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Geothermal and other mineral resources joint exploration and development potential in Sanshui Basin

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ABSTRACT

Abstract: Located in Guangdong Province, Sanshui Basin is a Cretaceous-Paleogene fault basin developed on the crystalline substrate of shallow marine carbonate rocks and Mesozoic igneous rocks in the upper Paleozoic, with petroleum and salt rock resources have been developed. It is found that in addition to conventional oil and gas exploration and development potential, this area also has the prospect of geothermal energy, CO_2, He and other resources. At the same time, the underground caverns formed by the early mining of rock salt provide favorable geological conditions for underground gas storage and compressed air energy storage. It is recommended to carry out joint exploration and development of various mineral resources in the area to help regional economic development and resource security.

1.INTRODUCTION

Sanshui Basin is located in the Great Bay Area of Guangdong, Hong Kong and Macao, with developed economy, convenient transportation, and strong demand for resources and energy. Previous studies have shown that the basin is rich in oil and gas, geothermal, helium, CO_2, salt and other mineral resources, but at present it is in a single mineral development mode, with low development and utilization efficiency, which not only causes repeated investment in exploration, but also destroys other resources and causes resource waste. In order to improve the efficiency of comprehensive exploration, development and utilization of various mineral resources and avoid repeated exploration and resource waste, this paper analyzes and studies previous achievements and drilling data, preliminarily analyzes the development potential of geothermal resources, CO_2 and helium resources, as well as salt cavern gas and energy storage resources in Sanshui Basin, and puts forward the direction of future resource exploration and development and comprehensive utilization mode of the basin.

2. REGINAL GEOLOGICAL

2.1 Division of tectonic units

The Sanshui basin is a Cretaceous Paleogene fault basin superimposed on the Indosinian-Early Yanshanian folded basement. From the perspective of oil and gas geology, the Sanshui basin still includes the late Paleozoic residual basin of the unmetamorphic platform type. According to the regional geological characteristics, combined with the drilling and geophysical data of the Sanshui Basin, the former Cretaceous erosion top, the former Triassic erosion top, and the former Devonian erosion top are the boundary. The Sanshui Basin has an obvious four-layer structure, namely, the Sinian-Silurian structural layer, the Devonian-Permian structural layer, the upper Triassic structural layer, and the Cretaceous-Paleogene structural layer.

The maximum cumulative thickness of the stratum in Sanshui Basin is more than 7000 meters and the area is about 3300 km2. The basin is generally distributed in a rhombic NW-SE direction, and the overall structural pattern is "four sags and four uplifts". From north to south, it can be divided into Dasha sag, Baoyue sag, Hekou Dalian uplift, Xiaotang sag, South China Sea uplift, Yanbu sag, Hefeng uplift and Luzhou sag (Figure 1). Yanshanian granite is

exposed on the north and south sides of the basin, and a small number of Paleogene volcanic rocks are found in the basin.

