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Research Advances

Multi-Stage Fluid Charging and Critical Period of Hydrocarbon Accumulation of the Sinian Dengying Formation in Central Sichuan Basin

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Objective

The natural gas exploration of the Sinian reservoirs in the central Sichuan Basin has made a significant breakthrough in recent years, and has thus attracted much attention among geologists. The Sichuan Basin is known to have complicated geological settings, which has experienced multiple stages of tectonic evolution, fluid charging and hydrocarbon accumulation. This research aims to determine the geochemical characteristics of each stage of fluids, the features and time interval of fluid activity in different geologic periods, and further to restore the critical period and geological age of the hydrocarbon accumulation.

Methods

This study described the filling sequence of minerals and bitumen filled in reservoir pores, vugs and fractures from a microscopic view, and conducted geochemical tests of Sr, C, O isotopes, fluid inclusions and microelements on them. Besides, we did chronology analysis on the typical minerals and bitumen. This allows us to verify and constrain mutually both the geochemical and geochronological information for each stage of fluids.

Results

Through the observation of minerals and bitumen in the Dengying Formation reservoirs from exploratory wells in the Gaoshiti-Anpingdian structure of the central Sichuan Basin under microscope, it is indicated that the filling relationship has following types of sequence: dolomite (the first generation)→bitumen (the second generation)→dolomite (the third generation), and dolomite (the first generation) →bitumen (the second generation)→dolomite (the third generation)→bitumen (the fourth generation). Thus, it is inferred that two stages of brine water charging and two stages of oil charging have occurred in the Sinian Dengying Formation reservoirs, and that the oil is mainly come from the second-stage oil charging of the overlying Qiongzhusi Formation of the Lower Cambrian.

The chromatography of saturated hydrocarbons of the Sinian reservoir bitumen shows the association of UCM with high-abundance n-alkane series, indicative of a complex process of crude oil accumulation→oxidative degradation→new crude oil charging→crude oil cracking; this feature is well matched with the development feature of the microscopically observed bitumen. The carbon isotope characteristic of the Sinian gas in the study area is significantly different from that in other marine carbonate strata within the basin due to its heavy ethane carbon isotope results. This is considered to be caused by the mixing of large amounts of bitumen cracked gas. Besides, the bitumen cracking is later than the oil cracking, which has greatly supplemented the formation of the Sinian Dengying Formation gas reservoirs.

On the basis of the geochemical analysis of the reservoir bitumen, we discussed the relationship between hydrocarbon accumulation and bitumen in order to restore the accumulation processes of the study area. From the Cambrian to Silurian, the Lower Cambrian Qiongzhusi Formation source rock in the Mianyang-Changning intracratonic sag began to substantially generate hydrocarbons, and the generated crude oil migrated laterally towards the Gaoshiti-Anpingdian structure to the east and accumulated to form the early-stage ancient oil pools. In the late Silurian, the paleo-uplift in the central Sichuan Basin was again uplifted due to the impact of the Caledonian movement. As a result, the top part was eroded severely and then be flattened, resulting in the absence of the Devonian, Silurian and part of Ordovician strata in the study area. Given the long duration of this stage and the significant burial depth (about 1000 m) of ancient oil pools, crude oil was strongly water-washed to form oxidatively degraded bitumen. Since the Permian, due to the rapid subsidence of the Permian and Triassic strata, the Qiongzhusi Formation began to substantially generate hydrocarbons again, and the generated crude oil continually charging the Gaoshiti-Anpingdian structure, which was situated at relatively

