A Study of Various Monobore or Near-Monobore Well Construction Concepts with application to geothermal well drilling

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ABSTRACT

This paper is presenting several monobore well concepts that make it possible to achieve depths of 6000 m in the North German Basin to reach deep geothermal reservoirs. The presence of salt is characteristic for the North German Basin. Salt formations are strongly affecting the well integrity (especially the long-term integrity). The concepts shown in this paper will specially focus on how to generate a well construction capable to withstand the salt loads. The results show that a monobore or near monobore well construction can be used to drill through salt formations.

1. INTRODUCTION

The monobore well concept considers the well construction as having one single diameter from surface down to target depth. The monobore well construction has been repeatedly reported as the dream of any driller because it allows cost savings while drilling safely, which motivated this study to investigate new solutions for monobore well construction. In order to achieve a cost reduction in the well design for gebo research association, a well concept was proposed where a conductor casing is firstly rammed according to the existing legislation followed by the first section of the well (surface casing) drilled with conventional or preferably casing drilling technology. Finally the last well section is drilled using the monobore concept, providing a constant or near to constant diameter to the final depth.

The research program gebo is proposing to use the geothermal potential of the North German Basin by lowering the well construction costs. The main targets are the formations at depths of 6000 m. For this concept a monobore well concept as shown in Figure 1 is proposed, but the geological particularities of the North German Basin may require an optimization strategy.

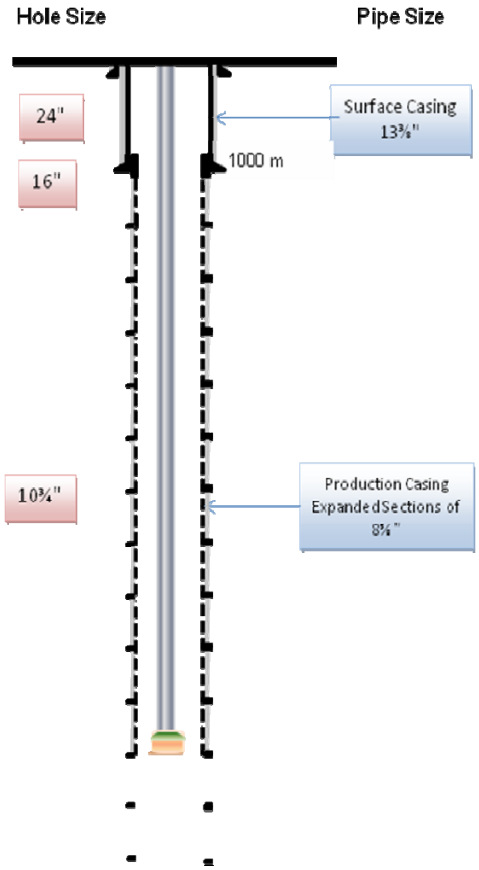

Figure 1 Monobore concept for Geothermal applications.

2. WHY MONOBORE?

Well construction, especially casing selection and design, will affect the well costs with more than 50% if deep drilling is required. Geothermal drilling requires large diameters in order to economically produce heat. The references studied within this paper showed the need to increase wellbore diameter while

keeping the costs at an acceptable level by new well design: monobore (Reinicke et al., 2009), linear casing design and use of expendables (Polsky et al., 2009), single well instead of doubles (BGR, 2009) and/or reducing drilling costs (Reinicke et al., 2009). Historically, the geothermal industry has moved from classic well construction to the use of liners and expandables and probably will end with a full monobore construction. The figures 2 a), b) and c) show such an evolution based on existing current research projects.

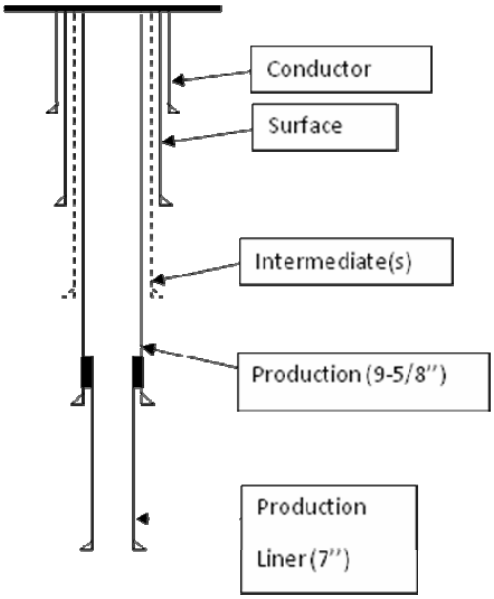

Figure 2 a) Typical geothermal well (Teodoriu and Falcone, 2009).

