AAPG
6th Edition
AAPG Siliciclastic Reservoirs of the Middle East GTW
1-3 December 2025 | Kuwait City, Kuwait

Experimental Formation of Authigenic Chlorite: Assessing the Role of Kaolinite as a Precursor

Abdulwahab Muhammad Bello[1], Anas Muhammad Salisu[2], Abduljamiu Olalekan Amao[1], and Khalid Al-Ramadan[2,1]*

[1]Center for Integrative Petroleum Research, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia
[2]Geosciences Department, College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Abstract

Chlorite is a key clay mineral in sandstone reservoirs across numerous hydrocarbon-bearing basins, forming from a variety of mineral precursors. Among the commonly proposed precursors such as berthierine, smectite, and odinite, the transformation of kaolinite into chlorite remains the least well understood. In this study, we conducted a series of hydrothermal experiments at temperatures of 50, 100, 150, 200, and 250 °C, each lasting 336 hours. The experiments were carried out in a solution containing 0.1 M NaCl, KCl, $CaCl_2 \cdot 2H_2O$, and $MgCl_2 \cdot 6H_2O$, with an additional run using Red Sea water to evaluate clay transformation under natural brine conditions.

The starting material was a quartz-rich sandstone from the Upper Ordovician Qasim Formation (Quwarah Sandstone Member, NW Saudi Arabia), characterized by authigenic kaolinite and hematite cement. No new clay phases were observed at the lower temperatures (50 and 100 °C). At 150 °C, kaolinite partially transformed into dioctahedral smectite (montmorillonite), alongside minor quartz cement precipitation. At 200 and 250 °C, authigenic smectite, chlorite, and illite formed in both the synthetic and natural fluids.

Chlorite developed through two primary pathways: (1) direct dissolution of kaolinite followed by chlorite crystallization, and (2) stepwise transformation via an intermediate smectite phase, which subsequently converted to chlorite through coupled dissolution-reprecipitation and solid-state mechanisms. Prior to this conversion, smectites incorporated Fe and Mg into their structure, resulting in the formation of both trioctahedral and tri-dioctahedral smectites with distinct compositional gaps.

The transformation of kaolinite to chlorite led to enhanced intercrystalline porosity due to the finer crystal size of chlorite. Illite also formed from kaolinite and smectite, facilitated by K^+ ions in the solution. Notably, experiments using Red Sea water produced Fe-rich smectite and chlorite relative to those formed in the synthetic solution, likely due to the lower Mg content of the seawater.

Silica released during kaolinite dissolution and smectite-to-chlorite conversion precipitated as quartz overgrowths, particularly where clay coatings were absent. These findings enhance our understanding of the

kaolinite-to-chlorite transformation process and offer valuable data for modelling chlorite and quartz cementation in deeply buried sandstone reservoirs.