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Development Law and Target Area Optimization of Ordovician Karst-Fracture Type Geothermal Reservoir in Qianmiqiao Area of Huanghua Depression

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INTRODUCTION

- Carbonate reservoirs account for 70%-80% of China's total hydrothermal geothermal resources, owing to advantages of wide distribution, large thickness, and easy recharge, serving as the primary focus of hydrothermal geothermal development in China[1] [2] [3] [4].
- Carbonate reservoirs show strong heterogeneity, leading to marked variations in spatial distribution, porosity-permeability characteristics, and fluid migration laws [4] [5].During the formation and evolution of carbonate geothermal reservoirs, karstification shapes complex and diverse reservoir spaces through the dual effects of chemical dissolution and physical transformation [6] [7].
- Taking the Ordovician karst-fractured geothermal reservoir in the Huanghua Depression as the research object and karstification as the main thread(Fig 1)., this paper studies reservoir characteristics, analyzes reservoir distribution laws, reveals the development model of this reservoir type, proposes target optimization indicators, and provides a scientific basis for the exploration and development of such geothermal reservoirs.

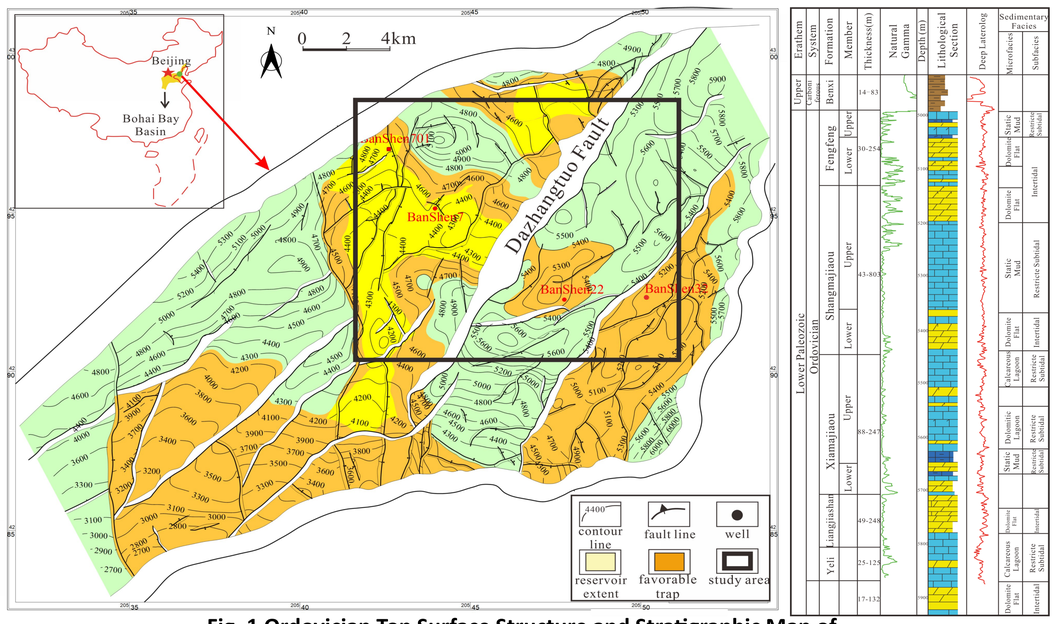


Fig. 1 Ordovician Top Surface Structure and Stratigraphic Map of the Qianmiqiao Area

KARST DEVELOPMENT STAGES AND THEIR RESERVOIR RECONSTRUCTION EFFECTS

- Huanghua Depression's Ordovician reservoirs are dominated by dissolution pores and fractures, with negligible primary pores, controlled by multi-stage differential karstification[8] (Fig 2). Via Well Banshen 701 (Qianmiqiao) lithological cathodoluminescence and U-Pb dating, this study determines karst stages and timing (Fig 3).

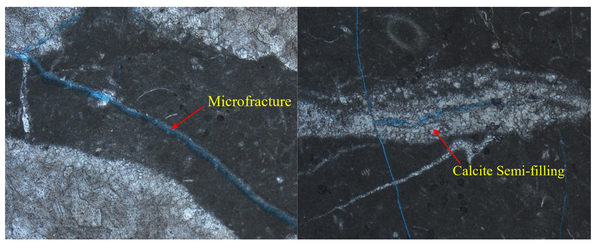


Fig. 2 Microfractures and Mineral Filling

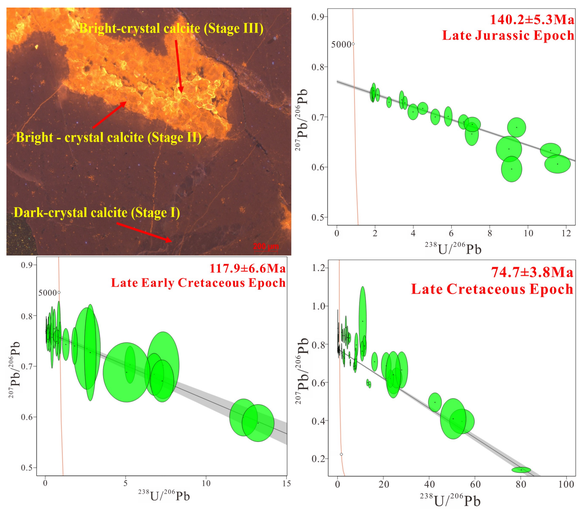


Fig. 3 Cathodoluminescence and Diagenetic Stage Analysis of Lithology from Well Banshen 701 (4618.18 m)

