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Research/Technical Note

Application of Potassium-Based Film-Forming Drilling Fluid in the Exploration of Wzk-4 Hole in Tanjianshan Gold Deposit, Dachaidan Town, Qinghai Province

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Abstract

Hole WZK-4 of "Tanjianshan Gold Mine Exploration Project in Dachaidan Town, Qinghai Province" is a key exploration well. During the early stage of construction, the alluvial-diluvial layer is loose and expanded, the stratum is broken and collapsed, the diameter shrinks and the spalling phenomenon is serious, during the drilling process, it is difficult to raise and lower the drill, and it is necessary to clean the hole to the bottom each time the drill is lowered. Conventional polymer drilling fluid systems cannot meet the construction requirements. In view of that above complicate difficulties, a potassium-based film for flushing solution system is adopted, and the main formula is as follows: 0.1%~0.2% caustic soda +0.5%~ 1% soda ash +3%~ 5% sodium clay +0.2%~ 0.6% salt resistant polymer STQ+1%~2% filtrate loss agent +3%~ 5% film forming system SCM+0.1%~0.2% liquid viscosity increasing inhibitor SN+0.5%~1% sloughing prevention plugging agent while drilling +3 - 5%KCl, by incorporating film-forming SCM treatment agent and liquid viscosity enhancer inhibitor SN, the above complex issues have been resolved, and no such difficulties arose during the construction process. The density 1.03~1.11g/cm^3, API=5.2ml, the quality of mud cake is thin yet tough, drilling quantity planned for the project is 300m, The actual final hole is 303.8m. The effective drilling time of Tanjianshan Gold Mine in Dachaidan is about 15 days, which is equivalent to about 74.54 yuan/meter of washing fluid material cost per meter of footage, which can provide reference for subsequent construction.

Keywords

Potassium Salt, Collapse, Flake, Potassium-Based Film Formation, Rinsing Solution, Leak Sealing While Drilling

1. Introduction

The Jinlonggou gold deposit in Tanjianshan, Dachaidan Town, Qinghai Province is mainly composed of a set of regional metamorphic carbonate rocks and normal sedimentary clastic rock series, which can be divided into upper and lower rock groups. The lower formation consists of dolomite marble and banded dolomite marble, with carbo-

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naceous sericite phyllite in the upper part and siliceous quartzite in the bottom. The Upper Rock Formation consists of a suite of schist, phyllite and carbonate-intercalated middle-low metamorphic chlorite-quartzite schist series, in which spotted carbonaceous sericite phyllite is composed of sericite (leucite) (30~60%), quartz (25~50%), carbonaceous (5~15%), graphite (1~3%), a small amount of calcite, chlorite, pyrite and tourmaline. Chlorite quartzite solution, grayish green, brownish gray, with scale granular metamorphism structure, sheet structure. The main minerals are chlorite (15~40%), calcite (25~55%), quartz (15~25%) and sericite (2~5%). The rocks in the survey area generally contain carbon and are composed of gray-black carbonaceous sericite phyllite interbedded with quartz schist, mica schist, quartzite and thin banded marble interbedded with sericite quartz schist. In the process of core drilling, wellbore instability is one of the main difficulties in coring drilling. Formation alteration is serious, and fractures and microfractures are developed seriously.

2. Geological Overview

The Project of "Tanjianshan Gold Mine Exploration in Dachaidan Town, Qinghai Province" is designed to construct 1 hole, No. WZK-4, and the engineering drilling quantity is 300m. The drilling and coring construction of 300m has been completed from July 5, 2024 to July 22, 2024 [1, 2]. The total time is 18 days. The drilling construction quality and core collection meet the qualified requirements. According to the geological conditions of the drilling area, it provides a basis for guiding the next drilling work in this area [3, 4].

2.1. Geographical Location and Regional Geological Profile

Kuangqu is located about 75km northwest of Dachaidan, under the jurisdiction of Dachaidan Town of Haixi Mongolian and Tibetan Autonomous Prefecture of Qinghai Province, with convenient transportation.

