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**Rare-earth element-niobium mineralized carbonatite,  
Clay Howells Alkalic Complex, Kapuskasing, Ontario:  
significance of magnetite saturation and fractionation**

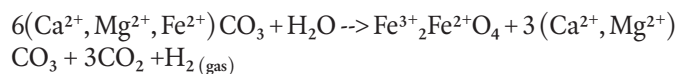
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The Clay Howells Alkalic Complex is located 40 km north-northeast of Kapuskasing in central Ontario. It is a 110 km<sup>2</sup> layered syenite – nepheline syenite – carbonatite ring dyke complex, with a parabolic ring structure for the carbonatite deposit, as defined by an airborne magnetic and radiometric geophysical survey completed by Rare Earth Metals Inc. in January 2010. Monazites have been dated using Laser Ablation – ICPMS (Pb/Pb and U/Pb ratios), returning an age of 1056.1 ± 3.9 Ma making it the youngest in that group of middle Proterozoic carbonatites. The Clay Howells REE-Nb deposit is magnetite rich and has been recently estimated at 8.5 million tonnes averaging 0.73% TREO and 0.14% Nb<sub>2</sub>O<sub>5</sub> with 44.5% Fe<sub>2</sub>O<sub>3T</sub>, with 10% of the TREO being HREO. Two arcuate carbonatitic lenses within the alkali complex have been identified with an average width of 67 m. In these magnetite cumulates, higher grades of Nb-REO have been measured, represented by 2.7% TREO (with 10% as HREO) over 4.9 m.

The (auto-)oxidation of ferrocarbonatite (ankerite) magma to crystallize magnetite during emplacement with migration to shallow depth seems to involve volatile exsolution (H<sub>2</sub>O, CO<sub>2</sub>, H<sub>2</sub>). This process may also be used to explain the crystallization of these large magnesian calcite and dolomite bodies that were an extremely fractionated Fe-Mg-rich carbonatite magma with high RE and Nb oxides at low temperature and pressure, with increasing O<sub>2</sub> fugacity. Carbonatite magmas have extremely low viscosities and liquidus temperatures that enable emplacement to shallow levels and possibly even erupt. H<sub>2</sub>O exsolution from the crystallizing ferroan carbonatite magma, possibly released H<sub>2(gas)</sub> by the reaction:



As the carbonatite melt becomes depleted in ferrous iron with oxidation, calcite and dolomite begin to crystallize with magnetite; this cogenetic crystallization relationship between calcite and dolomite grains is manifested as euhedral dolomite within calcite phenocrysts all within a dolomite host. Areas where large amounts of dolomite and calcite have crystallized also contain fractionated euhedral niobates (chiefly columbite, but locally as exsolution lamellae in pyrochlore). The euhedral and anhedral crystals form along crystal boundaries, and pyrochlore (grain size ~ 50 μm) also occurs as inclusions within magnetite. Magnetite saturation also initiates the nucleation of anhedral late-stage monazites (~ 200 μm) at crystal boundaries. General rheological properties of carbonatites below the

decarbonation threshold of 1 bar have been estimated to have a viscosity of  $5 \times 10^{-2}$  poise, density of  $2.2 \text{ g/cm}^3$ , thermal conductivity of  $1.65 \times 10^{-2}$ , thermal diffusivity of  $4.2 \times 10^{-3}$ , heat of fusion of 125, heat capacity of 2, and a thermal expansion of  $2.3 \times 10^{-4}$ . These characteristics have been used to estimate settling velocities for magnetite with diameters ranging from 0.2 to 4 mm within the range of 10–30 cm/s. The calculated settling velocities of magnetite, columbite-pyrochlore, and monazite crystals in the magnesian carbonatite are relatively similar; this produces dynamically interlayered massive magnetite and magnetite-carbonate layers, with REE and Nb abundances most enriched with the magnetite cumulates.