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Exploration for Deep Geothermal Energy of Granite Reservoir in Hainan Island, China

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INTRODUCTION

Geothermal energy can be divided into low-temperature geothermal energy, medium temperature geothermal energy, and high-temperature geothermal energy according to temperature, corresponding to temperatures below 90 °C, 90-150 °C, and above 150 °C. High temperature and medium temperature geothermal resources are mainly enriched in special tectonic backgrounds, such as plate edges and mantle plumes. Low temperature and low heat resources, due to their wide distribution and broad application prospects, have received widespread attention around the world. The heat source in the Crust is mainly from mantle conduction heat and radioactive heat generation of granite, which was widely tested as the geothermal reservoir for Enhanced (or engineered) Geothermal System (EGS) in Rosemanowes of UK, Soultz of France, Australia and Pohang of South Korea (Richards et al., 1992; Genter et al., 1995; Goldstein et al., 2008; Brown et al., 2012; Breede et al., 2013; Olasolo et al.,2016; Parisio and Yoshioka et al., 2020; Park et al., 2020)

In this paper, the geological conditions for the formation of deep geothermal resources in Hainan Island were comprehensively studied by means of structural geology, the geological characteristics, genetic background and geological model of deep geothermal resources were defined, and the exploration direction and prospect area of deep geothermal resources were pointed out. There are 43 regional faults, 5 in east-west direction, 4 in North-South direction, 18 in northeast direction and 16 in NW direction (Figure. 1).

METHODS

The distribution of deep geothermal resources in Hainan Island is mainly influenced by two high-temperature geothermal belts, namely, the Mediterranean - Himalayas and the Pacific Rim. What are the geological conditions of geothermal formation and where are the favorable areas for deep geothermal development and utilization? In order to solve these problems, this paper carries out regional geological survey and adopts geological geophysics, geochemistry and petrology.

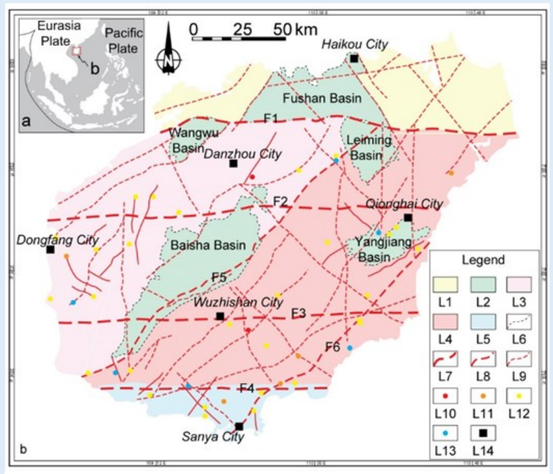


Figure 1. Tectonics and geothermal distribution map

L1: Leiqiong faulted depression; L2: Mesozoic to Cenozoic basins; L3: Baoban uplift; L4: Wuzhishan uplift; L5: Sanya depression; L6: Tectonics units boundary; L7: Major deep fault zone; L8: Basement fault zone; L9: Shallow fault; L10: Geothermal point which the temperature of the geothermal fluid is above 90 degree centigrade; L11: Geothermal point which the temperature of the geothermal fluid is between 70 and 90 degree centigrade; L12: Geothermal point which the temperature of the geothermal fluid is between 40 and 70 degree centigrade; L13: Geothermal point which the temperature of the geothermal fluid is lower 40 degree centigrade; L14: City.

F1: Wangwu-Wenjiao fault zone; F2: Changjiang-Qionghai fault zone; F3: Jianfeng-Diaoluo fault zone; F4: Jiusuo-Lingshui fault zone; F5: Ding'an-Ledong fault zone; F6:Qionghai-Sanya fault zone.

RESULTS

1.Compared with the land heat flow value of typical cratonic continental areas and oceanic areas in the world (Gao et al., 2020), Hainan Island has a moderate to higher regional land heat flow value in the whole. The distribution of terrestrial heat flow in Hainan Island has a good correlation with the fluctuation of Curie isothermal surface, which spreads in a northeast- or northeast-ward direction (Figure. 2).

2. In general, general faults or more secondary faults on the side of thermal conductivity and water conduction faults of geothermal resources often control the distribution of reservoir in geothermal fields (hot springs), and thus control the scope and scale of its distribution. These faults are the main channels for deep geothermal energy conduction to the shallow crust for that all the typical geothermal fields and hot springs are mainly distributed on both sides of these faults.

3.The geothermal reservoir on Hainan Island is mainly dominated by widely developed igneous rocks, especially the Hercynian-Indosinian granite geothermal reservoir, which is widely distributed (Figure.3). The geothermal cover layer of Hainan Island is mainly composed of quaternary loose sedimentary layer and Cretaceous clastic rock sedimentary layer (Figure. 4).

4.The heat source mainly comes from the radioactive heat generation of the granite itself in the crust and the conducted heat energy of the mantle. A part of the geothermal water moves vertically upward along the fault, and is discharged by hot water spring in the weak cap layer, forming a hot spring. The other part moves horizontally in the high water level area of the hot mineral spring, and mixes with the surface normal water at the boundary of the geothermal reservoir, and the water temperature decreases (Figure. 5).