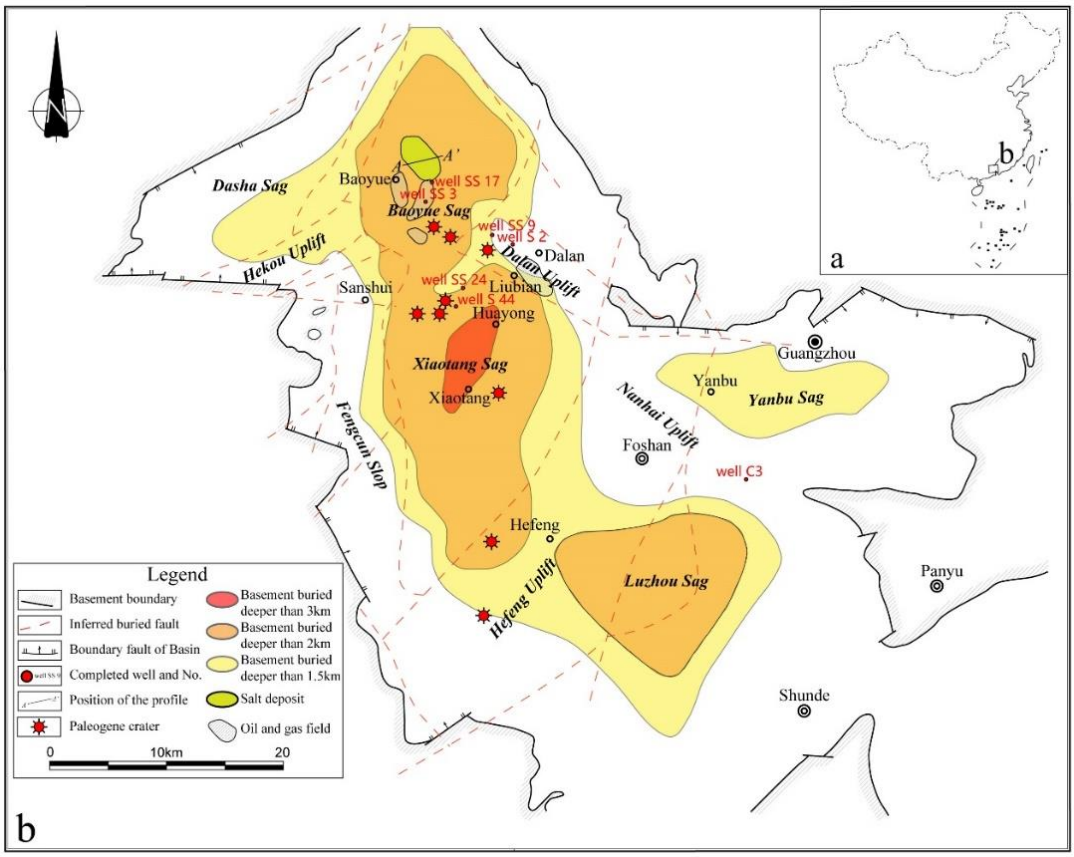

Figure 1: Structure outline map of Sanshui Basin

2.2 Volcanic activities

The volcanic activity in Sanshui Basin is frequent and intense. Since the late Early Cretaceous, there have been small-scale acidic magma intruding into the lower sandstone of the Baihedong Formation in the Pingzhou area of the South China Sea; At the end of the Early Cretaceous, there were rhyolite, dacite, pyroclastic rock and subvolcanic rock in the Fenggang-Shuzhugang area of Guangzhou, which were distributed in the NE-NNE direction. From the late Late Cretaceous to the Late Eocene-Early Oligocene Huayong stage of the Paleogene, the volcanic magma activity was frequent and intense, and the volcanic rocks were thick and widely distributed.

2.3 Stratum development characteristics

According to the basin drilling data and seismic profile interpretation data, combined with the distribution of strata at the edge of the basin, the sediments of the Sanshui basin are developed in the Middle and Upper Devonian, Carboniferous, Permian, Upper Triassic, Cretaceous and Paleogene.

3. CO_2 AND HE DISPLAY CHARACTERISTICS

Since 1950s, petroleum exploration has been carried out in Shui Basin. Oil, gas and CO_2 have been obtained and exploited from Permian limestone fractures and sandstone reservoirs of the third member of Paleogene Buxin Formation in Baoyue sag.

CO_2 is found in large quantities in the Sanshui Basin. In May 1977, the well SS9 drilled in Shatouwei, Nanhai County, obtained a high-yield CO_2 gas layer, and a strong blowout occurred, with a self-blowout of more than 100

meters high. In the 1429.2~1432.7m limestone section of E_2b_2, the gas yield of 59128.6m^3/d was obtained, and the CO_2 content was as high as 99.6% (Fu Xuebin et al., 2004).

It is concluded (Yang Changqing et al., 2004) that CO_2 in Sanshui Basin is mainly magma-mantle source genesis, a small amount is carbonate thermal alteration metamorphism, magma-volcanic activity controls the source and scale of carbon dioxide gas reservoir, fault activity controls the formation and distribution of CO_2 reservoir, and pre-Cretaceous uplift controls the accumulation space of CO_2.

