European Mineralogical Conference
Vol. 1, EMC2012-470, 2012
European Mineralogical Conference 2012
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Petrogenesis and REE enrichment of the Semarule Syenite, south-eastern Botswana

A.S Walters (1), P.A.J Lusty (1), R.M Key (1), A.G Gunn (1), and G Kewame (2)
(1) British Geological Survey, United Kingdom (abig@bgs.ac.uk), (2) Geological Survey of Botswana, Botswana

Due to growing global concerns about security of rare earth element (REE) supply, there is considerable interest in identifying new deposits and in understanding the processes responsible for their formation. Collaborative studies in Botswana between the British Geological Survey and Geological Survey of Botswana, focusing on the potential for REE mineralisation associated with Precambrian igneous rocks (of the Zimbabwe and Kaapvaal cratons and Limpopo Orogenic Belt) have identified elevated REE values in the Semarule Syenite, south-eastern Botswana.

The Semarule Syenite is a small, three kilometre wide anorogenic intrusion, within the Neoarchaean Gaborone Granite of the Kaapvaal Craton. It has an overall elongate WNW–ESE-trending shape, suggesting that a pre-existing fracture in the host Gaborone Granite controlled its emplacement, although the main exposure forms a crescent-shaped body. The outer northern part of the intrusion is concentrically zoned, predominantly consisting of quartz-syenite. The inner part of the intrusion is more complex and compositionally varied, consisting of medium-grained syenite, coarse to pegmatitic syenite and zoned syenite veins. A thick (∼50 metres), subhorizontal, dolerite sheet intrudes the eastern part of the intrusion.

New mapping suggests the Semarule Syenite developed from several phases of magma emplacement. An initial medium-grained, equigranular phase was intruded by a slower crystallising magma, forming a very coarse-grained to pegmatitic syenite. A final phase of syenitic magmatism involved the injection of steeply dipping, cross-cutting, zoned veins. Dolerite emplacement post-dated the main period of syenitic magmatism, although field relationships suggest it may have been contemporaneous with the late zoned veins. Newly acquired U-Pb dates have been used to develop a conceptual genetic model for the petrogenesis of the pluton and its associated REE mineralisation.

Maximum total rare earth oxide (TREO) values in the Semarule Syenite approach 3000 ppm, and the elevated values are associated with the more mafic variants of the syenite. Samples with the highest TREO concentrations display similar proportions of individual REO, ranging from 22–27% $La2O_3$, 33–40%, $Ce2O_3$, 21–23% $Nd2O_3$, 3–4% $Sm2O_3$, 6% Pr2O5 and 5–6% total heavy rare earth oxide (TREO). Chondrite-normalised REE patterns show LREE enrichment relative to HREE, with a distinct negative Eu anomaly in the majority of samples. REE-bearing minerals identified in the syenite include allanite, apatite and rarely monazite. Allanite occurs in association with apatite, as inclusions within pyroxene and garnet, and as secondary micro-veinlets cutting all other mineral phases.