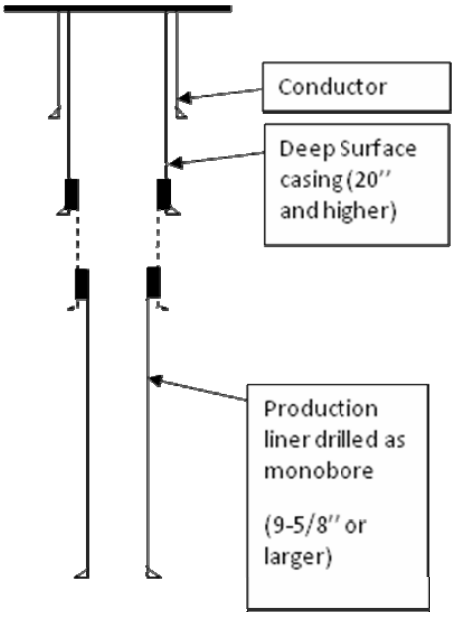

Figure 2 b) Use of liners and expandables (Teodoriu et al. 2009).

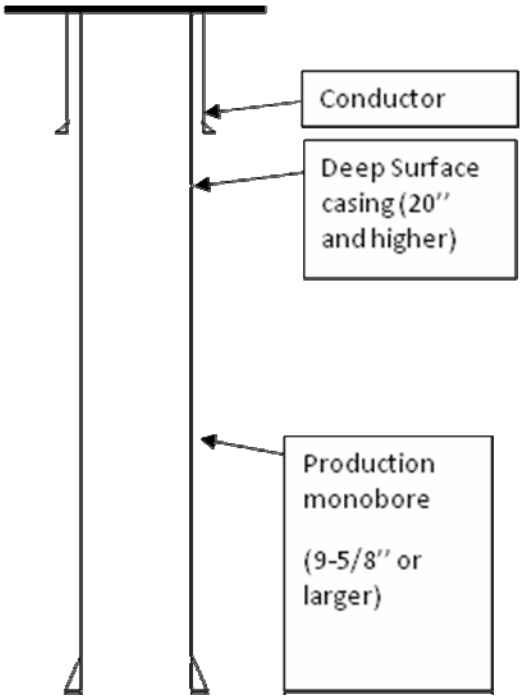

Figure 2 c) A monobore construction.

3. THE NEAR MONOBORE WELL CONDITIONS

As presented above, the monobore consists of a single diameter construction from top to bottom. Due to the problems associated with the North German Basin, especially due to salt formations, monobore may not be a solution that will offer acceptable well integrity. In what follows, a short description of the North German Basin is shown, pointing out the associated well construction challenges.

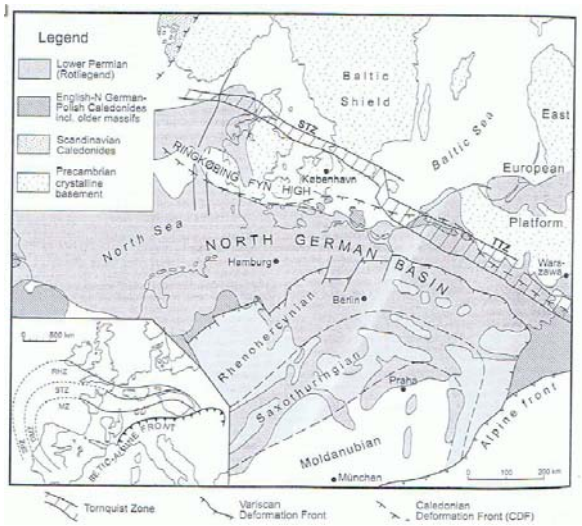

Figure 3 Structural sketch map of the Lower Permian (Rotliegend) and the main tectonic elements of the Central European Basement (McCann, 2008).

