Seeing resources beneath our feet with geophysics

Geophysics uses instruments that can make very precise measurements to reveal subtle patterns that give us remarkable insights into our planet, from sea level rise to the makeup of the core. That includes imaging the world hidden beneath our feet, just as medical imaging can reveal what's going on inside your body. Some clean energy technologies rely on this sort of imaging—read on for two real-world examples and a link to free educational resources related to this topic.

Geothermal energy

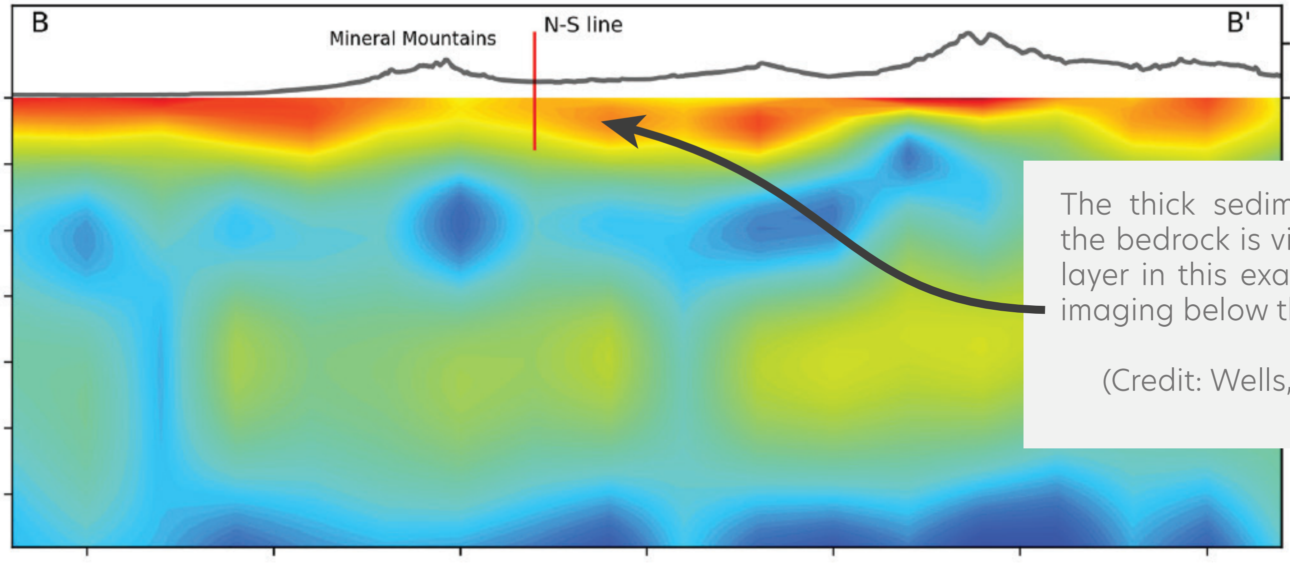
Geothermal power plants use heat underground to spin turbines that generate electricity. This has traditionally been done in areas with obvious hydrothermal activity like hot springs, where you can drill a well that will produce hot water and steam. But it's possible to harness geothermal energy in far more places, where it could provide consistent, clean energy—and geophysical techniques help us identify and develop them.

One technique to broaden that feasibility is called an "enhanced geothermal system". This involves creating or widening fractures in hot, dry bedrock so that cold water can be pumped down one well, heated by contact with the bedrock, and then brought back up to the surface from a second well to generate electricity. In order to study and improve these techniques, the US Department of Energy funded the Utah Frontier Observatory for Research in Geothermal Energy (FORGE). While drilling enhanced geothermal wells, this project is collecting a host of geophysical data to map out the local geology, monitor the drilling process, and detect any changes while water is pumping through the system.

Utah FORGE aimed to use hot granite bedrock thousands of feet below the surface, which meant imaging the ground beneath to see where this rock was located, and whether its properties varied from one location to another. A number of boreholes were drilled to collect cores of rock for analysis, but this is expensive work. Geophysics allows for those datapoints to be extrapolated across the site in three dimensions.

Seismic data were used to map out the bedrock surface buried under a thick layer of sediment, and to identify the areas of hottest rock. Gravity surveys helped differentiate different types of rock based on their density. Magnetotelluric surveys mapped the presence of fluids (like a nearby hot spring) and areas with more or fewer fractures.

