Visualization and measurement of CO_2 flooding in heterogeneous sedimentary rock

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To investigate CO_2 flow mechanisms and fluid recovery processes in heterogeneous rock, we designed a laboratory experimental system which visualizes CO_2 movements during flooding experiments by using X-ray CT. We carried out laboratory experiments of CO_2 flooding in heterogeneous sandstone, together with porosity calculation, fluid saturation monitoring based on CT images, and mass flow measurements for ejected fluids. Based on the experimental results, we try to understand the flooding characteristics of CO_2 in heterogeneous rocks having complex sedimentary structures, which will contribute to CO_2 geological sequestration and oil recovery. Sarukawa sandstone (diameter: 34.80mm, length: 79.85mm, north central Japan) was used in this study. Porosity of the specimen determined by X-ray CT imaging was 31.2%. As shown in figure1a, the specimen has a heterogeneous structure. Especially, upper part of the specimen is more complex than the lower part. The experiment was conducted under the pressure and temperature conditions that simulate underground environments; pore pressure: 10MPa, temperature: 40 degrees Celsius. The confining pressure selected in this study was 12MPa. Fluid pressure and its injection rate were controlled by high-precision syringe pumps. A high-pressure vessel having high transparency for X-ray was utilized in this study. The specimen was first saturated with KI aqueous solution (12.5%), and then oil was injected to change the specimens into oil-water mixed state. Totally, ten steps of CO_2 flooding were performed for this experiment. For each step, KI aqueous solution and oil were carefully recovered from the syringe pump which plays a role of back pressure. The CO_2 flooding test was carried out until the CO_2 injection reaches 3.03PV (pore volume). Figure 1b shows the differential CT images when the CO_2 injection reaches 0.26PV. In the figure, almost all of the CO_2 preferentially moves through the upper part of specimen. This represents that the sedimentation heterogeneity is the main factor that affects the CO_2 flooding pattern. The oil recovery was identified as 48.9% when injected CO_2 reached 1.0PV in the specimen. We increased the differential pressure to examine the influence of differential pressure on oil recovery in heterogeneous media. The oil recovery was 69.7% when injected CO_2 reached 2.0PV. The increment of oil recovery from 1.0PV-step to 2.0PV-step, 20.8% corresponds to more CO_2 flooding into the non-recovering zone (low porosity and/or low permeability) due to increasing of capillary pressure.

Keywords: CO2 flooding, heterogeneity, X-ray CT, visualization, CO2-EOR

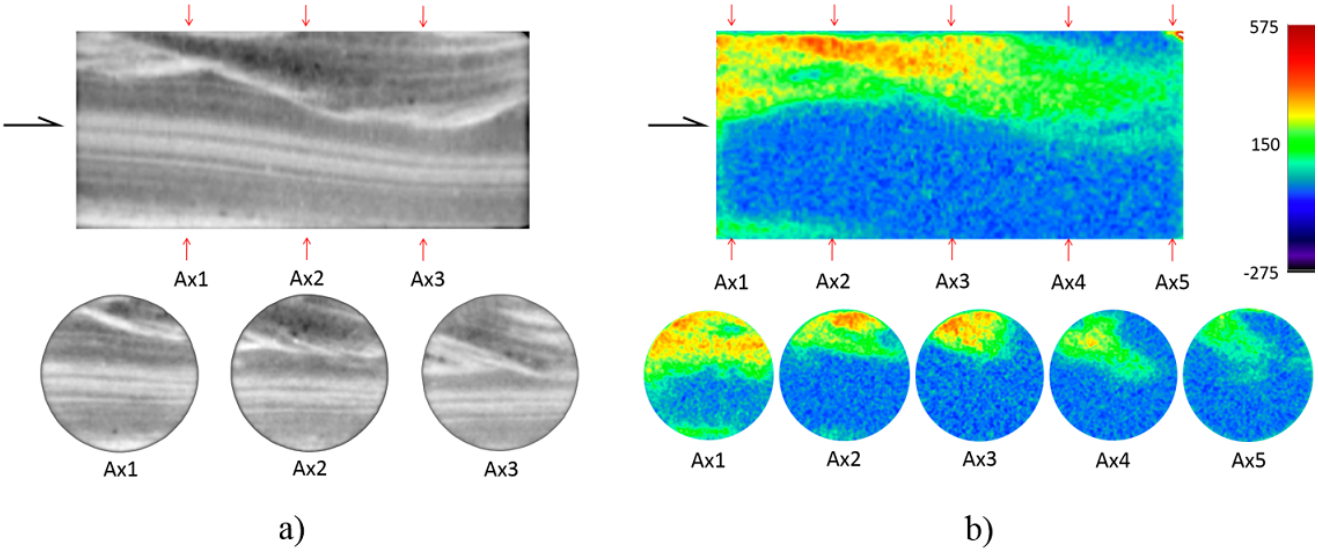

Figure 1: X-ray CT images of CO_2 flooding experiment.
a) core in dry condition, b) differential CT images at 0.26PV(pore volume) CO_2 injected

