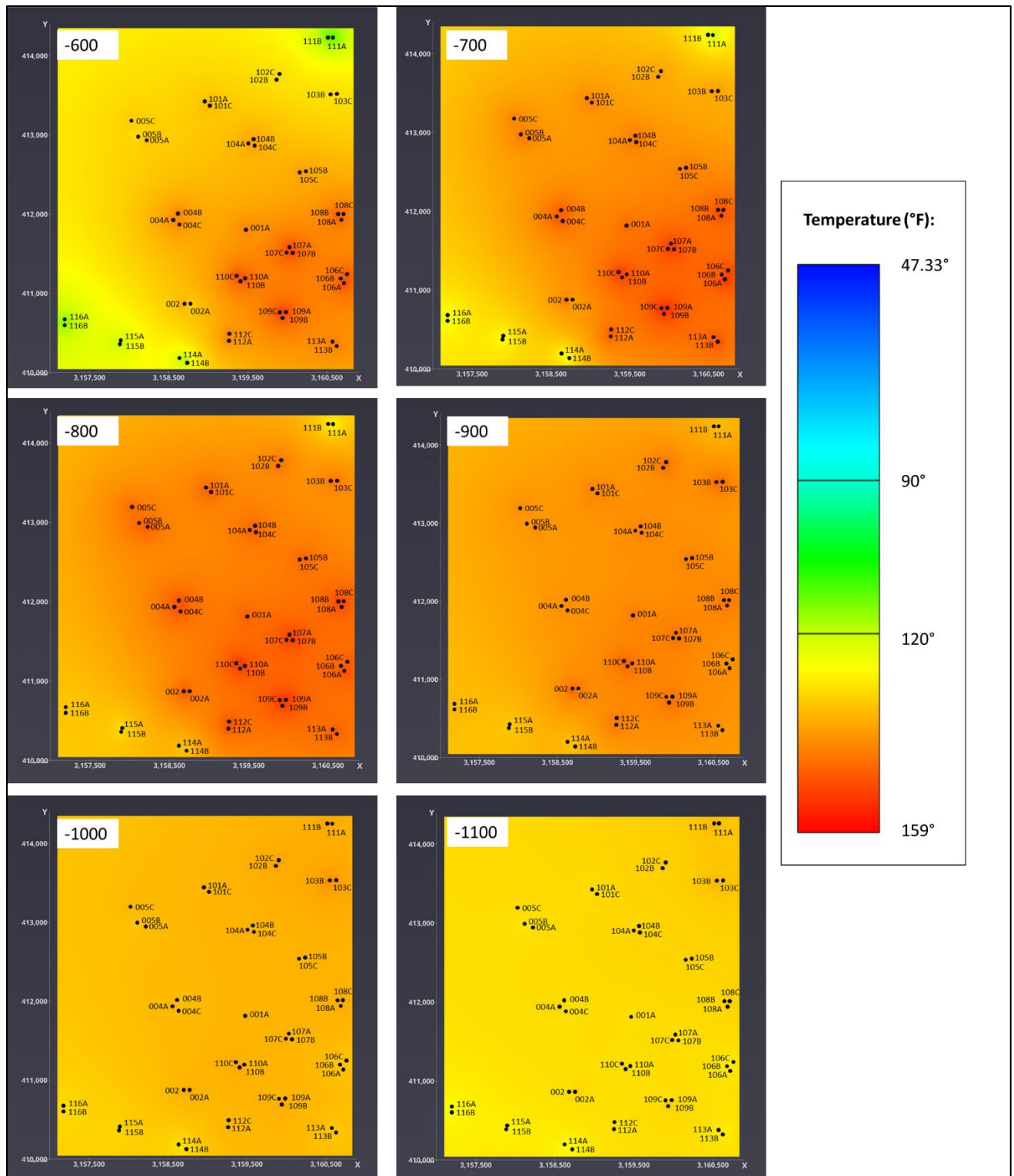


Figure 4-4. Horizontal cross sections from Bryan Mound 3D temperature model

At this time, the temperature data at the site shows a significant increase in temperatures near the caprock region most notably around 700-900 feet, which is also the same general depth region

where sulphur mining took place. In terms of temperature variations between wells, there do not seem to be any trends strong enough to differentiate between the wells that experience collar compression and those that do not. Prior to 2024 a case could be made for the wells at the slightly cooler northeast and southwest regions of the dome being of less concern for extreme deformation, however the failure of BM-116A does complicate this theory. Although the temperature data alone cannot be used to provide a well-specific explanation for the collar compression locations, it does further illustrate that the geologic effects of the sulphur mining are still very much present in the subsurface today as seen by the high temperatures observed in the caprock.