GPS instruments and satellite InSAR data were also used to measure how the ground surface moves up and down with the seasons—or any surface movement caused by the activity in the wells. And during the hydraulic fracturing process, seismometers mapped the locations of new fractures as the granite cracked around the first well, giving a clear view of where to drill the second well to ensure water would have a connected path between them.



The thick sediment cover over the bedrock is visible as the red layer in this example of seismic imaging below the site.

(Credit: Wells, et al./JGR Solid Earth)

Critical minerals

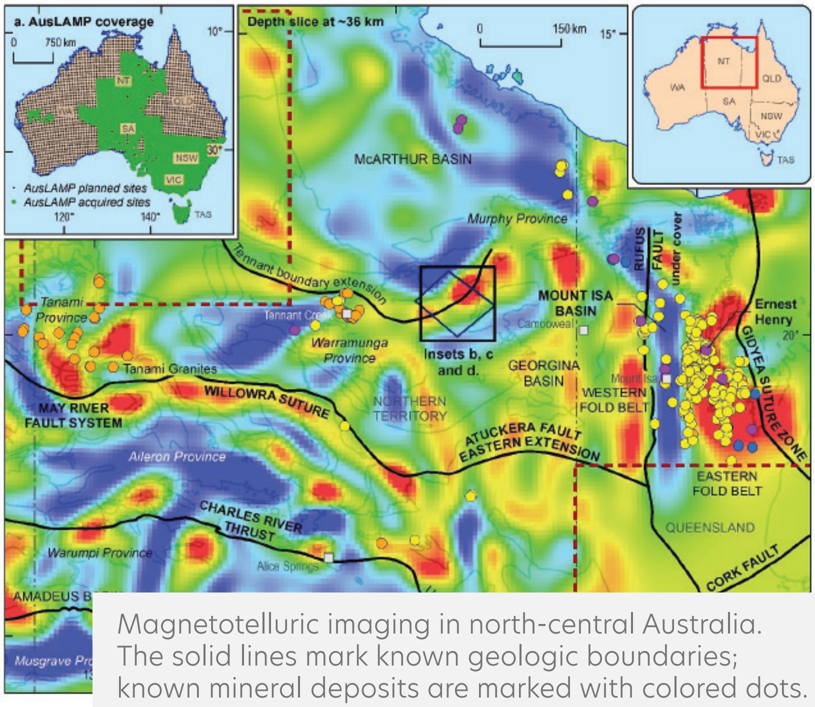
Some clean energy technologies rely on certain minerals, like lithium, nickel, and graphite for batteries, or rare-earth elements like neodymium that are used to make magnets inside turbines. These minerals have to be mined, so there's a need to identify and develop new deposits.

Geophysical imaging can be used to help identify the three-dimensional shape of a specific ore body, guiding the mining process. But something similar can also play out on a regional scale. Different mineral deposits are created by specific geologic processes, so seeing the big picture can tell you where you could expect to find those minerals on closer inspection.

Australia has undertaken national geophysical surveys and data compilations for just this reason. Seismic, magnetotelluric, magnetic, and gravity data all map out geologic structures like bedrock types and fault systems.

For example, nickel sulfide deposits could be found where a combination of factors line up. A specific type of magma provides the ultimate source, but it needs a pathway through the thick continental plate like the boundaries between the tectonic pieces of Australia that have been assembled together over time. Then, fluid flow pathways like fault systems might hold hydrothermal waters that carry nickel sulfide and concentrate it in ore deposits.

Geophysical mapping is more than just a metal detector that beeps as you scan randomly along a beach—it can map out all the parts of this system so we can see how different rocks are connected.



Magnetotelluric imaging in north-central Australia. The solid lines mark known geologic boundaries; known mineral deposits are marked with colored dots.

(Credit: Doublier/Geoscience Australia)

Combined with physical sampling data, this has allowed Australia to make "mineral potential" maps that highlight areas with all the geologic ingredients for a particular ore to be present.

Resources you can use

Use this QR code or visit earthscope.org/earth-science-week to see a collection of classroom resources. We've created some simple primers for many of the topics in this handout, a number of relevant videos, and a collection of curriculum modules. The page will also point you to some related resources available from other organizations.

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