

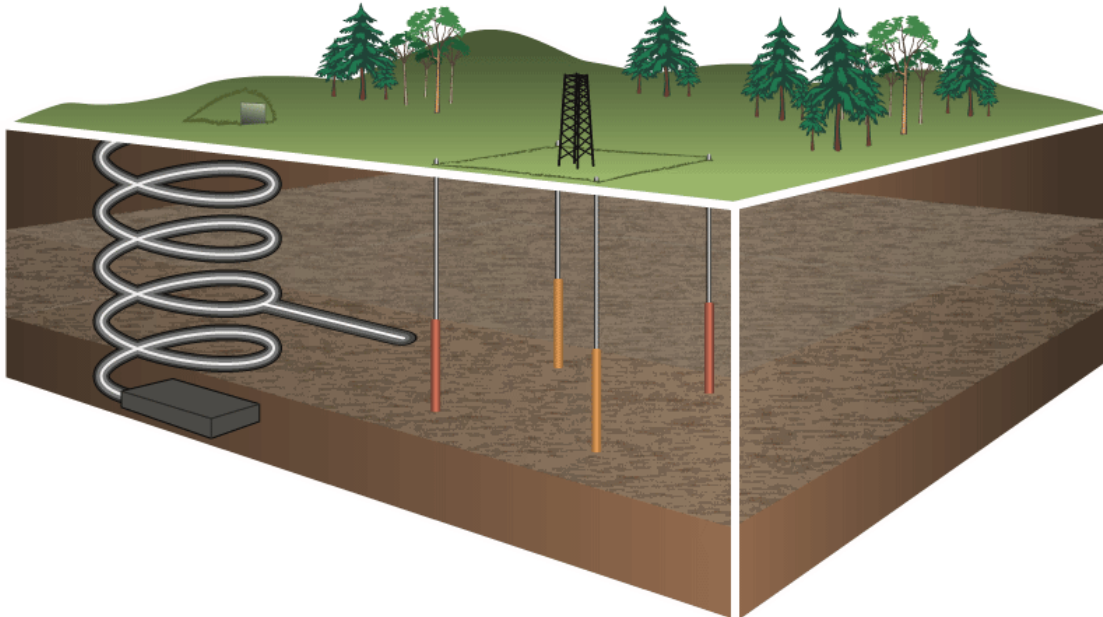
# Permeability Anisotropy and Seismic Anisotropy

Wayne Pennington, Matthias Imhof, Roger Turpening

Permeability is a measure of the flow of fluids through a rock, a parameter that can be anisotropic, a function of direction of flow. The velocity of a seismic wave also exhibits anisotropy. It is tempting to postulate a relationship between these two forms of anisotropy but the underlying physics does not support a connection. Velocity anisotropy can be created by thin layers of alternating high and low velocities, or by a mass of fractured rock with aligned fractures. One might attribute the low velocity layers to zones of high permeability but merely high porosity (or varying saturation) would achieve the same low velocity. Small scale (core) lab experiments are often used to establish weak relationships between high porosity and high permeability, in the absence of other input. In like manner, fractures can direct the flow of fluids, but the magnitude of the flow can not be quantitatively related to the magnitude of seismic anisotropy in fractured rocks.

These are not merely topics of academic, scientific interest. More than half of the major oil fields of the world are in fractured formations. If images of the direction of permeability could be produced the economic savings and increase in efficiency of oil and gas production would be enormous.

It is very difficult, if not impossible to conduct lab scale investigations on fractured cores....core can not be retrieved from fractured zones. Full scale field experiments are the only way to correctly represent fractured formations. The mining operations coupled with a Deep Underground Science and Engineering Laboratory (DUSEL) would be an excellent setting for research concerning fracture controlled permeability anisotropy and its relationship to seismic anisotropy. (Figure)



Fluids containing dyes or other benign tracers can be allowed to flow through a large fractured zone. Boreholes completed at multiple levels will let the fluids enter and exit the reservoir zone in three dimensions. The fluids will not be injected under pressure into the formations because that might artificially create permeability. Instead, the fluids will be presented to the formations under ambient borehole pressures and allowed to flow slowly into the reservoir zone as part of the natural flow system in the formation. This makes the experiment a long term investigation.

Seismic imaging, especially using shear waves, will be performed on the reservoir block using high-frequency, high-resolution, borehole seismic methods (Vertical Seismic Profiling, VSP; Reverse Vertical Seismic Profiling, RVSP; and cross-well tomography and reflection methods). Images displaying the seismic velocity anisotropy of the fractured rock volume will be obtained over a very wide bandwidth.

Gentle mine-back operations incorporating nuclear magnetic resonance imaging will expose the fluid paths used and these will be compared to the images of seismic anisotropy.