Trace metal mobility during magnetite-hematite transformation: classifying ore types and alteration conditions

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Synopsis

Hematite is an ubiquitous mineral, especially occurring as an alteration/weathering/metamorphic product in primarily magnetite-bearing rocks and ores. Its chemical complexity is poorly understood, but might be a proxy, like magnetite, to characterize either rock/ore forming or alteration conditions. We used in-situ LA-ICPMS data from hematite and precursor (or coeval) magnetite to investigate metal mobility and partitioning during natural iron oxide transformation. Hematitization modifies the oxides trace metal budget systematically.

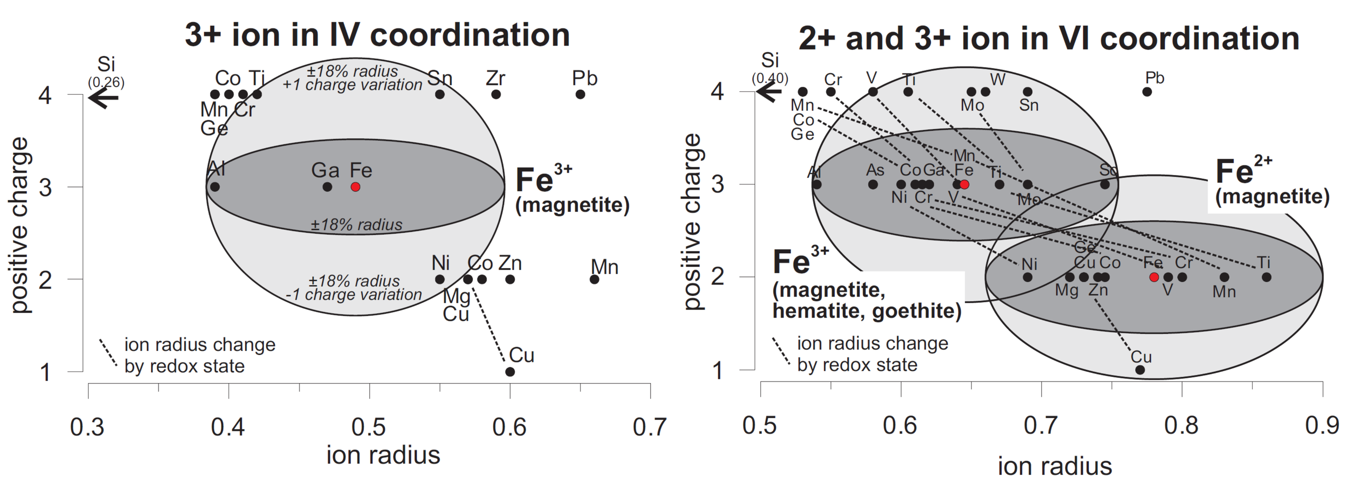
Specifically, metamorphic hematite is, compared with (equilibrated) magnetite, depleted in low- and enriched in high-valent elements.
Metal mobility during magnetite breakdown (martitization) is divers. It allows discrimination of hydrothermal from supergene conditions, a very useful criteria for metallogenesis and exploration.
Elements commonly used in magnetite discrimination diagrams may be modified by up to several orders of magnitudes during hematite formation, and are thus impractical for ore discrimination.

Mechanisms

Magnetite-hematite transformation take place by redox and non-redox coupled dissolution-(mobility)-reprecipitation, C(M)DR, both in static or dynamic structural state (Lagoeiro 1998, Ohmoto 2003, Mücke and Cabral 2005).