3.1 GEOLOGICAL CONDITIONS IN THE NORTH GERMAN BASIN

The Central European Basin (CEB) is the biggest intracontinental structure in Middle Europe and has

been formed by a complex history of deposition, and periods of uplift and erosion. The basin is generally subdivided into two large sub-basins (the Northern and Southern Permian Basins (SPB)), is bordered by the Sorgenfrei-Tornquist/Teysseire-Tornquist Zone in the north and by the Variscan mountains in the south. The final phase of Variscan extension during latest Carboniferous and early Permian time produced a series of small strike-slip and extensional continental basins. Within these basins, Stephanian and Lower Rotliegend continental successions were deposited and subsequent thermal subsidence led to the formation of the large Southern Permian Basin (McCann, 2008). This basin, that extends from the Southern North Sea to Poland, developed between the northern foreland of the Variscan Mountains and the Ringkøbing-Fyn High and is superimposed on the Late Carboniferous Variscan foredeep (McCann, 2008). The SPB may be subdivided from west to east into the North Sea Rotliegend Basin, North German Basin, and the Polish Trough (Schöner, 2006).

The North German Basin (Fig. 3) was modified by intense early Permian rifting and related extrusive volcanism followed by mid-Permian extension (Doornenbal, 2010). During early Permian times, low sea-level, Carboniferous-Permian glaciations and Variscan uplift led to a restriction of sea-water influx combined with arid climate which influenced the Rotliegend sedimentation in many areas. Later in the Permian, the Zechstein Sea was formed because of the rising sea level, rifting in North Sea and erosion of the Variscan foreland uplift. The presence of salt is the major challenge for well construction, especially if the target is located below the Zechstein horizons. For geothermal applications the interesting formations are the volcanic formations (Vulcanites) which are located mainly below Zechstein and Rotliegend.

3.2 Selected lithology for monobore well construction

To show the need for near monobore well construction, several virtual well locations have been selected, which are based on the following assumptions:

- Salt formation thickness
- Salt formation depth
- Presence of hydrocarbons
- Thickness of vulcanites
- Drilling problems

Salt formation thickness and depth will strongly affect the collapse pressure load acting on casing, which then dictates the casing grade and wall thicknes. For this example three scenarios will be used: one with one thin salt layer, a second one with a massive salt layer and a third one with two salt layers at different locations.

The presence of hydrocarbons may additionally impose higher than hydrostatic pressure load on the casing and at the same time could require enhanced well integrity in that area. The presence of hydrocarbons will be neglected in this paper.

The thickness of vulcanites will affect the well construction by requiring short radius for well deviation

Finally the drilling problems considered here refer to the shallow formations down to 1000 m, which may require a deep instalation of the surface casing. For this paper the asumptions made by Teodoriu et al. (2012) will be used: due to well purpose reasons for the gebo concept that the surface casing must be set at minimum of 1000 m (3000 ft) is considered.

3.3 THE gebo MONOBORE CONCEPT

The proposed concept consists of a special shaped pipe which has a smaller diameter when run in the hole, which is then expanded to reach its final shape.

At this stage the gebo pipes are limited in wall thickness and strength, therefore the development of a near monobore concept that will include monobore sections combined with conventional or multilayer zone is considered.

A monobore section is defined as a string with constant ID from top to bottom.

A conventional section is defined as a casing with flush connections available on the market at this time.

A multilayer zone is defined through multiple expanded casing which will work in the end as a single strong system.

Figure 4 shows a schematic of proposed casing shape and expansion for the gebo monobore concept, after Varahram et al. 2011.

