Imaging Hydraulic Fracture Stress Perturbations Using Time-Lapse Electrical Resistivity Tomography

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Tim Johnson

Jeff Burghardt

Dr. Tim Johnson and Dr. Jeff Burghardt, with Pacific Northwest National Laboratory (PNNL), will speak on Thursday, April 18, 2024. The topic is "Imaging Hydraulic Fracture Stress Perturbations Using Time-Lapse Electrical Resistivity Tomography."

Abstract

Hydraulic fracture growth is directly influenced by the in-situ stress field, but fracture growth also changes the stress field, creating a highly nonlinear process. This nonlinearity makes understanding and predicting the behavior of hydraulic fractures very challenging. This challenge is made greater by the fact that hydraulic fracture behavior is typically only observable through microseismic events and where fractures intersect other wells. Recent field studies at the Sanford Underground Research Facility (SURF) have led to the discovery of a new fracture imaging technique using time-lapse electrical resistivity tomography (ERT). In saturated crystalline rocks, hydraulic fractures alter the electrical properties of the subsurface through two primary mechanisms. First, the opening of the hydraulic fracture itself increases the electrical conductivity since the fluid in the fracture is usually more conductive than the rock matrix. Second, the increase in compressive stress surrounding the fracture (stress shadow) causes a decrease in electrical conductivity. Although prior laboratory-scale studies have established a sensitive relationship between effective stress and bulk electrical conductivity in crystalline rock, that relationship has not been extensively leveraged to monitor stress evolution at the field scale using electrical or electromagnetic geophysical monitoring approaches. In this paper, we demonstrate that this effect is significant and can be leveraged to image hydraulic opening, growth, and closure. This technique has now been demonstrated in several hydraulic fracture treatments. Most recently, the

sensitivity and resolution of the technique has been demonstrated by imaging perturbations in the stress field generated by pressurized borehole packers deployed a 1.25 km deep metamorphic crystalline rock formation.

Biography

Dr. Jeff Burghardt is an Earth Scientist at the Pacific Northwest National Laboratory (PNNL) with 12 years' experience in hydraulic fracturing research and over 15 years in experimental and computational geomechanics. He received his Ph.D. from the University of Utah where his dissertation work focused on modeling large deformation and high-rate constitutive behavior of rock and soils. Subsequently, he spent 5 years working in R&D and operations for Schlumberger, where he was technical lead of several large interdisciplinary research projects focused on hydraulic fracturing and drilling. He joined PNNL in 2016, where he has continued to work on experimental and computational geomechanical research with application areas in geothermal energy, geologic carbon storage, environmental remediation, and nuclear non-proliferation.

Dr. Tim Johnson is a computational geophysicist at the Pacific Northwest National Laboratory. He is internationally recognized for his contributions toward characterizing and monitoring subsurface properties and processes using autonomous geophysical measurements, with an emphasis on electrical methods.