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Extracting mineral system event histories from geophysical and geochemical data in geologically complex terrain – an example from the southeastern Fennoscandian Shield.

Peter Sorjonen-Ward (1), Asko Kontinen (1), Jouni Lerssi (1), Satu Mertanen (2), Ferenc Molnar (2), Hugh O'Brien (2), Esa Pohjolainen (2), Jaana Halla (3), Fawna Korhonen (4), and Jussi Mattila (5)

(1) Geological Survey of Finland, Kuopio, Finland (peter.sorjonen-ward@gtk.fi), (2) Geological Survey of Finland, Espoo, Finland, (3) Geological Museum, Univeristy of Helsinki, Kumpula, Finland, (4) Geological Survey of Western Australia, East Perth, Australia, (5) Posiva Oy, Eurajoki, Finland

The mineral systems concept is intended to extend and inform exploration capability, through understanding processes of metal extraction, transport and precipitation within a well-defined architectural framework, as opposed to simple – or even sophisticated – targeting of geophysical or geochemical anomalies. Given that geophysical and geochemical data represent a summation of all events and processes that have affected a body of rock, the use of advanced inversion techniques could be impeded unless we can extract an accurate event history and derive a comprehensive understanding of the history of hydrothermal events and their structural framework, even in a qualitative sense. In ideal cases, we may be able to place age constraints using isotopes or paleomagnetism, if hydrothermal mineral reactions enhance (or disperse) geochemical and geophysical signals. Given a the tendency for deformation in the brittle regime to occur preferentially by reactivation of existing zones of weakness, we might also expect a progressive linear enhancement or dilution of anomalies, where fluid-flow is focused within permeable fault zones.

We illustrate these issues through an analysis of event histories and their relationship to diverse mineralization styles and episodes in the southeastern part of the Fennoscandian Shield, where the oldest mineral systems are represented by orogenic gold deposits in Neoarchean greenstone belts and the youngest events are recorded locally by Paleozoic crystallization of uraninite in repeatedly reactivated fault zones. The Neoarchean Karelian craton was subjected to thermal reworking as the foreland terrain to the 1.9-1.8 Ga Svecofennian Orogeny, as demonstrated by resetting of K-Ar, Ar-Ar, Rb-Sr and locally Pb-Pb isotopic systems in feldspars and pyrite, both within gold deposits, and regionally. However, retention of Archean strain patterns and observations of the strain state of Proterozoifc dyke swarms indicate an essentially brittle response, with extensive fracture-controlled alteration of Archean mineral assemblages and the recognition of isolated domains in which Archean remanence is retained. However, this mosaic-like pattern of disturbance to primary magnetic anomalies has not precluded effective use of geophysical data in mapping the structural architecture of the Archean orogenic gold systems. Conversely, the presence of fault-controlled Svecofennian late orogenic retrograde hydrothermal processes provides a plausible opportunity for mobilization of uranium in proximity to the Archean – Paleoproterozoic unconformity. Evidence to support this comes from the presence of fracture-controlled hydrothermal alteration with hematite-calcite-chlorite assemblages in underlying Archean basement monzogranites, some of which display prominent radiometric anomalies, and can also be reconciled with the interpreted kinematic framework, both regionally and at known uranium prospects, involving partitioning of deformation into steep strike-slip fault zones subparallel to the craton margin, coupled with small scale thrusts and duplex systems. Alternative scenarios may be considered, consistent with apatite fission-track data, such as burial beneath transient Mesoproterozoic or Paleozoic terrestrial basins across the study area, although current isotopic and paleomagnetic data favour a late Svecofennian age.