Hydraulic fracture imaging with galvanic measurements

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Hydraulic fracturing is a technique to fracture rocks by pumping fluid under high pressure into a segment of a well. The created fractures help to release a hydrocarbon resource such as oil or natural gas from the rock. To keep the fractures open, proppants are pumped into the newly created fractures to support the openings. Understanding the location of proppant is important for the evaluation of the fracture treatment. Since most unpropped portions of fractures rapidly collapse, identification of proppant location better represents the region which contributes to the ultimate recovery. It can be used in real-time to evaluate whether the entire reservoir is being sufficiently stimulated, whether the optimal fracture length has been achieved, and whether adjustments need to be made to the existing treatment design.

A group of small-scaled fracturing field tests are carried out by the Advanced Energy Consortium (AEC) for the purpose of monitoring fractures in reservoirs with galvanic measurements. To achieve detectable EM scattered fields from the injected proppants, some specialized proppants are designed which possess EM characteristics (conductivity (σ), electrical permittivity (ϵ), and magnetic permeability (μ)) that differ from the surrounding formation. They can have a contrast in any one, or any combination of these properties with respect to the surrounding medium. This work focuses on the conductive and dielectric properties. To image the created fractures, a fast BIM-BCGS method with FFT acceleration is introduced to simultaneously reconstruct fractures in conductivity and permittivity. The method combines the advantages of the efficient BCGS-FFT method as the forward method with a full 3D nonlinear inverse scattering algorithm based on the BIM method.

Firstly, to test the capability of the inversion solver and the designed experimental setting for successful fracture imaging, the noise-polluted synthetic data is used to image the fracture on a theoretical model. Successful mapping of the fracture shows that the designed experimental setting can be used to map the fracture and the inversion solver is able to map the fracture both in conductivity and permittivity.

The inversion method is then applied to two field tests with injected high contrast materials, Loresco Coke Breeze and steel shot, respectively, as proppants into hydraulic fractures. In the field tests, two groups of data - pre-fracturing and post-fracturing - are collected. The background properties are reconstructed with pre-fracturing data first. The fracture filled with high contrast proppants is reconstructed based on the field difference between the post-fracturing and pre-fracturing data, which is attributable to the fracturing. The reconstructed fracture profiles are compared with the coring samplings to show the reliability of the inversion results. Their good agreement demonstrates that the experimental setting and the EM inverse solver are able to estimate the fracture size and location.