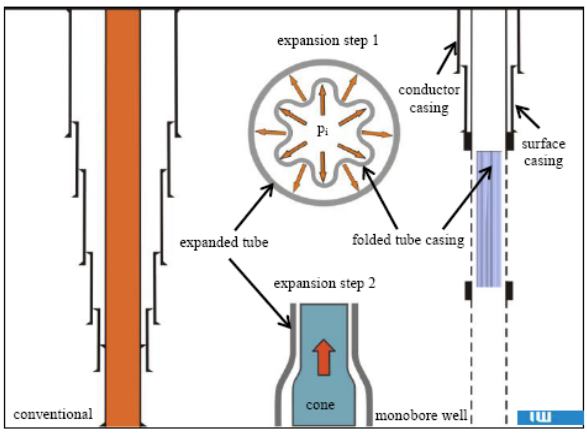

Figure 4. Conventional and the gebo monobore well design, after Varahram et al. 2011

4. THE NEAR MONOBORE WELL

Use of expandable casings or liners to reduce risks and simplify well constructions has been reported in literature. Siddiqui and York (2011) showed an extensive overview of the various solid expandable liners currently available as of 2011, and compared them to conventional solid expandable solutions. It is worth mentioning the solutions shown in figure 5, especially design numbers 3c to 3e.

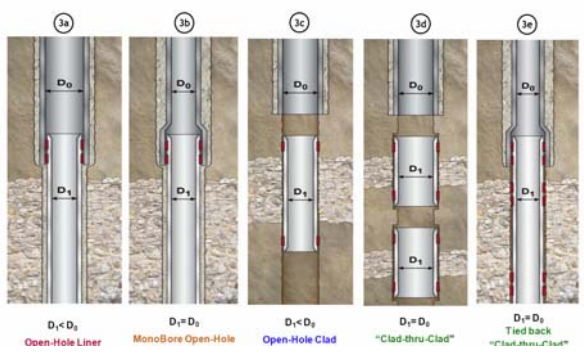

Figure 5 Comparison of the conventional solid and the monobore expandable systems, after Siddiqui and York (2011).

For all cases used for this paper it is assumed that a deep surface casing will be applied for the well designed, according to the gebo monobore well concept presented by Teodoriu et al. (2012), see also figure 1.

4.1. THE NEAR MONOBORE WELL FOR CASE ONE

For this case one single thin salt layer located at a depth between 3500 and 4000 m is assumed. Because of its relatively deep position, the salt layer will impose high collapse resistance for the casing crossing the salt zone. For this situation, and considering the relatively low thickness of the formation a conventional string is recommended. The use of conventional casing strings will also require an expandable liner hanger solution, as the available clearance will not allow a classic casing hanger. Figure 6 shows a comparison between classic and expandable casing hanger. Figure 6 a) shows the near monobore well construction proposed for this case.

An alternative version of the well construction is shown in figure 7 b), where the second monobore section is installed inside the conventional casing liner as well. This has the advantage of a more uniform ID of the well and thus reduction of pressure losses, while the conventional high collapse casing is protected against corrosion for the entire well life.

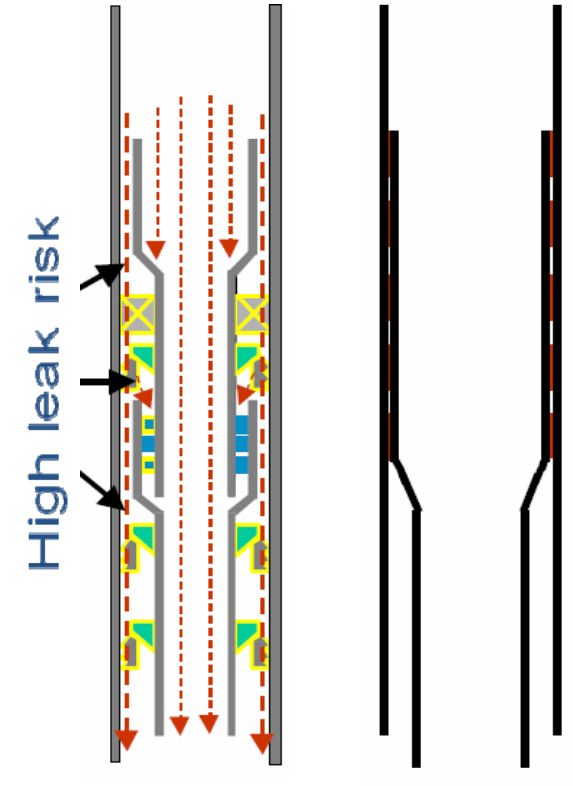

Figure 6 Expandable liner hanger (right) versus conventional liner hanger (left), Lohoefer, C. et al. (2000).

