Characteristics of fluid inclusions in the Shiwandashan Basin, China, and its application to petroleum geology

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Geological background and fluid inclusion distribution. Shiwandashan basin is located in southern Guangxi province, south China, with an area of 11000 km^2. Its long axis oriented in N-E direction. A Paleozoic sedimentary stratum is developed in the basin, mainly carbonate, normal fractures and pelites. Submarine extrusive volcanic is mainly developed in the north part of the basin, and lots of Indosinaian acid intrusive rocks in the south part. The oil and gas flow and accumulation from Cambrian to Tertiary are found. The Lower Triassic, Permian and Devonian strata are the main source rocks and reservoirs (Li, 1989).

According to the formation time and occurrence of the fluid inclusions in the basin and the calculated thermodynamic parameters, the distribution of fluid inclusions during the deposition is as followings:

(1) Compaction: Besides preserving undissolved clay and organic compounds in the sutures, some small primary organic-bearing inclusions are frequently found in minerals, such as fine dolomite and autogenetic quartz.

(2) Cementation: calcites (fibrous-short prismatic, fine-grained and poikilitic) were formed in three episodes of cementation, and contain fine liquid hydrocarbon inclusions and different number of bitumen solid inclusions.

(3) Metasomatism: During dolomitizating, dolomites contain abundant solid fine-grained bitumen inclusions and liquid hydrocarbon inclusions, often with blasting in the inclusions.

(4) Corrosion: The filling crystals in the corrosive panes and cavities can be classified into two types: cavity-margin-filling crystal, and cavity-bosom-fill crystal. The former is characterized by primary inclusions containing saline daughter minerals aqueous solution, companied by primary gas and liquid hydrocarbon inclusions. The latter mainly includes primary gas hydrocarbon inclusions, accompanied with solid bitumen inclusions, and the quantity is high.

(5) Recrystallization: recrystallized oolite calcites are developed, which contain primary anomalous fine graininess bitumen, bituminous hydrocarbon and liquid hydrocarbon inclusions.

As the variation of the processes of sedimentation and diagenesis, the number of inclusions varies. In the east part of the region, more dolomitization and corrosion occurred, while in the west, the inclusions are densely distributed in the reel limestone and dissolve –and recrystallization is common.

The occurrence of the inclusions during periods of tectonism is quite complex. Based on the main occurrence direction, it can be divided into three episodes:

(1) At the early stage, the structural fissures parallel to the bedding plane. It contains wide calcite veins during early time of this stage and thin calcite veins during late time. The inclusions in the former is mainly liquid aqueous hydrocarbon solutions in the margin of the veins, sandwiching bitumen and gas hydrocarbon inclusions in the middle. The latter inclusions contain H_2O, liquid hydrocarbon and bitumen.

(2) At the middle stage, the Structural fissures are in the direction oblique to the bedding plane. They also can be divided into calcite veins during early time and calcite veins at late one.

The main component of the former calcite vein is gas/liquid hydrocarbon and gas bituminous hydrocarbon inclusions. The latter has the same component as the former, but with less amount.

(3) At the late stage, the structural fissures are in the direction vertical to the bedding plane. they also contains wide calcite veins during early time and thin calcite veins during the late. The former is characterized by more primary aqueous solution, liquid hydrocarbon and bituminous inclusions. The latter has the same component as the former but less amount. The Calculated methods are seen in Liu and Shen (1999).

Diagenesis and structural movements and their effects on the generation and migration of hydrocarbon. Based on the shape and genetic feature of the fluid inclusions and other geological data, the diagenesis, structural movement, hydrocarbon generation and migration are analyzed. Two stages of hydrocarbon expulsion process can be divided:

(1) Initial hydrocarbon generation, expulsion and migration stage: it occurred in the period of shallow-intermediate burial and compaction. The calcites, from different areas and formed through multi diagenesis and cementation, contain many liquid hydrocarbon inclusions and solid bitumen inclusions. Moreover, the phenomenon of blasting in larger inclusions is very obvious, indicating that the initial hydrocarbon expulsion during compaction is remarkable.

