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Geomechanical Insights from Ultrasonic Borehole Image Logs in Geretsried, Germany

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ABSTRACT

Eavor is progressing a commercial-scale Eavor-Loop™ project in Geretsried, southern Germany. This first-of-a-kind project consists of multiple horizontal Eavor-Loops targeting the carbonate Malm Formation at a depth of 4.5 km. The drilling and execution of a closed-loop system is highly complex, which was compounded by initial uncertainties in the subsurface at Geretsried. As part of the data collection program for Loop 1, Eavor conducted a series of open-hole logging runs. Over 8 km of ultrasonic image logs were acquired in the horizontal wells, and these logs helped to resolve several critical uncertainties that had previously challenged the project. Key geomechanical observations were made on the stratigraphic and structural trends, as well as the rock mechanical failure mechanisms contributing to suspected borehole enlargement. Based on the insights from the ultrasonic image logs, the geomechanical model was revised, leading to a recommendation to adjust the drilling practices and fluid properties. Drilling results demonstrated that these modifications significantly improved performance and wellbore stability. The detailed findings from this phase of the project will be explored, and the invaluable insights gained from ultrasonic image logging will be highlighted.

1 INTRODUCTION

Eavor Technologies Inc. (Eavor™) is a closed-loop geothermal energy company founded in Calgary, Alberta, Canada in 2017. An Eavor-Loop is a novel geothermal solution for large-scale power generation and district heating. The key technical differentiator compared to a conventional geothermal system is the use of a subsurface multilateral closed-loop system that relies only on conductive heat transfer, as opposed to relying on convection or fluid flow. A prototype of the first-generation closed-loop system was successfully built and operated at the Eavor-Lite™ facility from 2019 to 2024, in a low-permeability sandstone in Alberta (Zatonski & Brown, 2023; Toews et al., 2020). In 2023, Loop 1 of the first commercial scale project began in Geretsried, Germany, located in the Bavarian Molasse Basin. To complete the Eavor-Loop, two wells (named GEL-A1 and GEL-B1) were drilled to a vertical depth of ~4.5 km and landed at a ~88° inclination in the carbonates of the Upper Jurassic Malm Formation. GEL-A1 was placed 65 m above GEL-B1, and these wells became the cased tie-in points for the multilateral open-hole section of the loop. A series of lateral sidetracks were then drilled from the cased wellbores, with extended reach horizontal sections up to ~3 km in length. Associated lateral wellbores from GEL-B1 and GEL-A1 were connected at the toes to complete the lateral pairs as part of the closed-loop system. An example schematic demonstrating a horizontal Eavor-Loop design is shown in Figure 1.

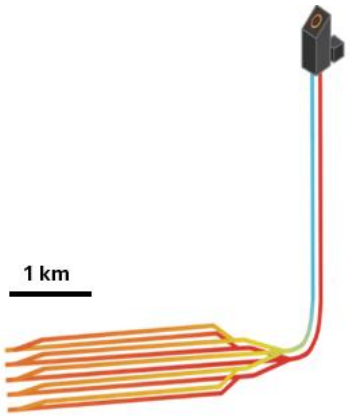


Figure 1: Schematic of the horizontal Eavor-Loop design. Note this is for visualization purposes and does not display the well plans, flow direction, or relative sizes of the loops at Geretsried.

1.1 Pre-Drill Assumptions

Nearby offset wells GEN-1 and GEN-1ST-A1 were drilled in 2013 and 2017, respectively. These wells were drilled from the same pad as GEL-A1 and adjacent to GEL-B1, and the acquired logging data was used to constrain the geological and geomechanical pre-drill assumptions for the Eavor-Loop development (Longfield et al. 2022). GEN-1 and GEN-1ST-A1 were intended to be conventional geothermal wells but failed to find sufficient permeability (Backers et al., 2022). No other direct field data was available prior to drilling. Furthermore, the lack of horizontal drilling experience in the basin limited the ability to directly apply best practices from offset wells, requiring a local geomechanical model. Prior to Loop 1, in the wider Munich area near Geretsried, there were only three wells with near horizontal sections of up to only 400 mMD. Calibrating a geomechanical model prior to drilling can be extremely challenging in a data sparse environment like Geretsried. There are often uncertainties in in-situ stress, pore pressure, and rock properties.

Both the magnitude and azimuth of the in-situ stresses can vary laterally and with depth, making the task of estimating the stress tensor notoriously difficult. There is significant uncertainty in the stress regime in the Bavarian Molasse Basin, as normal, strike-slip and reverse faulting regimes have all been predicted in the areas adjacent to Geretsried (Reinecker et al., 2010; Drews et al., 2019; Ziegler & Heidbach, 2020; Backers et al., 2022; and Ahlers et al., 2021). Despite the uncertainty in the stress regime, the S_{Hmax} azimuth is consistent in the World Stress Map and is oriented north/south (Heidbach et al., 2025). Additionally, pore pressure in the Malm Formation was well constrained and known to be sub-hydrostatic from GEN-1 and GEN-1ST-A1 data.

