AGH DRILLING, OIL, GAS • Vol. 33 • No. 3 • 2016

http://dx.doi.org/10.7494/drill.2016.33.3.571

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PERCUSSION-ROTARY METHOD OF DRILLING LARGE-DIAMETER DEWATERING WELLS IN 'BEŁCHATÓW' LIGINTE MINE***

1. INTRODUCTION

Geological conditions of lignite deposition in 'Bełchatów' lignite field necessitate downhole dewatering of the rock mass. In the 'Bełchatów' field conditions, large-diameter dewatering wells turned out to be most suitable for this purpose. These wells are most frequently drilled with an invert mud and airlift. This method is not very efficient when drilling deep wells, when the Mesozoic basement, mainly represented by limestones, has to be drilled up. A hardly drillable, and a few meters thick layer of carbonate stone run is encountered in the carbonate roof. It is also considerably caverned on a large area of Szczerców Field. Such difficult geological conditions met while drilling with invert mud do not allow for obtaining high drilling rates and are the frequent causes of drilling complications and failures.

A considerable drop indrilling rate and a high number of drilling complications faced while drilling in carbonate strata prompted a search for new technological solutions, thanks to which the time of drilling could be significantly shortened and the operation made more reliable. The large-diameter well technology and the use of downhole hammers meet these requirements.

2. THE CHARACTERISTIC OF GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS IN THE AREA OF 'BEŁCHATÓW' LIGNITE DEPOSIT

The presently extracted Bełchatów Field and Szczerców Field are parts of the 'Bełchatów' lignite field deposited in the Kleszczowa tectonic trough, divided by 'Dębina' salt dome, which is a local elevation of the Permian salt deposit [1].

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*** This study was supported AGH University of Science and Technology statutory research No. 11.11.190.555 (Faculty of Drilling Oil and Gas)

The Kleszczowa trough is a narrow subsidence structure filled with Tertiary sediments, which also runs in the Mesozoic structures. In the Szczerców Field area there is a caprock represented by a complex of Quaternary and Tertiary sediments, whereas the floor is most frequently represented by earth brown coal, earth brown and xylite coal and xylite and earth brown coal. The sub-carbon Tertiary is mainly composed of silts and mudstones with sand intercalations. as well as Mesozoic basement in the form of limestones, more rarely Upper Jurassic Marls.

The caprock of the elevated wings is made of Quaternary and Tertiary sediments about 40 m thick in the south and to about 140 m in the north, the Mesozoic basement is represented by the Upper Jurassic limestones, i.e. Oxfordian and Kimmeridge. These limestones frequently appear in the form of loose rubble or breccia, with numerous fracture zones and karstic voids secondarily filled with silt, coal dust and limestone breccia [4]. The geological NS cross-section of the Szczerców Field has been presented in Figure 1.

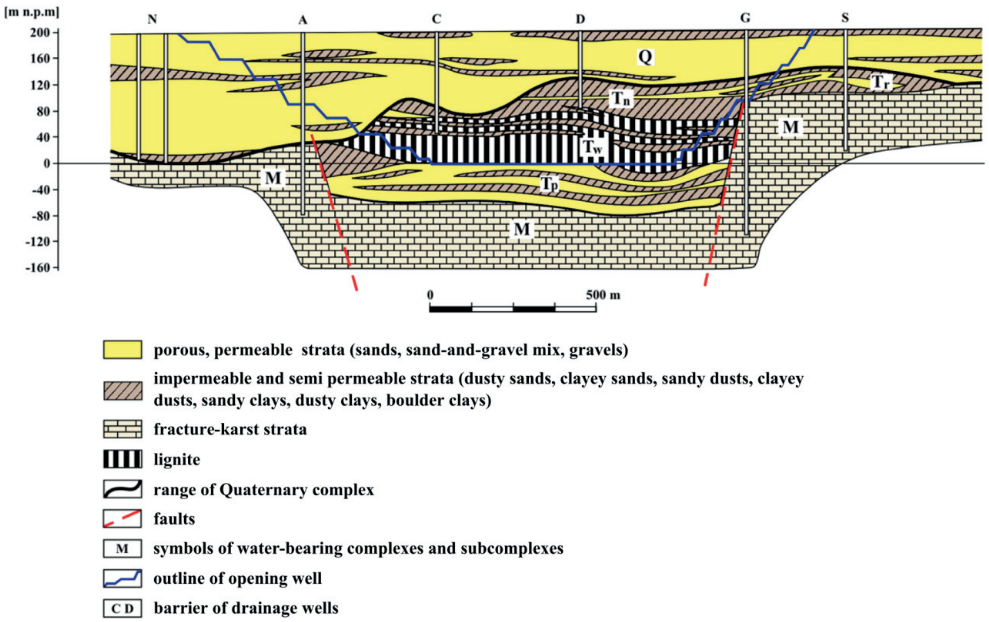

Fig. 1. Cross-section of the Szczerców Field with barrier lines of dewatering wells [5]

