Seismically active volume not a good indicator of the stimulated reservoir: evidence from Paralana

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ABSTRACT: The goal of hydraulic stimulation is to increase formation permeability in the near vicinity of a well. However, there remain technical challenges around measuring the outcome of this operation. During two Enhanced Geothermal System (EGS) stimulations in South Australia, Paralana in 2011 and Habanero in 2003, extensive catalogs of microseismicity were recovered, which indicated reactivation of large planar structures. It is often assumed that shear failure of existing fractures is the main mechanism behind both the induced earthquakes and any permeability enhancement. This underpins a common notion, that the seismically active volume is also the stimulated reservoir. Here, we compute the density of earthquake hypocenters and provide evidence that, under certain conditions, this spatiotemporal quantity is a reasonable proxy for pore pressure increase. We then apply an inverse modeling approach that uses the earthquake observations and a modified reservoir simulator to estimate the parameters of a permeability evolution relation. We show that, although there are an infinite number of permeability enhancement regimes that replicate changes in a well's injectivity, only a small subset of these are able to replicate the hypocenter density profiles. The regime implied by the data indicates that most permeability enhancement occurred very near to the wellbore and was not coincident with the bulk of the seismicity, whose volume was about two orders of magnitude larger. Thus, we conclude that, in some cases, it is possible for permeability enhancement and induced seismicity to be decouple, in which case the seismically active volume is a poor indicator of the stimulated reservoir. Our results raise serious questions about the effectiveness of hydroshearing as a stimulation mechanism in EGS reservoirs. This study extends our understanding of the complex processes linking earthquakes, fluid pressure, and permeability in both natural and engineered settings.