Crystalline reservoirs offer multiple geoenergy opportunities: Deep geothermal, CO_2 mineralisation, native hydrogen, and hydrocarbons

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Crystalline reservoirs have been offering multiple opportunities for geothermal heat production and hydrocarbon exploration for decades. Presently, global efforts to reduce greenhouse emissions are opening new frontiers for studying crystalline reservoirs, mainly to (i) increase the uptake of deep geothermal resources beyond high-enthalpy areas, (ii) outline prospects for permanent CO_2 sequestration, and (iii) investigate potential occurrences of native hydrogen and helium gases. Crystalline rocks commonly comprise interlocking crystals that produce a rock mass with low porosity and low permeability and thus are rarely of interest to the geoenergy industry. Although previous hydrogeological, geothermal, and O&G research has significantly improved our understanding about the potential of crystalline reservoirs, their formation is complex, typically reflecting multiple igneous, tectonic-structural, and mineral alteration processes. The combination of fracturing and mineral alteration is understood to produce strong changes in thermal and petrophysical parameters such as rock density, acoustic impedance, thermal conductivity, and specific heat capacity – all critical factors that determine the reservoir potential and help to delineate geoenergy resources within crystalline rocks. Today, novel research is demonstrating that processes such as rock fracturing and mineral alteration can create highly porous and permeable crystalline reservoirs, up to 25% and 1 Darcy (10^{-12} m^2), respectively. In some cases, these crystalline reservoirs can have petrophysical properties comparable to conventional prolific sedimentary reservoirs and thus can provide ideal prospects for new geoenergy developments. In this talk, we will present the state-of-the-art of geoenergy technologies in crystalline settings, discussing the main geological processes that create crystalline reservoirs, and highlighting novel seismic reflection methods to recognise them in the Earth's subsurface. We will show how the relationship between rock fracturing, faulting and mineral alteration affects parameters such as porosity, permeability, pore-space morphology, and connectivity of complex crystalline reservoirs. We will also discuss the size and geometry of crystalline reservoirs formed within or near ancient igneous intrusions and crustal fault zones, examining the ability of seismic reflection methods to detect discrete fracture networks. Making crystalline reservoirs commercially available and predictable at industrial scales will ensure a steep change in our global strategic energy security, maximising reliable renewable sources while supporting our decarbonisation goals.

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