2.2. Brief Geological Survey of Hole WZK-4

The strata encountered by drilling hole WZK-4 are mainly composed of Middle Proterozoic Wandonggou Group (Pt2wd) and Ordovician-Silurian intertidal mountain group (OST) from top to bottom, and Quaternary cover is distributed in large areas between mountains and valleys.

2.2.1. Stratigraphic Profile

1) Wandonggou Group (Pt 2wd)

It is distributed in the area of Tanjianshan-Wandonggou, and its plane shape is zonal distribution with south east wide and north west narrow. According to lithological association, it can be divided into two rock groups a and b. Rock group a (Pt 2wda) is composed of dolomite marble and sericite quartz schist. B rock formation (Pt 2wdb) is dominated by spotted carbonaceous phyllite, carbonaceous sericite phyllite and calcareous schist with marbles and dolomite marble lenses.

2) Ordovician-Silurian Tanjian Mountain Group (OST)

Widely distributed in the west of the survey area, divided into four rock groups a, b, c and d according to lithologic combination, all of which are continuous sediments.

3) Quaternary (Q4)

Widely distributed in the piedmont, valley and middle beach of the survey area, alluvial and diluvial deposits, residual slope deposits and aeolian deposits are unconformably covered on Wandonggou Group and Inter-beach Mountain Group. Alluvial deposits are distributed in gullies and intermountain shoals, and consist of alluvial sand and gravel; residual deposits are mainly distributed in foothills, followed by small areas distributed in lower concave parts of hillsides, mainly composed of rock fragments; aeolian deposits are distributed in mountain edges and shoals, and are mostly composed of yellow fine sand.

2.2.2. Tectonic Profile

1) Wrinkle

Tanjianshan anticline and Jinlonggou syncline are developed in the survey area.

2) Fault structure

Fault structures are developed in the area, and can be divided into two groups, NW and NE, according to their distribution rules.

2.3. A Survey of Drilling Operation of WZK-4 Hole

2.3.1. Drilling Equipment and Tools

CSD1800X self-propelled full hydraulic drilling rig is adopted for drilling according to formation conditions, designed drilling depth, final hole diameter, drilling workload and drilling method in Kuangqu. Main drilling equipment, drilling materials and mud materials are shown in Table 1 below.

Table 1. *Main Drilling Equipment.*

name	model	unit	numbers
drilling rig	CSD1800X	set	1
slush pump	BW-160	set	1
dynamo	15KW	set	6
sinking pump	lift 40m	set	6
blender	self-control	set	3

name	model	unit	numbers
water pot	self-control	set	2
inclinometer	BZM-R	set	2

2.3.2. Wellbore Structure and Drilling Parameters

In order to meet the construction requirements and ensure the quality requirements of deep holes, combined with the previous deep hole construction experience, the drilling structure adopts three-level casing four-level structure. That is, Φ150mm drilling tool is used to drill to a certain depth and run Φ146mm hole casing, PQ drilling tool is used to drill to stable formation and then PQ casing is run, HQ drilling tool is used to drill (in order to ensure smooth implementation of deep hole later drilling, 800m hole HQ needs to be drilled to more than 200m) and HQ casing is run, and finally NQ drilling tool is used to drill to the final hole. See Figure 1 below for specific borehole structure.

