Influence of organic matter on smectite illitization: A comparison between red and dark mudstones from the Dongying Depression, China

YINGLI LI1, JINGONG CAI1,*, MINGSHUI SONG2, JUNFENG JI3, AND YUJIN BAO2

1State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China
2Geological Scientific Research Institute, Shengli Oil Field Company, Sinopec, Dongying 257015, China
3Department of Earth Sciences, Nanjing University, Nanjing 210093, China

ABSTRACT

Interactions between organic matter (OM) and clay minerals have received considerable attention in previous studies. The influence of OM on smectite illitization has been analyzed primarily in simulation experiments rather than in diagenetic studies. The present study explores the influence of OM on smectite illitization during diagenesis. Thirty red and dark mudstone samples from the Dongying Depression were analyzed. X-ray diffraction (XRD) analyses revealed that the illite percentages in mixed-layer illite-smectite (I-S) of both types of samples were dispersive above 3100 m and more convergent below this depth. The stacking mode of I-S in dark mudstones above 3100 m remained primarily at R0–R0.5 ordering with the average number of layers (Nave) dispersively distributed between 2 and 4.5. In red mudstones, the I-S changed from the R0 to R0.5 mode with the Nave increasing from 2 to 5. Over this range, the smectite illitization in dark mudstones was slower than that in red mudstones. Below 3100 m, the I-S stacking mode of dark mudstones changed from R0.5 to R3 ordering with the Nave increasing sharply from 4 to 8. In red mudstones, the I-S displayed R1.5 and R3 ordering with the Nave varying between 4.5 and 6.5. Over this range, the smectite illitization in dark mudstones accelerated rapidly, whereas the process in red mudstones was retarded. Additionally, the red mudstone samples contained little OM, whereas the dark mudstone samples contained abundant total organic carbon (0.17–4.43%). Thermo-XRD, near-infrared (NIR) as well as mid-infrared (MIR) spectroscopy analyses suggested that the OM in dark mudstones exhibited a significant transition at 3100 m, coincident with the illitization change. Above 3100 m, the smectite illitization in dark mudstones was delayed due to the OM pillar effect in the interlayer spaces of smectite. Below 3100 m, the interlayer OM became varied and desorbed, discharging organic acid. This led to the dissolution of smectite structural layers. Consequently, illitization in the dark mudstone was accelerated. This study revealed that the existence and occurrence of OM could influence the smectite illitization in diagenesis. Further study on the interactions between OM and clay minerals is needed to facilitate our understanding on the mechanism of smectite illitization as well as its geological applications.

Keywords: Smectite illitization, dark mudstone, red mudstone, organic matter, Dongying Depression, reaction mechanisms

INTRODUCTION

Mudstones, particularly argillaceous source rocks, contain various levels of inorganic matter, pore water, and organic matter (OM, Tissot and Welte 1984; Tyson 1993; Li and David 2005; Pacton et al. 2011). As the two most important components in mudstones, the interactions between OM and clays have been frequently discussed (Barker 1980; Ganor et al. 2009; Ugochukwu et al. 2013). Several studies suggested that mudstone smectite illitization can affect the occurrence and evolution of OM (Burst 1969; Bruce 1984). However, the counter effects of OM on smectite illitization require further investigation.

The conversion of smectite to illite is a common geologic phenomenon (Pollard 1971; Ahn and Peacor 1986; Altaner and Ylagan 1997; Baronnet 1997; Putnis 2002; Cuadros 2012). Various mechanisms of smectite illitization were proposed, including the broadly accepted concepts of solid-state transformation (Hower et al. 1976; Bethke and Altaner 1986; Drits et al. 1997; Cuadros and Altaner 1998; Olives et al. 2000) and dissolution-recrystallization (Boles and Franks 1979; Nadeau et al. 1985; Eberl and Srodon 1988; Whitney and Velde 1993; Mosser-Ruck et al. 1999, 2001; Lanson et al. 2009; Bobos and Eberl 2013). The solid-state transformation model emphasizes gradual changes in the chemical components of phyllosilicates. In contrast, the dissolution-recrystallization model emphasizes the mutation and dissolution of the smectite structural layer. These processes are assumed to occur in the water-rock environment. In all models, researchers emphasized the importance of such parameters as the temperature (Perry and Hower 1972; Cuadros and Linares 1996), time (Eberl and Hower 1976; Pytte 2003-004X/16/0001-134$05.00/DOI: http://dx.doi.org/10.2138/am-2016-5263 134