The extraction of lignite is possible thanks to the existence of a developed system of deep dewatering wells and an auxiliary one if suspended waters have to be removed or the local water table lowers. Among the most important ones are external barriers S and G in the south and A and N in the north. Their task is overtaking waters flowing from the Mesozoic basement to the extracted deposit [2]. Depending on the geological conditions, deep dewatering wells (ca. 250 m in the northern part of the mining area to over 300 in the south) are performed in the outer barriers. A considerable part of the geological profile of the well (especially in the south, because of the shallow deposition of the Mesozoic basement) covers the rocks of the Mesozoic basement. This necessitates using tools with developed technological parameters; the drilling equipment and bits have to be adjusted to operation in consolidated rock conditions. The karstic phenomena occurring in the basement rocks, i.e. voids, cracks, breccia in the top of the basement, accompanied by a lower groundwater table below the basement top, make drilling complications very likely, therefore wells frequently have to be drilled in new sites.

3. THE TECHNOLOGY OF DRILLING DEEP DEWATERING WELLS IN PERMANENT OUTER BARRIERS

Since 1999 the method of drilling deep dewatering outer barriers with invert mud and an airlift has been the leading method until the end of the first decade of the 21st century [1–3]. The technological and economic indices of drilling obtained with this method in 'Bełchatów' lignite mine were relatively low. The total time of drilling a well 250–300 m deep was 2 to 3 months, though the cost of their realization was relatively low because of the undemanding hardware requirements. Only in the Szczerce Field the main drilling contractor, i.e. PH 'Hydropol' S.A. Kraków, performed over 50 wells using this technology. The total footage of 13 620 running meters constituted almost 68% of all realized works. All wells were drilled with the use of rigs of Wirth – L4 family. The remaining works were realized by five other contractors, i.e. Hydrokop-2 (Wirth-B3A), ZRGOiR Wrocław (Wirth-B3A), Hyd-Rol (Wirth-L3A), PRWIG Warszawa (Bauer BBA-90) and Hydrokop Kraków (Wirth-B3A). The percent participation of all contractors in the realization of dewatering wells in outer barriers has been presented in Figure 2, and the participation of particular rigs in Figure 3.

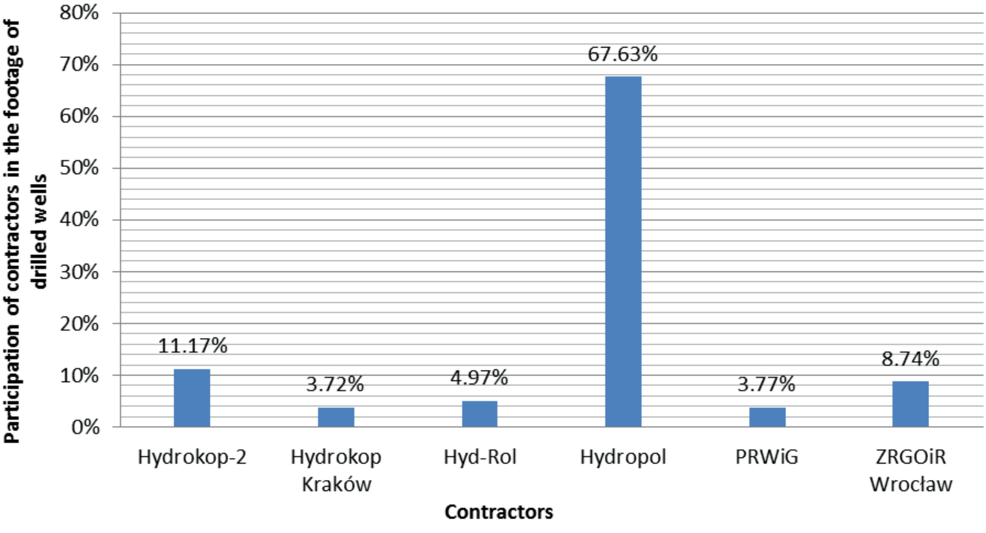

Fig. 2. Participation of particular contractors in the footage of drilled outer barrier wells over 250 m deep