4.3. Pulsed Eddy Current Logs

Sandia currently has pulsed eddy current (PEC) logs for seven wells at the Bryan Mound site: BM-102B, BM-105C, BM-106C, BM-108B, BM-111B, BM-113A, and BM-116B. These logs are taken using a pulsed eddy current to determine the pipe thickness of multiple casings in a given well. A review of the current PEC logs at the Bryan Mound site was completed to see if there were any correlations with the collar compression seen at the Bryan Mound site and unusual PEC data. Table 4-2 shows a summary of the casings evaluated for each BM well that had a PEC log taken on it. For the BM-106C log, the only data on file at Sandia is a PDF of the well log, and no summarized report or actual data file is currently available at the time. From the available logging data two casings were listed on the front page of the report so it is presumed those were the two casings evaluated, although that is not explicitly stated in the data results.

Table 4-2. Bryan Mound PEC Log Summary

| Well | PEC log Date | Casings evaluated |
|---------|--------------|---|
| BM-102B | 10/4/2021 | <ul style="list-style-type: none"> • 13-3/8" • 16" • 20" |
| BM-105C | 10/26/2021 | <ul style="list-style-type: none"> • 16" • 20" • 26" |
| BM-106C | 1/12/2021 | <ul style="list-style-type: none"> • 13-3/8" • 20" |
| BM-108B | 6/9/2021 | <ul style="list-style-type: none"> • 13-3/8" • 20" • 26" |
| BM-111B | 7/29/2021 | <ul style="list-style-type: none"> • 16" • 20" • 26" |
| BM-113A | 6/10/2020 | <ul style="list-style-type: none"> • 13-3/8" • 20" |
| BM-116B | 11/17/2020 | <ul style="list-style-type: none"> • 13-3/8" • 20" • 30" |

For all of the wells besides BM-116B, the PEC did not capture anything out of the ordinary. The BM-106C log did note an anomaly around 849' which had already been identified by the MAC data as a depth of collar compression. Most casings evaluated for each well had reported maximum thickness losses around 0-10% for each joint. An example of a typical max thickness figure (taken from the PEC report for the 20" casing in BM-111B) is shown in Figure 4-5 below (GOWell 2021).



Figure 4-5. BM-111B pipe thickness loss for the 20" casing

The PEC log taken on BM-116B had some interesting results. Figure 4-6, Figure 4-7, and Figure 4-8 show thickness loss percentages for the 13-3/8", 20", and 30" casings surveyed in BM-116B (GOWell 2020). All figures shown for BM-116B were taken from the 2020 report. The 13 3/8" casing shows a similar casing loss graph to those seen in the PEC logs taken at other wells with some small variations measured within 0-10% thickness loss. The 20" casing shows a slight peak around 800'-1000', the same region in which collar compression is typically noted. The 30" casing follows a similar pattern with a much more dramatic increase, reaching almost 40% thickness loss at the end of the casing around 872' (depth is measured relative to the BHF).

