

Hydrothermal Alteration and Porosity Enhancement in Sandstones: An Example from the Pearl River Mouth Basin, South China Sea

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Diagenesis of sedimentary rocks at elevated temperatures may be divided into two types: normal burial and hydrothermal. In the latter case, the diagenetic fluids have temperatures higher than those under normal burial conditions. Such diagenesis in carbonate rocks has been recognized as an important process in enhancing porosities, e.g., in hydrothermal dolomites. Similar effects may be produced by hydrothermal fluids acting on sandstones, although they are more difficult to be recognized or distinguished from those of normal burial diagenesis. In this paper, we provide an example from the Pearl River Mouth Basin in the South China Sea, where the hydrothermal nature of the diagenetic processes related to sandstone porosity enhancement is supported by mineralogical, fluid inclusion, and vitrinite reflectance data.

The Pearl River Mouth Basin, located in the northern part of the South China Sea, hosts a number of oil and gas fields, mainly discovered in the past 10 years. The western part of basin (study area), the Zhu III Subbasin, consists of 6 half-grabens and 3 horsts. The reservoir rocks are composed of sandstones of the Zhuhai and Zhujiang formations (Early Miocene), which are now buried to a maximum depth of 1580m and 2416m, respectively. The maximum burial temperatures of these two reservoir units are estimated at 77°C and 101°C, respectively, based on a geothermal gradient of 41°C/km and a surface temperature of 12°C on the seafloor. The porosities of the reservoir sandstones range from 23.6 to 40.6%. These values are much higher than those of non-reservoir rocks in the same intervals and than what would have been expected from normal compaction, suggesting that significant secondary porosities have been generated. Petrographic studies indicate extensive dissolution of framework grains, especially feldspars.

Homogenization temperatures of aqueous fluid inclusions average 135°C in carbonate cements in the sandstones, and 160°C in quartz overgrowth as well as in detrital quartz where aqueous inclusions coexist with oil inclusions in fractures. These temperatures are significantly higher than the normal burial temperatures. The vitrinite reflectance values (Ro) increase with depth at a gradient of 0.1 to 0.18% / km from surface to the reservoir units, where the gradient sharply increases to 0.33 to 0.51% / km, indicating higher-than-normal temperatures in the reservoirs.

These data indicate that the sandstones of the Zhujiang and Zhuhai formations have been subject to temperatures significantly higher than normal burial conditions. We interpreted this abnormal heat to be related to hydrothermal activities, which ascended to the reservoir units from subvertical faults and then migrated laterally. Large amounts of secondary porosities were generated from dissolution of framework grains, enhancing the reservoir quality. Petroleum migration may have followed the same pathways as the hydrothermal fluids.