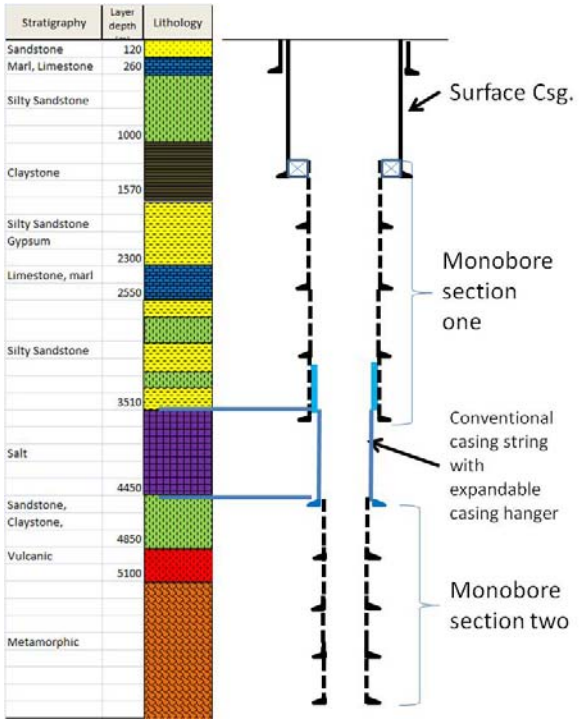

Figure 7a Near monobore concept using two monobore sections and a conventional string with expandable casing hanger.

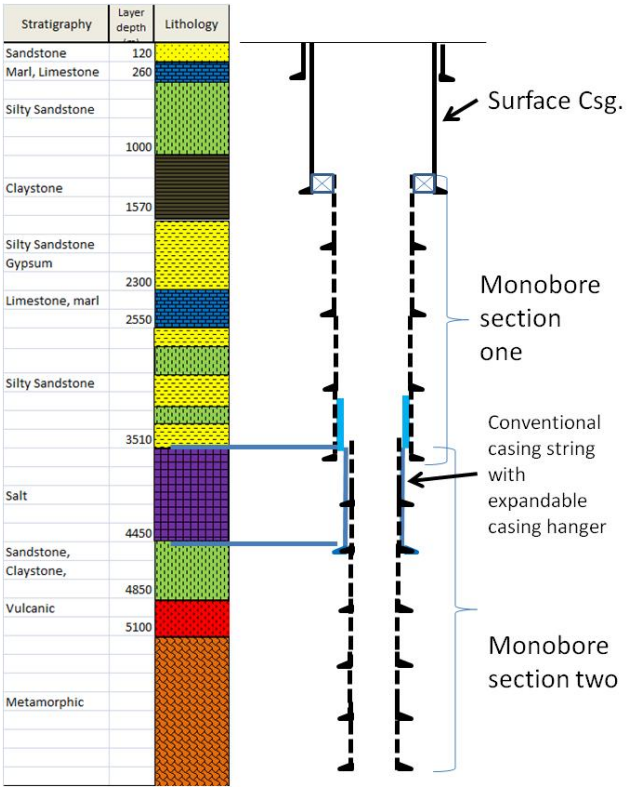

Figure 7b Near monobore concept using two monobore sections and a conventional string with expandable casing hanger and internal cladding of the conventional casing string.

