Formation mechanism of carbonate cemented zones adjacent to the top overpressured surface in the central Junggar Basin, NW China

YANG Zhi1,2, ZOU CaiNeng1,3, HE Sheng2*, LI QiYan1, HE ZhiLiang3, WU HengZhi5, CAO Feng1, MENG XianLong4, WANG FuRong2 & XIAO Qilin2

1 State Key Laboratory of EOR, Research Institute of Petroleum Exploration & Development, PetroChina, Beijing 100083, China; 2 Key Laboratory of Tectonics and Petroleum Resources of Ministry of Education, China University of Geosciences, Wuhu 430074, China; 3 State Key Laboratory of EOR, Research Institute of Petroleum Exploration & Development, Petrochina, Beijing 100083, China; 4 Research Institute of Petroleum Exploration and Production, SINOPEC, Beijing 100083, China; 5 Southwest Branch Company, SINOPEC, Chengdu 610051, China

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Carbonate cemented zones are normally adjacent to the top overpressured surface in the central Junggar Basin, NW China. Stable carbon and oxygen isotopic compositions and petrological investigations of carbonate cements in the carbonate cemented zones indicate that: (1) carbonate cements are composed dominantly of ferrocalcite, ferroan dolomite, and ankerite; (2) carbonate cements are formed under a high temperature circumstance in the subsurface, and organic fluid migration has an important effect on the formation of them; and (3) carbon and oxygen ions in the carbonate cements migrate from the underlying overpressure system. This suggests that the occurrence of carbonate cemented zones in this region results from multiple phases of organic fluid expulsion out of the overpressure compartment through geological time. This study provides a plausible mechanism of the formation of carbonate cemented zones adjacent to the top overpressured surface in the clastic sedimentary basins, and has an important implication for understanding the internal correlation between the formation of carbonate cemented zones adjacent to top overpressured surface and geofluids expulsion out of overpressured system.

carbonate cemented zones, formation mechanism, stable carbon and oxygen isotopic, top overpressured surface, central Junggar Basin, coal-bearing strata

As one of the most familiar diagenetic authigenous minerals in clastic reservoirs, carbonate cements, have variable mineralogy, texture and chemical compositions, and can be formed under various geochemical conditions [1, 2]. Previous work on carbonate cements focuses mainly on their influences on reservoir quality, tracing the sources and migration-pathways of geofluids and the sealing effects of geofluids [2–7]. Most studies hold that carbonate cementation is a destructive diagenetic process, because reservoir quality becomes much worse than before due to the cements’ filling into the pores and thus decreasing the porosity and permeability of the reservoir, and improving heterogeneity of the reservoir by dividing thick sandstone bodies into thinner units [4, 8–14]. Carbonate cements formed in different phases record variations in fluid compositions during the course of diagenesis, which helps decipher the processes of fluid-rock interaction and fluid composition evolution at geological time scale [2, 5, 15–24]. Particularly,
carbonate cements formed in the late stage of diagenesis can be utilized as indicators to trace the processes of petroleum generation, migration and accumulation [25–29]. Carbonate cements, as a type of efficient seal [2, 17, 30, 31], are usually associated with abnormally pressured fluid compartments, especially abnormal high pressure fluid compartments. Overpressured fluid compartments that are composed of overpressured strata and seals are considered to be a completely sealed three-dimensional compartments [32–36]. Three types of seals involving basal, lateral and top seals usually occur in a sedimentary basin [30]. Basal seal, located at the bottom of a compartment, tends to distribute along a specific stratigraphic unit. Lateral seal, paralleled with vertical or high-angle faults, develops in fractured and faulted zones filled by calcite or silica. Top seal, a planar or near planar surface, goes along a specific stratum or through a structural unit. Top seals in most clastic sedimentary basins consist of several carbonate mineralized zones which are formed by carbonate cementation adjacent to top overpressured surface during the process of episodic expulsion of geofluids from overpressured system [30, 33]. Previous work has indicated that [9, 30, 36–42] occurrence of carbonate cemented zones vary with the types and evolutionary stages of overpressured basins.

Overpressured fluid flow involves the processes of geofluids being expelled out of overpressured system and then charged into the overburden strata. This makes the quantity of transported matters such as dissolved materials, acids, water and hydrocarbons, and dissolved unstable inorganic minerals increasing continually. Accordingly, a large amount of geological and geochemical information can be found in the sandstone reservoirs near the top of overpressured system [33, 41, 43]. Previous researchers normally recover the process of overpressured fluid flow in accordance with petroleum geochemistry and formation water chemistry information [41], but neglect the information recorded by carbonate cements in sandstone reservoirs. A related study has been carried out by Hunt [33, 34], however, in which he merely provides us a model of carbonate mineralization seals. In this paper, we investigate the vertical distribution range, compositions and sources of carbonate cements adjacent to top overpressured surface in the central Junggar Basin, NW China. We then provide a plausible mechanism for the formation of carbonate cemented zones in this region, aiming at supplying a novel method to study the correlation between carbonate cemented zones formation at the top of overpressured fluid compartments and overpressured fluid expulsion from abnormal high overpressured system in clastic sedimentary basins.

1 Geological setting

The Junggar Basin, located in the northern part of Xinjiang, is one of giant petroliferous basins in China. It is bounded by folded mountains shown as a triangle-shaped in plane with an area of about $13.6 \times 10^3$ km$^2$. The sedimentary rock sequence consists mainly of Carboniferous-Neogene rocks that overlie a pre-Carboniferous basement of mostly Devonian sedimentary and metamorphic rocks, with the thickness of it is up to 14000 m along the North Tianshan foreland region. Four phases of tectonism have been recognized from the Carboniferous to present, namely the Hercynian, Indo-China, Yanshanian, and Himalayan orogenies. As shown in Figure 1, the study area, the central Junggar Basin, is composed of the West Pen1 Well Sag and the west Changji Sag in the Central Depression. It belongs to SINOPEC Blocks 1 and 3 in mining right. Faults that cut through the Permian source rocks do not develop in this region. Due to uplifting during the Middle to Late Jurassic, the Che-Mo palaeo-uplift occurred in the Central Depression [44, 45]. It has a controlling effect on the formation of the Jurassic and Cretaceous stratigraphic-lithologic reservoirs, and the current discovered hydrocarbons originating from the Permian and Jurassic source rocks are produced mainly from the Jurassic and Cretaceous stratigraphic-lithologic reservoirs in the study area [46, 47].

In the central Junggar Basin, abnormal high overpressured system is situated mainly in the Jurassic, Triassic, and Permian, and the highest pressure coefficient is up to 2.07 [48]. Depths of the top of overpressured surface differ in individual tectonic units. It is 4400–4700 m in the West Pen1 Well Sag, 4700–5700 m in the north of West Changji Sag, and 5700–6100 m in the south of West Changji Sag, respectively. However, it is normally located at the top of the Jurassic System. Top overpressured seals consist mainly of shales, siltshales, siltstones, and the carbonate cemented strata. The overpressured zones are distributed along the Jurassic matured source rocks with burial depth of 4500–6500 m, containing interbeded shales and sandstones, and have been compacted completely. Drilling into the overpressured zones encounters a large amount of gas. Previous works [2, 3] have indicated that the timing of significant petroleum generation from the Jurassic source rocks is in Late Cretaceous, whereas the timing of the occurrence of overpressure is consistent with it. Accordingly, we deduced that mechanism of forming overpressure in this region is the integrated effects of petroleum generation from Jurassic source rocks and sealing of the effective seals.

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