The Eavor-Loop development targeted the tight transitional platform-to-basin carbonates of the Malm Formation. Prior to spud, the stratigraphic subunits in the Malm Formation at Geretsried were weakly defined due to the limited full-section well penetrations and isolated core data. The composition was anticipated to only subtly vary from dense limestone to dolostone. The Malm was expected to be a competent formation with high rock strength and low geomechanical instability, and this had been supported by drilling and logging data in the GEN-1 and GEN-1ST-A1 wells. The Technical University of Munich extensively studied both GEN-1ST-A1 core and analogue outcrops of the Malm Formation and summarized the properties in the “Dolomitkluft” research report (Thuro et al., 2019). Eavor had no access to view the core, so the “Dolomitkluft” research report and the associated study by Stockinger (2022) were the primary sources for understanding rock properties. The range of Malm UCS from “Dolomitkluft” was 80 – 250 MPa, which can be classified as strong to very strong rock (Stockinger, 2022). As with many carbonates, a large degree of variability can occur over short distances, so despite the nearby offset well data, uncertainty in the rock properties was carried as a risk.

Due to the subsurface uncertainty, prior to drilling, several geomechanical risks were identified for the open-hole section in the Malm Formation. While the Eavor-Loop development was planned to be away from major faulting identified in 3D-seismic, the potential for structure in the reservoir was considered to be likely as the offset wells had intersected the Gartenberg Fault zone and a complex network of natural fractures (Moeck et al., 2022). It was expected that these complex structural features may be associated with weakened or damaged zones. Another risk included borehole breakouts due to stress-induced failure, particularly if the in-situ stress state differed from expectations, or if rock properties varied away from the offset wells. This could lead to stuck pipe or tool loss. Thermal stress-induced tensile failure was identified as a low-likelihood risk, but with the potential to cause fracture propagation and lost circulation.

1.2 Early Observations

The drilling of the GEL-A1 and GEL-B1 laterals began in Q1 2024. The first pair of lateral wellbores was drilled without incident and connected at the toes. However, after the intersection of the wellbores, the team observed that a larger volume than expected was needed to flood the wellbores with Eavor's proprietary Rock-Pipe™ treatment. Further lookback indicated that a continual increase in volumes was observed during the drilling operations, and calculations by the drilling team suggested that an overall enlargement was present, but the specific location of the enlargement was not known. No cavings had been reported, so the wellbore enlargement had not been expected, and the root cause was not understood. However, at the time, the cuttings returns were poor, with cuttings and cavings likely being pulverized and clumped into aggregates.

Shortly after the kickoff of the first lateral sidetrack, a stuck pipe incident occurred. Due to the suspected wellbore enlargement and stuck pipe drilling issues, the decision was taken to acquire ultrasonic image log data in the lateral wells to better understand the downhole conditions.

2 DATA COLLECTION

The relevant data collected in Loop 1 included continuous cuttings analysis by mudloggers, a wireline logging program in the GEL-B1 vertical section, gamma ray while drilling in all wells, and ultrasonic image logging in select laterals. Combined, this valuable subsurface data contributed to the evolution of the geomechanical model; however, the focus of this discussion will be on insights from the ultrasonic image logs.

Ultrasonic image log data with acoustic caliper was initially acquired in three lateral wells in Q2/Q3 2024 (GEL-B1-ST01, GEL-A1-ST01 and GEL-A1-ST02). The logging program objective was to identify potential root causes for the wellbore enlargement. Across the three wells, ~6500 mMD of unique lateral length was logged, with ~500 mMD logged in a repeat pass, bringing the total logged length to ~7000 mMD (Figure 2). GEL-B1-ST01 data was collected as a memory pass after drilling, GEL-A1-ST01 was a combination of logging-while-drilling (LWD) and a memory pass after drilling, and GEL-A1-ST02 was entirely collected while drilling. The data quality improved over time, with GEL-A1-ST02 having the highest quality image.

In Q1 2025, an additional logging proposal was made for GEL-A1-ST04. The logging program objective was to monitor borehole shape, and to reduce uncertainty in stratigraphic trends and rock strength variability. A combined tool with azimuthal spectral gamma ray, azimuthal sonic and ultrasonic image with acoustic caliper was selected. In this second logging program, a total of ~1300 mMD of lateral length was logged with no repeat passes (Figure 2).

