REE and Y enrichment in peralkaline felsic rocks of the Siwana region, Rajasthan, northwestern India

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In the modern world, rare earth elements (REE) and yttrium (Y) dominate the development of high-end electronic equipment and green energy technologies. The global economic deposits of REE and Y are primarily associated with alkaline and peralkaline igneous rocks. The REE deposit of the Siwana ring complex, Rajasthan, India, is entirely composed of peralkaline igneous rocks. This complex is made up of REE and Y-enriched (both LREE and HREE) peralkaline granite, rhyolite and its younger felsic intrusives such as rhyolite, microgranite, aplite and felsite dykes. We present a study of the REE and Y potential of granites, volcanic rocks and felsic dykes from 17 quarries in the Siwana area. Monazite, zircon and apatite were the primary (magmatic) REE-bearing phases identified under a microscope. The late/post-magmatic replacement in granite is evident as coarsening of perthite lamellae, pseudomorphic replacement of alkali feldspar grains by aegirine, replacement of aenigmatite by aegirine, etc. The granites, volcanic rocks and dykes show significant enrichment of REE + Y and other trace elements (Sn, Hf and U). A total of 20 rock samples were analysed using inductively coupled plasma mass spectrometry, which indicated significant REE + Y values ranging between 1061.22 and 9088.62 ppm, with an average of 2361.89 ppm. This includes LREE (707.42–5743.83 ppm, avg. 2080.40 ppm) and HREE (135.77–1422.23 ppm, avg. 402.41 ppm) Hf up to 425.55 ppm. Totally five samples from a soil profile were also analysed, yielding REE + Y values between 223.39 and 3175.75 ppm, with an average of 1714.51 ppm. The ion adsorption clay horizon developed within the soil profile showed a maximum REE + Y value of 3175.75 ppm.

Keywords: Alkaline granite, igneous rocks, rare earth elements, soil profile, yttrium.

phosphorescent properties. In the contemporary decades, REE deposits have been a prime target for India's mineral exploration endeavours, which may lead to the development of green energy and cutting-edge technologies in the country. About 13.07 million tonnes (mt) *in situ* monazite (containing ~55–60% total REE oxide) resource occurring in the coastal beach placer sands in parts of Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra, Gujarat, and in the inland placers in parts of Jharkhand, West Bengal and Tamil Nadu was considered to be the only exploitable REE reserve of India in the past decades. Significant resources of REE and associated rare metals like niobium have been established in northwestern India in recent times[1]. The highly valued REEs are dysprosium and terbium used in REE permanent magnets, which are not available in extractable quantities in the Indian reserves already under exploitation[1]. Based on this critical fact and recent discoveries of potential HREE reserves in peralkaline intrusive complexes and their weathering products in China, Russia and Canada, there has been a paradigm shift in the targeted host rocks for REE in the Indian subcontinent[2,3].

The Siwana Ring Complex (SRC) of the Malani igneous suite (MIS) of the Neoproterozoic peralkaline felsic magmatism in northwestern India hosts significant REE mineralization[4–7]. Previous REE explorations in SRC peralkaline rocks have revealed an abnormally high concentration of REE, and Rb, Ba, Sr, K, Zr and Nb in the Siner granites and microgranites[8–10], anomalous total REE values ranging from the 428 to 3719 ppm from the northern part of SRC[8,9], total REE up to 3.4% associated with Zr up to 9944 ppm, Nb up to 1385 ppm, Th up to 571 ppm and U up to 169.25 ppm in felsite dykes of the Phulan area[11,12], and total REE up to 2.04 wt% in Gudanal (east), 2.23 wt% in Gudanal (west), 2.15 wt% in Meli and 2.5 wt% in Bhatikhera[13].