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SELECTING A DRILLING FLUID FOR MINERAL EXPLORATION – DIAMOND CORE DRILLING AND PLANNING THE MUD PROGRAM FOR APPLICATIONS IN THE CHELOPECH Cu-Au DEPOSIT (BULGARIA)

Summary. This paper presents a review of geology Chelopech Cu-Au Epithermal deposit (Bulgaria), drilling technology, chemistry, composition and prepared polymer drilling fluids applicability for drilling operation for mineral exploration diamond core drilling. The present investigation is focused on recommended, mud program selection and application of the polymer drilling fluids and wireline NQ complex from deposits Chelopech, Bulgaria. The key is to provide affordable drilling fluid solutions that will reduce overall drilling costs.

DOBÓR PŁUCZKI WIERTNICZEJ W PRACACH POSZUKIWAWCZYCH – WIERCENIA KORONKĄ DIAMENTOWĄ I PLANOWANIE SYSTEMU PŁUCZKI DLA ZŁOŻA Cu-Au CZEŁOPECZ (BUŁGARIA)

Streszczenie. W artykule zaprezentowano zarys budowy geologicznej epitermalengo złoża Cu-Au Czełopecz (Bułgaria). Przedstawiono ponadto technologie wiercenia koronkami diamentowymi oraz skład i charakterystyki płuczek wiertniczych możliwe do zastosowania podczas prac dokumentacyjnych i poszukiwawczych w rejonie opisywanego złoża. Praca ukierunkowana jest na optymalizację kosztów wiercenia przez opracowanie składu i zastosowanie fluidów na bazie składników polimerowych odpowiednich do współpracy z rdzeniówką systemu NQ.

1. Introduction

The Chelopech volcanic complex is located in the Central Srednogorie magmatic zone (Fig. 1a) and hosts one of the largest Cu–Au deposits in Europe [8, 9].

The Chelopech Mining Ltd is a subsidiary of Dundee Precious Metals Inc. It is a copper-gold mining and processing operation that ultimately produces copper-gold concentrate. The Plans include upgrading of the operation to 1.5 Mt per annum and metal production on the site [5, 6].

The Chelopech Deposit is situated near Chelopech village, in the northern part of the Zlatitza valley. The deposit is at the foot of the Balkan Mountains and is on about 700 meters elevation. The geological prospecting of the deposit began as early 1840s. The Chelopech copper-gold mining and processing operation was commissioned in late 1950s with initial capacity of a few thousand tonnes. The mine was expanded and a new concentrator was build In the early 1970s.

Balkan Mineral and Mining EAD company's currently the exploring on 10 license areas located throughout Bulgaria. Desire to place the Projects into production by early 2007 -2009 and applies the most sophisticated and up-to-date exploration technologies and methods in Bulgaria such as [5, 6]: *1. Compilation and analysis of geological, geophysical and geochemical data in text format and map materials; 2. Regional methods of preliminary prospecting - primarily stream sediment sampling; 3. Preliminary local-scale research in conjunction with detailed geological mapping; 4. Additional detailed research - petrography, XRD analysis; 5. Local-scale geophysical research; 6. Exploration diamond core and RC drilling; 7. Processing, qualitative and quantitative analysis of samples; 8. Computer processing and development of GIS models utilising specific geological computer software.*

2. Geology of the Chelopech deposit

The basement of the volcanic rocks consists of high-grade metamorphic rocks (two-mica migmatites with thin intercalations of amphibolites, amphibole-biotite and biotite gneisses), and low metamorphic phyllites and diabases of the Berkovitsa group (Early Paleozoic island-arc volcanic complex, Haydoutov, 2001). The base of the Chelopech volcanic rocks is partly exposed on the surface, although it has been intersected in the underground mine. The Upper Cretaceous succession in the Chelopech region starts with conglomerates and coarsegrained sandstones intercalated with coal-bearing interbeds (coal-bearing formation, Moev and Antonov, 1978) covered by polymictic, argilleous and arkose sandstones to siltstones (sandstone formation). Collectively, these units have a thickness of less than 500 m. Pollen data suggests that both formations are Turonian (Stoykov and Pavlishina, 2003). The sedimentary rocks are cut by volcanic bodies and overlain by sedimentary and volcanic rocks of the Chelopech Formation (Moev and Antonov, 1978). It comprises the products of the Chelopech volcanic complex, epiclastics, as well as the Vozdol sandstones (Fig. 1b, c). The latter are recently paleontologically dated as Turonian in age (Stoykov and Pavlishina, 2003). These formations have been partly eroded and transgressively covered by sedimentary rocks reddish limestones and marls, which are in turn overlain by flysch of the Chugovo Formation (sandstones, aleurolites, argilites and marls with clear turbidite marks) Campanian-Maastrichtian in age (Fig. 1b, c).