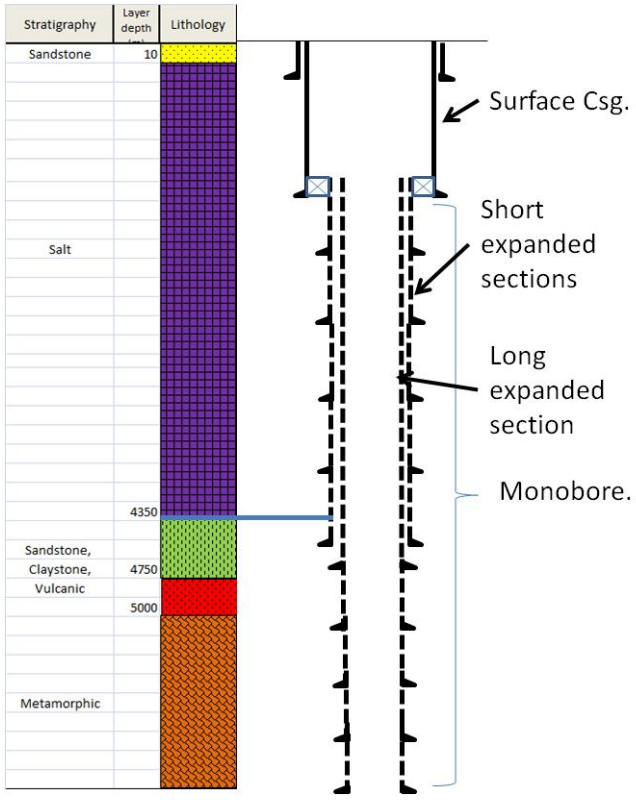

Figure 8a Near monobore concept using the multilayer method (combined short and long sections).

4.2. THE NEAR MONOBORE WELL FOR CASE TWO

For this case a single thick salt layer with a thickness of 1000 m is assumed. It is known that salt is easy to drill in comparison to other formations, and therefore for this case a multilayer monobore structure, as shown in figure 8, is proposed. As the drilling process in salt is fast and should pose no problems, two different approaches are considered: drill and run the short length sections and cement, followed by a long section that will cover the whole thickness (figure 8a) or drill and run the long section followed by a second or third long expanded section (figure 8b).

4.3. THE NEAR MONOBORE WELL FOR CASE THREE

The case three refers to a situation with two salt layers located at shallow and deep positions. In this case the monobore well construction will have to combine the two methods presented above: use of multilayer system for shallow salt and a conventional casing for a deeper zone. This concept is shown in figure 9. This case is the most unfavourable one because there will be a triple change of wellbore ID: monobore section one, conventional casing and, respectively, monobore section two.

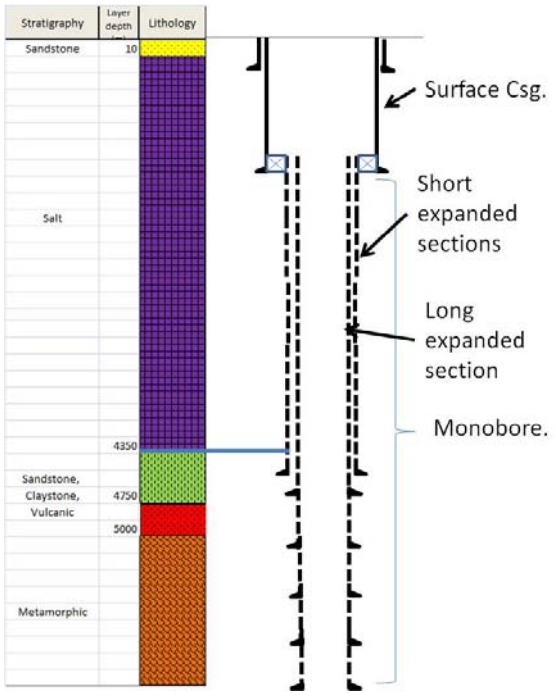

Figure 8b Near monobore concept using multilayer method (using long sections only).

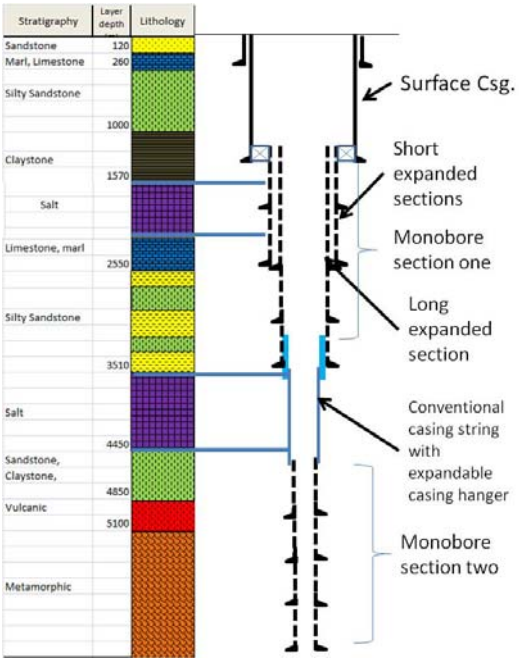

Figure 9 Near monobore concept using a combination of multilayer method (using long sections only) and conventional string.

