HFSE and REE mineralization at Machinga prospect in the Chilwa Alkaline Province, southern Malawi

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Machinga prospect is situated at the north-eastern margin of Zomba-Malosa syeno-granitic pluton, which intruded the Precambrian basement gneiss. The syenite of the Malosa pluton are of various lithologies including quartz syenite that grade into alkaline granite. There is also a granitic pegmatite swarm chiefly associated with the mineralization at the prospect.

Petrographic observation indicates that the syenitic rocks are fine to coarse grained and comprise both quartz-rich and quartz-poor types. Alkali feldspar (including microcline) is abundant and crystals range in form from subhedral to anhedral. Plagioclase occur as tabular, equant and laths shaped crystals. They enclose small prismatic amphibole in few cases. Some zircon enclose plagioclase. Granite principally comprise interlocking alkali feldspar, microcline, plagioclase, quartz, aegerine, and magnesio-arfvedsonite. In some cases abundant eudialyte is present. Pegmatite chiefly comprises alkali feldspar, microcline, quartz, amphibole and aegerine. Alkali feldspar is subhedral to euhedral commonly forming tabular crystals and measure up to several mm in length.

A range of REE and HFSE minerals is observed in the rocks. Quartz syenite contain pyrochlore, monazite, zircon and unidentified thorium rich REE mineral. On the other hand, pyrochlore, zircon, eudialyte and monazite is observed in pegmatite. Pseudomorphs after eudialyte comprising zircon and quartz occur abundantly in the pegmatite. In the pegmatites, besides partially decomposed eudialyte, pyrochlore is also associated with the elevated concentration.

Granite and granitic pegmatite contain either eudialyte or zircon. Consequently, they were divided into zircon and eudialyte bearing types. The eudialyte-bearing granitic pegmatite shows less mineral destabilization. In the granitic pegmatite, K-feldspar replaces albite in altered tabular plagioclase cores, with associated precipitation of fine grained fluorite and secondary REE minerals.

The other observed assemblage is characterized by presence of zircon, titanite, manganoan-ilmenite and magnetite. Zircon occurs either as primary crystals or as secondary zircon that commonly outline pseudomorphs. Primary zircon displays euhedral to subhedral form and commonly interlock with quartz and alkali feldspar, either as single crystals or clusters. Mangano-ilmenite, associated with magnetite, is enclosed within the perthitic alkali feldspar. The assemblage is somewhat preserved in granitic pegmatites though late stage metasomatic overprint texture is more common.

Whole rock geochemistry data indicate that the rocks display typical characteristics of A-type metaluminous to peralkaline granitoids. They are generally enriched in REE and HFSE and are also highly ferroan. The TREE is up to 5.2 weight percent while Zr is up to 6.9 weight percent. Nb and Ta are up to 1.6 weight percent and the rocks further display high Na_2O+K_2O. The alkalinity index (Al/Na+K) values are generally below unity.

Using geochemistry and field mapping results, the study demonstrates that the rocks comprising the Machinga prospect are a product of extended fractionation of silica saturated alkaline magma. As the magma fractionation proceeded, alkaline granite were emplaced adjacent to the quartz syenite as an outer ring. And later associated granitic

pegmatite lenses crystalized as final stage of emplacement of the pluton which is supported U-Pb age of zircon in pegmatite. The concentration of HFSE and REE minerals in the rocks, including Zr, Y, La, Ce and Dy, generally increase from quartz syenite to granite and pegmatite. However the trend is not clear, especially between granite and pegmatite. This is attributed to post magmatic redistribution of the rare metals through hydrothermal/metasomatic processes.

Based on petrography and mineralogy, three stages of mineral evolution associated with HFSE and REE minerals are distinguished. The first stage crystallized zircon and related minerals whilst the last two stages besides precipitating eudialyte also involved late magmatic to early hydrothermal replacement reactions between minerals that crystalized during the second stage and metasomatic fluids. The last two stages are closely associated and likely occurred concurrently. This had two fold effect; (1) incomplete replacement of stage two HFSE minerals commonly eudialyte resulting in precipitation of secondary REE minerals such as monazite and (2) full replacement textures preserved as quartz-zircon pseudomorphs.

HFSE and REE are variably distributed in the three rocks types. However, the most elevated concentration of TREE (between 1.0 wt% and 5.2 wt %) corresponds to highest Nb+Ta+Zr concentration (between 1.5wt % and 7.5 wt %). The elevated concentration largely occur in altered/metasomatised granitic pegmatite and altered/metasomatised quartz syenite (intruded by granitic pegmatite in parts) but also correspond to relatively fresh eudialyte bearing alkaline granite.