Kiruna-type apatite-iron ore in Svalbard: the evidence from main and accessory minerals

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Apatite-iron oxide deposits (so called „Kiruna-type" iron ores) are phosphate-rich magnetite-hematite ores associated with magmatic or volcanic rocks. They are originally known from Paleoproterozoic rocks of the Baltic Shield in Sweden, and subsequently recognized in formations of various age in many other places around the world. Recent studies suggest a complex, combined magmatic and post-magmatic origin for iron oxides, and phosphates that crystallized from evolved siliceous melt, highly enriched in fluids and REE. This is reflected in the trace element chemistry of the ore as well as accessory minerals, for example enrichment in V, Mn, Cr and depletion in Ti and Ni in iron oxides, and high concentration of F and REE in phosphates. However, hydrothermal post-magmatic overprint obscures the primary geochemistry.

Small apatite-iron oxide ore lensoidal bodies were found in the northeast Prins Karls Forland, an island of the Svalbard Archipelago. They occur locally within a narrow (~1 km wide) shear zone between two distinct units: (1) the amphibole facies Pinkie Unit comprising metapelites, calc-silicate rocks and marbles to the east and (2) the greenschist facies metasediments of the Grampianfjella Formation to the west. Hydrothermally altered and slightly metamorphosed cumulate gabbro bodies, several meters in size, occur in the vicinity of the ores (Maraszewska et al. 2016). The gabbros contain relatively high amounts of ilmenite with secondary titanite rims and xenomorphic chlorapatite. Both the gabbros and the ores are hosted by tectonized metasediments of the ductile-brittle shear zone.

Iron oxides in the ores are present as magnetite and hematite. The latter is probably the product of magnetite alternation resulting from the increase of oxygen fugacity during the hydrothermal event. They are accompanied by chlorapatite and cut by quartz-chlorite veins. The structures and textures of the ore vary from augen structure to massive and even skeletal. In the augen type, strongly deformed porphyroblasts of magnetite are surrounded by hematite-dominated matrix. In the massive ore, magnetite form porphyroblasts whereas specularite hematite is developed along extension cracks and veins. In skeletal form, significantly altered type, dendritic iron oxide aggregates are overgrown by secondary titanite and iron hydroxides.

Electron microprobe chemical analysis shows that most of iron-oxides are depleted in Ti (~0.01-0.1 wt%) as well as Zn, Mn, and Ni. The content of Al and Cr is moderate, whereas V (up to 0.35 %) and Si (0.1-0.4 %) occur in relatively higher amounts. Projection of the results on Al+Mn vs. Ti+V as well as Ti vs. Ni/Cr plots indicates that these magnetites could be related to the Kiruna-type deposits (Fig. 1).

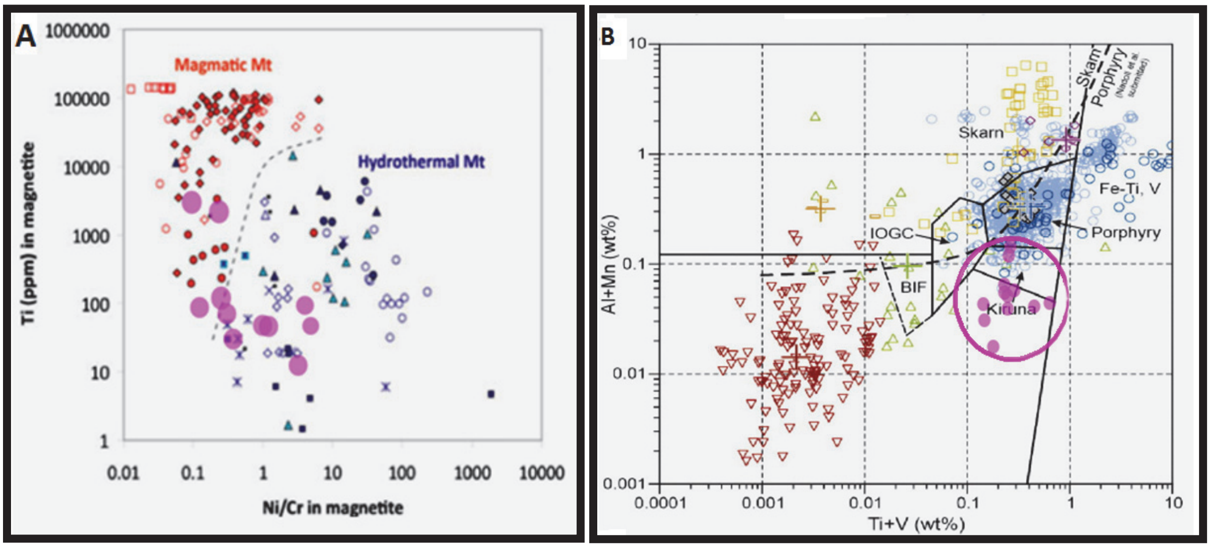

Fig. 1. *A – Plot of Ti versus Ni/Cr in magnetite. B – Al+Mn versus Ti+V in magnetite discrimination diagram. Large pink dots represent magnetite samples from Prins Karls Forland on Svalbard. All other data after Dare et al. (2014) in A and after Dupuis et al. (2011) in B*

Accessory REE phosphates, such as monazite and xenotime form ahedral inclusions, several μm in size, in magnetite crystals, less commonly in silicate matrix. Monazite is Ce- and Nd-enriched (25.5-29 wt% and 10.5-13.5 wt%, respectively). Y-xenotime is generally homogenous. However, some zones show slight enrichment in LREE. Uranium and thorium content in both minerals does not exceed 0.5 wt%. Such chemistry of these phases is typical in Kiruna-type deposits (Jonsson et al. 2016).

Co-existence of iron oxides with apatite and REE-phosphates as well as geochemical signature of magnetite indicate that the Prins Karls Forland ores belong to the Kiruna-type. However, such deposits contain usually fluorapatite and are associated with intermediate or felsic magmatic rocks (e.g. Harlov et al. 2002; Jonsson et al. 2016). The Prins Karls Forland ores seem to be associated with more mafic rocks. The presence of Ti-Fe-oxides and chlorapatite in these gabbros strengthens the possible genetic link. It is the first occurrence of such ores in the High Arctic.

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