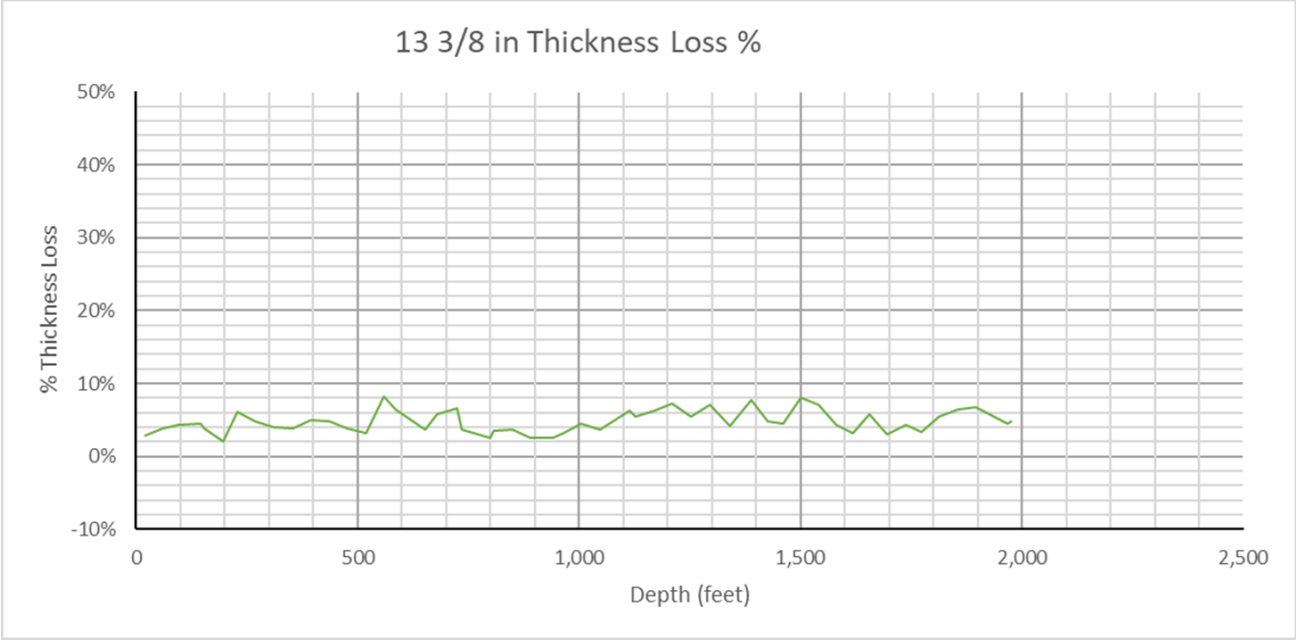


Figure 4-6. BM-116B pipe thickness loss for the 13 3/8" casing

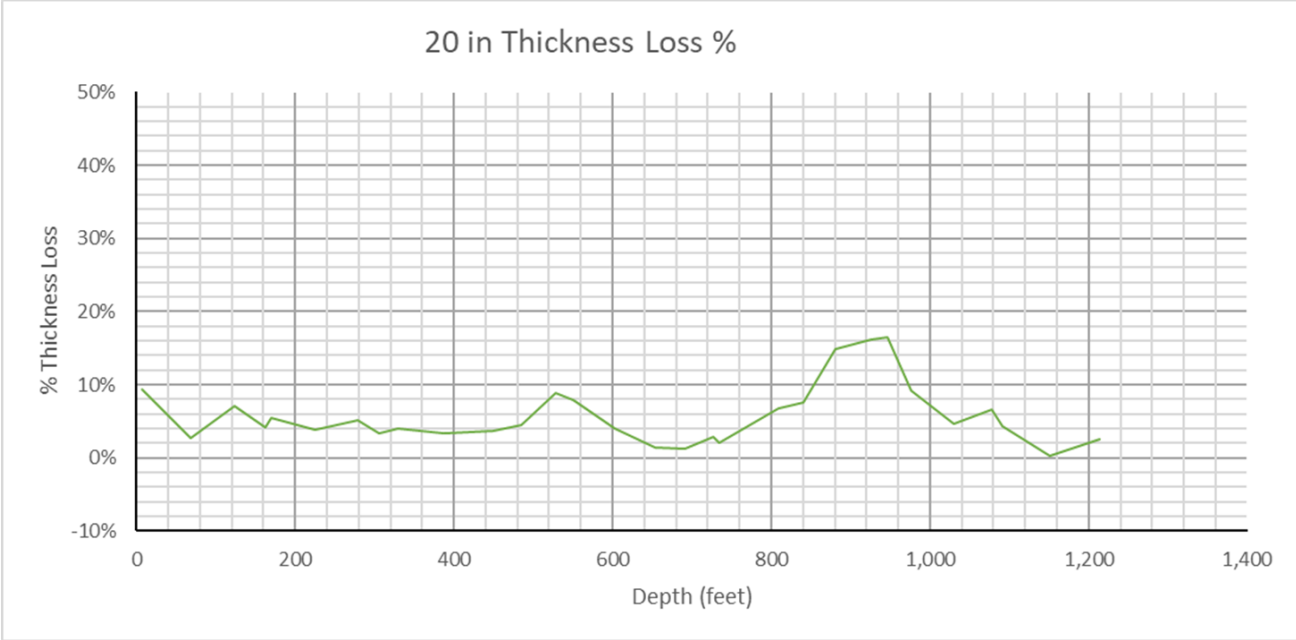


Figure 4-7. BM-116B pipe thickness loss for the 20" casing

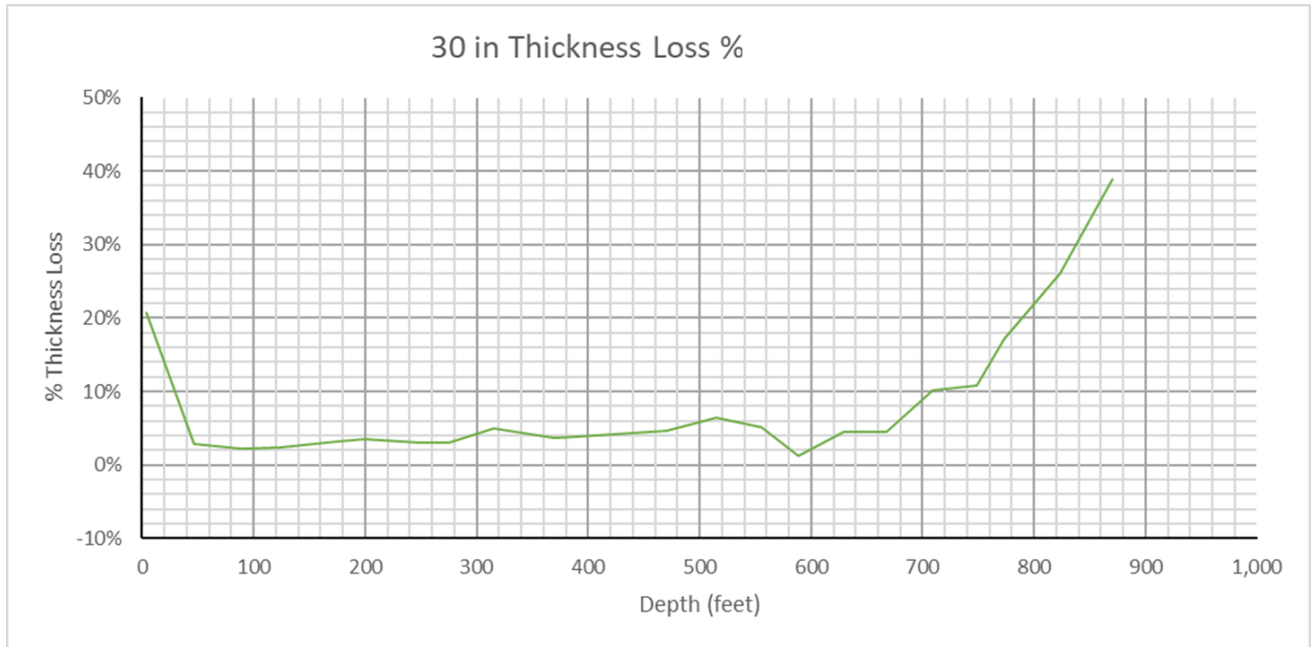


Figure 4-8. BM-116B pipe thickness loss for the 30” casing

In any analysis of the above data, it should be noted that there have only been a limited number of PEC logs taken at the Bryan Mound site, making it difficult to draw conclusive correlations from the results with such a small sample size. However, the BM-116B log does provide interesting results, especially considering its close proximity to BM-116A, which has recently experienced extreme well deformation. The BM-116B log does show higher thickness loss than expected, especially around 750’-1000’ feet in both the 20” and 30” casings. This could be a result of corrosion or direct contact of the outer pipe with the surrounding formation. The collection of more PEC logs from other wells at the Bryan Mound site would provide more insight into how unique this type of thickness loss truly is across the site.

4.4. Sulphur Well Locations

As mentioned earlier in the report, prior to being an SPR storage site, the Bryan Mound salt dome was used for sulphur mining operations. Due to the temporal and geologic effects of this type of mining, it is helpful to understand where the sulphur mining took place. Sandia has location data for a total of 436 known sulphur wells drilled at the Bryan Mound site. The data for each well includes the unique well identifier, well name, operator, total drilling depth, and the surface (X,Y) coordinates. The operator for each well is listed as “Sulphur Expl”. Figure 4-9 shows a collection of total depth values recorded for each of the BM Sulphur wells. Two wells (UWI #593 and UWI #1434) had a total depth of 10,000 feet listed and were excluded from the graph. With the exception of those two outliers, the total depth values range from 683’-1800’.

