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An Integrated Geophysical Strategy for the Characterization of a Gas Permeable Structure

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Geophysical methods have been used extensively to study deep reservoirs and geological structures for the purposes of resource exploration, however their application to characterise and monitor CO2 geological storage sites is relatively new and less well tested. Although similar in some ways, the goals, challenges and requirements of a geophysical survey conducted at a CO2 storage site will in many ways be quite unique. For example, whereas a fault may only be studied at the depth of a petroleum reservoir due to its potential as a trapping mechanism, the characteristics of a fault near a CO2 storage site must be understood from reservoir to surface to understand if it represents a migration pathway to the biosphere and atmosphere. An added complication is the fact that there will be a phase shift in the target material should it begin to migrate from the injection depth towards surface, with supercritical CO2 changing to gas as pressure and temperature decreases; whereas the supercritical phase can be imaged with seismic techniques, geophysical imaging of a vertical plume of gaseous CO2 will be much less likely. And finally sensitivity of the applied method may need to be greater than that normally required, as gas may be able to migrate along smaller, more closed structures and channelled flow along isolated fault intervals will control potential release points at surface.

In order to examine these issues it is necessary to test different geophysical methods at sites where deep CO2 is migrating along fault structures to the ground surface. As none of the man-made storage sites have been observed to leak the only other alternative is to use sites with leaking, naturally-produced CO2. One such site is the Latera Caldera in central Italy, a faulted geothermal reservoir where thermo-metamorphically produced CO2 migrates along faults in the overlying volcanic rocks and is released at surface from features known as gas vents.

In this study a single, isolated gas vent was studied, first with gas geochemical methods (CO2 soil concentration and flux) to define its extent and form, and then with a number of geophysical methods (hammer seismic, microgravity, ground penetrating radar, time domain reflectometry, frequency domain electromagnetic and 2D and 3D electrical resistivity tomography) to test their response and sensitivity, and to extend previous work conducted on this site (e.g. Annunziatellis et al., 2008; Pettinelli et al., 2008). The various datasets were merged and compared, with the combined results giving a coherent picture of the gas permeable structure. In fact, all methods are in good agreement, and show lateral variations in the soil physical properties which are related to the influence of the gas vent on the mineralogy and the water content of the shallow sediments and soil. In particular, the electrical and electromagnetic techniques put in evidence that the non-vegetated central part of the gas vent has extremely conductive. Finally, the results obtained with the different methods allowed us to define the orientation of the buried fault which causes the CO2 migration at surface.

References

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