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Characteristics of seismoelectric interface responses at dipping boundaries

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When crossing an interface between two layers with different petrophysical properties, a seismic wave generates a time-varying charge separation which acts as a dipole radiating electromagnetic energy independently of the seismic wave. If we consider a monochromatic seismic source located above a horizontal interface between such media, the seismic wave traverses the interface and causes relative displacement of ions at the matrix-fluid interface in the pore space. The resulting electric field is due to the streaming current imbalance at the interface. This is equivalent to the case of an electrical dipole oscillating in phase with the seismic wave along such boundary. As a consequence, electromagnetic disturbances are radiated away from the dipole source and can be recorded at various receiver lines. This seismic-to-electromagnetic field conversion at petrophysical boundaries in the 1st Fresnel zone is the so-called seismoelectric interface response.

Conceptual field models and theoretical modelling indicate that the interface response should be a multi-pole electrical source. Higher-order terms will diminish more rapidly with distance and therefore will leave the dipole term to dominate. Thus, a seismoelectric interface response emanating from a horizontal boundary in a homogeneous half-space is expected to exhibit symmetry and amplitude characteristics similar to those of a vertical electric dipole (VED) centred on the interface directly below the shot point. However, no general theoretical predictions concerning the characteristics, the shape and the morphology of the VED induced by seismic waves at dipping interfaces can be found in the literature. To gain insight into the spatio-temporal occurrence and evolution of the seismoelectric interface response for dipping interfaces we run several numerical simulations using different petrophysical parameter set-ups. For the modelling, we make use of a simplified time-domain formulation of the coupled physical problem and its efficient implementation in a finite-element framework. In particular, variation in the contrast of the electrical bulk conductivity is investigated for embedded, horizontal and dipping interfaces, respectively. We show that there is a difference between the response patterns of the generated seismoelectric interface responses depending on the geometry of the converting geological structure.