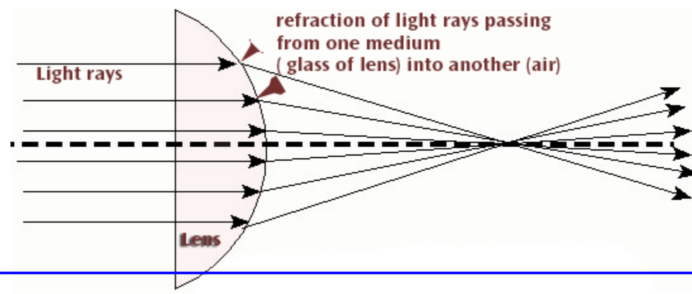
# Employing and Modifying Seismology Codes to Refine and Improve the Ability to Detect Tunnels and Other Buried Structures

## Challenge

Detecting underground structures from above ground—such as tunnels and buried ordnance (e.g., mines)—is an endeavor that often turns out to be even harder than it appears, and Sandia researchers are closing in what they hope will be some more-reliable methodologies.

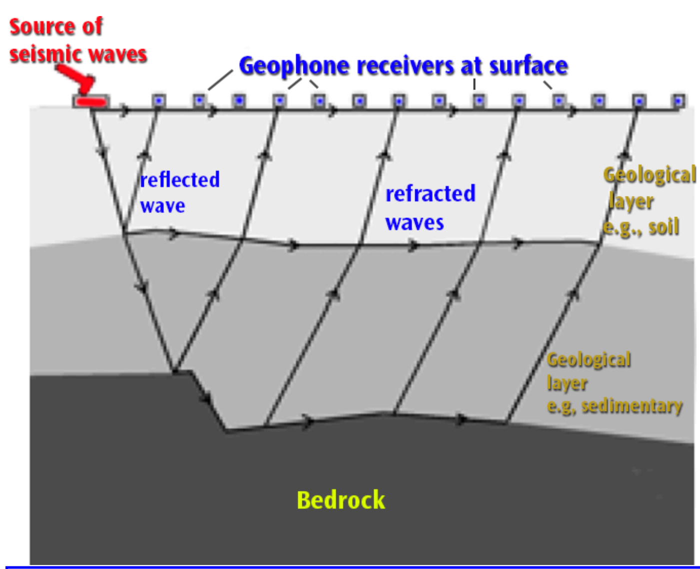
In an early career LDRD project, geophysicist Nedra Bonal is pursuing the modification of seismological methods for solving this detection problem.

The principles underpinning seismology methods are similar to those in optics, where Snell's Law tells us that because the speed of light rays is different in different media, light rays bend or refract when passing from one medium to another, for example from the air to the glass or plastic in a lens in your eyeglasses (or the protein lens of your eye).




Drawing illustrating the refraction of light waves at the interface between a glass/plastic lens and air.

This bending also occurs for acoustic waves traveling from air into the soil and from the soil into deeper layers of the earth, such as sedimentary rock and bedrock. By generating acoustic waves at the surface and monitoring—via an array of "geophone" detectors—the collective energy (seismic) waves reflected by the underground geology, geophysicists can map out the underground layers at which waves are either reflected or refracted. If a tunnel is located within those layers, the pattern of wave reflection and refraction should change as waves travel from geological layers & into the airspace of the tunnel or vice-versa. When processed by software algorithms, such changes in wave patterns should be able to reveal a tunnel's existence and location.




Schematic drawing of the reflection and refraction of seismic waves from geological layers (strata) and the recording of the returning waves' position by an array of geophones.



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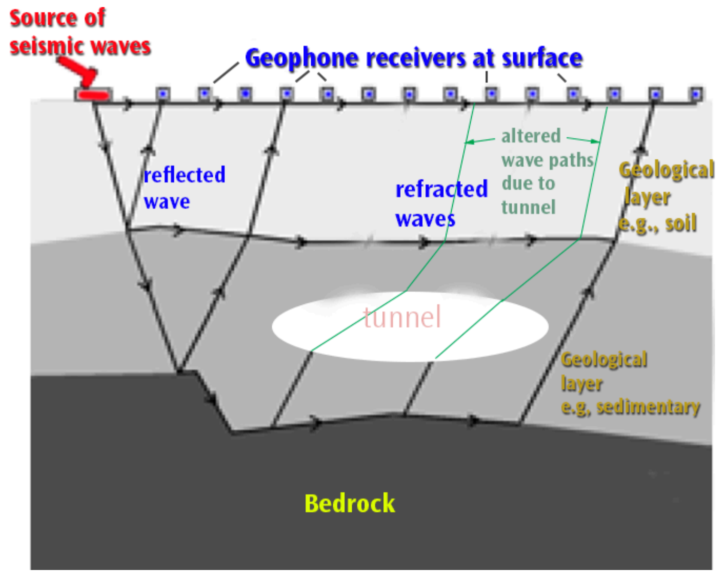
**Research**

The problem with these methods is that they frequently don't work precisely, and this early career LDRD project is focusing-in on the reasons for this disparity. Bonal has pinpointed a quite important factor, namely hydrology, that is the degree of water saturation of different layers—from soil to the pores in rocks. Although tunnels such as those dug at borders to move illegal immigrants are usually constructed above the water table (they would otherwise be flooded by groundwater), other factors can mask tunnels. First, building the tunnel creates fractures in the surrounding rock, thereby "dulling" what might otherwise be a sharp transition with respect to seismic wave refraction. Even more important, these fractures create more pores that can change the degree of water saturation.




Schematic drawing to illustrate the general concept that the presence of an underground tunnel would be expected to change the wave paths of some of the returning seismic waves.

Bonal has found that this hydrology aspect is the key issue to more thoroughly understand. Events such as heavy rains, which can change the profile of overlying soil and underlying rock layers, can greatly interfere with accurate mapping, changing the way the subsurface energy waves are refracted. Hydrated soil particularly complicates these measurements. The computer codes used by the oil and gas industry for their subsurface operations are not much help because of the greater depths at which they are investigating; at those depths, pressure is much greater, rocks are more consolidated (less porous), and changes in hydration are less of a factor. Border tunnels are generally in the 10 to 15 meter subsurface regime, with mines and buried ordnance even shallower. At these depths, the effect of hydration turns out to be quite significant. Hence, a large aspect of this work has, by necessity, focused on hydrology codes. Because Bonal has a much better handle on the appropriate applicable hydrology codes, she is now able to translate that understanding into improved seismology codes that that take the hydrology into account.

One of the critical connections between hydrology and seismology codes involves the theory of converting elastic parameters of soil and rock layers to seismic parameters, namely the velocities at which the seismic waves travel through a geological layer (which will ultimately determine where they will be detected at the surface by an array of geophones). A key parameter is bulk modulus, which describes the compressibility of a material, and thus its elasticity and its change in density with compression. Bulk modulus will change with the water content, even in dense layers, and it is one of the main properties that will influence the velocity of seismic wave propagation.

## Significance:

Detection of underground tunnels is a key aspect of border security, and can therefore contribute to the borders mission of NISAC (National Infrastructure Simulation and Analysis Center, a joint Sandia-LANL facility supported by DHS). Buried ordnance such as roadside bombs have been a particularly harmful source of injury to US military personnel, and their rapid and accurate detection is therefore extremely important to our soldiers in the field. And finally, even though actual fossil fuel reserves are generally located at greater depths than those directly studied by this research, exploration companies need to know about any factors at shallower depths that might interfere with initial drilling operations.

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