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A comprehensive study on shale pyrolysis dynamics by real-time in-situ imaging technology

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Shale oil and gas primarily exist in nanoscale pore-fracture networks. Despite of the large resources of the oil shale and low-medium mature shale, limited removable hydrocarbon and extremely low permeability due to limited pores restrict in the development of those unconventional resources. Therefore, different pyrolysis technologies, such as in situ conversion pyrolysis, superheated steam, nitrogen, electrofrac and etc., were emerged to accomplish the recovery. With the pyrolysis and maturing process, the kerogen was transformed into oil and gas, and more fractures and pores were generated, which increases both the permeability and hydrocarbon in the shale.
In order to study this dynamic process, a real-time in-situ imaging via environmental scanning electron microscope was applied to characterize and analyze the nano to micro scale changes of the shale quantitatively. Afterwards, Energy Dispersive Spectrometer (EDS), Rock Evaluation, and Thermal Gravity Analysis-Fourier Transform Infrared Spectroscopy (TGA-FTIR) were conducted for the physical and chemical alternation of the shale components and expulsed fluid. The real-time in situ SEM showed that 1) nano-fractures started to appear below 100 ℃; 2) inorganic nano-fracture width demonstrated a non-monotonous relationship with temperature; and 3) kerogens amount decreased monotonously as temperature increased, especially during 400-500oC. TGA-FTIR indicated 4 pyrolysis stages with different characteristic changes, in which main expulsed products were CO_2, H_2O, and light hydrocarbons C1-C5. SEM images along with EDS characterized the inorganic components and their changes after pyrolysis.
These findings will promote fundamental understanding of oil shale pyrolysis dynamics at nanoscale and provide key guidance on oil shale extraction at reservoir scale.

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