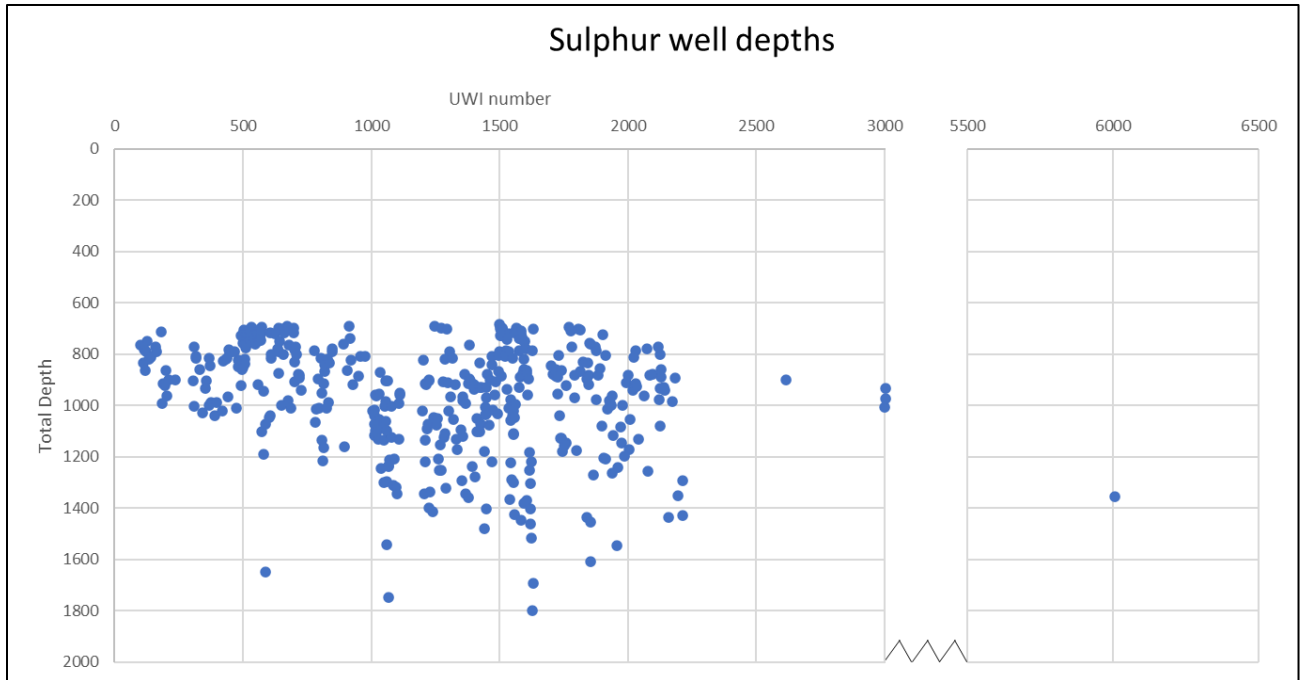


Figure 4-9. Summary of Bryan Mound sulphur well total depths

Figure 4-10 displays the sulphur well locations according to the surface coordinates listed for each well. Each well has been color coded based on its total depth (TD) value. According to this data, sulphur wells seem to be more concentrated around the perimeter of the dome, and the TD value tends to increase as wells approach the edge of the dome as well. The data provided does not include any details about the actual production volumes of each well, so we cannot say for sure which portions of the dome were affected the most by this sulphur mining, only where the drilling occurred according to well data. It has also been estimated that over 1897 sulphur wells were drilled at Bryan Mound, so the available dataset is not a complete record of all sulphur wells drilled at the site.