- Huanghua Depression had three tectonic phases: Late Caledonian-Early Hercynian, Indosinian-Yanshan, Himalayan Orogeny. Qianmiqiao's three karst phases are direct products of these cycles (Fig 4).

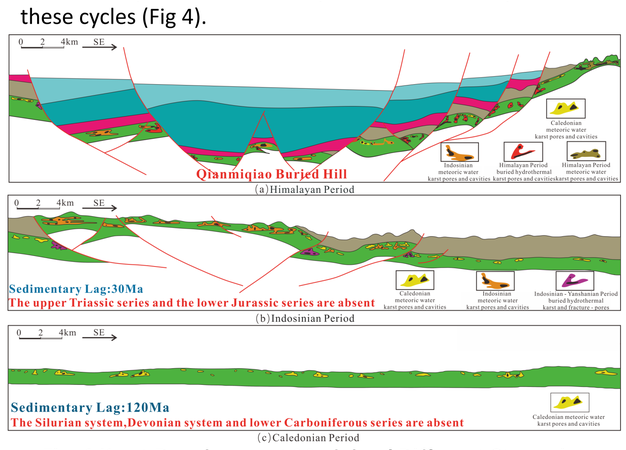


Fig. 4 Karst Development Models of Different Stages in the Qianmiqiao Area

- Dynamic coupling of tectonic movement and mixed fluids determines the intensity, modification mode, and final reservoir impact of each karstification phase (Table 1).

Table 1 Porosity and Permeability Characteristics in Areas with Superposition of Different Karst Stages

Karst Stages	Sample No.	Depth (m) H	Permeability (mD) K	Porosity (%) ϕ
Caledonian Period	Cang Shen1	2300	0.024	2.046
	Bo Gu1	2105	0.000	1.601
Caledonian Period + Himalayan Period	Qi Gu1	4195.5	/	0.891
	Qi Gu11x1	2786.91	0.092	2.169
Caledonian Period + Himalayan Period + Indosinian-Yanshanian Period	Ban Shen701	4625.88	0.139	12.916
	Gang Gu16101	2863	4.554	13.523

SPATIAL DISTRIBUTION LAW OF GEOTHERMAL RESERVOIRS

- From the exploration of Huanghua Depression's Ordovician carbonate geothermal reservoirs, their porosity-permeability shows obvious vertical zonation; drill pipe emptying and mud loss concentrate 20-100m below the weathering crust, with porosity peaking at 20-150m, jointly forming main vertical reservoirs (Fig 5).

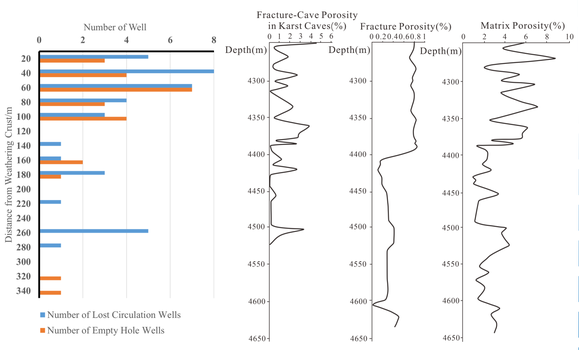


Fig. 5 Vertical Zonation Characteristics of Geothermal Reservoirs

- Ordovician lithological stratification (upper dolomite-lower limestone) offers a "material screening basis" for karstification; vertical variation of "groundwater migration-CO_2 dissolution" further selects the "horizontal phreatic zone" as the optimal interval in dolomite layers. Their coupling designates the Upper Fengfeng Formation and main Shangmajiaogou Formation as key vertical geothermal reservoirs (Fig 6).

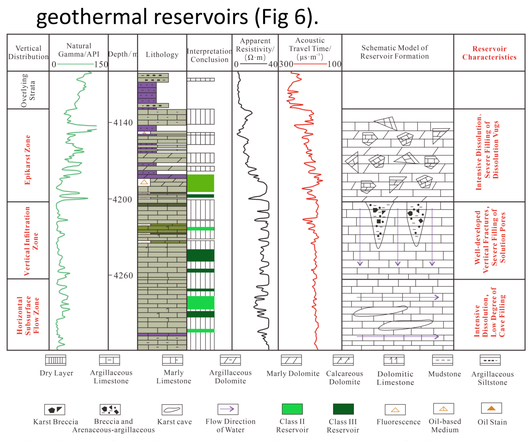


Fig. 6 Vertical Comprehensive Characteristics of the Ordovician Reservoir in the Huanghua Depression

- Using seismic exploration data and the "impression-residual thickness method", the Ordovician palaeogeomorphology of Qianmiqiao buried hill area was recovered, dividing into three karst units (highland, slope, depression) that correspond to groundwater recharge-runoff-discharge areas, with key wells selected to establish well-tie sections (Fig 7).

