Heavy rare earth potential of apatite resources

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Phosphorous is one of the three major nutrients (N, K, P) required by plants and 80-90% of the phosphate mined in the world is used to produce chemical fertilizers. Securing stable supply of phosphate fertilizers is essential to a sustainable food production considering a continuing rapid growth of world population (Van Kauwenbergh et al., 2013). The world resources of phosphate rocks are more than 300 billion tons (U.S. Geological Survey, 2015). “Phosphate rock” is the term generally used in industry to describe mineral assemblages with a high concentration of phosphate minerals, commonly francolite ($Ca_5(PO_4, CO_3)_3(OH, F, Cl)$) - apatite ($Ca_5(PO_4)_3(OH, F, Cl)$) series. There are two main types of phosphate deposits: sedimentary and igneous. The former deposits sometimes are called phosphorite and contain varieties of francolite (CO_2-rich fluorapatite), the latter mainly consist of fluorapatite (F-rich apatite) (Ihlen et al. 2014).
Apatites contain a variety of REEs in concentrations from several thousands of ppm to several wt.%. They are generally enriched in LREEs (e.g., Roeder et al., 1987), however, some apatites are rich in HREEs: apatites in sedimentary phosphate rocks (Emsbo et al. 2015) and deep sea mud (e.g., Kon et al. 2014), and igneous phosphate rocks (e.g., Hoshino et al., 2015). In addition, both Th and U contents in apatite are very low in contrast to common REE minerals such as monazite and xenotime, and this may be a big advantage over the other types of REE deposits (e.g., alkaline REE deposits). In view of the future of HREE supply (considering both feasibility and sustainability), one of the most promising sources of HREEs is apatite ores that are mined for fertilizer production, because apatite ores are sufficient in reserves and contain enough amounts of the whole REEs that can cover the world demand.

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