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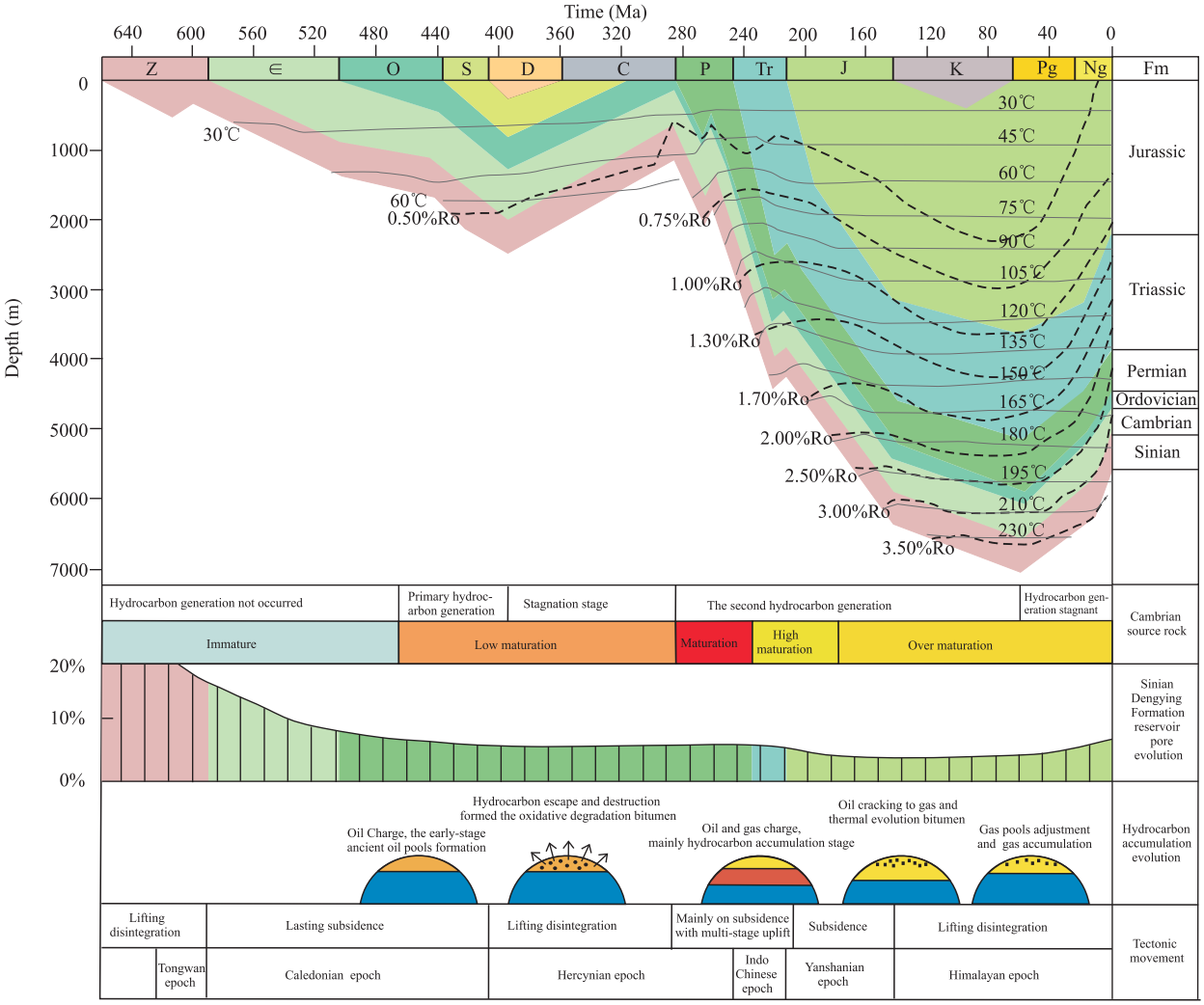

Fig. 1. Formation and evolution of the Sinian reservoir bitumen and oil & gas pools in the Gaoshiti-Anpingdian structure.

higher position, allowing an ancient oil pool to reform in the Sinian strata. As the Jurassic and Cretaceous strata deposited, this ancient oil pool was buried at a depth exceeding 7000 m, reaching a paleo-geotemperature of 200ºC. Under such a high temperature, essentially all of the crude oil accumulated in oil pools was cracked to natural gas and bitumen, which resulted in a mixing of a great amount of bitumen cracked gas. The Himalayan movement since the Late Cretaceous caused the Sichuan Basin to be uplifted and eroded considerably, but the study area was predominately vertically displaced. As a result, the shape and size of traps remained essentially unchanged, and consequently the paleo gas pools were well-preserved to form the present Sinian gas pools (Fig. 1).

Conclusion

The Sinian Dengying Formation has experienced two stages of brine water charging and two stages of oil charging, and the oil is mainly sourced from the second-stage oil charging of the overlying Qiongzhusi Formation of the Lower Cambrian. The chromatography of saturated hydrocarbon of the Sinian reservoir bitumen reveals a complicated processes of crude oil accumulation → oxidative degradation → new crude oil charging → crude oil cracking, and the present gas pools have mixed with large amounts of bitumen cracked gas. This research has preliminarily determined the process and critical period of the central Sichuan hydrocarbon accumulation.

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