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REE fractionation and element transfer within weathering profiles in a mild and humid climate: alteration zones of the Fen-Carbonatite Complex, Norway

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Rare earth element (REE) and major element geochemistry as well as mineralogy were investigated in profiles derived from weathering alteration of the Fen-Carbonatite Complex/Southern Norway. The climate conditions in Southern Norway are mild and humid with average annual temperatures of 9.8°C and an average annual rainfall of 770 mm. This is in strong contrast to lateritization processes in tropical areas, on which numerous studies exist.

The intrusive carbonatite complex is mainly composed of calcite- (søvite), dolomite- (rauhaugite) and iron-carbonate-dominated carbonatites as well as ultrabasic bodies, in a metasomatized (finitized) Precambrian basement. The main constituents beside carbonates are celsian, quartz, magnetite, biotite, barite, and apatite, as well as the dominant rare earth minerals monazite, parisite, bastnaesite and Nb-Ta phases. Carbonatites, alteration crusts and subsoils are studied in detail using geochemical electron microprobe and scanning electron microscopy analyses on thin sections, elemental concentration determinations and imaging spectroscopy in rock samples. The latter was used to investigate spatial gradients of local REE concentrations in rock samples and their alteration crusts.

Chemical alteration starts with the dissolution of carbonates and results in residual concentration of unweathered or slightly weathered Ba-feldspars, barite and rare earth minerals (e.g. monazite, parisite, bastnaesite and Nb-aeschnyite). Dissolution inserts at grain boundaries of carbonates. The up to 5mm thick alteration crusts are characterized by an increased porosity and permeability resulting in an increased pathway for solution agents. Here, a network of hematite, goethite and/or lepidochroite with residual silicate minerals is formed. However, in some parts a thin micritic carbonate accumulation is formed below the leaching zone. Dependant on location and protolith, secondary gypsum, hematite and Ba-phases, Al-rich chlorites and minor clay minerals are formed in the subsoils.

Higher SiO₂, Al₂O₃, Fe₂O₃, MnO and lower CaO and MgO concentrations characterize the leached alteration crusts. These trends are intensified in the subsoils. The analyses of the subsoils and leached crusts reveal a diverging behavior of the REE. In contrast to the leached crusts, with slightly higher REE concentrations, the soils show an increase in REE of up to 10 times and highly fractionated REE. The La/Yb ratio decreases significantly. The latter phenomenon is probably enhanced by the biological

activity of siderophores, complexing and transporting the REE. However, roots of moss indicate a preferential incorporation of middle to heavy rare earth elements (Tb-Er).

Mass balance calculations by isocon-modeling reveal complex solubility reactions. Most major elements are suffered by solution and removal during weathering, whereas the MREE and HREE remain nearly unaffected. Furthermore, hyperspectral data are a crucial tool for mapping the localization of REE.