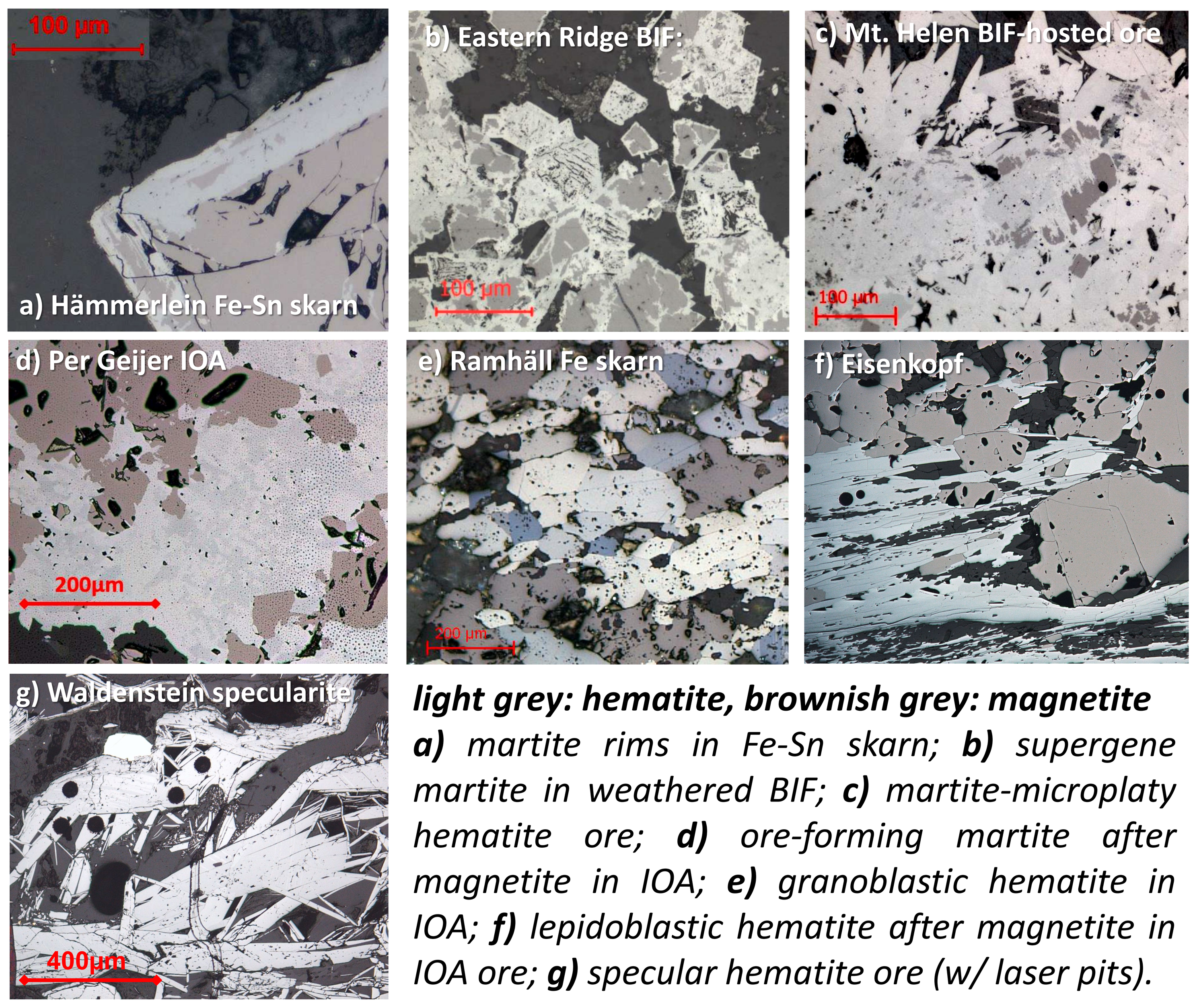
oxidation: $2\,Fe^{2+}Fe_2^{3+}O_4 + 0{,}5\,O_2 = 3\,Fe_2^{3+}O_3$
non-oxidation: $Fe^{2+}Fe_2^{3+}O_4 + 2\,H^+ = Fe_2^{3+}O_3 + H_2O + Fe^{2+}$

Metals can substitute for Fe in the oxide structures according to charge and radius, and by coupling, and thus transformations should impact oxide elemental budgets.



