Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.14083

Scaling laws in geochemistry – Insights from gamma rays spectrometry

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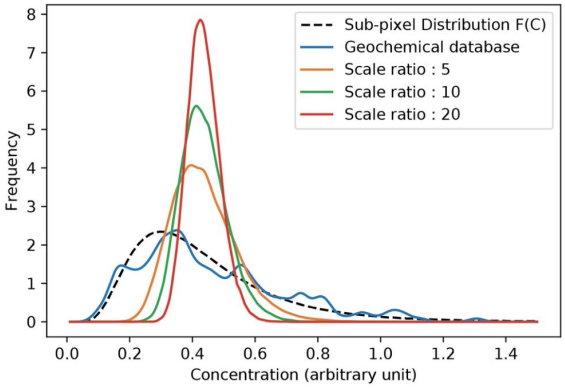

In a pioneering work on scaling laws in geochemistry, Allegre and Lewin [1] established the potential existence of universal scaling laws in geochemistry, based on the consideration of elementary geochemical processes (fractional melting, dissolution-precipitation), and exemplified by the frequent cases of log-normal distributions of trace elements in different contexts. Despite the relevance of this research for mineral exploration, it has received limited attention, due in part to the lack of appropriate (large enough) data sets. Gamma ray spectrometry is a technique that was developed in the 70s and applied more widely over the last three decades on various contexts. It is able to map the surface concentration of K, Th and U based on the natural emission of gamma rays of ^{40}K,^{232}Th, ^{238}U or their daughter elements. On planets or satellites with thin atmosphere (e.g., Mars) or no atmosphere (e.g; the Moon), it is possible to map these elements at the global scale from the orbit, and also use the interactions of cosmic rays' particles with the surface to map other elements, such as Si and Ca. Large geochemical databases, and ground-based radiometrics may be combined with satellite or airborne radiometrics to build multi-scale data sets, that are particularly appropriate to explore scaling laws in geochemistry. This presentation will focus on such recent cases studies on earth and Mars. We will show that geochemical distributions of incompatible or trace elements (such as K, and Th) generally show a strong dependence to the scale of analysis, but that this is not the case for major elements. This behavior is a consequence of the central limit theorem applied to elements with variable distances of spatial auto-correlation, as illustrated in several empirical variograms from regional airborne and ground-based radiometrics. These finding opens a new research avenue calling for the exploration of the relationships between the geostatistical properties of chemical elements and their geochemical behavior. Preliminary applications in the context of tropical weathering (regolith), hydrothermalism and magmatism will be discussed.

[1] Allègre, C.J., Lewin, E., 1995. Scaling laws and geochemical distributions. Earth and Planetary Science Letters 132, 1–13. https://doi.org/10.1016/0012-821X(95)00049-I