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Research and Field Application of Drilling Technology for Karst Geothermal Wells in Xiong'an New Area

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INTRODUCTION

Regional & Resource Advantages

- Xiong'an New Area is a national-level new area with abundant geothermal resources; it is one of China's premier regions for karst geothermal energy, featuring good connectivity, large water volume, high temperature, easy reinjection, and strong economic benefits.
- Geothermal development is a key component of the region's green and low-carbon development strategy.
- Drilling construction faces frequent accidents and complex operational challenges.

Previous Research & Achievements

- Reservoir characterization: 3D seismic and logging technologies to map geothermal reservoir distribution; dynamic exploitation models based on formation temperature and pressure fields; optimized well spacing and production intensity.
- Drilling technology optimization: High-temperature geothermal drilling fluid systems and casing anti-corrosion technologies; deep geothermal drilling solutions including small-diameter exploration holes, packer-based cement leakage control, diamond full-face coring tools, and optimized casing depth and size grading.
- Intelligent drilling & safety: Unmanned drilling platforms to reduce human error and accident rates.
- Reinjection systems: "One extraction, multiple reinjections" same-layer tailwater reinjection; closed-loop reinjection pipelines with filtration and pressurization; improved reinjection efficiency via perforation optimization and reservoir acid stimulation.
- Remote monitoring: Real-time flow, temperature, and pressure data collection; anomaly early warning; "one well, one file" management for dynamic tracking of production, reinjection, and environmental impacts.

Existing Technical Challenges

- Unclear characteristics of the upper cap rock of geothermal reservoirs.
- Difficult coring in fractured formations.
- Mismatched wellbore structures.
- Challenging drilling fluid performance regulation.
- Severe leakage in karst geothermal reservoirs.
- Low mechanical penetration rate.

This Study's Objectives & Methodology

- Analyze regional tectonic evolution using seismic, geological, and drilling data; clarify formation features and finely characterize the top-bottom structures and fault development of Ordovician and Jixian geothermal reservoirs.
- Establish fracture identification and evaluation methods using core samples, conventional logging, and imaging logging data; accurately describe fracture development.
- Optimize stratigraphic identification and wellbore structure.
- Develop coring technologies for carbonate and limestone fractured formations; conduct laboratory testing and improvement of coring tools.
- Implement field applications with favorable results.

METHODS

1 Detailed geological research resolves issues related to reservoir-caprock combinations and strati graphic identification .

