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Magnitude-recurrence statistics for stratabound fracture networks in layered media

David Eaton (1) and Joern Davidsen (2)

(1) Department of Geoscience, University of Calgary, Canada (eatond@ucalgary.ca), (2) Department of Physics and Astronomy, University of Calgary, Canada (joern.davidsen@ucalgary.ca)

Variants of the Gutenberg-Richter (G-R) relation, which express scale-independent behavior of earthquakes over a range of values, are almost universally used to describe magnitude-recurrence statistics for microseismic observations. The b value, which is the slope derived from classic G-R plots, is a particularly important parameter that effectively measures the abundance of large-magnitude events relative to small events. Hydraulic fracture monitoring programs often yield apparent b values of 2.0 or greater. These values are exceptionally high compared to earthquake fault sysems, which typically exhibit b values close to 1.0. In some reports, a sudden reduction in b value during treatment has been attributed to unintended activation of a pre-existing fault. An alternative model is developed here to describe magnitude statistics of microseismic events that occur on steeply dipping to vertical fracture surfaces in horizontally layered media. Termination of fractures at mechanical layer boundaries imposes a size-dependent scaling relationship and results in a stratabound fracture networks, which are well described in a number of field studies. In the case of constant stress drop, microseismic magnitude distributions will mimic bed-thickness distributions under these circumstances. A lognormal distribution of mechanical bed thickness, which provides a good fit for three examples considered here from various parts of North America, leads asymptotically to a Gaussian distribution of microseismic magnitudes that readily explains apparent observed b values of close to 2.0. This model is consistent with a sudden reduction in b value arising from uninended triggering of a pre-existing fault, and also implies that subtle changes in b value during a treatment program may be indicative of spatial variations in reservoir facies.