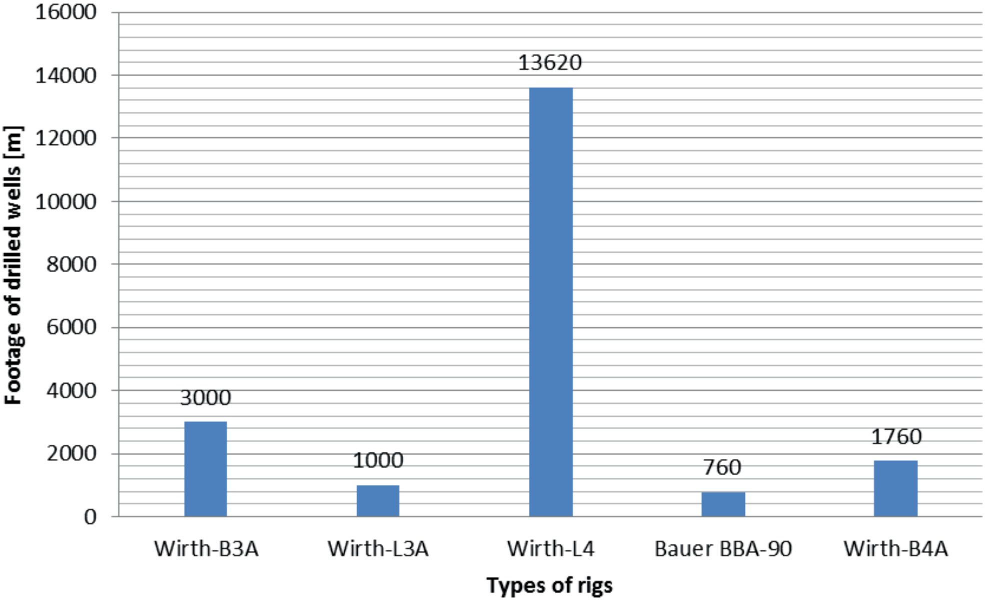

Fig. 3. Participation of particular types of rigs in the total footage of drilled dewatering wells

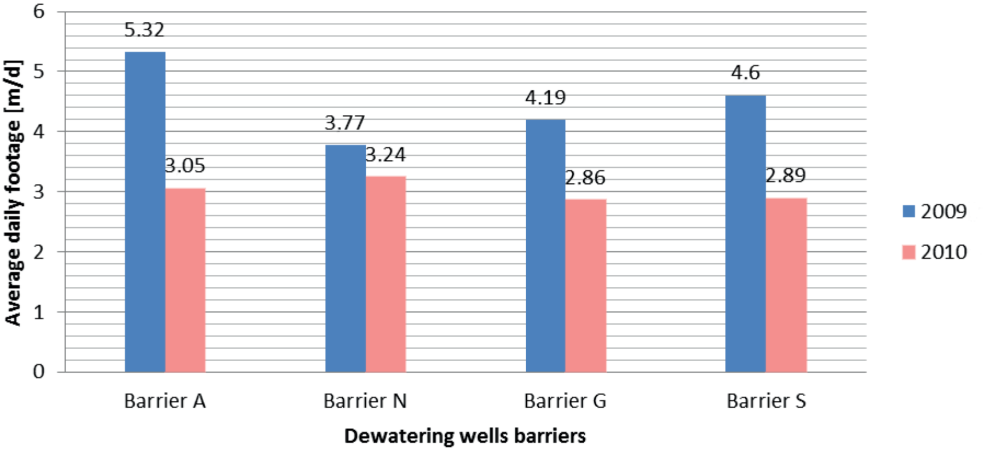

Fig. 4. Average daily footage in deep dewatering wells in A, N, G and S barriers in the years 2009 and 2010

With the development of the dewatering system in Szczerce Field and lowering the groundwater level below the top of the Mesozoic basement there was observed an increasing number of drilling complications and failures, mainly relating to the placement of intermediate casing in the top of carbonate strata. The number of drilling complications also considerably increased when drilling in carbonate karstic voids and large fractures. These difficulties greatly contributed to the elongation of time of drilling and in many cases were the cause of closing of wells before the planned depth had been reached and moving drilling operations to a new place. As a result the obtained technological and economic parameters of drilling deteriorated, mainly for deep wells localized in A, N, G and S barriers. Before the year 2005 the daily yield of such wells in the Szczerców Field was only 4.83 m/day, 4.33 m/day in 2005–2009, whereas for wells realized since 2010 it totaled to only 2.95 m/day. The average daily footages obtained during the realization of deep dewatering wells in A, N, G and S barriers in 2009 and 2010 have been presented in Figure 4.

The biggest drop of drilling rate (nearly double) was observed when drilling wells in A barrier, where the number of complications and drilling failures relating to the karst phenomena was highest.

4. THE TECHNOLOGY OF DRILLING LARGE-DIAMETER DEWATERING WELLS WITH THE USE OF DOWNHOLE HAMMERS

A considerable drop of rate of drilling of deep dewatering wells and the increasing number of drilling complications made specialists look for new technologies which would shorten the time of drilling and make the process more reliable and failure-free. In 2010 an innovative technology of large-diameter drilling of dewatering wells in carbonate rocks in strongly developed karstic conditions with the use of downhole hammers was worked out [3].

