

## Research Advances

## Evolution of the Carboniferous Reef in Eastern Qaidam Basin and its Hydrocarbon Significance

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### Objective

Reef reservoirs have recently been receiving more and more attention due to their important role in petroleum exploration. Large-scale reefs have been previously discovered in the Paleozoic strata of western China, such as the Late Permian of the Sichuan Basin, Late Ordovician of the Ordos Basin, and Late Ordovician of the Tarim Basin, which are all important hydrocarbon reservoirs in these areas. However, no reef has been found in the Qaidam basin, with only earlier records about coral fragments. It is therefore necessary to study and search for reefs during the hydrocarbon evaluation of Paleozoic marine carbonate rocks in the Qaidam Basin.

### Methods

Our field geological survey confirmed the existence of Paleozoic reef skeletons in the Qaidam Basin. Furthermore, through analyses of sedimentary petrology, reef species identification, inclusion temperature and burial history of the Early Carboniferous reefs in the eastern part of the Qaidam Basin, we made progress in characterizing reef morphological characteristics, revealing biological community characteristics, and indicating the oil and gas significance.

### Results

Coral reefs were found in the Huaitoutala Formation ( $C_1h$ ), which show asymmetric mounds shape (Fig. 1a), small scale, and vary from 1.2 m to 7.0 m in diameters with some up to 15.5 m. A series of reef bodies shows distinct zonality. The reef structure is clear, and multiple sets of reefs are stacked in the vertical. The reef core consists of cluster and massive coral colony and the lower attached reef organisms. Oriented sections show three groups of coral communities in the study area, i.e.,

*Siphondendron*, *Lonsdaleia* and *Lithostrotion* communities. *Siphondendron* community is prosperous particularly (Figs. 1b and 1c), above 60% in the components of the frame reef, with more than three varieties. *Lonsdaleia* and *Lithostrotion* communities are small-scale, with a great percentage of accessory reef organisms, and include *Yuanophyllum* solitary coral, crinoids, brachiopods and cephalopods. Thin layers of carbonaceous mudstone among reef bases and intervals (Fig. 1d), whose organic matter abundance is rich, With the TOC up to 1.27%, could be high quality source rocks. Moreover, several types of shoals are developed in the fore reef, and under or above the reef, including oolitic limestone shoal, shell shoal and coral clastic shoal.

According to the extremely narrow ecosystem adaptability of modern coral reef, reefs in the study area are characterized by four stages of evolution. The first stage is the forming stage, corresponding to the duration from the late Devonian extinction to the sedimentary period of Chengqianggou Formation of early Carboniferous, when large-scale reefs were absent and only small amounts of tetracoral and crinoids could be seen. Then comes the revival stage, corresponding to the early stage of Huaitoutala Formation, when the climate became warmer, and crinoids with strong adaptability began to recover and formed reefs significantly due to the absence of competition. The third stage is the thriving stage when coral reefs considerably expanded due to the suitable open platform environment, 20–30° C temperature, and 27‰–42‰ salinity brought by further warming climate. They shared prosperity with crinoids in the depth varying from 0 to 50 m, where sunshine was sufficient. The last stage is the recession stage with increasing terrigenous material supply or short-term storm during late Carboniferous, and at that time only the solitary coral with stronger adaptability to the environment survived.

Primary porosities in colonial corals and crinoid fragments are demonstrated to be well developed in

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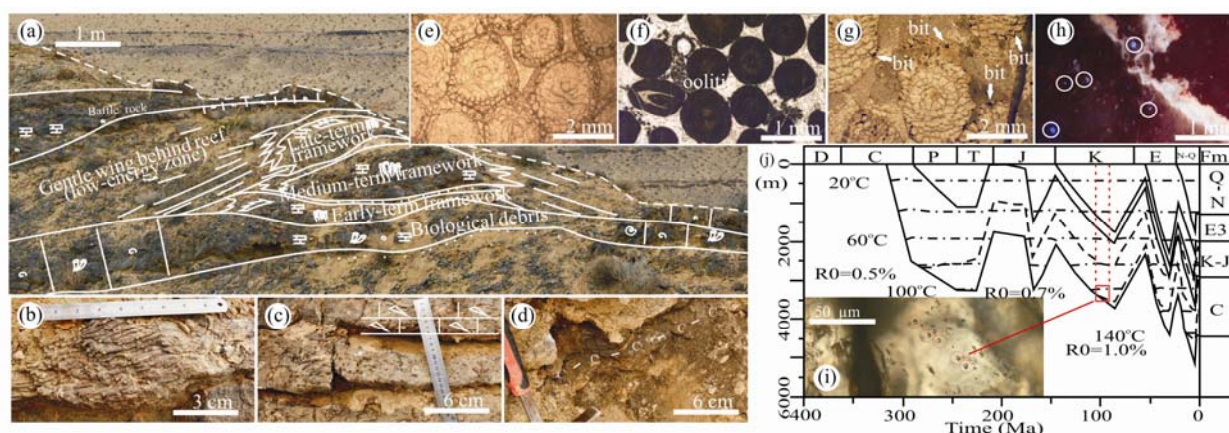


Fig. 1. Petrological characteristics and hydrocarbon of Carboniferous reefs in eastern Qaidam Basin.

casting thin sections. Specifically, the surface porosity in crinoid reefs could amount to 25%, with large-scale various shoal associated (Figs. 1e and 1f), showing good reservoir properties. When tapping at the fresh surface of rocks in coral reefs, shell shoals, and syringopora clastic shoals in Shihuigou and Gaihainanshan sections, there is obvious smell of oil. In casting thin sections, organic corrosion phenomenon could be observed in the edge of some corals (Fig. 1g), where fluorescent displays quite intense green color (Fig. 1h), indicative of hydrocarbon emplacement. Homogenization temperature of hydrocarbon inclusions in the bioclastic shoal limestone predominantly ranges from 105 to 115°C, with an average of 102.8°C. The temperature data are further combined with the burial history chart, demonstrating the formation time of organic acid dissolution in  $(110\text{--}120) \pm 5$  Ma (Figs. 1i and 1j), which is correlated to the hydrocarbon migration during the early Cretaceous. The normal salinity of the inclusions is 3.71 ~ 5.86 wt%, which is not high and thus indicates features of oil and gas during the mature stage.

## Conclusions

(1) It is confirmed that hermatypic organism in eastern Qaidam basin recovered during the Early Carboniferous after the late Devonian extinction.

(2) Most coral reefs in the area are small-scale patch reefs, which show multi-period and multiple type features. With them, a series of high quality reef-bank reservoirs are formed. In addition, there are a large number of asphalt veins and hydrocarbon inclusions inside the reefs, which are proved as the products of hydrocarbon migration during the early Cretaceous. It is suggested that there are good prospects for hydrocarbon exploration in the study area.

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