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Environmental consequences of shale gas exploitation and the crucial role of rock microfracturing

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The growing exploitation of unconventional gas and oil resources has dramatically changed the international market of hydrocarbons in the past ten years. However, several environmental concerns have also been identified such as the increased microseismicity, the leakage of gas into freshwater aquifers, and the enhanced water-rock interactions inducing the release of heavy metals and other toxic elements in the produced water. In all these processes, fluids are transported into a network of fracture, ranging from nanoscale microcracks at the interface between minerals and the kerogen of the source rock, to well-developed fractures at the meter scale. Characterizing the fracture network and the mechanisms of its formation remains a crucial goal. A major difficulty when analyzing fractures from core samples drilled at depth is that some of them are produced by the coring process, while some other are produced naturally at depth by the coupling between geochemical and mechanical forces. Here, I present new results of high resolution synchrotron 3D X-ray microtomography imaging of shale samples, at different resolutions, to characterize their microfractures and their mechanisms of formation. The heterogeneities of rock microstructure are also imaged, as they create local stress concentrations where cracks may nucleate or along which they propagate. The main results are that microcracks form preferentially along kerogen-mineral interfaces and propagate along initial heterogeneities according to the local stress direction, connecting to increase the total volume of fractured rock. Their lifetime is also an important parameter because they may seal by fluid circulation, fluid-rock interactions, and precipitation of a cement. Understanding the multi-scale processes of fracture network development in shales and the coupling with fluid circulation represents a key challenge for future research directions.