Nb and Zr Mineralisation Driven by Carbonatite Metasomatism at the Mt Weld Carbonatite, Western Australia

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The growing demand for Nb in green technologies, coupled with supply chain risks, solidifies it as a critical metal, currently sourced exclusively from carbonatites. Zirconium is another critical metal commonly associated with Nb, but with restricted economic in carbonatites. Instead, Zr-bearing minerals (e.g., baddeleyite, zircon) are key targets for petrochronological studies in such systems. However, many carbonatites are cumulates overprinted by carbo-hydrothermal fluids, hindering the understanding of the petrogenetic relationships of pyrochlore (main Nb mineral) and Zr-minerals during magmatic and post-magmatic evolution.

Here, we examine the Mt Weld carbonatite (Western Australia), a world-class REE deposit with significant Nb-Ta and Zr resources. The intrusion consists of an outer calcite carbonatite containing phoscorite clasts (olivine/biotite-apatite-magnetite cumulates) and inner ferroan-dolomite carbonatite. Early magmatic phases (calcite carbonatite, olivine phoscorite) were overprinted by carbo-hydrothermal fluids linked to REE-mineralisation. Alkali-rich fluids altered olivine to biotite in phoscorites and transformed magmatic baddeleyite ($\delta^{18}O$=0.15‰) into metasomatic zircon ($\delta^{18}O$=4.61‰) and, with prolonged fluid activity, into hydrothermal zircon ($\delta^{18}O$=3.97‰). The formation of pyrochlore and Nb-ilmenite (<2.5wt.% Nb_2O_5) is also related to metasomatised biotite phoscorite. Incomplete replacement of Nb-bearing baddeleyite (<2.2wt% Nb_2O_5) by zircon with associated pyrochlore±REE-rich carbonates demonstrates that baddeleyite may be an important Nb carrier during magmatic stages subsequently released to form pyrochlore.

These observations confirm that carbo-hydrothermal fluids at Mt Weld are Si-rich, as seen by common phlogopite-amphibole veinlets (often carrying fine-grained pyrochlore, zircon, and Nb-ilmenite) and uncommon quartz veins in the ferroan dolomite carbonatite, favouring formation of zircon. Similar processes in large Nb carbonatite deposits (e.g., Araxá, Catalão I, and St. Honoré) suggest SiO_2 may enhance Nb mineralisation during phoscorite metasomatism. These findings highlight the importance of carbo-hydrothermal fluids in carbonatites, not only for REE deposits, but also as a significant factor for Nb remobilisation and concentration to form higher grade deposits.