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Dissolution and its impacts on reservoir formation in moderately to deeply buried strata of mixed siliciclastic–carbonate sediments, northwestern Qaidam Basin, northwest China

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ABSTRACT

Petroleum exploration is increasingly extending from shallowly to moderately to deeply buried strata, with reservoir quality being a key. The formation mechanism of conventional clastic and carbonate reservoirs under such conditions has been widely investigated. However, the mechanism of mixed siliciclastic–carbonate reservoirs has not been well studied. In this paper, we address this issue using a case study in the northwestern Qaidam Basin, northwest China (N_1–E_{1+2} age, 2500–4500 m). Dissolution pores and fractures dominate the reservoirs. However, only the fractures were the focus of previous studies. Thus, here we investigate dissolution and its impacts on reservoir formation, providing a complementary understanding of the reservoir formation in the basin. Using core observations and examining thin section, it was discovered that dissolution was both random and followed bedding. The dissolved components primarily included calcareous and gypsum minerals, with fingerprints that are characteristic of burial dissolution. Further electron probe analysis on authigenic minerals revealed that the dissolution fluid might have originated from acidic formation fluids associated with hydrocarbon generation. The fluids passed through faults and fractures. Dissolution pores were an important component of the reservoir, providing approximately 60% of the porosity. In addition, segments of high porosity generally above 5% are associated with dissolution. Based on these observations, a schematic model was established to explain the impacts of dissolution on reservoir formation. Specifically, organic acidic formation fluids enter tectonic fractures, resulting in dissolution as they pass through them. This dissolution enhances the size of the pore space and the reservoir properties of the rocks, eventually developing a fracture-dissolution reservoir.

1. Introduction

As the exploration of oil and gas becomes more and more difficult worldwide, extending the exploration from the shallowly to moderately to deeply buried strata generally below 2500 m has become a prominent trend (Wilkinson et al., 1997; Bloch et al., 2002; MΦrk and Moen, 2007; Zhong and Zhu, 2008; G.Y. Zhu et al., 2009; Wilkinson and Haszeldine, 2011). Due to this relatively greater depth, there is an increase in sensitivity to reservoir development and preservation (Katz, 2001; Dutton and Loucks, 2010; Ma et al., 2010b, 2011). Previous studies have shown that dissolution pores constitute an important type of reservoir (Beavington-Penney et al., 2008; Jin et al., 2009). Thus, it is not surprising that the relationship between dissolution and reservoir formation has attracted substantial and persistent interest in the field of petroleum and reservoir geology (Moore and Druckman, 1981; Mazzullo and Harris, 1992; Qian et al., 2006; Higgs et al., 2007; Zwingmann et al., 2008; D.Y. Zhu et al., 2009; Poursoltania and Giblingb, 2011).

The Qaidam Basin (Fig. 1) is an important area for petroleum exploration and production in northwest China, with a commercial production of oil and gas at approximately 7×10^6 ton by 2012. The moderately to deeply buried strata has attracted increasing exploration and research attention recently along with the deepening of the exploration. The N_1–E_{1+2} strata between 2500 and 4500 m in the northwestern basin (Fig. 2) is one of the key targets, which