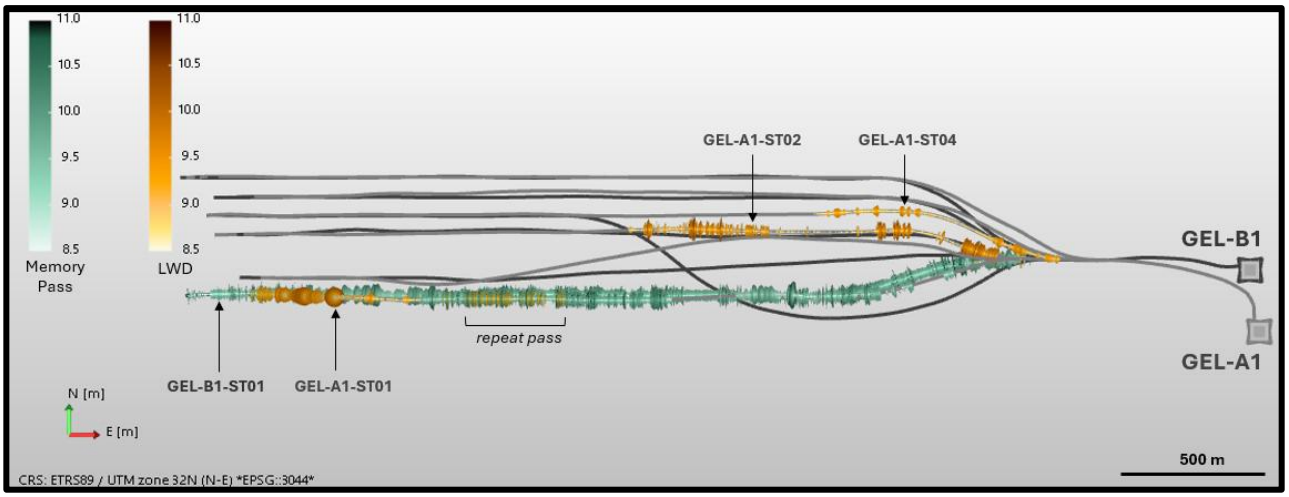


Figure 2: Map view of connected lateral pairs from Loop 1. Wells displayed with 3D curve for average acoustic caliper, colored by Memory Pass or LWD. 3D acoustic caliper log is displayed symmetrically and scaled by 200%. Ultrasonic image logs were collected in GEL-B1-ST01, GEL-A1-ST01, GEL-A1-ST02 and GEL-A1-ST04, with the latter two logs being the highest quality.

3 ULTRASONIC IMAGE LOG OBSERVATIONS

Prior to the delivery of the ultrasonic image logs, there was limited data to complete a geomechanical analysis related to the enlargement and suspected associated wellbore instability. After the interpretation of the acquired image log data in the laterals of Loop 1, key geomechanical observations were made on the stratigraphic and structural trends, as well as the rock mechanical failure mechanisms contributing to suspected borehole enlargement. Four key observations will be further discussed here: multiple failure modes, subtle stratigraphic variations, bedding planes, and stress-induced borehole breakouts. These observations helped to update the geomechanical model and supported mitigations to improve stability. The highest quality GEL-A1-ST02 and GEL-A1-ST04 LWD runs provided significant learnings to the project.

A limitation of this study is that not enough high-quality repeat pass data was collected to be able to draw conclusions on the time component of failure. Operational practices, including bit and BHA design, changed significantly between the early runs, which meant that general observations from LWD and post-drill memory passes between different wells could not be used to understand time dependence. There was one dedicated repeat pass collected in the image logging of GEL-A1-ST01, and this section of the wellbore had sporadic borehole enlargement. The first image log pass was LWD, and the second pass was on memory and imaged the same section ~3 days later. In the areas with borehole enlargement, it was observed that there was minor change in the damage zones in the repeat pass as compared to the initial run, suggesting that the failure developed suddenly. The base case assumption is that time was not the primary factor in wellbore damage.

3.1 Multiple Failure Modes

Multiple failure modes were observed within a single lateral, and enlargements due to breakouts and bedding were both observed (Figure 3). From the high-quality GEL-A1-ST02 and GEL-A1-ST04 image logs, 50-60% of the wellbores were in gauge, but the remainder was categorized as having either rugose hole, breakout, or minor enlargement. Washouts were exceedingly rare in all the laterals; however, breakout and minor hole enlargement were observed in all logged wells.

Failure on weak bedding planes and stress-induced breakouts appeared to contribute to the majority of the wellbore enlargement. Symmetric breakouts, which are related to compressive failure due to maximum hoop stress around the hole exceeding rock strength, are referred to here as stress-induced breakouts (Zoback, 2010). The same failure trends could be correlated between GEL-A1-ST02 and GEL-A1-ST04, suggesting that the failure was predictable, and therefore mitigatable, with a calibrated geomechanical model. Notably, although structure (faults and fractures) was present, there were limited observations to suggest it was a primary contributor to instability. While strong correlations could be found between stability and stratigraphy, direct correlation with structure was minimal. Additionally, after >8 km of image logs, no induced tensile failure was observed.