Analysis of natural gas found that the helium content in some samples reached industrial grade (⩾0.1%) (Zhang Chi et al., 2022), and the gas source identification believed that most of it came from the deep mantle. Based on the understanding that CO_2 and He are mainly magma-mantle source genesis, it is speculated that there may be large-scale natural gas resource potential in the area deeper than the gas reservoirs that have been discovered so far, so that the exploration space of natural gas, oil and gas is CO_2 and He gas is further expanded to the depth.

4. SALT CAVERN GAS STORAGE AND ENERGY STORAGE PROSPECTS

The Paleogene Buxin Formation of the Sanshui Basin is built with red salt in a large area, and there is a salt rock ore layer in the adjacent pit, the salt mine is buried at a depth of 1210-1450, the total thickness of the ore-bearing stratum is 200-450m, and the thickness of the sandwich layer is generally less than 5 m (Tang Zhongyu, 1992). The salt mine began to mine salt in 1988, and generally has 1~3 wells for production. The method of salt mining is to inject clean water with a pressure of 2.8~4.0MPa into the well, and then pump it out after the salt rock is dissolved into clean water underground to become brine. When a single well is produced, 8~10m^3 of clean water is injected every hour, and 7~9m^3 of brine is produced, with the extraction ratio is more than 90%.

After years of mining, a number of sinkholes have been formed underground, mostly barrel-shaped, inverted cone-shaped, and the 1999 literature (Wei Berlin et al., 1999) reported that its radius is 20~31m, and the buried depth is about 1300m (Figure 2). So far, after more than 20 years of continuous exploitation, the volume of the cavity is roughly estimated to have been expanded by more than twofold, and it has the conditions for site selection as an underground natural gas storage or compressed air energy storage.

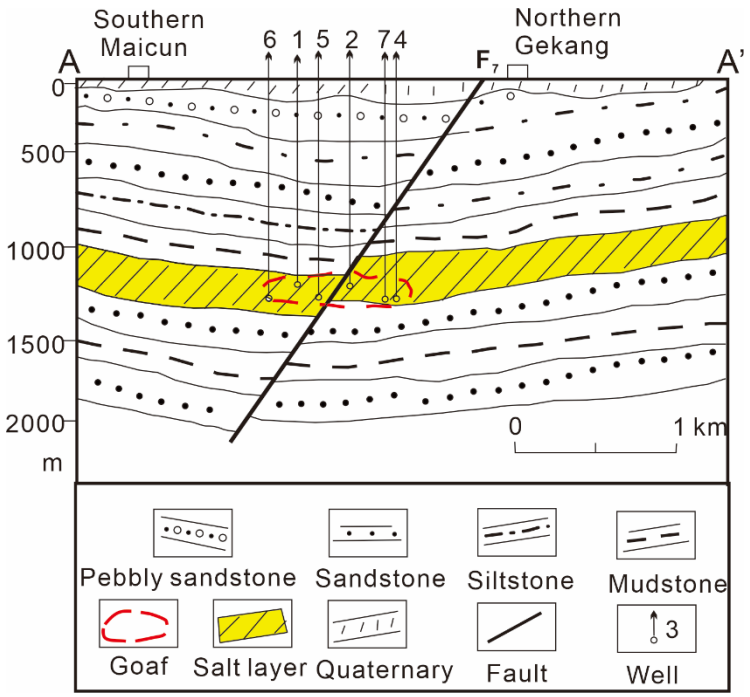

Figure 2: The synoptic·diagram of A-A' profile of Gekang salt deposit (modified after WEI, 1999)

5. CONCLUSIONS

Sanshui Basin is located in the Pearl River Delta region of Guangdong Province and belongs to the Guangdong-Hong Kong-Macao Greater Bay Area, which is the most economically dynamic area in the world. The demand for resources and energy is very strong. At present, shallow-buried oil and rock salt resources are mainly exploited in the area. In the future, oil and gas exploration and development will expand to the deep, and the exploration of oil and gas controlled by deep faults, especially helium-rich gas, will become the main direction. The comprehensive exploration and development of various mineral resources combined with geothermal, petroleum(especially helium-rich natural gas)，rock salt ，salt cavern gas storage and energy storage will become the "characteristics of Sanshui Area".

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