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Trace Elements Characteristics of Reservoirs in the Sinian Dengying Formation in Southeastern Sichuan Basin, China

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During the formation processes of quality reservoir, much geochemical evidence is preserved. The Sinian Dengying Formation is one of major reservoir horizons, where reservoir rocks can be divided into three categories according to genesis, i.e., paleo-karst reservoirs related to tectonic uplift, buried dissolution reservoirs due to burial and dissolution and hydrothermal dolomite reservoirs.

The host rock of the Dengying Formation contains Na, Mn, Fe, Sr on the average of 48.40 ppm, 76.40 ppm, 816.00 ppm and 211.50 ppm, respectively; paleo-karst reservoirs contains Na, Mn, Fe, Sr on the average of 17.62 ppm, 122.98 ppm, 1579.86 ppm and 144.93 ppm, respectively; buried dissolution reservoirs contains Na, Mn, Fe, Sr on the average of 23.80 ppm, 282.60 ppm, 191.00 ppm and 151.00 ppm, respectively; hydrothermal dolomite reservoirs contains Na, Mn, Fe, Sr on the average of 48.40 ppm, 76.40 ppm, 816.00 ppm and 211.50 ppm, respectively; Paleo-karst reservoirs have characteristics of lower Na, higher Mn, higher Fe and lower Sr compared with the host rock. The content of Na element in carbonate is always controlled by the salinity in its formation environment (Li, 2000). However, the formation of paleo-karst reservoirs related to tectonic uplift is definitely influenced by surface freshwater, so that the reservoirs are formed in the environment with freshwater involved, characterized by very low content of Na element. For Mn and Fe element, sea water is an environment with lower Mn and lower Fe than fresh water. The contents of Mn and Fe elements in fresh water will 50 times and 197 times more than sea water (Liu et al., 2010). Therefore, paleo-karst reservoirs have rather higher contents of Mn and Fe elements than the host rocks (sea water environment). However, lower content of Sr element is also related to fresh water genesis. In short, the characteristics of trace elements in paleo-karst reservoirs generally reflect their freshwater genesis.

The trace elements in buried dissolution reservoirs have

significant characteristics of higher Mn and lower Fe. It is considered in classical theory (Brand and Veizer, 1980) that the diagenesis of carbonate is an acquisition process of Mn and Fe, i.e., the greater the burial depth is and the stronger the diagenesis is, the greater the contents of Mn and Fe element in carbonate participating in diagenesis will be. However, as viewed from test results, the content of Mn element in buried dissolution reservoirs is indeed higher than the host rocks, but the content of Fe element is rather lower than the host rocks, which seems incompatible with classical theory. Due to microcrystalline dolomite with gypsum widely developed at the bottom of the Dengying Formation in the study area, organic acids are bound to dissolve the gypsum with the maturity of organic matters. In addition, the "intrusion" of hydrocarbons in overlying Cambrian strata may cause thermal reduction of sulfate (TSR) (Liu Shugen, 2007). Both processes will produce large amounts of H₂S gas, while H₂S is easy to be reacted with Fe, Ca, Ni, Co and other heavy metal elements in reservoirs to form metal sulfides (Rickard et al., 1997). Therefore, a large number of Fe element in the Dengying Formation is consumed with occurrence form of pyrite in the reservoirs. As a result, buried dissolution reservoirs are always exposed to diagenetic fluid environment with lower Fe during the formation, and thus causing the characteristics of low Fe and high Mn.

Hydrothermal dolomite in the Dengying Formation of study area has rather lower contents of Fe and Sr than the host rocks. For hydrothermal dolomite reservoirs, the contents of trace elements in hydrothermal itself have a significant influence on hydrothermal dolomite. As viewed from global prospective, great differences exist in the contents of Fe and Mn elements in various regions of hydrothermal dolomite. For example, hydrothermal dolomite in Upper Ordovician Black River Formation, New York, U.S. has very high contents of Fe and Mn, of which Fe content is ranged from 1,600 ppm to 13,804 ppm with an average of 4,250 ppm, and the average content of

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Mn element also reaches 880 ppm (Langhorne, 2006). However, hydrothermal dolomites in three different Upper Carboniferous stages in southwestern Cantabrian, Spain have average contents of Fe element at 2,069 ppm, 2,933 ppm and 2,400 ppm respectively, and average contents of Mn element at 354 ppm, 418 ppm and 400 ppm respectively (Marta et al, 2006). The contents of Fe and Mn element are significantly lower than hydrothermal dolomite in Upper Ordovician Black River Formation, New York, U.S. by about a half, but rather higher than hydrothermal dolomite in the Dengying Formation of study area (average contents of Fe and Mn are 66 ppm and 168.5 ppm respectively). The contents of Fe and Mn element is 345 ppm and 60 ppm in Mesozoic Zugna Formation at Monte Grappa in the southwestern Alps, Italy (Paola et al., 2011), of which the content of Fe element is significantly higher, but the content of Mn element is lower than that in the Dengying Formation of study area. However, the contents of Sr in all hydrothermal dolomites are seemed very low, mostly in several dozens of ppm. For example, the contents of Sr in previously-mentioned hydrothermal dolomite in three Upper Carboniferous stages of southwestern Cantabrian, Spain are 20 ppm, 26 ppm and 24 ppm respectively (Marta et al., 2006), that of hydrothermal dolomite in the Zugna Formation in the southwestern Alps is 29 ppm (Paola et al., 2011), and that of hydrothermal dolomite in the Dengying Formation of study area is only 63 ppm. The likely interpretation for this phenomenon is that due to larger radius, Sr ion is difficult to replace Ca and Mg ions in carbonate, and thus diagenesis (hydrothermal dolomitization) is always a process of Sr losing (Huang et al., 2007), resulting in a substantial reduction of Sr content in hydrothermal dolomite with little relations to Sr content of hydrothermal itself.

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