# SEISMIC METHODS OF HOT DRY ROCK EXPLORATION

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Seismic methods applied to hot dry rock exploration of the continental crystalline crust have had limited use but are potentially significant for both regional and local studies. Both active (seismic refraction and reflection profiling) and passive (local earthquake monitoring and teleseismic delay time studies) provide data on the velocity and attenuation structure of the crust which may be related to the thermal environment and potential hot dry rock resources.

Seismic techniques can be applied to hot dry rock exploration on a regional or a local scale. Regional studies are most useful for defining the structural framework, velocity and attenuation characteristics of the upper crust, depth to crystalline basement, stress determinations and possible correlations with temperature. Local studies may be useful for inferring composition, determining depth to basement, and mapping the configuration of potential hot dry rock volumes associated with plutons or other three-dimensional features.

Passive seismic techniques yield information on earthquake locations, and through focal mechanisms, on the prevailing regional stress pattern in the crystalline crust. Earthquakes are associated with hydrothermal anomalies in the tectonically active regions of western North America. In cratonic regions, zones of active seismicity are probably indicative of pre-existing geologic structures within the cystalline crust, which may serve to localize thermal anomalies. Focal mechanisms of earthquakes provide an important measurement of the regional stress pattern within the upper crust, which is important to the exploitation of hot dry rock resources. If earthquake monitoring is performed on a reasonably close station spacing, teleseismic delay time data may be used to infer seismic velocity anomalies at depth beneath an array of seismograph stations. Within tectonically active regions, these velocity anomalies are commonly related to thermal anomalies. Similar observations may apply to cratonic regions as well, although the expected anomaly due to velocity variations in cratonic regions is near the limit of resolution of the technique. The distribution of seismograph stations within cratonic regions is generally not adequate and additional studies will be required to demonstrate the utility of these techniques.

Laboratory studies of the seismic velocity of rocks consistently show that seismic velocity is inversely related to temperature. However, the effect is relatively small (on the order of -0.001 km/s/°C) and most thermal anomalies associated with hot dry rock volumes may be too small to show a velocity anomaly above the level of precision of seismic methods. In addition, other effects such as rock composition, porosity, and fluid content may produce large velocity differences. On a continent-wide basis for North America, both heat flow and inferred temperature at depth within the crust have been related to average seismic velocity properties. One study has shown a correlation between low Pn velocity (seismic velocity of the upper mantle) and high temperatures for data averaged by province. Heat flow is also approximately inversely proportional to crustal thickness, geologic age and average seismic velocity of the crust. Thus, seismic methods can be utilized to infer regional thermal characteristics as an aid to hot dry rock exploration.

Seismic refraction and reflection profiling techniques have considerable use in both regional and local hot dry rock exploration programs. Velocity structure of the upper crust may be an indicator of temperature and structural information such as depth to basement, presence of faults, locations of plutons and the thickness of plutons providing valuable information on potential heat sources.

Although seismic methods have good potential for utilization in hot dry rock exploration programs, both at a regional and local scale, and have been used successfully in several studies to date, the velocity effects and structural features which are expected to be associated with thermal anomalies are near the limit of resolution of available techniques. Thus, more detailed accurate and high resolution methods will generally be required for application of seismic techniques in hot dry rock exploration.