

Imaging Subsurface Reservoirs for Hydrogen, Geothermal, and Critical Minerals: Multi-Physics Imaging and AI-Assisted Interpretation

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The accelerating demand for low-carbon energy and critical mineral resources is driving renewed interest in subsurface systems capable of hosting geothermal fluids, geologic hydrogen accumulations, and mineralized reservoirs. These systems are controlled by complex geologic structures, fracture networks, and fluid pathways that are difficult to characterize using single-method approaches. Advances in multi-physics geophysical imaging, combined with AI-assisted interpretation, are enabling a new generation of integrated subsurface characterization workflows. Our work examines how the integration of seismic, electromagnetic, gravity, and well data can be used to image reservoir architecture across multiple spatial scales. By jointly analyzing complementary geophysical signals, multi-physics approaches help resolve structural controls, permeability pathways, thermal regimes, and mineralization patterns that govern the formation and productivity of subsurface reservoirs. Recent developments in machine learning and physics-informed AI provide powerful tools for interpreting these complex datasets. AI-assisted workflows can identify subtle patterns, integrate heterogeneous datasets, and accelerate inversion and interpretation processes while remaining constrained by geologic and physical principles. These approaches improve the detection of fracture systems, fluid migration pathways, and alteration zones that are critical for hydrogen systems, geothermal reservoirs, and critical mineral exploration. Case studies demonstrate how multi-physics imaging combined with AI-driven interpretation can reduce exploration uncertainty and improve the prediction of subsurface resource potential. The integration of geophysical sensing, computational methods, and geologic knowledge provides a unified framework for imaging and evaluating energy and mineral systems in the subsurface.