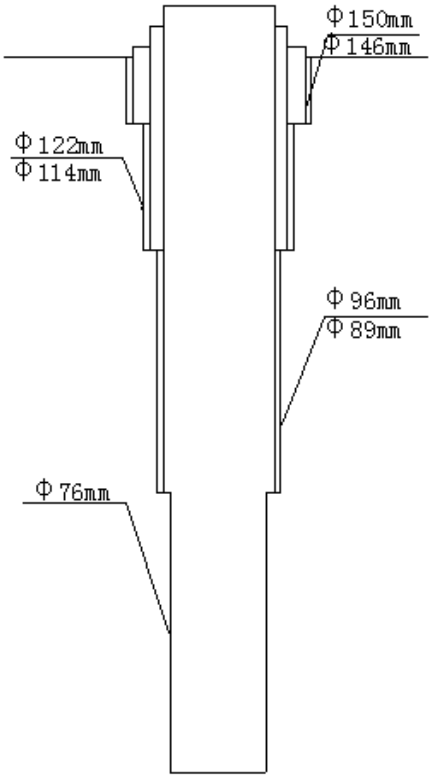

Figure 1. *Structure Diagram of WZK-4 Hole Three-stage Casing Four-opening System.*

See Table 2 for technical parameters of diamond drilling.

Table 2. *Technical Parameters of Diamond Drilling.*

drilling parameters	Drill bit specification				
	NQ	HQ	PQ	Φ150mm	Φ172mm
bit pressure /KN	8~10	10~13	13~15	15~17	17~19
rotate speed / (r/min)	400~800	350~700	250~500	200—300	100—200
pump volume (L/min)	40~70	60~90	90~110	90~110	90~110

3. Main Problems and Measures in Construction of WZK-4 Hole

3.1. Loosening and Expansion of the Fourth Alluvium and Diluvium

Hole WZK-4 is distributed in the front of the mountain, valley and middle beach of the survey area, mainly alluvial deposits widely distributed in the gully and intermountain beach, composed of alluvial sand and gravel, etc., which is easy to cause wellbore instability during drilling. In the thick overburden formation, due to the large formation soft plasticity, large sand content, poor formation stability and the release of formation pressure after drilling, it is easy to cause hole shrinkage and sticking phenomenon [5, 6].

3.2. Formation Fragmentation and Collapse

The lithology of the drilled formation is mainly quartz sandstone, quartz diorite sandstone, dolomite and mudstone, mixed with multi-stage carbonaceous sericite phyllite. In the fractured formation, the Young's modulus of the rock block is large, the ground stress is small, the fracture pressure is small, and cleats and microfractures are developed. [7-9], As a result, it is hard, brittle and easy to break. There are many cracks between rock blocks and low compressive strength. Therefore, under the collapse pressure generated by the hole wall stratum, rock blocks in the formation are easy to collapse and fall off. The irregular well wall has certain influence on drilling, tripping and running pipes. See Figure 2.

Figure 2. *Loose, broken core retrieved from field.*

3.3. Shrinkage, Spalling, etc

There are multiple layers of lithologic rocks with speckled carbonaceous sericite phyllite in this hole: it is the main wall rock of gold ore body in Jinlonggou Kuangqu mining area. The rock is gray black, with granular scale metamorphism structure, speckled structure and thousand-plate structure. Mineral composition: sericite (muscovite) (30-60%), quartz (25-50%), carbonaceous (5-15%, including graphite 1-3%), a small amount of calcite, chlorite, pyrite and trace tourmaline. Carbonaceous sericite phyllite is also the main wall rock of gold ore body in Kuangqu gold deposit. The rock is gray black, with granular scale metamorphism structure and thousand phyllodes structure, composed of sericite (35-72%), quartz (17-50%), carbonaceous (7-13%), graphite (1%) and a small amount of calcite and met al minerals. There are spalling, dispersion when meeting water, collapse and serious falling blocks. Requirements: flushing fluid has strong plugging and anti-collapse performance [10-14].

4. Study and Application of WZK-4 Porous Potassium-based Filming Wash Solution System

4.1. Polymer Drilling Fluid System Used in WZK-4 Hole

In view of the conventional polymer bentonite flushing fluid system used in the early stage of WZK-4 hole, there are many times of resistance and block loss in the drilling process. Main formula: 4-6% sodium soil +0.2 - 0.5% CMC-HV+1%KHm, main properties see Table 3, See Figure 3 for the core taken out. The core is loose and broken.