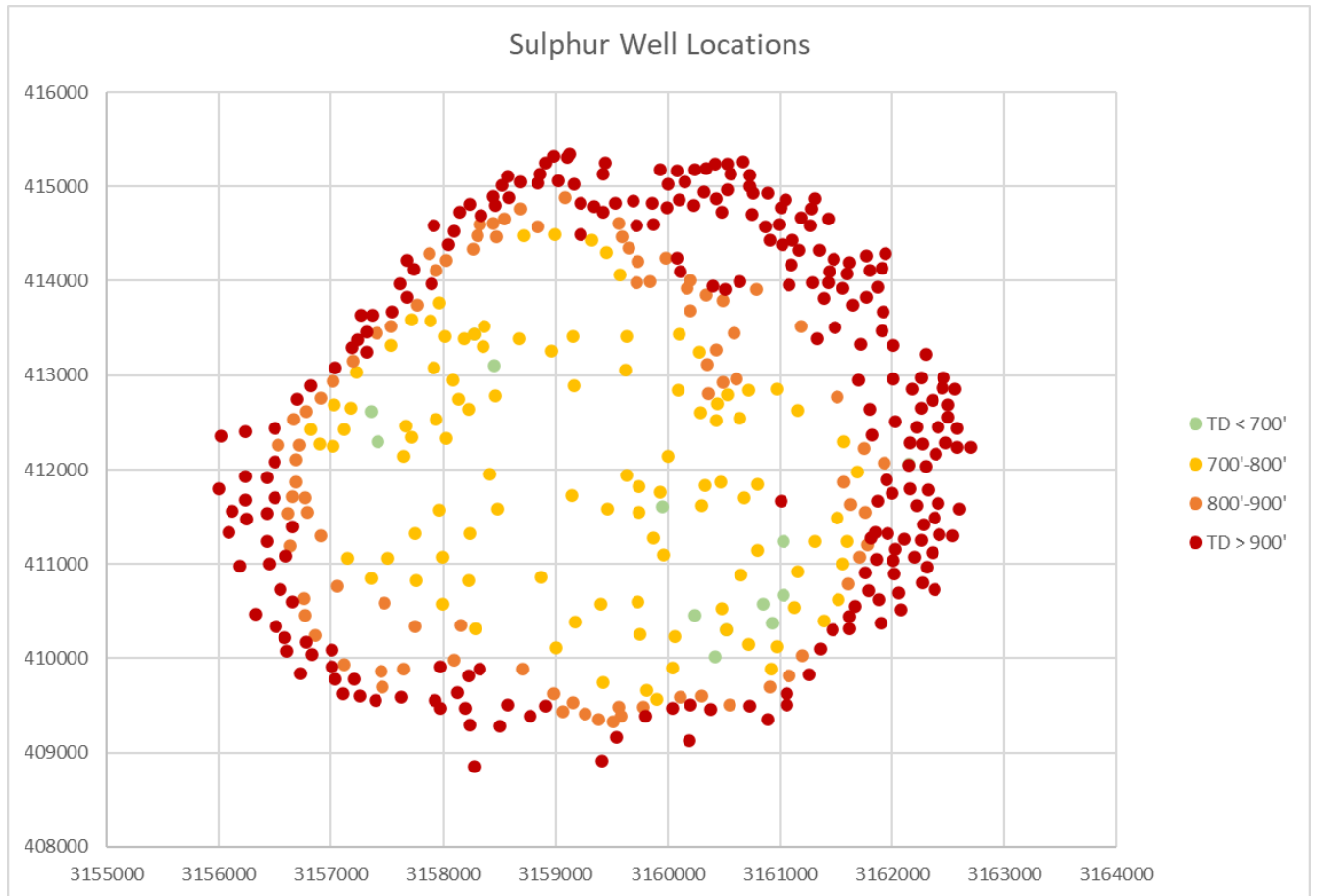


Figure 4-10. Bryan Mound Sulphur Well Locations

Figure 4-11 and Figure 4-12 show the locations of BM Sulphur wells in relation to current SPR wells, with the labels removed from the latter graph for visual simplification. SPR wells that exhibit a collar restriction are shown in orange, and SPR wells without a collar restriction are shown in grey. In the labeled figure, BM-116A has been noted with a star. As seen in the figures below, all SPR wells are within relative proximity to sulphur mining wells.