Textures

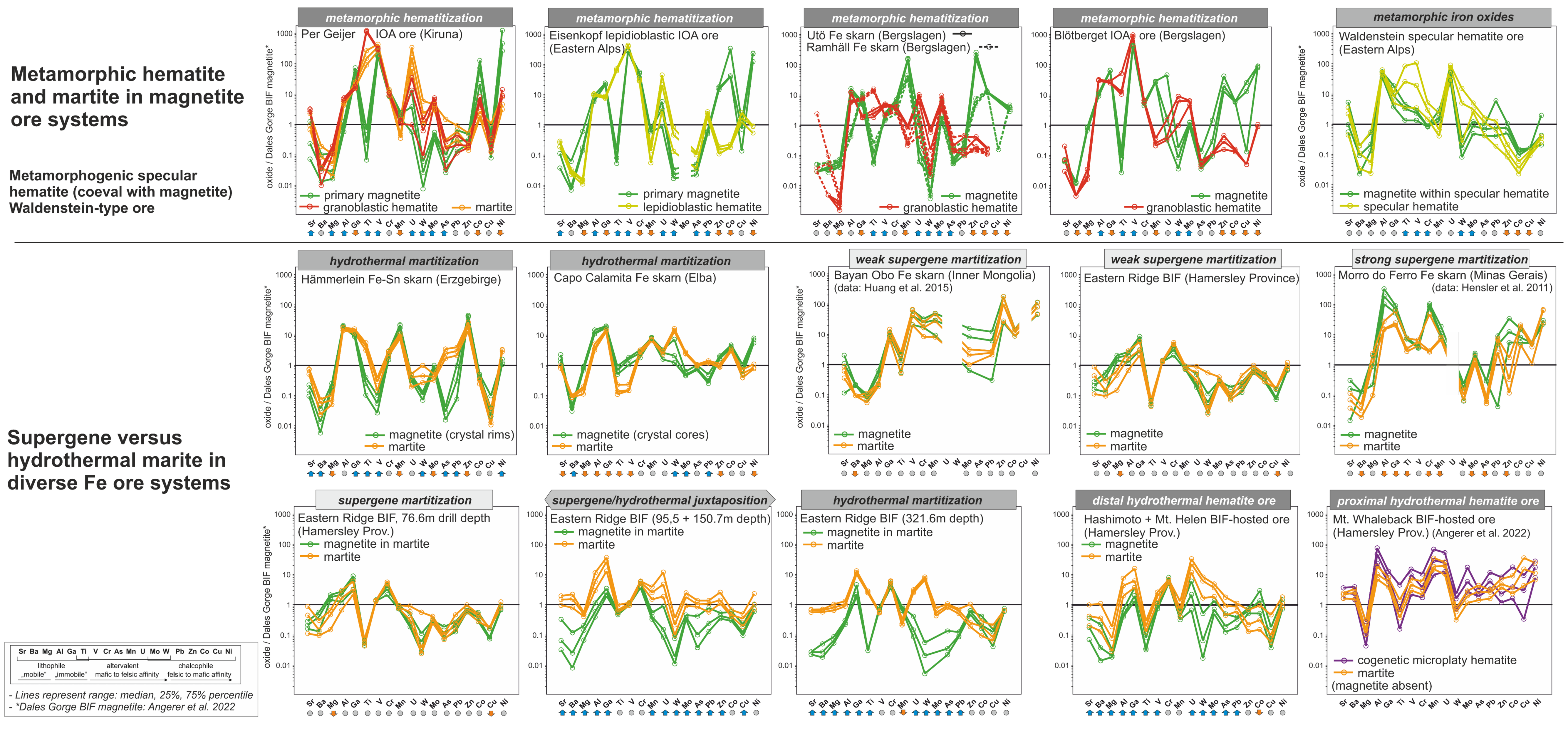
Various ore settings (iron oxide apatite IOA, Fe skarns, BIF and associated hematite ore, and metamorphogenic specularite ore) are investigated.
Martites show internal "crisscross" or "patchy" textures and replacement is variably complete (a-c).
Metamorphic hematite may or may not in textural equilibration with primary magnetite (d-f). Metamorphogenic hematite ore with random textures and local magnetite (g).