Figure 3. *Core taken in situ with original bentonite polymer.*

Table 3. *Properties of original bentonite drilling fluid system.*

name	Funnel viscosity (S)	AV mPa.s	PV mPa.s	YP Pa	GEL (10″/10′) Pa	API FL ml
original system	30-40	15-25	9-12	3-7	5-7/9-12	14

4.2. Application of WZK-4 Hole Potassium-Based Film-Forming Flushing Fluid System

In response to the main difficulties presented by the loose and expansive nature of the fourth alluvial fan deposit, the fragmentation and collapse of the sandstone stratum, and the presence of carbonaceous sericite phyllonite stratum, in order to meet the performance requirements of the flushing fluid for the drilling operation at the Jinlonggou gold mine, research on potassium-based film-forming flushing fluid technology was carried out on the basis of the original polymer flushing fluid system, with the aim of enhancing the inhibition, plugging and anti-collapse properties of the flushing fluid [15, 16].

4.2.1. Formula of Potassium-based Film-forming Rinse Liquid System

Main formula: 3% ~ 5%Na-Bet + 0.2% ~ 0.6% salt resistant polymer fluid loss agent STQ + 3% ~ 5% film-forming system of SCM + 0.1% ~ 0.2% SN liquid viscous inhibitors + 0.5% ~ 1% while drilling plugging agent GBJ + 3-5% KCl collapse prevention.

4.2.2. Properties of Potassium-based Film Forming Rinsing Solution System

The conventional properties of the potassium-based film forming flushing solution system are shown in Table 4.

Table 4. *Conventional properties of high density drilling fluid.*

Density (g/cm^3)	AV mPa.s	PV mPa.s	YP Pa	YP/PV	GEL (10″/10′) Pa	API FL ml	FV s	pH	Cake quality
1.03	18	11.5	6.5	0.57	1/3	5.2	37	10	Thin tough and dense

4.2.3. Comparison Chart of Mud Cake Quality Effects

Table 5 is a simplified example of a comparison chart for mud cake quality effects, which is used to visually demonstrate the differences in mud cake quality under different drilling fluid systems.

Table 5. *Comparison of Mud Cake Quality between Potassium-based Film-forming Drilling Fluid and Conventional Drilling Fluid.*

Type of Drilling Fluid	Mud Cake Thickness (mm)	Mud Cake Toughness	Comprehensive Evaluation of Mud Cake Quality
Conventional Drilling Fluid System	≥2	Low (in quality)	Poor, prone to peeling and easy to break
Potassium-Based Film-Forming Drilling Fluid System	≤1	High (in quality)	Excellent, thin yet tough, and resistant to peeling

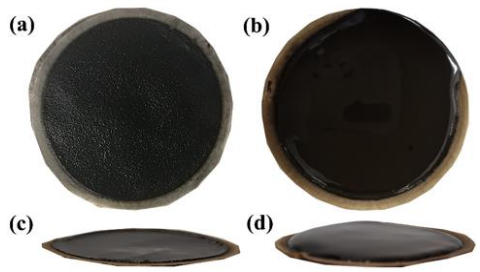

Figure 4. *Core taken in situ with original bentonite polymer. (a), (c) Properties of potassium-based film forming rinsing solution system;(b), (d) original bentonite drilling fluid system.*

1) Mud Cake Thickness:

(1) Under the conventional drilling fluid system, the mud cake thickness is typically greater than or equal to 2mm, which may lead to poor wellbore stability and an increased risk of drilling accidents.

(2) With the potassium-based film-forming drilling fluid system, the mud cake thickness is controlled below 1mm, effectively reducing the burden on the wellbore and enhancing the safety of drilling operations.

2) Mud Cake Toughness:

(1) The mud cake formed under the conventional drilling fluid system exhibits low toughness, making it susceptible to peeling or breaking under external forces, which affects the effectiveness of wellbore protection.