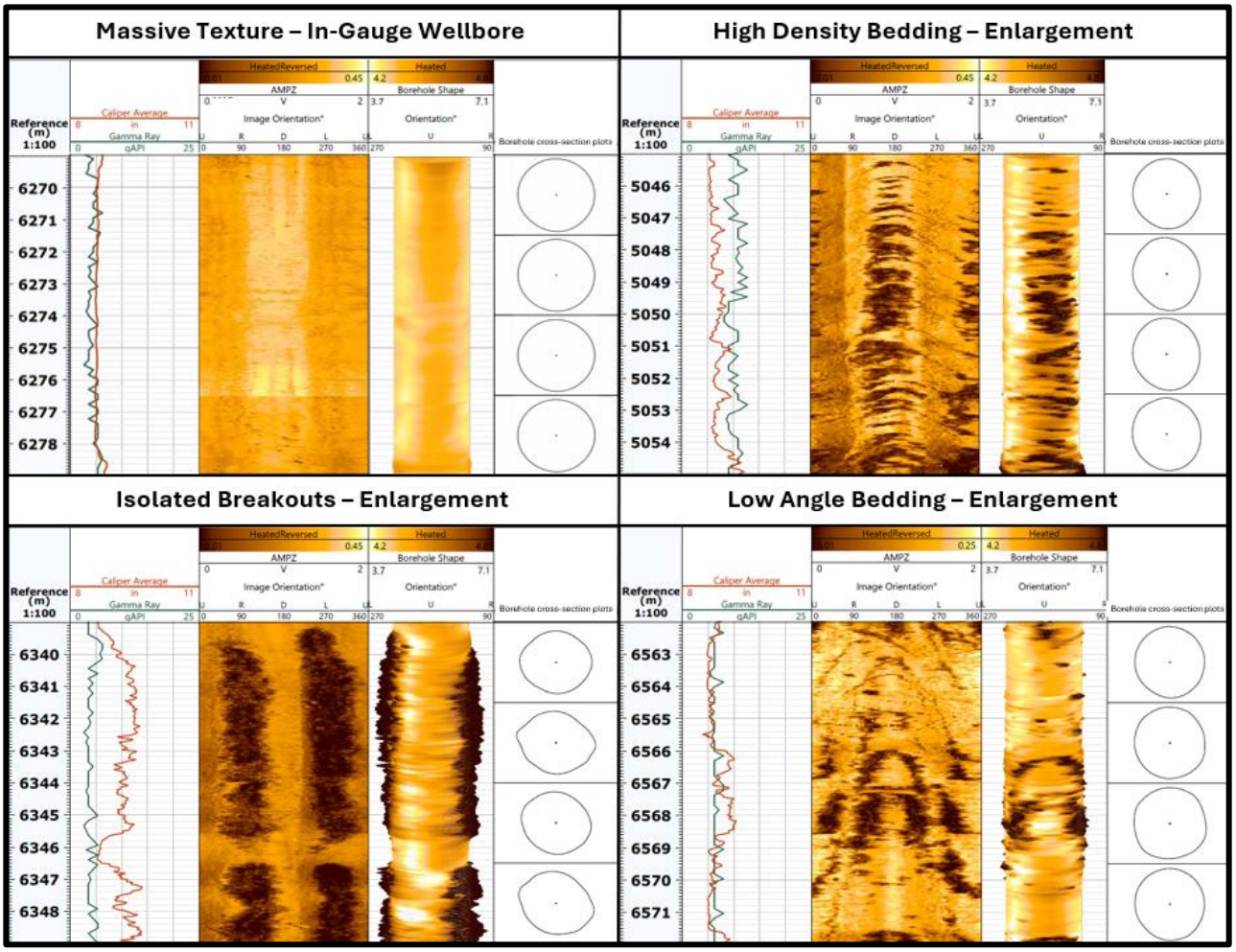


Figure 3: Characteristic wellbore features observed in a LWD ultrasonic image run in GEL-A1-ST04.

3.2 Subtle Stratigraphic Variations

Subtle stratigraphic variations influenced wellbore stability. The initial hypothesis was that damage zones related to structure (faults and fractures) would have a stronger influence than stratigraphy on wellbore instability. As a result, initially, a stratigraphy-agnostic data science approach was used in Spotfire® and Python™ to determine correlations with wellbore enlargement. Simplistic data correlations were run on the image log interpretation, gamma ray, and logged drilling data. The analysis looked at ~50 parameters to determine the highest correlation.

The review found the strongest relationships were between acoustic caliper, gamma ray, and bedding density. An especially strong correlation in GEL-A1-ST02 could be seen between average caliper and gamma ray, with caliper increasing with slight increases of gamma ray (Figure 4). This implied that in some sections, the enlargement of the wellbore was related to lithology and stratigraphy. This observation concluded that subtle stratigraphic variations influenced wellbore stability, supporting the idea that an updated stratigraphic model and associated geomechanical model would be beneficial to the operations team.

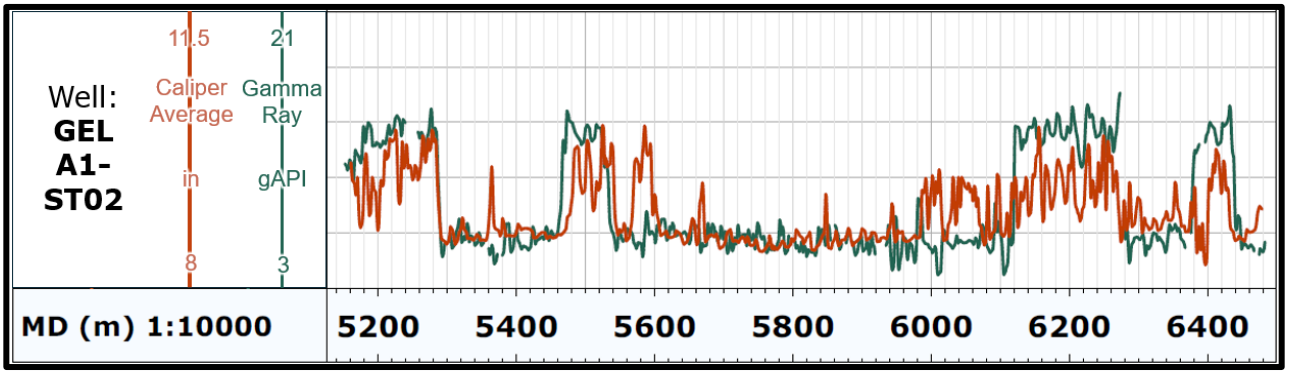


Figure 4: A correlation in GEL-A1-ST02 was observed between average acoustic caliper and gamma ray. Due to the low radioactivity of the carbonate formation, the range for gamma ray investigated was limited to ~0 - 20 gAPI. This implied that in this section, the enlargement of the wellbore was related to lithology.

