

## **(Y+REE)PO<sub>4</sub>-Fluorapatite Associations in Kiruna-type Magnetite-Apatite Ore Deposits**

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Magnetite-apatite ore bodies of the Kiruna type occur worldwide and are associated with volcanic rocks, which suggests that they represent highly evolved, late-stage, igneous melts/bodies, associated with volcanism, either as surface lavas or as shallow intrusions, with a later metasomatic component. However opinion varies with regard to this origin with a sedimentary origin suggested for some ore bodies (e.g. see discussion in Naslund et al., 2002, Porter, T.M., ed., *Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective*, volume 2, PGC Publishing, Adelaide, pp. 207–226). Notable examples of Kiruna type magnetite-fluorapatite ore bodies include the Kiirunavaara ore body, northern Sweden (Harlov et al., 2002a, *Chem. Geol.*, 191, 47–72); the Mineville ore body, Adirondacks, New York, USA (McKeown and Klemc, 1956, *U.S. Geol. Sur. Bull.* (1956), pp. 9–23); the Pea Ridge ore body, Arkansas, USA (Kerr, 1998, MS Thesis, University of Windsor, 113 pp); a series of ore bodies from the Bafq Region, central Iran (Torab and Lehmann, 2007, *Mineral. Mag.*, 71, 347–363); and a series of ore bodies associated with volcanic activity in the Plio-Pleistocene Chilean High Andes and the Cretaceous Coastal Andean Cordillera (Naslund et al., 2002).

In each of these ore bodies (except the last example) monazite +/- xenotime inclusions are commonly found in areas of the fluorapatite, which have experienced obvious fluid-induced alteration in the form of (Y+REE) + Na + Si + Cl depletion (e.g. Kiirunavaara, northern Sweden; Harlov et al., 2002a) with the fluorapatite serving as the source of P + (Y+REE). Formation of monazite and xenotime inclusions in fluorapatite has experimentally been demonstrated to result from fluid aided coupled-dissolution-reprecipitation processes (Harlov et al., 2005, *Contrib. Mineral. Petrol.* 150, 268–286). Fluid sources could range from 800–900 °C, residual acidic (HCl, H<sub>2</sub>SO<sub>4</sub>) grain boundary fluids remaining after the last stages of ore body crystallization to later stage, cooler (H<sub>2</sub>O-CO<sub>2</sub>-(Na,K)Cl) fluids originating in the surrounding country rock or fluids associated with events such as regional albittization or actinolization. Re-integrating (Y+REE)PO<sub>4</sub> inclusions back into the fluorapatite indicate original (Y+REE)<sub>2</sub>O<sub>3</sub> contents ranging from 3 – 5 wt% suggesting that in addition to being mined for their iron ore, the fluorapatite in these ores could be mined for (Y+REE) as well.