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ORIGINAL PAPER

# Mineral processing and extraction of rare earth elements from the Wadi Khamal Nelsonite Ore, Northwestern Saudi Arabia

**Hesham M. Harbi · Abdelmonem A. Eldougdoug · M. S. El-Shahawi**

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**Abstract** A technological sample (50 kg) from Wadi Khamal Nelsonite ore was subjected to magnetic and flotation concentration techniques. Excellent recovery percentages of 72.95% and 71.22% were achieved by the dry/wet magnetic and flotation concentration techniques, respectively. The weight of the apatite concentrate reached a reasonable percentage of approximately 23.5% with an overall 40.23% $P_2O_5$ total content. Analytical data of the apatite concentrate after digestion in concentrated sulfuric acid revealed that the total content of the rare earth elements (REE) constitutes about 0.2% of the total apatite content. The REE content (0.2%) was partitioned between phosphoric acid liquor (65%) and gypsum precipitate (36%). The extraction of the REEs from the phosphoric acid liquor using oxalic acid and sodium carbonate–bicarbonate mixture (1:10 *w*/*w*) yielded the RE oxide cake which constitute about 1.2% (*w*/*w*). The produced rare earth oxide cake contains traces of various metal oxides, e.g., SrO, $Na_2O$, etc. in addition to rare earth oxides. Attempts to determine quantitatively the constituents of the cake will be considered in future work.

H. M. Harbi (✉) · A. A. Eldougdoug
Department of Mineral Resources and Rocks,
Faculty of Earth Sciences,
King Abdulaziz University,
P.O. Box 80206, Jeddah, 21589, Kingdom of Saudi Arabia
e-mail: harbihesham@hotmail.com

M. S. El-Shahawi
Department of Chemistry, Faculty of Science,
King Abdulaziz University,
P.O. Box 80206, Jeddah, 21589, Kingdom of Saudi Arabia

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## Introduction

Last decades have seen an upsurge of interest on the potential use of REE and their extraction from ores and minerals. REE and compounds find application in many advanced materials of current interest, e.g., high-performance magnets, fluorescent materials, chemical sensors, high-temperature superconductors, magneto optical disks and nickel–metal hydride batteries. Trace concentrations of REE's are present as impurities in certain ores and minerals, such as apatite, columbite, tantalite, and others. Thus, information as to its actual contents in these is necessary in order for metallurgists to choose the most suitable separation technique for economic exploitation of metals, e.g., niobium, tantalum, and samarium.

Igneous apatite deposits that are rich in apatite, magnetite, and/ or ilmenite represent an economic source of phosphate, i.e., for the production of phosphoric acid, fertilizers, and iron and/or titanium for steel industries. These deposits are associated with different types of igneous rocks, e.g., alkaline-rich intermediate and ultramafic rocks and carbonatites such as Khibiny and Kovador complexes in the USSR (Notholt 1979), Palabora carbonatite complex in South Africa (Palabora Mining Company Limited Mine Geological and Mineralogical Staff 1976), alkaline and alkaline-rich carbonatite from Brazil (Morbidelli et al. 1995; Ribeiro et al. 2005), apatite-magnetite ore associated with alkali-rich volcanic rocks of Sweden (Frietsch 1973, 1978), Sokli and Siilinjarvi carbonatite complex of Finland (Vartiainen