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Mixing processes of the oil-water-CO_2 systems and the fluid-mineral interactions in different fluid phases: Insights to CO_2 sequestration in depleted hydrocarbon reservoirs

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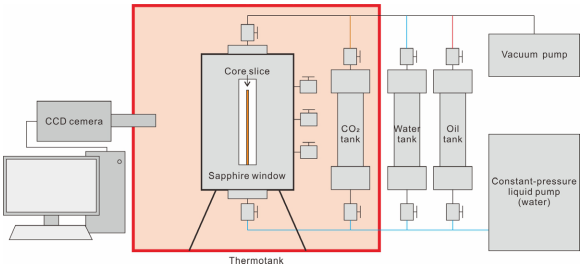

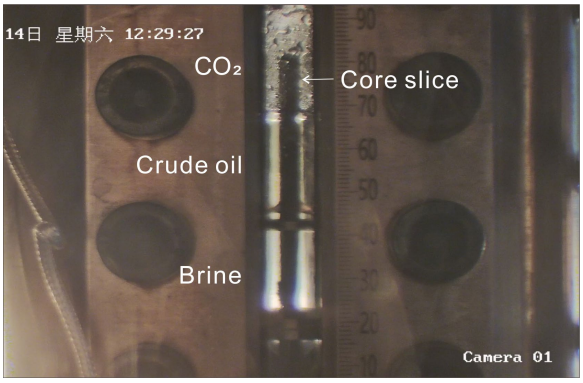

In depleted hydrocarbon reservoirs, the oil-water-CO_2 system exhibits complex phase behaviors and mineral interactions in different reservoir conditions, which is crucial for CO_2 sequestration stability and mineral trapping. After CO_2 injection, vertical stratifications of fluid phases may form, including wet-supercritical CO_2, miscible or near-miscible CO_2 with residual hydrocarbons, and CO_2 saturated or unsaturated brines. However, there is still a lack of accurate characterization of the fluid-rock interaction process and its mechanism in different fluid phase zones.

In this study, cylindrical core samples (25 mm diameter) were cut into slices (80 mm height, 20 mm width, 5 mm thickness) using a wire cutting machine. One surface of each slice was polished with abrasive sandpaper, followed by an X-reflorescence (XRF) scan to determine the elemental composition of the polished surface. A core slice was placed vertically in a high-temperature, high-pressure visual reactor with a sapphire window (Fig. 1 and 2). Simulated brine and crude oil were sequentially injected into the reactor, which was subsequently sealed and CO_2 was introduced into the reactor after vacuuming. The temperature and pressure were gradually increased to 120°C and 25 MPa, respectively. Contact areas between the core surface and gas-oil-water interfaces were recorded during the reaction. After 10 days, post-reaction samples (gas, brine, hydrocarbons) were collected and analyzed through gas chromatography, inductively coupled plasma mass spectrometry, and hydrocarbon chromatography. The core slice was retrieved, cleaned, and re-analyzed by XRF for changes in surface elemental composition. Mineral surface variations and authigenic minerals in different contact zones were identified using scanning electron microscope and energy dispersion spectrum. CMG-GEM and TOUGHREACT simulations were used to investigate mass transfer and fluid-mineral interactions between different fluid phases and various mineral assemblages.

The study clarified how factors (e.g. crude oil saturation and types, pore water chemistry and partial pressure of CO_2) may control the phase behaviors of the oil-water-CO_2 mixed fluids and their contact relation with minerals in different geochemical systems. We also provided potential reaction pathways and reaction kinetics in depleted hydrocarbon reservoirs after CO_2 injection. The study will improve our understanding of the CO_2 sequestration process in depleted hydrocarbon reservoirs.