SEG 100 Conference: Celebrating a Century of Discovery

ST.178
Tracing Crustal-Scale Fluid Pathways Under Cover with Magnetotelluric Imaging: Examples from the Central United States

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Magnetotelluric (MT) imaging work in Australia has shown a spatial correlation between major iron oxide copper-gold/iron oxide-apatite (IOCG-IOA) deposits and zones of elevated bulk electrical conductivity that transect much of the crust. In the United States, three-dimensional MT imaging similarly reveals subparallel northwest-striking high-conductivity zones at mid- to lower-crustal depths beneath Mesoproterozoic IOCG-IOA deposits in the Missouri Iron Province. Both in Missouri and in Australian districts, these conductive anomalies have generally been interpreted as zones of fluid flow and crustal metasomatism; however, the exact cause of elevated electrical conductivity has previously been unclear, particularly because these anomalies are found within stable Precambrian crust. Here, we interpret these conductors specifically to be the result of graphite precipitation associated with magmatically driven $CO_2 \pm H_2O$ fluid flow through the crustal column. We propose that graphite precipitated during cooling through ~800-500°C along crustal-scale, tectonically controlled fluid pathways either via the oxyexsolution reaction $6Fe_2TiO_4 + CO_2 = 2Fe_3O_4 + 6FeTiO_3 + C$ or via carbon saturation in a C-O-H fluid with oxygen fugacity near the fayalite-magnetite-quartz buffer. In either case, the CO_2 involved in these reactions would have exsolved from mafic to intermediate magmas at mid- to lower-crustal depths and been concentrated along deep-rooted, tectonically controlled pathways; saline magmatic fluids that could drive mineralization are likely derived from intrusions at shallower crustal levels. In this interpretation, graphite is then a marker of magmatic fluid movement along localized crustal-scale conduits that could underlie near-surface magmatic or magmatic-hydrothermal mineralization. Therefore, electrical conductivity anomalies that are associated with such graphite precipitation would demarcate zones of localized, deep-rooted magmatic activity. Although they do not directly mark the locations of mineral deposits, these anomalies do indicate regions that once hosted an appropriate lithotectonic environment for mineral system formation. We apply this model to interpret magnetotelluric images in conjunction with other geophysical and geochemical datasets within the central United States. We highlight three specific regions where a thin (<1 km) veneer of Phanerozoic overburden obscures Precambrian basement rocks that may be prospective for IOCG/IOA mineralization: northeastern Illinois, northwestern Indiana, and northwestern Ohio.