3.3 Bedding Planes

Bedding planes introduced complex failure mechanisms. It was interpreted from the image logs that the GEL-A1 and GEL-B1 laterals were drilled subparallel to bedding planes. Clear failure along weak bedding planes could be observed in the image log. The bedding features had low acoustic amplitude and increased transit time, suggesting that they were failing and becoming washed out (Figure 3). Additionally, when the wellbores intersected the bedding planes at low angles, complex multilobe breakouts occurred due to slip along these weak planes (Zoback, 2010; Kowan et al., 2021). These features are evident in 3D visualization (Figure 5). The upper lobes can result in a complete failure with roof collapse, so this type of failure is occasionally interpreted as symmetric high-side/low-side breakouts. It was also observed that bedded intervals could be correlated to specific subunits in the Malm, further supporting the need for a stratigraphic model for the operations team.

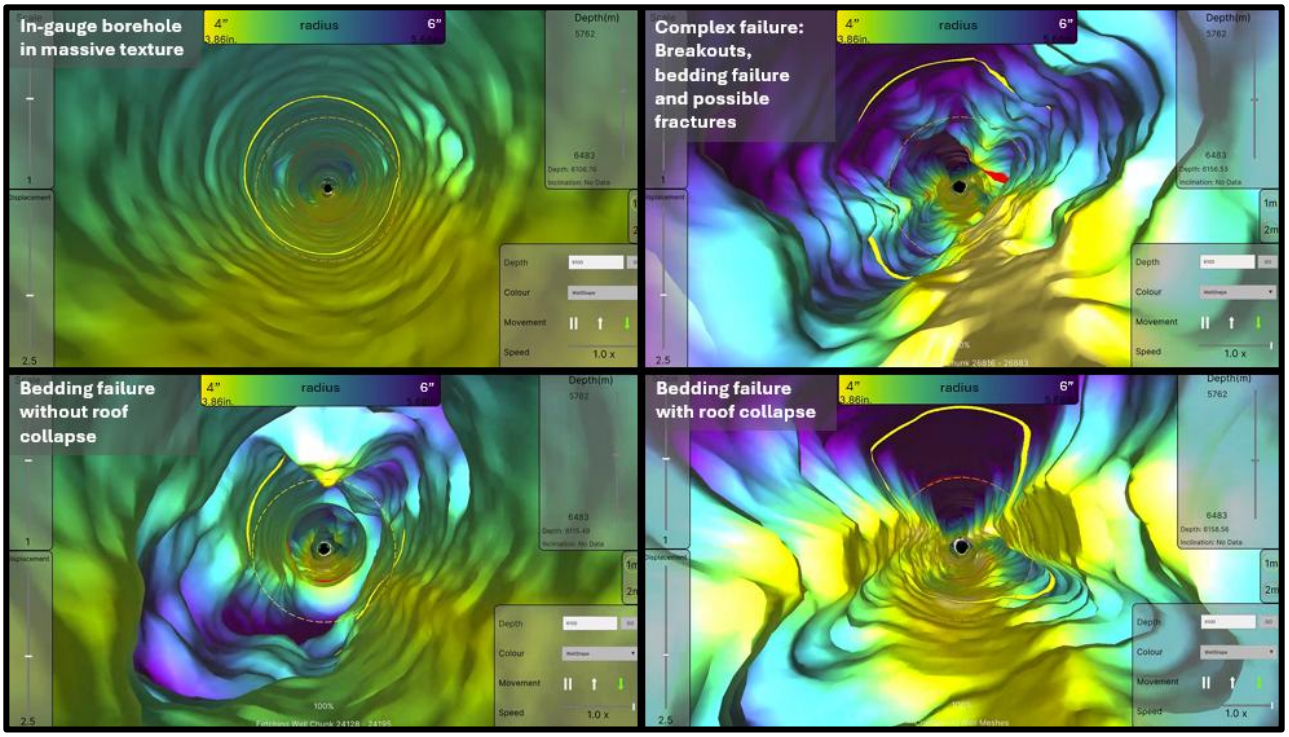


Figure 5: 3D visualization prepared by Well ID in GEL-A1-ST02. Indications of failure along weak planes and roof collapse are observed. Note the scale is exaggerated, but the shape is representative of the failure.