5. DISCUSSIONS

Although the cases presented within this paper are virtual, and the monobore technology is not yet available there are few things to be learned out of the exercises presented within this paper.

It must be noted that the major difference and thus challenge to the near wellbore geothermal well design is the ability to produce the fluids through the casing. This feature requires that the casing string design will be able to withstand the corrosion and thermal loads during the entire life of the well. The use of monobore sections combined with conventional casing strings will enhance the casing protection during the life of the well, and thus can contribute to a long-term production of geothermal energy.

All analysed cases showed that expandable casing technology must be refined to allow reliable connection of heavy walled casing strings, as well as the connection of monobore sections.

If several monobore sections are needed, a new standardisation of expandable casing is required. The authors assume that the future standard should consider the ID diameter of the expanded casing as the main parameter.

5. CONCLUSIONS

The interest in the geothermal exploitation of the North German Basin poses some special problems to well construction and design.

Monobore well construction can help to reduce costs and make geothermal exploitation economical in the Northern German Basin.

Several near monobore concepts have been presented with the aim to investigate the feasibility of drilling through salt formations.

As a result of the presented study two main future research directions were identified: development of new casing hangers and a new standardization concept for monobore expandable tubulars.

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REFERENCES

BGR (2009): GeneSys Bohrung website, www.bgr.de.

Doornenbal, H. and Stevenson, A.: Petroleum Geological Atlas of the Southern Permian Basin Area [Buch]. - Houten : EAGE Publications, 2010.

McCann, T.: The geology of central europe, Volume 1, Precaambrian and Palaeozoic [Buch]. - bonn university germany : geological society london, 2008.

Polsky, Y., Mansure, A. J. (Chip), Blankenship, D., Swanson, R. J. and Capuano, L. E. Jr: Enhaced geothermal systems (EGS) well construction technology evaluation synopsis, Proceedings, Thirty-Fourth Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, February 9-11, (2009), SGP-TR-187.

Reinicke, K. R., Ostermeyer, G. P., Overmeyer, L., Teodoriu C., Thomas, R. (2009): Der Niedersächsische Forschungsverbund Geothermie und Hochleistungsbohrtechnik (gebo), Energie und Rohstoffe 2009, Goslar.

Schöner, R.: Comparison of Rotliegend sandstone diagenesis from the northern and southern margin of the north German Basin, and implications for the importance of organic maturation and migration [Bericht]. - chemisch-Geowissenschaftlichen Fakultät der Friedrich-Schiller-Universität Jena : [s.n.], 2006.

Teodoriu, C., Lehr, J., Grimmer, H. A.: New Method for Casing Shoe Depth Calculation with Applications to Monobore Well Construction, DGMK/ÖGEW-Frühjahrstagung 2012, Fachbereich Aufsuchung und Gewinnung,Celle, 19./20. April 2012.

Teodoriu, C., Falcone, G.: Comparing completion design in hydrocarbon and geothermal wells: The need to evaluate the integrity of casing connections subject to thermal stresses. Geothermics (2009).

Siddiqui, A., York, P. (2011): Monobore Solid Expandable Liners – Re-designing Wells for a

More Economical and Operational Benefit, IPTC 14255, International Petroleum Technology Conference, Bangkok, Thailand, 7-9 February (2011).

Lohoefer, C. L., Mathis, B., Waddell, K., Ring, L., York, P. (2000): Expandable Liner Hanger Provides Cost-Effective Alternative Solution, 2000 IADC/SPE Drilling Conference, New Orleans, Louisiana, 23-25 February.

Varahram, A.; Bär, F.; Hassel, Th.; Overmeyer, L.; Bach, Fr.-W. (2011):Design of Folded Tubulars for Expandable Casing Applications, Proceedings of the 16th Annual International Conference on Industrial Engineering Theory, Applications and Practice. Stuttgart. Unter Mitarbeit von IJIE