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PARAGENETIC STAGES OF RARE EARTH ELEMENTS MINERALIZATION AT THE TUNDULU CARBONATITE OF THE CHILWA ALKALINE PROVINCE, MALAWI

There is increased demand for rare earth elements (REEs) due to their use in green technology and supply imbalance [1, 2]. Carbonatites have become target for exploration as they are generally enriched in REEs compared to other igneous rocks [3]. However, carbonatites are fully endowed with their REEs budget during the initial short lived magma intrusion and its enrichment to economic level is commonly associated with hydrothermal or metamorphic events which result in REEs remobilization [4]. We studied Tundulu Carbonatite to characterize its petrogenesis to assess its REEs mineralization potential. We integrated field observation, X-ray diffractometry, optical microscopy and scanning electron microscopy combined with energy dispersive spectroscopy to decipher the textural and mineralogy of Tundulu Carbonatite and establish a paragenetic sequence.

The Tundulu Carbonatite belongs to the Chilwa Alkaline Province of Jurassic to early Cretaceous age. The Tundulu Carbonatite is spatially related to the nepheline syenite. Based on field and petrographic observations, the carbonatite is emplaced as a ring structure with at least two igneous centers [5]. The first center is associated with the initial intrusion that emplaced the medium to coarse grained sovite, and fine to coarse grained carbonatite agglomerate. The second center is associated with the emplacement of fine to medium grained apatite-rich carbonatite, and fine to medium grained siderite carbonatite (Figure 1). From detailed petrographic observation of the samples collected, all carbonatites have variable proportion of carbonates (calcite, siderite, ankerite, strontianite, dolomite and synchysite), silicates (feldspar and biotite), oxides (hematite, pyrolusite and quartz), sulfate and sulfide (barite, pyrite and celestine), phosphate (fluorapatite, apatite) and pyrochlore. Magmatic and hydrothermal processes were responsible for considerable changes in rock texture and mineralogy. Hydrothermal activities were more effective in the second center due to probable multiple brecciation that open more space for low temperature fluid percolation [6].

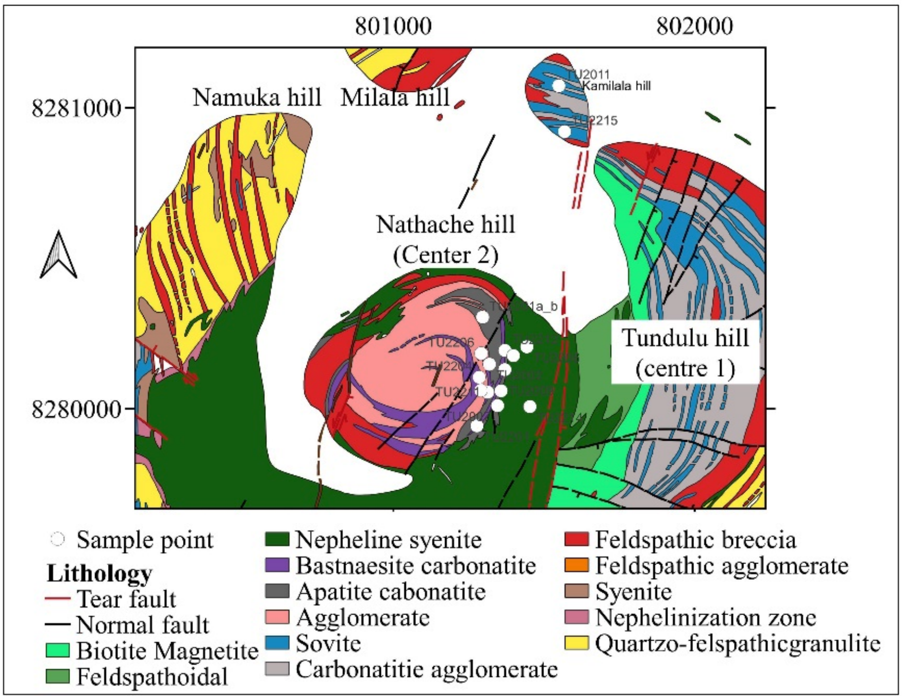

Fig. 1. Geological map of Tundulu Carbonatite showing the main two igneous centers and sample locations (Modified after [5])

