Hydrothermal influences on zircon from the Kiruna iron apatite ore district in the Norrbotten region of northern Sweden: a comprehensive geochemical study

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The iron oxide apatite (IOA) deposits of Kiruna are the type locality for this kind of deposit, but the ore genesis is poorly understood and suggested to be either magmatic or hydrothermal. Zircon crystals separated from these highly debated iron deposits located in northern Sweden show several distinct characteristics compared to zircon from adjacent metavolcanic and intrusive rocks. Detailed zircon imaging by BSE and CL revealed complex textures in several samples. Zircon from the iron ores shows xenocrystic cores that are overgrown by "spongy", inclusion-rich rims. In contrast, zircon from the host rocks and a granite intrusion exhibit typical igneous growth zoning.

Selected zircon crystals were analysed for major and trace elements using EPMA and LA-ICPMS. While zircon grains from the volcanic host rock and granite are of near stoichiometric composition, zircon crystals from the ore contained elevated Fe, P, and LREE concentrations and low analytical totals. EPMA elemental X-ray maps reveal Ferich inclusions, veins and/or zones in zircon crystals from the ore and syenite. FTIR spectroscopy done on selected zircon grains from the ore revealed that they contained up to several weight percent of H_2O. TEM analyses show no evidence of micro- or nano- inclusions of a LREE-rich phase such as monazite within high REE-zircon, suggesting LREE occur within the zircon structure. Combined with zircon texture and their water content, it is proposed that these zircon grains experienced hydrothermal fluid alteration.

The complex nature of the zircon crystals required analyses with a high spatial resolution: U–Pb data (SIMS) suggest that the metavolcanic host rocks were emplaced and intruded by a syenite (ca. 1884 to 1880 Ma), before the ore was formed (ca. 1877 to 1874 Ma), close to the emplacement of the granite intrusion. In situ oxygen (SIMS) and Hf (LA-ICPMS) isotopic composition show clear contrasts between ore zircon ($\delta^{18}O$ ~7‰, and εHf_i = -5 to + 3) on the one hand, and zircon grains from metavolcanic host rocks and from intrusions ($\delta^{18}O$ ~3‰, and εHf_i = -6 to -10) on the other hand. The oxygen isotopic signature suggests the involvement of high-T hydrothermal fluids and the Hf isotopic compositions indicate a source region for the ore that is different from its host rocks. To explain all observations, a high temperature (~600–700°C) magmatic fluid(s), at the magmatic to hydrothermal transition, seems the most likely heat and fluid source to have remobilised the iron and concentrated it in the massive iron oxide deposits located at Kiirunavaara and smaller deposits in the vicinity.

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