(2) The mud cake formed with the potassium-based film-forming drilling fluid system demonstrates high toughness, capable of resisting external forces, maintaining wellbore integrity, and extending the effectiveness of the drilling fluid.

3) Comprehensive Evaluation of Mud Cake Quality:

(1) The mud cake quality under the conventional drilling fluid system is poor, primarily manifesting as easy peeling and breaking, which is detrimental to wellbore protection and the smooth progress of drilling operations.

(2) The mud cake quality under the potassium-based film-forming drilling fluid system is excellent, characterized by being thin yet tough and resistant to peeling, significantly enhancing wellbore stability and the safety of drilling operations.

5. Application of Potassium-based Film Forming Rinsing Fluid System in WZK-4 Hole Construction

5.1. Application of Washing Fluid in Drilling Unit No. 4 (24wzk701) of Jianshan Gold Mine in Dachaitan, Qinghai Province

1. The project designed and constructed one hole, numbered 24WZK701, bearing 56 ° and dip Angle -60 °. The planned drilling quantity is 300 meters; The final hole is 303.8m. The mud ratio is adjusted in time for the complex geological conditions encountered in the drilling process.

The project started drilling from July 5, 2024 to the final hole from July 22, 2024, which effectively completed the timely adjustment of mud performance when encountering complex geological conditions in the area. The main construction effects are shown in Figure 5. The potassium-based film-forming drilling fluid, due to its excellent lubricating properties and wellbore stability, can effectively protect the core from damage during extraction. The core retrieval is continuous, with no breaks or losses observed. An extraction rate of 100% indicates that the actual length of the retrieved core is completely consistent with the theoretical length, without any loss or damage to the core.

Figure 5. *Coring of potassium-based film-forming drilling fluid used in field.*

5.2. Economic Benefit Analysis

By using the potassium-based film forming fluid system, the phenomenon of wall collapse and block fall is significantly reduced, which ensures the integrity of the borehole diameter. The borehole diameter expansion rate analyzed by logging is only 8%, which effectively improves the cementing quality in the later period. The washing fluid system can effectively improve the efficiency of rock cuttings and prevent repeated grinding of the bit. The lubrication performance of the washing fluid can effectively reduce friction and pressure, and the average penetration rate is nearly 0.5 times higher than before. In the early construction process, the downhole accident caused by the collapse of the block made the treatment of the accident take a long time and affected the construction progress. The drilling fluid system effectively controlled the occurrence of the accident and greatly shortened the processing time of the accident. A total of 4.55 tons of materials were used in the drilling of Dan Tan Jianshan gold mine, with a total cost of 22646.6 yuan, equivalent to about 74.54 yuan/meter. The traditional sodium bentonite-polymer drilling fluid system costs approximately 96.86 yuan/meter of footage drilled, representing a 23% savings in economic benefits.

6. Conclusion

1) The project is designed and constructed with a hole numbered 24WZK701, bearing 56 °and inclination -60 °. The planned drilling quantity is 300 meters; The final hole is 303.8m.
2) The potassium-base film forming flushing liquid system has strong inhibition and sealing ability, so the wall protection effect is good, the well wall is stable during the construction process, and the smooth drilling construction is ensured.
3) The potassium-based film forming washing fluid system has good sand carrying and lubrication effect, and the 24WZK701 hole construction has a total of 17 days, and the use cost of drilling fluid is about 74.54 yuan/meter, which effectively guarantees the drilling efficiency cumulatively.

Author Contributions

Duan Yinglong: Conceptualization, Data curation
Wang Xianjun: Methodology, Investigation
Pang Huaiwei: Methodology, Project administration
Xie Limin: Investigation
Li Baoshan: Project administration, Writing – original draft
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Mu Yuanhong: Project administration, Resources
Chen Long: Data curation, Investigation, Project admin-

istration

Ji Weijun: Methodology, Project administration, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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