Distribution of the ore minerals and micro-texture indicates variation in mineralization stages. The mineralization can be classified as primary and secondary during magmatic and hydrothermal processes, respectively. The primary REEs mineralization of the Tundulu Carbonatite characterized by calcite with comb texture and subhedral elongated apatite, synchysite occurred with syntaxial crystal intergrowth in hexagonal pseudomorphs associated with strontianite and barite [7] (Fig 2a-b). The secondary REEs mineralization is characterized by euhedral fluorapatite with dissolution texture and recrystallization that occurred as clear rim, associated with brecciated ankerite; synchysite occurs in interstitial between spaces of quartz and apatite, or overprinted hydrothermal quartz and recrystallized calcite [6] (Figure. 2c-d). The secondary minerals formed because of dissolution of carbonates and apatite as well as redistribution of REEs due to low temperature fluids that reacted with the solidified carbonate. The REEs mineralization paragenetic stages is shown in Fig. *3*.

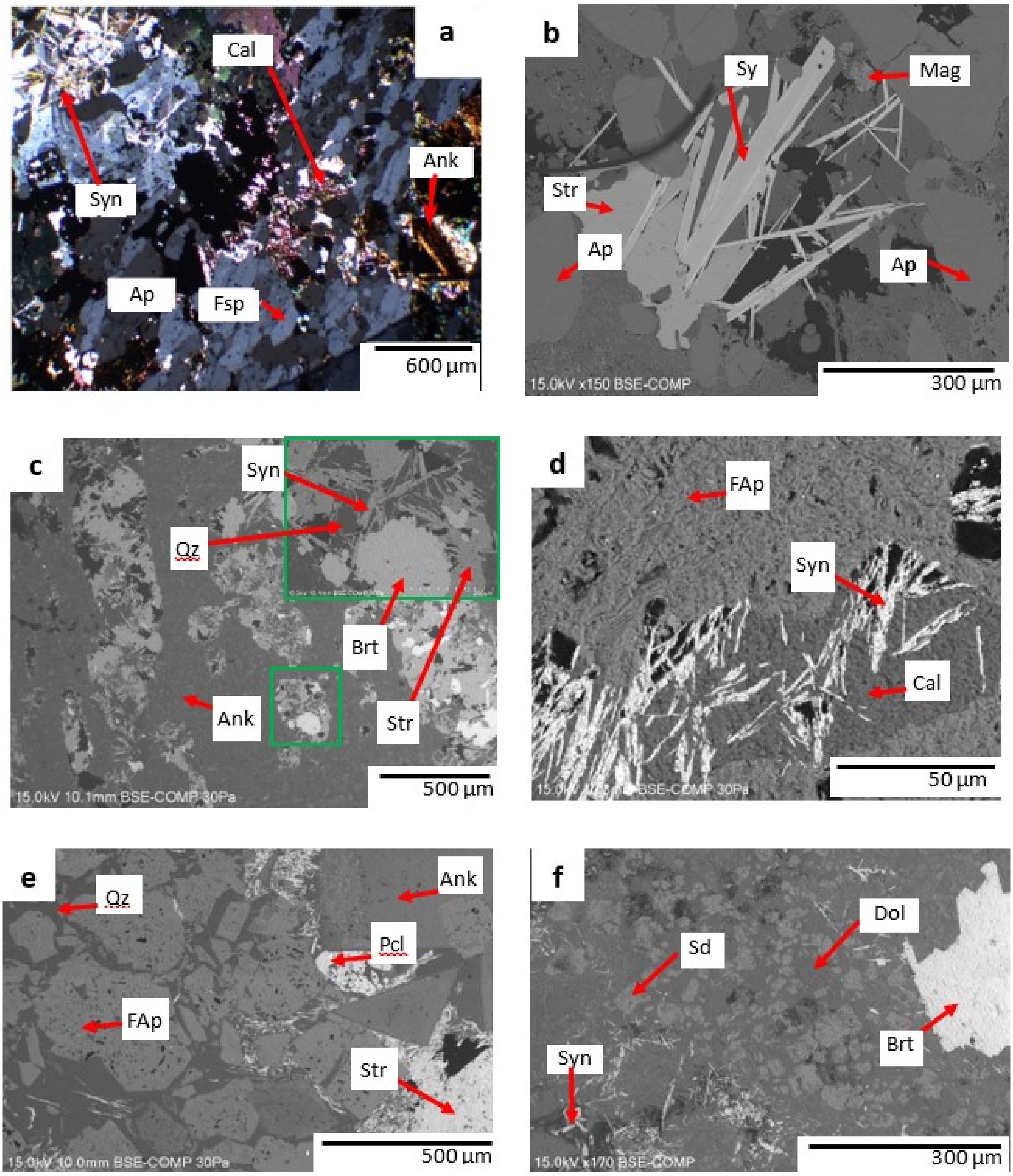

Fig. 2. Photomicrograph and back scattered electron images of samples from the Tundulu Carbonatite. (a -b) magmatic synchysite with syntax texture, subhedral elongated apatite and calcite with comb texture in soviet carbonatite (c) magmatic synchysite with syntax texture in association with strontianite and barite in

hexagonal pseudomorph in apatite-rich carbonatite, (d) re-crystallized calcite with inclusion of synchysite with fibrous texture in apatite-rich carbonatite, (e) Synchysite with fibrous texture inclusion in hydrothermal quartz in association with strontianite and apatite with dissolution texture in apatite-rich carbonatite, (f) Synchysite that overgrew dolomite that replaces siderite in siderite-rich carbonatite. Abbreviations: AFp, fluorapatite. Cal- calcite, Syn- synchysite, Qz- quartz, Pcl- pyrochlore, Str- strontianite, Brt- barite, Fsp- feldspar.

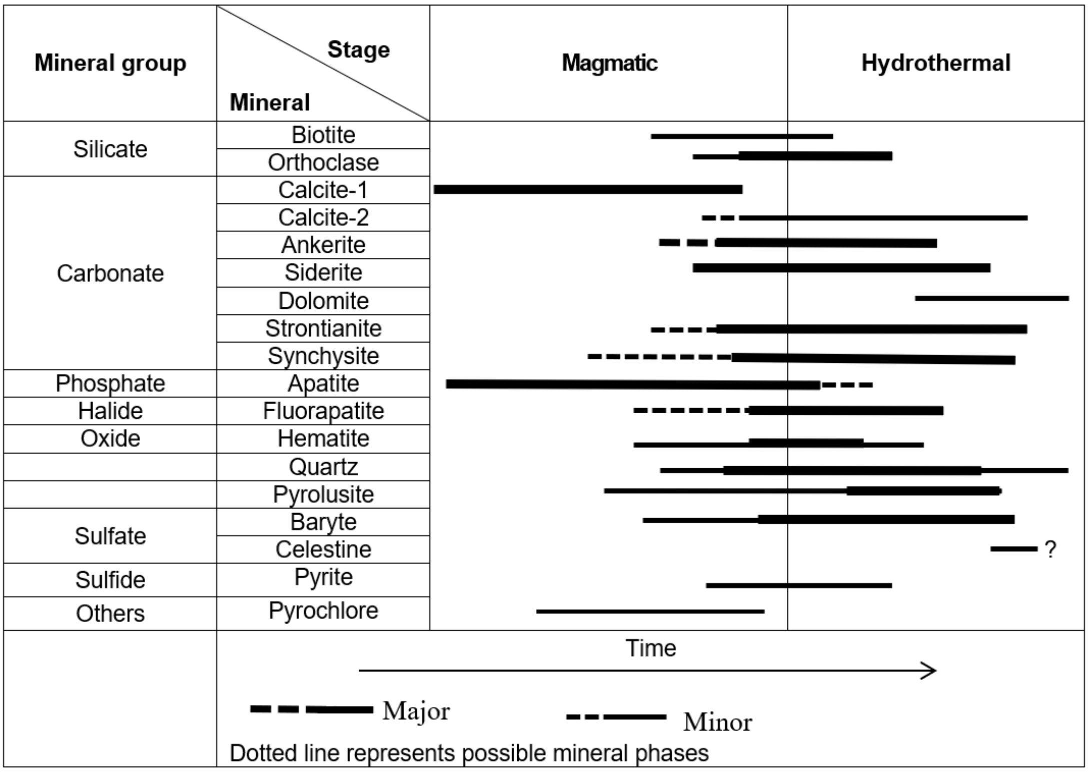

Fig. 3. REEs mineralization paragenetic sequence

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