1.1 The issue of the characteristics of the storage-cover combination ;

1.2 The development pattern of fractures in karst thermal reservoirs;

1.3 XRF elemental logging technology for identifying strata

1.4 Wellbore Structure Optimization Design(Fig.1,Table 1);

2 Malignant leakage formation plugging and drilling techniques

3 Fractured formation core sampling technology

4 Utilize high-quality drilling fluid technology to solve the problem of formation collapse

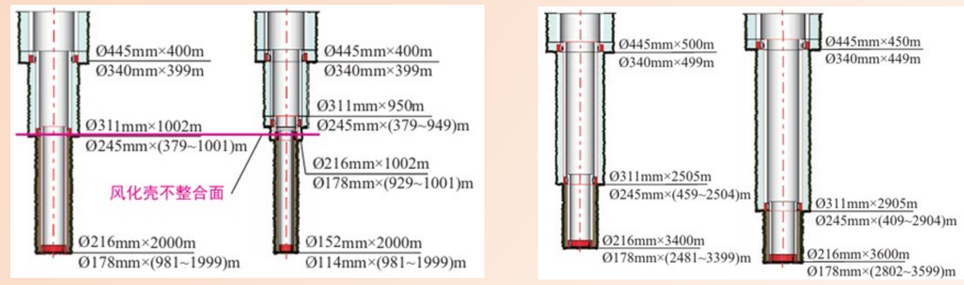


Fig.1 Schematic diagram of casing programme

Table 1 Data of casing programme

Reservoir-caprock type	Which drilling operation	Bit diameter（mm）	Drilling interval (m)	Outer diameter of the asing (mm)	The depth of the casing string (m)	Depth of the cement top (m)
Wumishan formation, Minghuazhen formation, Weathering crust without leakage	The first drilling operation	445	0～400	340	0～399	0
	The second drilling operation	311	400～1002	245	379～1001	379
	The third drilling operation	216	1002～2000	178	981～1999	
Wumishan formation, Minghuazhen formation, Weathering crust no-flowback leakage	The first drilling operation	445	0～400	340	0～399	0
	The second drilling operation	311	400～950	245	379～949	379
	The third drilling operation	216	950～1002	178	929～1001	929
	The fourth drilling operation	152	1002～2000	114	981～1999	
Wumishan formation, Paleogene system	The first drilling operation	445	0～500	340	0～499	0
	The second drilling operation	311	500～2505	245	459～2504	459
	The third drilling operation	216	2505～3400	178	2481～3399	
Ordovician system, Permo-Carboniferous system	The first drilling operation	445	0～450	340	0～449	0
	The second drilling operation	311	450～2905	245	409～2904	459
	The third drilling operation	216	2905～3600	178	2802～3599	

RESULTS

1 Stratigraphic identification technology

In the past two years, the rate of complete and accurate extraction of the Zhumeishan Formation of the Jixian Series and the weathered crust of the Ordovician System in this area has increased by 30%. In 2024, the accuracy rate reached 100%, setting a new high in Xiong'an New Area and achieving the goals of on-site technical services, comprehensive improvement of the quality of weathered crust layers, and facilitation and precision quantification of on-site construction.

2 Stratum leakage, coring technology

By adopting the double-wall drill pipe leakage detection technology and the core sampling technology for fractured formations, the first 2 rounds of core sampling operations were successfully completed in the Cengdong Exploration and Production Well. The final core sampling success rate was 99.4%, achieving the research goal of core sampling technology in this area and laying a certain foundation for subsequent operations in this region.

3 Drilling fluid technology

The above-mentioned high-quality drilling fluid system was applied in the exploration and production wells 1 and 3 of Rongdong, as well as in Well Xizhan 1 and Well Xizhan 2. This system is green, low-carbon, efficient and environmentally friendly, and has achieved good results .

4 Speed-up and efficiency-enhancement technology

Zg-Dr1 well, the average mechanical drilling rate for the third drilling operation was 8.15 meters per hour; the Da Wang Ke Shang 1 well had a total drilling depth of 3500 meters, with the final drilling position higher than the Zhuang formation. The wellbore quality was qualified, and the average mechanical drilling rate for the third open hole was 8.17 meters per hour. The water test temperature was 93.1 ℃, the water volume was 140 m³/h, the static liquid level was 116 m, the dynamic liquid level was 100 m, the drop depth was 16 m, and it achieved excellent drilling results.

DISCUSSION

Wellbore Structure Adaptability to Karst Geothermal Reservoirs

- Wellbore Structure Adaptability to Karst Geothermal Reservoirs
- Casing size and cementing optimization not only ensure wellbore integrity under complex stress but also extend service life, supporting long-term cyclic exploitation of geothermal resources.

Ecological Protection-Oriented Drilling Fluid Technology

- Biodegradable and non-toxic drilling fluid formulation conforms to Xiong'an's strict ecological and groundwater protection standards, reducing environmental risks from fluid leakage and discharge.
- Strengthened shallow geothermal zone protection measures balance resource development and ecological security, aligning with the green development orientation of national-level new areas.
- This environment-friendly technical path provides a reference for geothermal development in ecologically sensitive areas.

Drilling Efficiency Enhancement & Regional Promotion Value

- Turbine/high-speed screw drilling tools, high-performance bits and digital parameter optimization significantly improve mechanical drilling rate in hard fractured formations.
- Current technologies still face challenges in ultra-deep karst reservoirs with high-temperature and high-leakage conditions; long-term performance stability of drilling tools and fluids needs further monitoring.

CONCLUSION

Wellbore Structure Design

- Adopted a triple completion wellbore structure to satisfy geothermal development demand.
- Suspend micro-tube of production casing and install filter pipe in target interval.
- Optimize casing size and cementing process to ensure wellbore integrity and heat exchange efficiency, while meeting groundwater protection and ground subsidence prevention requirements.

Leakage Control & Core Sampling

- Use clean water, aerated clean water, and double-wall drill pipe technology for drilling highly permeable leaky formations.
- Apply specialized tools and combined technologies to obtain complete geological data of Wumishan Formation Dolomite fractured zones, solving core sampling issues in basement fracture zones.

Drilling Efficiency & Application

- Applied turbine drilling tools / high-speed screw bits, selected high-performance drill bits, and optimized digital drilling parameter system.
- The experience has important promotion value for clean energy development under similar geological conditions in North China.

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