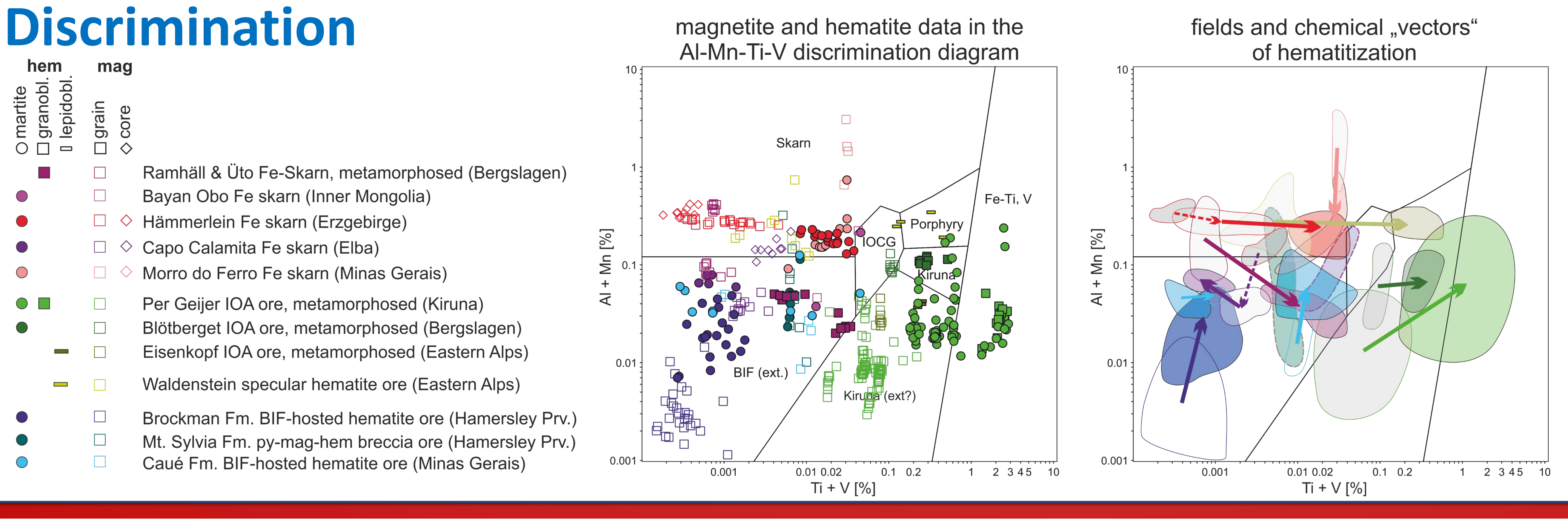
light grey: hematite, brownish grey: magnetite
a) *martite rims in Fe-Sn skarn;* ***b)*** *supergene martite in weathered BIF;* ***c)*** *martite-microplaty hematite ore;* ***d)*** *ore-forming martite after magnetite in IOA;* ***e)*** *granoblastic hematite in IOA;* ***f)*** *lepidoblastic hematite after magnetite in IOA ore;* ***g)*** *specular hematite ore (w/ laser pits).*

Mineral chemistry

Hematite-forming processes are associated with quite systematic element mobility:
1st row: hematite in textural equilibrium with magnetite are relatively enriched in high- (Ti, U, W, Mo) and depleted in low-valent (Mg, Mn, Zn, Co, Ni) metals. This points towards contrasts in metal availability in fluids and structural compatibility in oxides.
2nd and 3rd rows: Supergene martites are chemically inert, but depletion of metals increases with overprint intensity. Hydrothermal and ore forming martites show diverse addition of metals, most likely defined by fluid chemistry and oxidation state.



Discrimination



The evident metal mobility during transformation in hydrothermally, metamorphic and strongly supergene modified ore samples, severely hampers the (already limited) use of popular magnetite discrimination diagrams (Dupuis and Beaudoin 2011 or Nadoll et al. 2014, shown in the figure). Hematite data should thus be avoided when using mineral chemical discrimination.

Literature

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