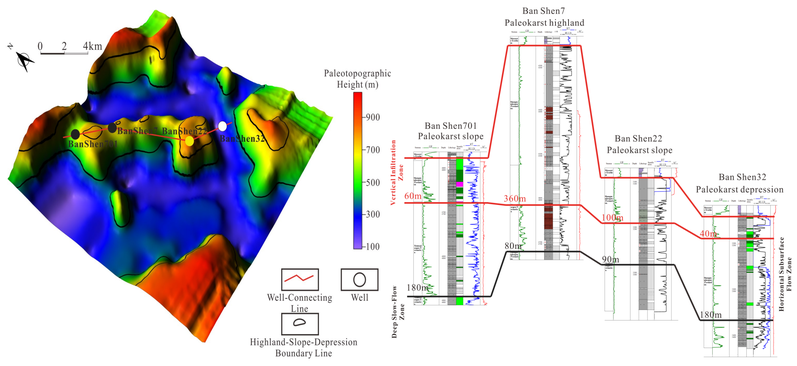


Fig. 7 Paleokarst Geomorphology Map (Indosinian-Yanshanian Period) and Well-Tie Section of Typical Ordovician Geothermal Wells with Zone Variations in the Qianmiqiao Buried Hill Area

- From karst highland → slope → depression, porosity-permeability exhibit "low-high-low" variation. In overlaps of karst slopes and faults, faults provide efficient groundwater pathways, intensify rock fracturing and expand dissolution space, forming "karst slope + fault" dual advantage zones (Fig 8).

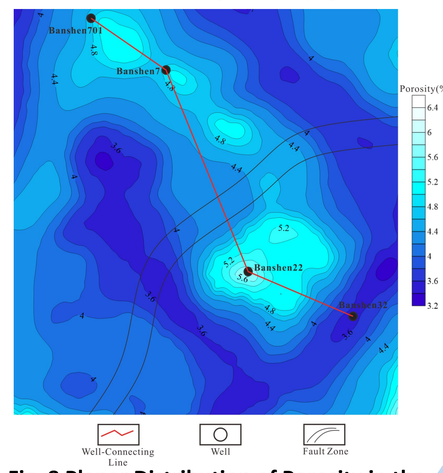


Fig. 8 Planar Distribution of Porosity in the Qianmiqiao Buried Hill Area

RESULTS

- Qianmiqiao Buried Hill's karst-fracture Ordovician geothermal reservoir formation & evolution is driven by "material basis, multi-stage modification, spatio-temporal coupling"(this study,2026).
- Based on marine dolomite, with full karst development during Indosinian-Yanshanian, areas at the intersection of horizontal phreatic zone and karst slope, locally modified by fault zones, are optimal for karst-fracture geothermal reservoirs (Fig 9).

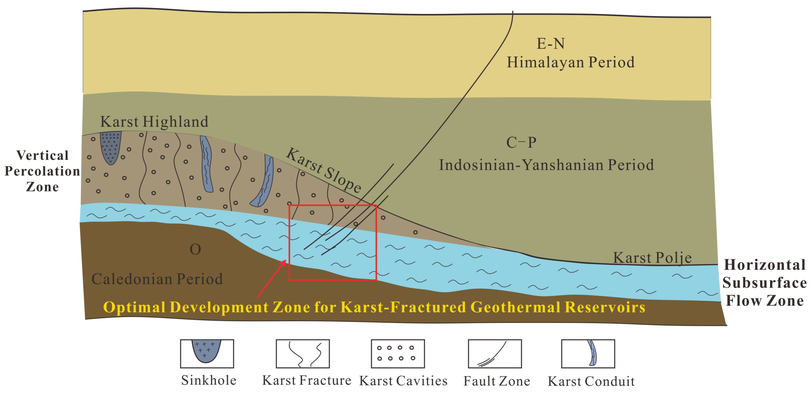


Fig. 9 Development Model and Optimal Zones of Karst-Fracture Type Geothermal Reservoirs

CONCLUSION

- Indosinian-Yanshanian is key for Huanghua's Ordovician reservoirs; Qianmiqiao's three karst stages couple to form reservoirs.
- Via lithology-hydrodynamics-CO_2 dissolution screening, high-quality reservoirs lie in Upper Ordovician dolomites' 20-150m horizontal phreatic zone.
- Paleogeomorphology-dominated, fault-optimized horizontal reservoir development: karst slope as core, others inferior.
- Proposed Qianmiqiao's reservoir model & exploration direction: triple-overlap zone as key target.

Acknowledgements

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