The first well was successfully realized with this method in 2011 with the use of KREMCO K-600 rig by PNiG Kraków (Fig. 5). The well was drilled in very difficult geological and hydrogeological conditions in the area of unsuccessful wells.

Fig. 5. KREMCO K-600 rig drilling a deep dewatering well [6]

The drilling of this well started from a pilot well 105 m deep with a bit of 0.311 m diameter. Upon reaching this depth the mud completely vanished and the string was seized. After it has been released and the cement plug performed, the well was reamed to a diameter of 0.864 m and casing ϕ 0.711 m of diameter seated at 102.5 m of depth. After the casing had been cemented, drilling operations were continued with the use of a bit of diameter ϕ 0.559 m to a depth of 137 m. Because of the complications connected with ultimate mud escapes and destabilization of the well's wall, a number of sealing works with the use of cement slurries, gypsum, sealing pastes of various composition and compactonit sealing material were undertaken [6]. In the lack of positive results, TOP DRIVE was installed on the rig and the ϕ 0.508 m casing drilling was performed to a depth of 131.5 m, i.e. 26.5 m below the stone run zone. Further drilling to the planed depth of 253 m was realized with the use of a downhole hammer of diameter 0.457 m (18"), 2–4 Mg weight on bit and 15–60 rpm.

The successive nine wells realized by PNiG Kraków were drilled at considerably higher rates without bigger complications. The average daily yield equaled to 8.22 m/day, to reach even 20 m/day when drilling some deep dewatering wells in the Szczerców Field.

Further improvements of the technology of drilling of dewatering wells with downhole hammers in the Mesozoic basement allowed for much higher drilling rates and better footages (70–100 m/day) in the years 2011–2015. Figure 6 illustrates the average daily footages of well in A, N, G and S barriers in the Mesozoic basement with invert mud and dowhole hammers in the years 2011–2015. The analyses of the plots reveal that drilling in carbonate strata with downhole hammers was 4 to 8 times faster than drilling with inverse mud and an airlift.

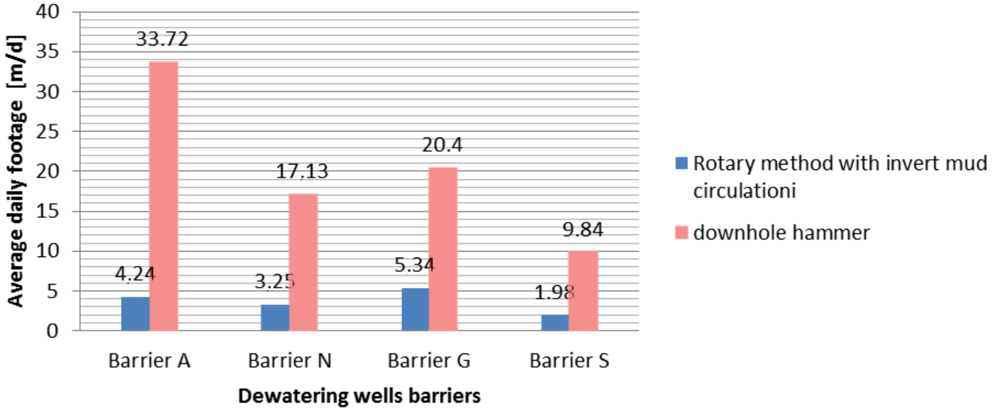

Fig. 6. Average daily footage of dewatering wells in the Mesozoic basement using the downhole hammer and rotary method with invert mud circulation in the years 2011–2015

5. CONCLUSIONS

1. The use of downhole hammers for drilling dewatering wells in the Mesozoic basement allowed for shortening the time of realization of wells 4 to 8 times and a considerable decrease in the amount of mud (water) injected to the rock mass as compared to the invert mud rotary method.

2. Thanks to the use of the new technology of drilling dewatering wells with the use of downhole hammers the time of realization of a well can be shortened and much better hydraulic parameters obtained. This is represented by significantly lower values of parameter C, measured in the course of pumping jobs preceding the well's start-up.
3. The average value of C for dewatering wells drilled in the years 2011–2015 with the rotary invert mud method was 1765 s^2/m^5, whereas in wells, where downhole hammers were used in the basement, the average C value equaled to about 1139 s^2/m^5, which makes a huge difference.
4. Owing to the fact that mining works in the Szczerców Field are performed in more and more difficult geological conditions and the groundwater level keeps lowering in the area of the dewatering wells, the method employing downhole hammers will have to undergo further modifications and improvements.

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