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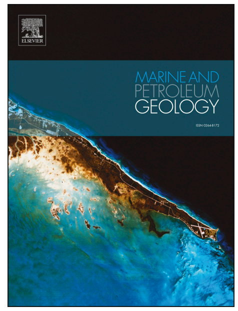

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In-situ imaging of fracture development during maturation of an organic-rich shale: effects of heating rate and confinement

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ABSTRACT

The statistics and dynamics of fractures formed during the accelerated maturation of kerogen-rich shale was investigated by heating Green River Shale (R-8 unit, Piceance Basin, northwestern Colorado) core samples while 3D X-ray microtomographic images were acquired. Previous studies have shown that, when there was no confining stress, fractures formed while the kerogen contained in the shale matured, and the produced hydrocarbon was expelled through these fractures. In the present study, X-ray tomographic scans at multiple voxel sizes were conducted on similar samples during heating. In one experiment, the shale sample was tightly fitted in a non-porous ceramic tube to confine it while it was heated. Three unconfined samples were heated and then held at different final temperatures to investigate the effects of the gas production rate on fracturing. 3D image processing was used to survey fracture network development, and time-lapse 2D digital image correlation analysis was used to monitor the development of the displacement and strain fields. The results revealed that fracturing is strongly dependent on the heating rate and the final heating temperature. While most of the fractures were oriented more-or-less parallel to the bedding plane, some were strongly inclined relative to the bedding plane. The formation of inclined fractures is attributed primarily to the shape and orientation of a minority of the flake-like kerogen patches, and also to the effective stress field and fractured zones of weakness. A conceptual model is proposed to explain the dynamics of fluid expulsion and the associate fracturing behavior.

Keywords: primary migration, kerogen, shale, fracture, X-ray microtomography, digital image correlation