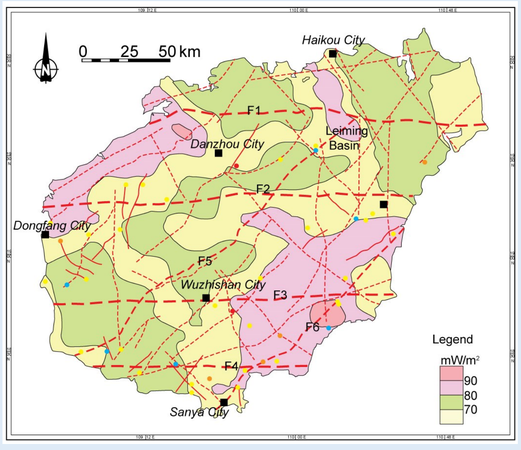


Figure 2. Geothermal heat flow map of Hainan Island

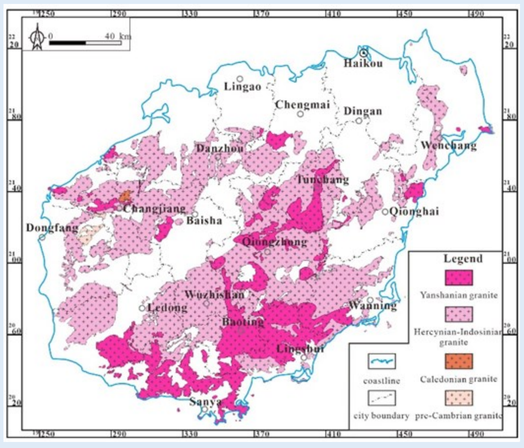


Figure 3. Granite distribution map of Hainan island



Figure 4. Reservoir and caprock of geothermal system

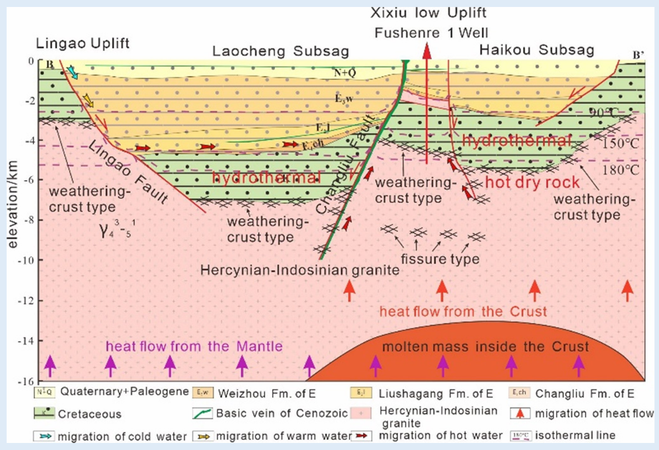


Figure 5. Deep geothermal genetic model of Hainan island

DISCUSSION

The weathering crust and lithologic contact surface of the Hercynian and Indosinian granite in Hainan Island are favorable places for the development of geothermal reservoir. Regional caprocks with large thickness, wide area, and stable distribution, distributed throughout vast sedimentary basins or depressions, play an important role in the accumulation of geothermal in the basin or depression. At a certain thickness of the caprock, the lower the thermal conductivity of the caprock, the more obvious the geothermal anomaly.

The screening method of geothermal favorable areas or geothermal dessert areas is established based on caprock and reservoir criteria and development criteria. In terms of the physical properties of the cover, only the Fushan depression is a high-quality cover with large thickness and high mudstone content, while the rest of the basins have good physical properties of the caprock as a whole, and the geothermal caprock in the uplift orogen area is generally or poorly developed.

In terms of 3.5km buried geothermal reservoir temperature, the geothermal reservoir temperature is mainly calculated based on silicon dioxide geothermal thermometer. In terms of geothermal reservoir lithology, it is mainly granite. According to the analysis of caprock and development criteria, the Hercynian and Indosinian granite geothermal reservoir covered by 3-5km thick caprock is a favorable area for deep geothermal resource enrichment. Finally, five favorable areas or geothermal dessert areas for deep geothermal development were selected, including Baisha Basin, Wangwu Basin, Leiming Basin and Yangjiang Basin in Fushan Depression.

CONCLUSION

(1) Hainan Island has a moderate to higher regional land heat flow value in the whole. The distribution of terrestrial heat flow in Hainan Island has a good correlation with the fluctuation of Curie isothermal surface, which spreads in a northeast-ward or northeast-ward direction.

(2) Hainan Island has experienced multi-stage tectonic events and formed a series of faults in different directions, most of which are near-east-west faults and northeast-southwest, among which near-east-west faults are deep faults that cut through the basement. In general, the faults or more secondary faults on the side of thermal conductivity and water conduction faults of geothermal resources often control the distribution of geothermal reservoir in geothermal fields (hot springs), controlling the scope and scale of its distribution.

(3) The geothermal reservoir on Hainan Island is mainly dominated by widely developed igneous rocks, especially the Hercynian-Indosinian granite geothermal reservoir, which is widely distributed. The reservoir rocks distributed in the fault fracture zone are mainly Indosinian granite, and the lithology is mainly syenite granite, monzonitic granite and granodiorite. The geothermal caprock of Hainan Island is mainly composed of quaternary loose sedimentary layer and Cretaceous clastic rock sedimentary layer.

(4) The weathering crust and lithologic contact surface of the Hercynian and Indosinian granite in Hainan Island are favorable places for the development of geothermal reservoir. Five favorable areas for deep geothermal development were selected, including Baisha Basin, Wangwu Basin,

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