3.4 Stress-Induced Breakouts

Stress-induced breakouts were prevalent and yet sporadic within the same geologic formation in the lateral wells. From >8 km of image log data, the lateral wells demonstrate an almost unanimous left/right orientation of the breakouts (Figure 6). Occasionally, symmetric high-side/low-side breakouts were interpreted and related to a fault or roof collapse from bedding failure, but ~85% of high confidence breakouts were due to stress-induced breakouts on the sides of the wellbore. Across all wells, the breakout width was consistent with an average of approximately 65°, however, the length was approximately 1 mMD on average. Approximately 1200 breakouts were interpreted in the runs. This implies that the breakouts are wide and prevalent and yet short and sporadic.

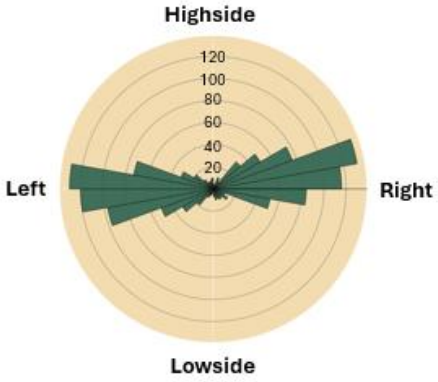


Figure 6: Breakout orientation trend across all lateral wells imaged in Loop 1. The symmetric breakouts interpreted in the horizontal wells demonstrate an almost unanimous left/right orientation (count: 1200).

Since the wells are all within the Malm Formation, it was challenging to understand what controlled the initiation of breakouts. In contrast, in a vertical well, breakout formation is often guided by mechanical differences between stratigraphic layers. Stress-induced breakouts appeared sporadically within the Malm Formation and lacked a consistent association with specific lithologies or sub-units. Figure 7 displays the frequency of the interpreted breakouts over a 10 m rolling average. The breakouts did not appear to correlate to wellbore trajectory or operational changes like mud weight or mud temperature. Using the sonic and gamma ray logging data from GEL-A1-ST04, a geomechanical model was built to understand the factors controlling breakouts.

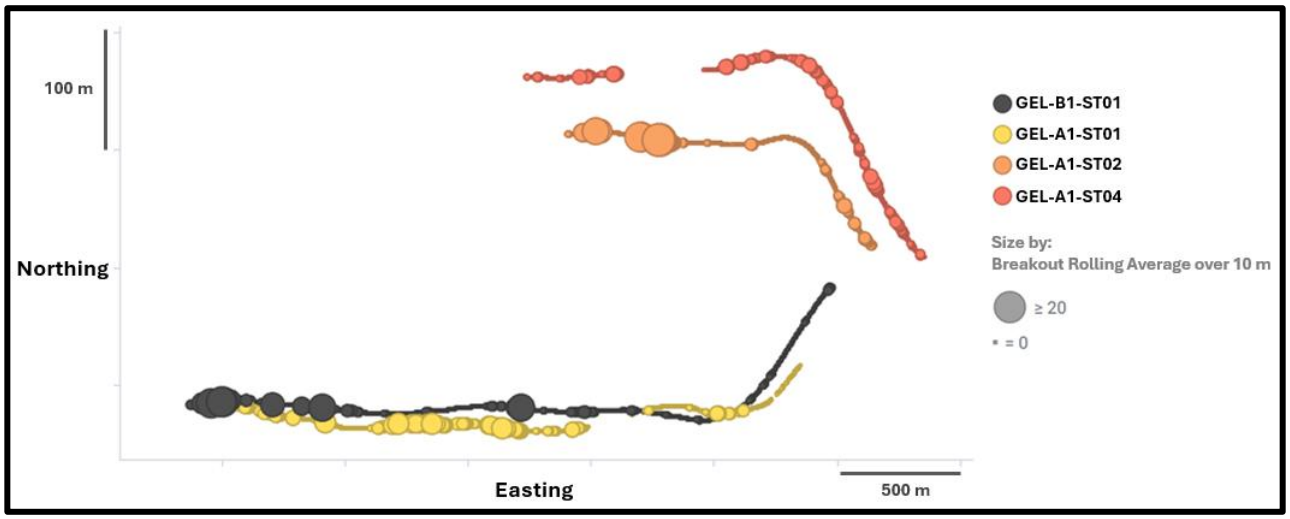


Figure 7: Frequency of breakouts interpreted from ultrasonic image logs, calculated from a 10 m rolling average. The breakouts did not appear to correlate to wellbore trajectory, stratigraphic sub-units or operational changes like mud weight or mud temperature.

4 GEOMECHANICAL MODEL UPDATE

With the sonic and ultrasonic image data from GEL-A1-ST04, a calibrated geomechanical model was built. Key components of a geothermal geomechanical model are rock properties, in-situ stress, pore pressure, and temperature. The model inputs are then iterated until the predicted failure aligns with what is observed in image log, for a specified mud weight and wellbore orientation. A detailed review of this updated model is out of scope for this paper, but the high-level learnings on the rock properties, in-situ stress, and calibration will be shared.

For the logged section of GEL-A1-ST04, there was evidence from image logs and cuttings of subtle stratigraphic variation with two primary lithologies: a bedded carbonate mudstone, and a massive limestone. The sonic data could be used to calculate rock properties, and the results were compared to the results by Stockinger et al. (2021). The geoscience team then developed a stratigraphic model with Malm subunits, and advanced modelling was used to assign weak bedding planes to the carbonate mudstone subunit. Both the stress-induced breakouts and slip on bedding planes were able to be calibrated as compared to the observations in the image log.

