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Initiation of Krauklis waves in fluid-filled fractures by an incident seismic body wave

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A detailed description and understanding of fractured fluid reservoir rocks is of great economic, environmental, and scientific interest, for example for CO_2-sequestration, hydrocarbon exploration, nuclear waste disposal, or groundwater aquifer remediation. Such fluid reservoirs are often probed using seismic investigation methods. Therefore, understanding the effects of fractures on the seismic response of a rock is essential for a reliable rock characterization.

Krauklis waves are a special wave mode bound to and propagating along fluid-filled fractures. Their propagation properties (e.g., velocity dispersion) have been well studied analytically, but only for the theoretical case of straight infinitely long fractures. For the more realistic case of finite fractures analytical methods fail, but numerical wave-propagation models reveal the behavior of Krauklis waves at a fracture tip. Krauklis waves are of great interest because when propagating back and forth a finite fracture, they may fall into resonance and emit a seismic signal with a characteristic frequency. This resonant behavior can lead to strongly frequency-dependent propagation effects for seismic waves and may explain seismic tremor generation in volcanoes or in fluid-reservoir rocks.

All existing studies assume a Krauklis wave initiation inside the fracture, for example by hydro-fracturing. Here, Krauklis wave initiation by a passing plane P- or S-wave wave is studied systematically by performing finite-element wave-propagation simulations and numerically resolving a single fracture in detail. The simulation results demonstrate that the incident body wave is not only scattered and diffracted at the fracture, but also two Krauklis waves are initiated, one at each fracture tip (i.e., diffraction-points of the fracture). For more realistic rough fracture surfaces and/or intersecting fractures, more diffraction-points increase the probability of initiating Krauklis waves by a passing body wave. The presented study shows how the initiation of Krauklis waves in a fluid-filled fracture depends on the incidence angle (or fracture orientation) and the incident wave mode (P- or S-wave). The fact that body waves can initiate Krauklis waves has important implications for Earthquake signals propagating through fluid-bearing fractured rocks (volcanic areas, fluid reservoirs) or for active seismic surveys.