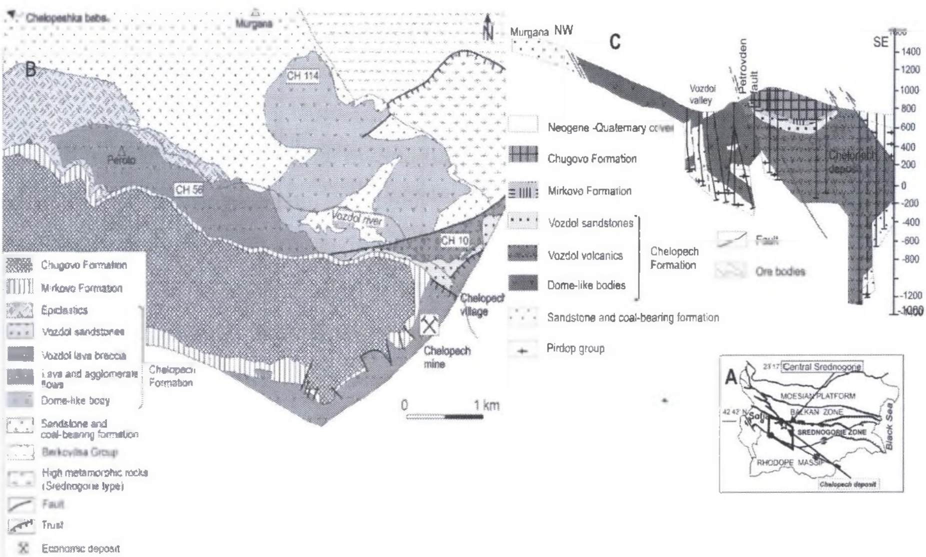

Fig. 1. (a) Major tectonic zones in Bulgaria with the location of the Srednogorie zone and Chelopech deposit; (b); Geological map of the Chelopech region (modified after Stoykov et al., 2002). (c) Geological section of the Chelopech region after Stoykov et al. (2002)

Rys. 1. (a) Główne strefy tektoniczne Bułgarii; zaznaczono strefę Srednogorie i złoże Czełopecz; (b) Mapa geologiczna rejonu Czełopecz (za Stoykov et al., 2002); (c) Przekrój geologiczny rejonu Czełopecz, wg. Stoykov et al. (2002)

Field observations and sedimentary relationships allow to distinguish three units of the volcanic complex: (I) dome-like bodies, (II) lava to agglomerate flows, and (III) the Vozdol lava breccias and volcanites [Stoykov et al., 2004]. The volcanic rocks are porphyritic with plagioclase and amphibole phenocrysts, quartz and biotite are rare. The lava flows contain fully crystallised, fine-grained enclaves of more basic composition.

3. Selecting drilling fluids for mineral exploration – diamond core drilling and planning the mud program

The economic importance of the information to be gained through diamond coring is well known to mining geologists [1, 2, 4]. The enormous capital investment required developing a low-grade ore body demands a reliable evaluation of the prospect based on adequate core rock samples. The cost of the core depends on the time and materials expended to get it; its value depends on the extent of recovery, and both are strongly influenced by the drilling fluid. The drilling fluid should be regarded as one of the tools in the planned program to *secure maximum results at the minimum cost.*

The cost of the drilling fluid can be evaluated only in terms of the total cost of drilling and not just on the price of the additives alone. Numerous inter-related factors affect the results of a drilling operation consideration should be given to the following significant factors: *1) The primary purpose of the drilling program: requirements for core, depth, time allotted; 2) The nature and properties of the rocks to be drilled: type and thickness of formation, and structural conditions as related to hole stability; 3) The site, in relation to the layout of the rig, sumps and working environment, disposal of wastes and the availability of and access to supplies of mud products; 4) Water: source, quality, and quantity; 5) The capabilities and limitations of the drilling equipment.*

4. Drilling technology and usage of drilling fluid for applications in the Chelopech Cu-Au deposit (Bulgaria)

The tool complex for drilling with a wireline core barrel NQ of the company "Board Longyear" is used for drilling of boreholes with reception and extraction of the core on a surface without wireline rising, and also for work on rise and descent of a column for rock cutting tool change.

Elements of the Complex NQ of the company "Board Longyear": rock core bit; core wireline barrel; drill rods (string); lifting equipment, auxiliary and emergency tool; cable hoist for rising of a retrievable core receiver.