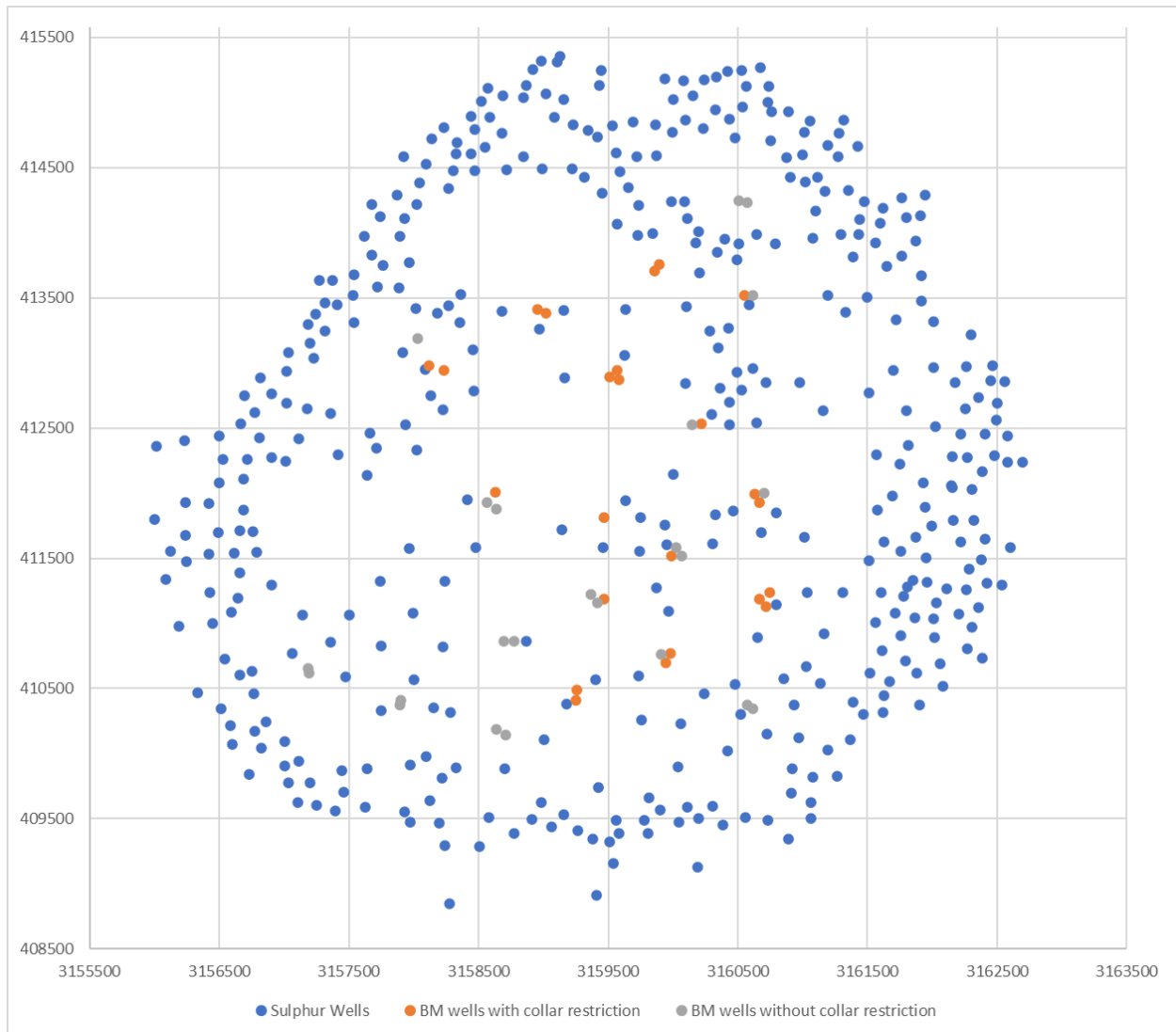


Figure 4-12. Bryan Mound unlabeled SPR and sulphur well locations

A summary of BM well proximity to sulphur wells can be seen below in Table 4-3. For all wells, a 2D distance between the x,y coordinates for each SPR well and the closest sulphur well were computed. For the wells experiencing collar restrictions, a 3D distance was calculated from the restriction depth to the closest sulphur well TD coordinate. For wells with two restriction depths, the closest distance of the two was included. When comparing the 2D distance between wells, the average distance was approximately 25 feet closer for wells with collar constrictions, however there was a wide range of proximity distances observed in both wells with and without constrictions, and therefore a significant amount of variation is present in each data set. For the wells experiencing casing restrictions, every single well restriction depth was found below the nearest sulphur well TD. As a result the 3D proximity values for each of those wells are higher than the 2D distances. Because the wells that are not experiencing casing compression have no downhole depth to use for a 3D distance calculation, there is no way to compare these 3D calculations between the two groups.

Table 4-3. Summary of BM SPR well proximity to sulphur well data

| Wells with collar restriction | 2D distance (x,y) to nearest sulphur well (ft.) | 3D distance from collar restriction to nearest sulphur well (ft.) | Wells without collar restriction | 2D distance (x,y) to nearest sulphur well (ft.) |
|-------------------------------|---|---|----------------------------------|---|
| BM-001A | 211.3 | 236.5 | BM-002 | 95.8 |
| BM-004B | 226.3 | 264.7 | BM-002A | 174.8 |
| BM-005 | 40.9 | 82.7 | BM-004A | 148.3 |
| BM-005A | 143.7 | 145.8 | BM-004C | 234.2 |
| BM-101A | 153.5 | 234.5 | BM-005C | 157.3 |
| BM-101C | 132.0 | 224.3 | BM-103C | 76.9 |
| BM-102B | 288.8 | 288.8 | BM-105C | 170.1 |
| BM-102C | 242.8 | 246.4 | BM-107A | 75.2 |
| BM-103B | 85.1 | 177.4 | BM-107B | 139.9 |
| BM-104A | 202.7 | 253.4 | BM-108C | 177.2 |
| BM-104B | 130.0 | 182.4 | BM-109C | 235.3 |
| BM-104C | 189.0 | 195.7 | BM-110B | 429.3 |
| BM-105B | 104.1 | 107.2 | BM-110C | 375.6 |
| BM-106A | 85.2 | 180.7 | BM-111A | 253.6 |
| BM-106B | 138.1 | 177.5 | BM-111B | 287.9 |
| BM-106C | 105.3 | 163.4 | BM-113A | 90.1 |
| BM-107C | 89.6 | 156.1 | BM-113B | 103.7 |
| BM-108A | 154.5 | 210.7 | BM-114A | 311.0 |
| BM-108B | 208.3 | 248.6 | BM-114B | 259.1 |
| BM-109A | 293.6 | 305.3 | BM-115A | 169.5 |
| BM-109B | 228.4 | 242.4 | BM-115B | 147.8 |
| BM-110A | 402.9 | 409.9 | BM-116A | 169.1 |
| BM-112A | 76.5 | 135.1 | BM-116B | 195.4 |
| BM-112C | 134.9 | 166.4 | | |
| Min | 40.9 | 82.7 | Min | 75.2 |
| Max | 402.9 | 409.9 | Max | 429.3 |
| Average | 169.5 | 209.8 | Average | 194.7 |

Figure 4-13 shows a comparison of the 2D proximity calculations for Bryan Mound wells with and without collar restrictions. Again, although the average proximity is slightly lower for wells with collar restrictions, there is significant variation in the data. Additionally, the 3D calculations for wells with collar restrictions was significantly higher, making it difficult to draw any statistically significant conclusions from the proximity data.