(2) Secondary hydrocarbon expulsion and migration stage: it occurred in the period when the burial depth was deep. It is characterized by high density of hydrocarbon inclusions, highly developed aqueous CO_2 solution inclusions and solid bitumen inclusions in the calcite cements, replacing dolomites and recrystallized calcites. It shows that secondary hydrocarbon expulsion and migration occurred when the rocks were berried under deep depth.

Secondary hydrocarbon migration in the area was closely related to the fracture caused by multiple regional tectonic movements. According to the properties of the veins and their intercalation in the hydrocarbon inclusions, secondary hydrocarbon migration can be divided into three stages:

(1) Early stage: it occurred with the fissures which is parallel to the bedding plane. Hydrocarbon inclusions were captured by extension fissure caused by tensile stress at early inversion stage of sedimentary basins.

(2) Middle stage: it occurred with the fissures which is oblique to the bedding plane. Hydrocarbon inclusions were captured by extension fissure caused by tensile stress at middle inversion stage of sedimentary basins.

(3) Late stage: it occurred with the fissures which is vertical to bedding plane. Hydrocarbon inclusions were captured by extension fissure caused by tensile stress at late inversion stage of sedimentary basins.

Analysis of source rocks and hydrocarbon migration. Based on the characteristics of hydrocarbon inclusions in different strata, the features of the source rocks are as followings:

(1) Three groups of source rocks were developed in this region. The lower Triassic source rocks were the major source rocks, with highest organic content and lower maturity in the hydrocarbon inclusions. The Permian source rocks were the secondly source rocks. The Devonian source rocks were gas source rock, with high content and high maturity gas hydrocarbon inclusions.

(2) Hydrocarbon inclusions in source rocks have high residual organic content, and are in the stage between mature and high mature.

(3) Generally two hydrocarbon expulsion times were found in hydrocarbon source rocks: Indo-Chinese epoch and Yanshan epoch. Hydrocarbon expulsion in Yanshan epoch was the most concentrated according to its high organic content in the hydrocarbon inclusions.

It can be showed that the initial hydrocarbon migration occurred at the stage of burial and diagenesis. The secondary hydrocarbon migration mainly happened in the structural fissures, and pressure-solution fissures sutures and dissolution cavities. The secondary hydrocarbon migration was complicated, which combined with hydrocarbon liquid gas/solid bitumen or salt-containing aqueous solution. There are three characteristics: (1) Hydrocarbon migration mainly contains water and immiscible hydrocarbon. (2) The proportion of hydrocarbon liquid gas and solid bitumen varied at different stages of the migration, or even at the same time(Mclimans

,1987).(3) Hydrocarbon migration is mainly immiscibility phase migration instead of a separate phase. Therefore the driving force for secondary migration comes from tectonic movements.

Hydrocarbon evolution, reservoir formation, and the influence of magma activities. Hydrocarbon evolution in this area varied in different strata or at different stages. The main hydrocarbon expulsions happened at Yanshan epoch. At the end of the Cretaceous period, the source rocks had reached a peak of its maturity. Hydrocarbon expulsions reached the peak at the middle or upper portions of the source rocks of lower Triassic. In the lower part of the source rocks of lower Triassic, it had been highly matured and passed the peak of oil generation. Source rocks of Permian period are highly matured, and source rocks of Devonian period are highly matured or over-matured. Therefore, hydrocarbon in Triassic and Permian source rocks have the feature of high or high-over maturated oil and condensate oil, and hydrocarbon in Devonian source rocks have the feature of high or high-over condensate oil, humidity gas, and dry gas.

Volcaniclastic rocks were distributed in the north of the basin, which cements and contains much bitumen. A lot of hydrocarbon inclusions exist in the micro-fissures during clastic rocks. It shows that volcanic activities happened before hydrocarbon filling, and volcaniclastic rocks could be the reservoirs.

Most of intrusive rocks in this area are acidic granites, which intruded along Ling-shan fault between hercynian and indo-chinese epochs. Hydrocarbon expulsions of Triassic and Permian source rocks mainly occurred at Yan-shan epoch, later than the intrusive time of granite. Hydrocarbon secondary inclusion existed in the later developed micro- fissures of granite quartz grains. It further proves that hydrocarbon expulsions occurred after intrusion of granite. Therefore, magma movements had little effect on reservoir formation.

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