The recommended fluid application for drilling in difficult geological conditions by the wireline core barrel complexes NQ of the company "Board Longyear" should meet the following basic requirements: *to create a thin and strong polymeric or polymeric-clay layer on borehole and core walls for increase of stability of borehole walls and core output; to possess a good greasing ability for maintenance of high speeds of bullet rotation and decrease of core friction in a core lifter; to give all the sludge to a sediment in circulating system (about 7 kg/m^3 of a borehole), leaving only thin sludge particles of solution (on the level of clay particles). It allows to carry out drilling on high speeds of bullet rotation without sludge crust formation on an internal surface of boring pipes.*

Table 1

Technical parameters wireline core barrel NQ of the company "Board Longyear"

System	External diameter of reamer, mm	External diameter of core bit, mm	Internal diameter of core bit, mm	Diameters of drill rods (string)		Length of drill rods, m	Weight of drill rods, kg	Length of core barrel, m	Borehole deviation, degree
				External ,mm	Internal, mm				
NQ	75,82	75,44	47,6	69,9	60,3	1,5; 3,0	11,7, 23,4	1,52; 3,05	90 - 45

The long-term experience in the Chelopech Mining Ltd. and laboratory experimental program in the Department of Drilling, Oil and Gas Production, *laboratory of Drilling fluids and cement slurry* at the University of Mining and Geology "St. Ivan Rilsky" – Sofia has development a series of laboratory experiments to quantify drilling fluids performance and has shown that the drilling solution prepared on the basis of basic polymeric reagents: PAC, PA and PHPA meets these requirements. Polymer muds incorporating generally long-chain, high-molecular-weight polymers are utilized to either encapsulate drill solids to prevent dispersion and coat shales for inhibition, or for increasing viscosity and reducing fluid loss. Various types of polymers are available for these purposes, including acrylamide, cellulose and natural gum-based products.

1. *PAC polymer* reagent is a high-molecular cellulose polymer. This reagent is nontoxical and it is not exposed to fermentation.

The basic function of PAC polymers: *viscosity increase of drilling solutions with small content of the firm phase, prepared on fresh, salty and sated with salts water; decrease in solution filtration; covering of slate surfaces to avoid swelling and destruction; formation of thin impenetrable filtration crust, preventing from water penetration into a layer.*

2. *PHPA ("Fibrospan" – Bulgarian trade mark) reagent* is a highly active (> 69 %) partly hydrolized polyacrylamide with a big molecular weight (10-15 million). This reagent is ecologically safe at the use in recommended concentration.

3. *PA ("Geolin K-D" – Bulgarian trade mark) reagent* modified water - soluble polymer of acrilonitril. Non-toxic, fire - proof. "Geolin K-D" is also used as a stabilizer of wash liquid in geological drilling operation.

The main reagents features: *slate stabilizer, strengthening the borehole walls; effective intensity decrease of dispersion of clay and slate particles in water by the attachment to particles that reduces the water penetration to the minimum; effective viscosity increase of drilling solutions on the water basis; polymer is dispersed in water and as a result of electrostatic and chemical interactions it forms a grid of polymeric chains, and it leads to the viscosity increase of drilling solution; flocculation of rock particles (sedimentation in circulating system); greasing ability increase of drilling solution (the content of reagent in water is 0,7 kg/m^3, solution greasing ability raises on 31 % in comparison with pure water.*

At work with the wireline core barrel NQ complexes the following borehole construction is usually used. The drilling works are carried out with the help of a conductor (112 mm) and casings (108 mm). The further drilling up to thick root rocks is made by drilling core bits (93 mm) and a borehole is settled by the casing (89 mm). After that the complex NQ can be used. The clay solutions are used for drilling works on the friable deposits and the clayless polymeric solutions are used for root rock drilling. The preparation of clay solutions from the lumpy clay is carried out in a usual clay mixer, and the addition of soda ash (0,5-1,0 kg/m^3 of solution) is necessary for clay mixing improvement. The solution viscosity (as well as the clay quantity) depends on the geological section complexity and it should be not less than 32-38 sec on the Marsh funnel viscosimeter.

Depending on complexity of geological conditions at borehole drilling the following kinds of drilling solutions can be used:

- clayless solution on the basis of polyacrylamide (PHPA - *"Fibrospan"*) with some reagent in water (1,0 - 1,5 kg/m^3) is used for drilling in rather favorable conditions (good stability of walls).

- clayless solution on the basis of two reagents (PAC and polyacrylamide - *"Geolin K-D"*) is used for drilling in rather difficult geological conditions, but the same quantity of reagents should be in the water (0,75-1,0 kg/m^3 of PAC and 1,0-1,25 kg/m^3 of polyacrylamide - *"Geolin K-D"*).

- polymeric clay solutions are used for drilling in very difficult geological conditions. Such solutions are made of highly colloidal montmorillonite bentonitic powder. The same quantity of reagents should be added into the prepared solution (0,7-1,0 kg/m^3 of PAC and 0,7-1,0 kg/m^3 of polyacrylamide - *"Geolin K-D"*). The viscosity of prepared polymeric clay solution should be within the limits of 32 - 48 sec on the Marsh funnel.

When such solutions are used the circulating system should have two sludge pits (1-2 m^3 and 3-5 m^3). The slime sedimentation is to go in the first pit.

Drilling with junk solution is inadmissible, as it leads to crust formation on internal surface of drilling pipes that impedes the descending of overshot and the rise of retrievable core receiver with overshot, because of the gland formations.

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