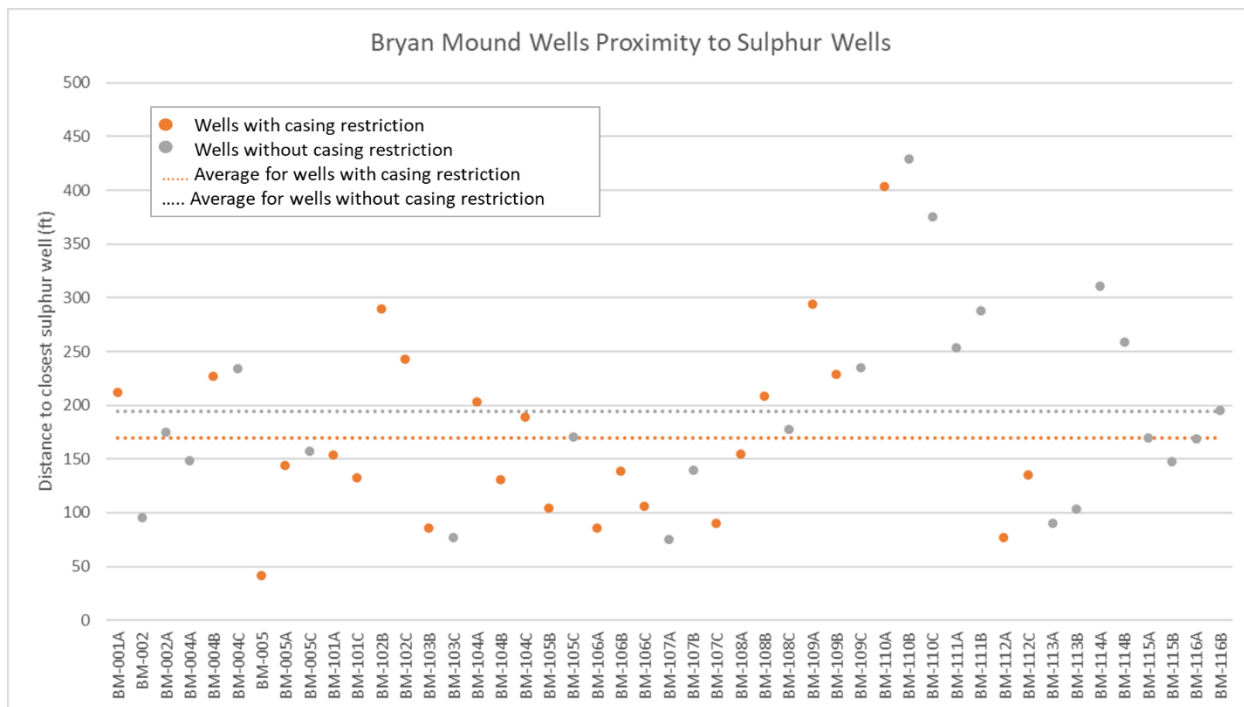


Figure 4-13. Bryan Mound well proximity to sulphur wells

Although the sulphur mining has almost certainly had a significant impact on the Bryan Mound dome geology within the caprock, the available location data for BM sulphur wells does not provide any strong correlations between their proximity to individual SPR wells, and the likelihood of a well experiencing collar compression. Furthermore, the sulphur well data available at this time does not include well-specific production totals and is also only a subset of the total number of sulphur wells drilled at the dome.

4.5. BM-116A Discussion

As referenced several times throughout this report, the BM-116A incident is an ongoing case study in well failure at the Bryan Mound dome. By almost every measure looked at in this study, the well did not appear to have any major indications of a well candidate that might experience the extreme deformation that it did. There was no collar compression or otherwise notable deformation observed in the MAC data. The temperature logs for this well (and other nearby wells) actually showed slightly lower temperatures in the caprock in comparison to the majority of BM wells. And although it is in relatively close proximity to sulphur mining wells, so are the majority of the wells at the Bryan Mound site, and the distance from BM-116A to the nearest sulphur well was close to the average proximity seen at the site.

The only indication from the data examined in this report that something was out of the ordinary in the area was the PEC log in nearby well BM-116B, which did show a higher-than-expected pipe thickness loss. It is possible that whatever was responsible for the pipe thickness loss in BM-116B, such as corrosive fluids that came in contact with the outer casing or general geologic forces in the area, was also affecting well BM-116A prior to failure. At this time, the exact cause for the BM-116A well failure is still unknown. The deformation occurred mid-casing at a depth of 983.3' relative to

the BHF and appears to be a result of axial compression in the wellbore, which is similar to the suspected mechanism behind the collar compression seen at other wells. Any future data collection at BM-116A such as fluid sampling data or an PEC log will help provide further insight into what might have led to the extreme deformation and ultimate well integrity failure that occurred.

5. SUMMARY AND CONCLUSIONS

Collar restrictions as a result of casing compression have been observed at 24 of the 47 Bryan Mound wells analyzed in this report. While several of these wells have since been lined, the restrictions are still present and deformation is likely ongoing, even if they can no longer be seen in recent MAC data because of the liners. The casing compression observed in the Bryan Mound wells is likely linked to the previous sulphur mining that took place in the caprock, however there are no obvious indications at this time as to why certain wells are experiencing these collar restrictions while others do not. It is likely a result of localized variations in the geology that have been impacted by the sulphur mining operations, in combination with each well's unique response to those geologic forces.

From the data evaluated in this report, there is no clear explanation as to why BM-116A experienced such severe deformation. Prior to the well failure there was nothing out of the ordinary observed in the MAC data, and temperature data for BM-116A and surrounding wells actually showed slightly lower temperatures than those typically observed in the caprock at Bryan Mound. The PEC log in nearby BM-116B did show higher than expected pipe thickness loss in the caprock region, which may be indicative of an issue in the area surrounding BM-116A. Any future data collection at BM-116A will help provide further insight into what might have led to the extreme deformation and ultimate well integrity failure that occurred.

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