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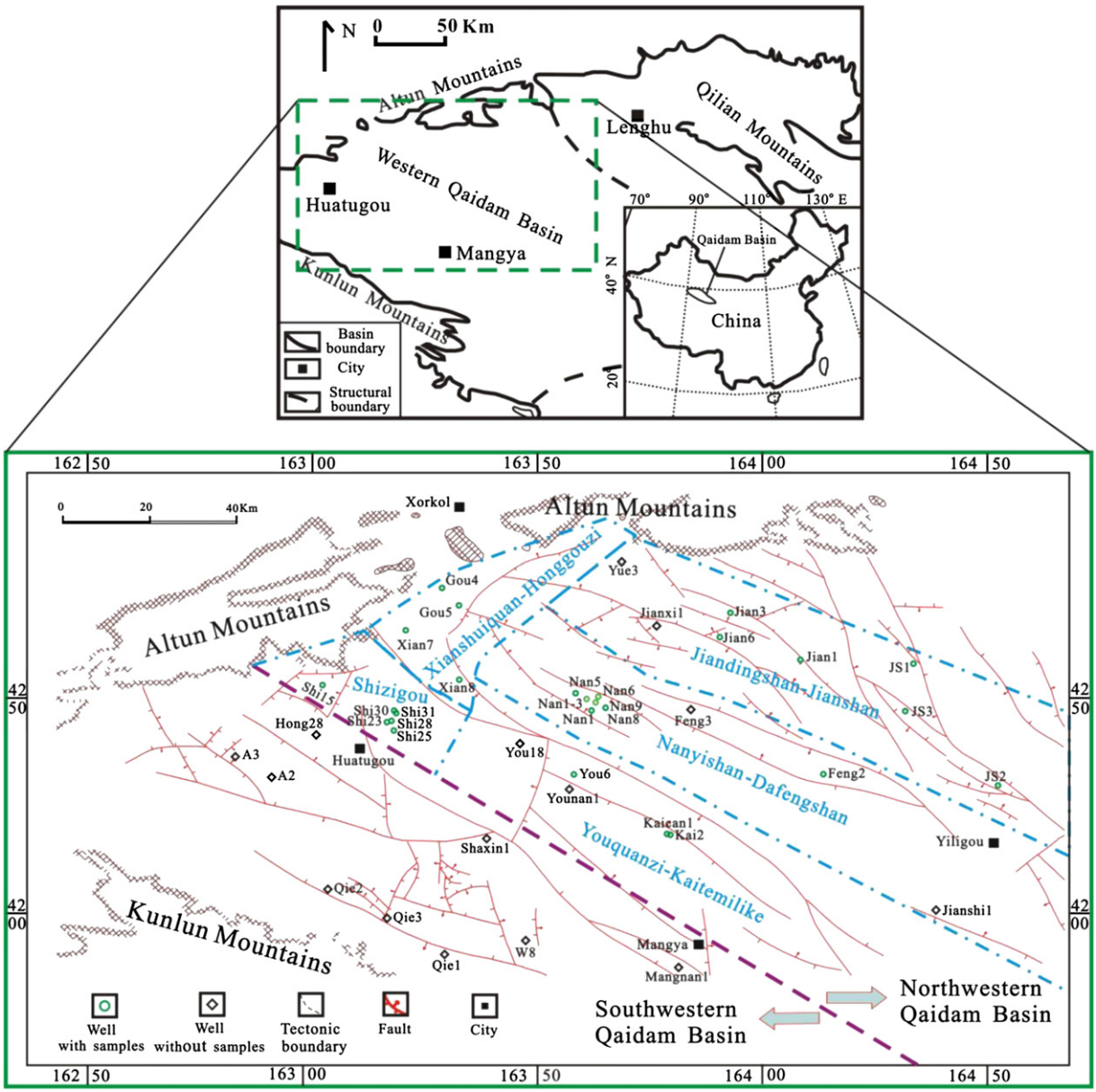

Figure 1. Schematic map showing tectonic division and units in the northwestern Qaidam Basin. Sampled wells are marked (the background map was based on Xu et al., 2011).

currently contains an oil and gas field (i.e., the Nanyishan field; Fig. 1). Thus, promising exploration prospects appear present. The strata here are somewhat special because of their mixed siliciclastic–carbonate natures. The formation of such a type of reservoir has not been well investigated previously worldwide in comparison with conventional clastic and carbonate reservoirs. Thus, a study of the formation mechanism of such reservoirs in the northwestern Qaidam Basin is of significance theoretically and locally to regional exploration. However, the issue has received relatively little attention likely due to the small volume of hydrocarbons discovered and production to date compared with the shallowly buried strata. Of the few available studies, it is generally agreed that dissolution pores and fractures dominate the reservoirs (e.g., Li, 2000; Li and Wang, 2001; Feng et al., 2011). However, only the fractures have proven to be a research focus; the reservoirs are associated with fractures, including fault-related fractures, fold-related fractures and dissolution-generated fracture caves that were formed via a fracture-cave and pore-space percolation system (e.g., Li, 2000; Li and Wang, 2001). In contrast, another significant mechanism of reservoir formation, dissolution, was comparatively overlooked (Feng et al., 2011). However, the contribution of dissolution to porosity reached approximately 60% (e.g., Li, 2000; Li and Wang, 2001; Feng et al., 2011). Thus, here, to expand on the previous studies and present a systematic and comprehensive picture of the reservoir formation, we focused on dissolution.

2. Geological setting

The Qaidam Basin is located in the north of the Qinghai–Tibet Plateau (Fig. 1). The Qilian Mountains are to the northeast, the Altun Mountains are to the northwest and the Kunlun Mountains are to the south, resulting in an irregular diamond-shaped basin with an east–west length of 850 km, a north–south width of 150–300 km and a total area of 1.2×10^4 km^2 (Pang et al., 2004). The northwestern basin is located in the western portion of the central depression and covers a region that extends from Kaitemilike in the