Breakout orientation provided convincing evidence of the in-situ stress regime. Consistent symmetric stress-induced side breakouts were observed on all laterals. In Section 1, it was discussed that the stress regime was highly uncertain pre-drill, but the World Stress Map demonstrates that S_{Hmax} azimuth is north/south. Since the lateral wells were drilled toward the east, and therefore towards S_{hmin}, the observed breakouts allow for a direct inference of the stress regime. From the consistent side breakouts observed, there is strong evidence that S_v is the maximum stress, and the Malm at Geretsried is in a normal faulting stress regime ($S_v > S_{Hmax} > S_{hmin}$).

As discussed in Section 3.4, it was challenging to identify the factors controlling the breakout formation, particularly since the lateral wells were drilled entirely within the Malm Formation, where similar conditions were expected. After incorporating the sonic data and image log observations, in general, the model adequately captured the breakout width, orientation, and breakout type. Notably, the discreet changes between high-side/low-side breakouts from slip on weak planes in the bedded carbonate mudstone, and the left/right side breakouts in the massive limestone were successfully modelled. Additionally, the model successfully reproduced the sporadic nature of the stress-induced side breakouts, confirming the high sensitivity of the formation with regards to breakout initiation. This model gave confidence to the team that the wellbore enlargement was now understood, and mitigations could be proposed.

5 PROPOSED MITIGATIONS FOR WELLBORE STABILITY

The analysis of ultrasonic image log data from multiple laterals in the Malm formation concluded that wellbore instability was a prevalent issue challenging the project. Wellbore instability is a complex issue in drilling operations, influenced by many variables, and can result in borehole enlargement and an increased risk of pack-off or stuck pipe events. Given ongoing drilling activities, it was recommended to implement both low-energy drilling practices and to modify the mud system.

5.1 Low-Energy Drilling Practices

In collaboration with the drilling engineering team, several low-energy drilling practices were recommended to minimize formation disturbance within the identified weak zones. These practices included limiting the time of lateral construction, modifying the bit nozzle design to reduce jetting force, controlling ECDs and surge pressures, and minimizing prolonged off-bottom circulation with the BHA. Where possible, minimizing backreaming operations was also recommended. When backreaming was necessary, the drilling engineering team provided guidance on BHA design to limit formation damage. Lastly, it was recommended to optimize tripping operations to mitigate risks associated with wellbore instability.

5.2 Changes to the Mud System

Image log observations from the Geretsried wells pointed to wellbore instability associated with planes of weakness and stress-induced breakouts, leading to a recommendation to revise the mud system to address both of these failure types. Poor cuttings and cavings recovery in the early lateral sections further supported the need for a modified mud program.

At the onset of drilling the lateral sections, the drilling mud was predominantly a clear fluid with minimal filter cake, very low viscosity, and no added density (1.01 SG). Based on the expertise of local operators, this fluid system had been commonly used in geothermal wells targeting the carbonates of the Malm Formation in the Bavarian Molasse Basin. Traditional geothermal wells in this area often target permeable faults and fractures, and drilling within the Malm can often result in significant losses from the sub-hydrostatic pore pressure conditions. Due to this, a simple fluid system is often used. However, these historic wells differed from the Geretsried laterals in inclination and production section length. Consequently, they did not experience the same impacts from wellbore instability when drilling with clear fluid and minimal filter cake.

Increasing mud weight was considered a viable option for improving wellbore stability in Loop 1, as it generally helps to prevent breakout formation and slip along weak planes. However, there are important caveats to this approach, as presented in literature (Edwards et al., 2004; Kowan et al, 2021). These studies highlight the challenges of designing an optimized mud program in a formation with weak planes. Edwards et al. (2004) found that while increasing mud weight could suppress stress-induced breakouts in intact rock, it may worsen instability when pre-existing weaknesses like bedding planes or fractures are present, as mud could infiltrate and destabilize these zones. The authors emphasized that addressing wellbore instability by increasing the mud weight must be balanced with the risk of mud invasion into weak planes, which may inadvertently lead to further destabilization and instability.

Based on the above considerations, it was recommended to replace the clear drilling fluid with a viscosified water-based mud (WBM), capable of forming a filter cake, and incorporate additives to minimize fluid loss into the formation particularly along weak planes. If a viscosity increase was not feasible, alternative methods to reduce mud invasion were to be explored. After the mud change, it was recommended to closely monitor the cavings. While few cavings were observed with clear fluid, the viscosified system was expected to improve cavings transport to surface.

Once viscosity and fluid-loss control were established, it was recommended to consider incremental mud weight increases but to avoid such adjustments until minimal invasion was achieved. The geomechanical model suggested that a mud weight of ~1.1 SG would mitigate most breakouts and slip on weak planes. However, the benefits of higher mud weight for wellbore stability would also need to be balanced with the risk of losses, given that the Malm pore pressure is sub-hydrostatic.

