Magmatic and hydrothermal transfers and mineral systems

Elements of economic interest concentrated in ore bodies correspond to the extreme expression of fractionation and as such provide key tracers of geological processes leading to crustal differentiation and to the formation of georessources. The specific behavior of elements during magmatic, hydrothermal, and alteration processes are directly controlled by their physical-chemical properties. Siderophile and chalcophile elements such as Cu, Ni, Mo, Au and, PGE, Re have little chemical affinity to oxygen and thus may only be mobile in hydrothermal fluids enriched in sulfur and salt (Cl). Accordingly, they tend to concentrate in ultramafic rocks or to form disseminated and/or vein-type ore-bodies providing precious clues to fluid generation and migration within the lithosphere. Other elements, such as U, Th, K and REE, Zr, Nb, Ta, relatively incompatible with respect to silicate crystalline structures, tend to concentrate in the silicate melt during partial melting and/or fractional crystallization, and thus may serve as excellent tracers of magmatic processes. Finally, alkaline and alkaline earth elements (often designated as LILE with reference to their large radius) and metalloids (As, Sb, Ge, Se, Te), are particularly mobile and preferentially concentrated in the hydrothermal H_2O (CO_2) fluid phase.

Integrating the characterization of the source of mineralizations and the conditions for mobilization, transfer and deposition of elements led to the concept of mineral systems (Wyborn, 1997; McCuaig & Hronsky, 2014). Ore deposits represent small-scale expressions of a range of Earth processes that take place at different temporal and spatial scales (Barley and Groves, 1992; Bierlein et al., 2002; Cawood and Hawkesworth, 2013; Groves and Bierlein; 2007; Groves et al., 2005; Kerrich et al., 2005; Meyer, 1988). Mineral deposits are heterogeneously distributed in both space and time (Lindgren 1909; Turneaure 1955; Meyer 1988; Barley and Groves 1992; Titley 1993; Groves et al. 2005b; Kerrich et al. 2005; Maier and Groves 2011, Jenkin et al. 2015; Groves and Bierlein 2007; Bierlein et al. 2009; Goldfarb et al. 2010; Cawood and Hawkesworth, 2015). Barley and Groves (1992) suggested that this uneven distribution is related to three major factors: (a) evolution of the hydrosphere–atmosphere; (b) secular changes in global heat flow; and (c) long-term tectonic trends, and mineral deposits must be seen as tracers of the global Earth evolution through geological times (references).

At large time scale, the age distribution of mineral deposits are currently used to decipher secular patterns of global tectonics cycles related to periodic assembly and dispersal of continents within the supercontinent cycle (Goldfarb et al. 2010). Cawood and Hawkesworth (2015) argue for some incompleteness of the time record, in relation to, not only the surficial effects of erosion and the consequent removal and/or recycling of material, but also systematic biasing of the preserved record through the periodic assembly and dispersal of continents. Indeed, the issue of a deposit preservation through time may be considered on different scales: the supercontinent cycle, the tectonic settings, as well as the depth of formation (Groves et al. 2005; Cawood and Hawkesworth, 2015).

As assessed by Stein (2014), to understand both ore deposit and crustal growth and evolution, we need to track element (metals) mobility through time and space in a three dimensional whole Earth perspective (3D; 4D with time and/or tracing, see Champion and Cassidy, 2015). Improvements in the robustness, accuracy and precision of geochronological methods, advances in microsampling techniques and/or mineral separation, new development allowing in-situ analyses, as increased analytical capacity of laboratories, have generated more systematic geochronological data on mineral systems (Stein, 2014). With these strong increase of geochronological data acquisition, temporal peaks in the distribution of mineral deposits are better defined and allows to discriminate peaks inside a supercontinent cycle, but also within a specific stage of a supercontinent cycle.