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Results of Six-Degree-of-Freedom Recording at The Geysers, California: True Backazimuth, Phase Velocity, and Site Characterization

Jiri Malek (1) and Johana Brokesova (2)

(1) Institute of Rock Structure and Mechanics AS CR, Prague, Czech Republic (malek@irsm.cas.cz), (2) Department of Geophysics, Charles University in Prague, Czech Republic (Johana.Brokesova@mff.cuni.cz)

This paper addresses a high-frequency microearthquake study at a major geothermal area in California, a large dry-steam electricity generating area known as The Geysers. This area is volcanic and lies within the Franciscan formation. The pluton by overlain by a mixed dry and liquid water zone and that is overlain by a dry-steam zone. In particular, we are using a six-degree-of-freedom (6DOF) geophone-based instrument called a Rotaphone. The instrument provides short-period collocated records of three seismic translational and three seismic rotational components. Beginning in June 2015 to the end of September 2015 we performed field tests of our latest Rotaphone prototype, model D, at this geothermal site. We recorded hundreds of shallow proximal microearthquakes with magnitudes up to 3.8 ML and epicentral distances from 260 m to 14.2 km and depths up to 6 km below sea level, though those in the field itself are shallower than about 2 km below surface. Thanks to relatively low noise, these 6DOF records are suitable for analysis aimed at retrieving the true backazimuth and S-wave phase velocity from a single Rotaphone. These quantities are obtained using rotation-to-translation relationships that allow single-site determinations. For distant earthquakes, these relations are based on an assumption that the S wave can be approximated as a plane wave, but that assumption is not adequate for proximal sources. In our study, the rotation-to-translation relations are expressed instead by equations derived for a spherical S wavefront radiated from a shallow point source in a homogeneous medium. Results of our analysis show that at local distances (up to several km), at lower frequencies (up to a few hertz), and at locations with rapid amplitude changes due to the radiation pattern (e.g., in the vicinity of nodal planes), the rotational components are a linear combination of terms proportional to translational velocity and acceleration, and none of the terms can be neglected in most cases. Our approach yields not only the true backazimuth and the apparent S-wave phase velocity, but, in certain cases, also the S-wave velocity near the surface. All these quantities are obtained from a single 6DOF instrument.The wave velocity is a weighted average down to a depth not exceeding one wavelength, so may be used to estimate vS30, from a single instrument, for example, for the purpose of characterizing site conditions affecting strong-motion records.