6 IMPLEMENTED MITIGATIONS AND IMPROVED DRILLING PERFORMANCE

Procurement and regulatory approval of a new viscosified WBM began shortly after the first high-quality image log results. Due to regulatory constraints, implementing the mud system required a comprehensive approval process. A phased approach was adopted, with the final improved system introduced in Q2 2025. First, the drilling fluid was carefully designed and laboratory-tested through multiple iterations. During field deployment, each drilling run included detailed fluid testing and systematic rheology measurements to quantify improvements resulting from the viscosified WBM. This approach allowed for measuring the new drilling fluid system's impact on drilling performance and wellbore stability, while considering other variables in well construction optimization. In parallel, the low-energy drilling practices were introduced.

Due to timeline constraints, no additional image logs were run after the final mud system was implemented, limiting the ability to verify improvements in wellbore stability. However, both the cuttings returns and drilling performance indicated a significant improvement compared to the early laterals. After the implementation of the viscosified WBM, the mudloggers reported an increase in fresh cuttings, demonstrating that hole cleaning efficiency improved. This likely further decreased the risk of stuck pipe. The lithology observations from the increased cuttings returns further supported the development of the stratigraphic model of the Malm subunits.

Results from multiple laterals in the GEL-A1 and GEL-B1 wells showed that combining low-energy drilling practices with a viscosified WBM significantly improved drilling performance. Three of the final lateral wellbores achieved steady on-bottom rate of penetration and consistent wellbore conditions. These laterals reached total depth in a single BHA run, setting a new record for extended-reach laterals in the Malm Formation. Performance gains were significant and total time spent per lateral was reduced by over 50% with nearly double on-bottom rate of penetration (Hodder et al., 2025). After the implemented changes, no stuck pipe issues occurred for the remainder of the lateral wells in Loop 1, implying that the wellbore stability had likely improved.

Although the mud weight increased slightly due to solids buildup (from 1.01 SG to 1.05 SG), the recommended further increase was not found to be needed in GEL-A1 and GEL-B1 wells. Viscosity and fluid-loss control were sufficient to prevent the drilling issues that had challenged the project in the earlier laterals. Based on improved stability and performance, the drilling team decided to maintain the existing fluid density to avoid introducing new downhole variables. However, if further breakout issues are observed in future Loops, incrementally adding weight is an option carried by the drilling engineering team, assuming continued optimization of the fluid system to minimize invasion along weak planes.

While the direct impact on the wellbore condition of low-energy drilling and the modified mud system could not be quantified without additional image logs, the substantial improvements in drilling performance indicate improved wellbore stability and hole cleaning efficiency. These changes likely reduced wellbore enlargement and minimized the associated risk of stuck pipe.

7 CONCLUSIONS

Eavor is currently progressing a commercial-scale multi-Eavor-Loop project in Geretsried, southern Germany. This first-of-a-kind project is targeting the carbonates of the Upper Jurassic Malm Formation. From the nearby GEN-1 and GEN-1ST-A1 offset wells and research studies, the Malm was expected to be a competent formation with high rock strength and low geomechanical instability. However, building a geomechanical model prior to drilling can be extremely challenging in a data sparse environment like Geretsried. There are often uncertainties in in-situ stress, pore pressure, and rock properties. Prior to drilling, several geomechanical risks related to borehole stability were carried, although considered to be low likelihood.

Early in the drilling phase of the lateral section of Loop 1, suspected wellbore enlargement was identified, and a stuck pipe incident occurred. The decision was taken to acquire more data in the lateral wells to better understand the downhole conditions, and Eavor conducted a series of open-hole logging-while-drilling runs. Over 8 km of ultrasonic image logs and acoustic caliper were acquired in the horizontal wells.

After the interpretation of the acquired image log data in the laterals of Loop 1, key geomechanical observations were made on the stratigraphic and structural trends, as well as the rock mechanical failure mechanisms contributing to the suspected borehole enlargement. Key learnings included: multiple failure modes were observed within a single lateral, subtle stratigraphic variations influenced wellbore stability, bedding planes introduced complex failure mechanisms, and stress-induced breakouts were prevalent and yet sporadic within the same geologic formation in the lateral wells. Although structure was present, there were limited observations to suggest it was a primary contributor to instability.

Based on image log observations, it was recommended to implement both low-energy drilling practices and to modify the mud system. While increasing mud weight can suppress breakouts, it may destabilize zones with bedding planes due to mud invasion (Edwards et al., 2004). As a result, it was recommended to replace the clear drilling fluid with a viscosified WBM and to minimize fluid loss into the formation. If no improvement was observed, it was then recommended to increase mud weight while balancing the risk of losses to the sub-hydrostatic Malm formation.

After the changes were implemented, drilling results from multiple lateral wells demonstrated that combining low-energy drilling practices with a viscosified WBM significantly improved drilling performance. No additional increase in mud density was required. Successes included a reduction of total time spent per lateral by over 50% and nearly double on-bottom rate of penetration (Hodder et al., 2025), with no additional stuck pipe incidents. The achievements in drilling performance indicate improved wellbore stability and hole cleaning efficiency. The findings outlined in this report highlight the critical role of the ultrasonic image logs in updating the geomechanical model. This model was then used to propose effective mitigation strategies, which ultimately contributed to the successful execution of the project.

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