Columbite-Tantalite and Pyrochlore as Indicator Minerals for Specialty Metal Deposits

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Abstract:

Columbite-tantalite series and pyrochlore supergroup (betafite, microlite, and pyrochlore groups) minerals are the main constituents of Ta and Nb ores. They are present in carbonatites (Fig. 1), pegmatites, peralkaline intrusions, Li, REE, Be, Zr, W, Sn, and Cs-bearing deposits associated with granitoids, in saprolites overlying these deposits, in associated stream and lake sediments, and till. Based on Ta/(Nb+Ta) and Mn/(Mn+Fe) atomic ratios, members of the columbite-tantalite series [$(Fe,Mn)Nb_2O_6$ and $(Fe,Mn)Ta_2O_6$ respectively; Fig. 2] can be divided into tantalite-(Fe), columbite-(Fe), columbite-(Mn), and tantalite-(Mn) [Fig. 3]. Li-Nb-Ta-REE-Sn enriched (specialty metal) granites are known to contain predominantly columbite-(Fe) with Mn/(Mn+Fe) atomic ratio > 0.1, columbite-(Mn), and tantalite-(Mn). Pegmatite-related deposits are known to contain tapiolite [tetragonal equivalent of tantalite-(Fe)], all major varieties of tantalite, and Ta-rich end members of columbite. There is a paucity of columbite analyses from carbonatite-hosted deposits; however, preliminary compilation suggests that they contain Nb-rich columbite-(Fe) with Mn/(Mn+Fe) atomic ratio ≤ 0.15. Pyrochlore supergroup minerals (Fig. 4) are present in the same deposits as columbite-tantalite minerals (Fig. 5). Betafite [$(Ca,U)_2(Ti,Nb,Ta)_2O_6(OH)$] is common in pegmatites and present in some carbonatites. Microlite [$(Na,Ca)_2Ta_2O_6(O,OH,F)$] is found predominantly in rare element pegmatites and in miarolitic cavities in granites. Pyrochlore [$(Na,Ca)_2Nb_2O_6(OH,F)$] is characteristic of carbonatites, but is also present in other alkaline rocks. Discrimination diagrams based on composition of columbite-tantalite (Fig. 6) and/or pyrochlore (Fig. 7) minerals may allow exploration geologists to relate indicator mineral chemistry to established specialty metal deposit models. For example, Nb-rich pyrochlore and columbite-(Fe) with Mn/Mn+Fe atomic ratio ≤ 0.15 are expected in carbonatite-related specialty metal deposits, while tapiolite, microlite, and Ta-rich betafite are characteristic of pegmatite-related mineralisation.

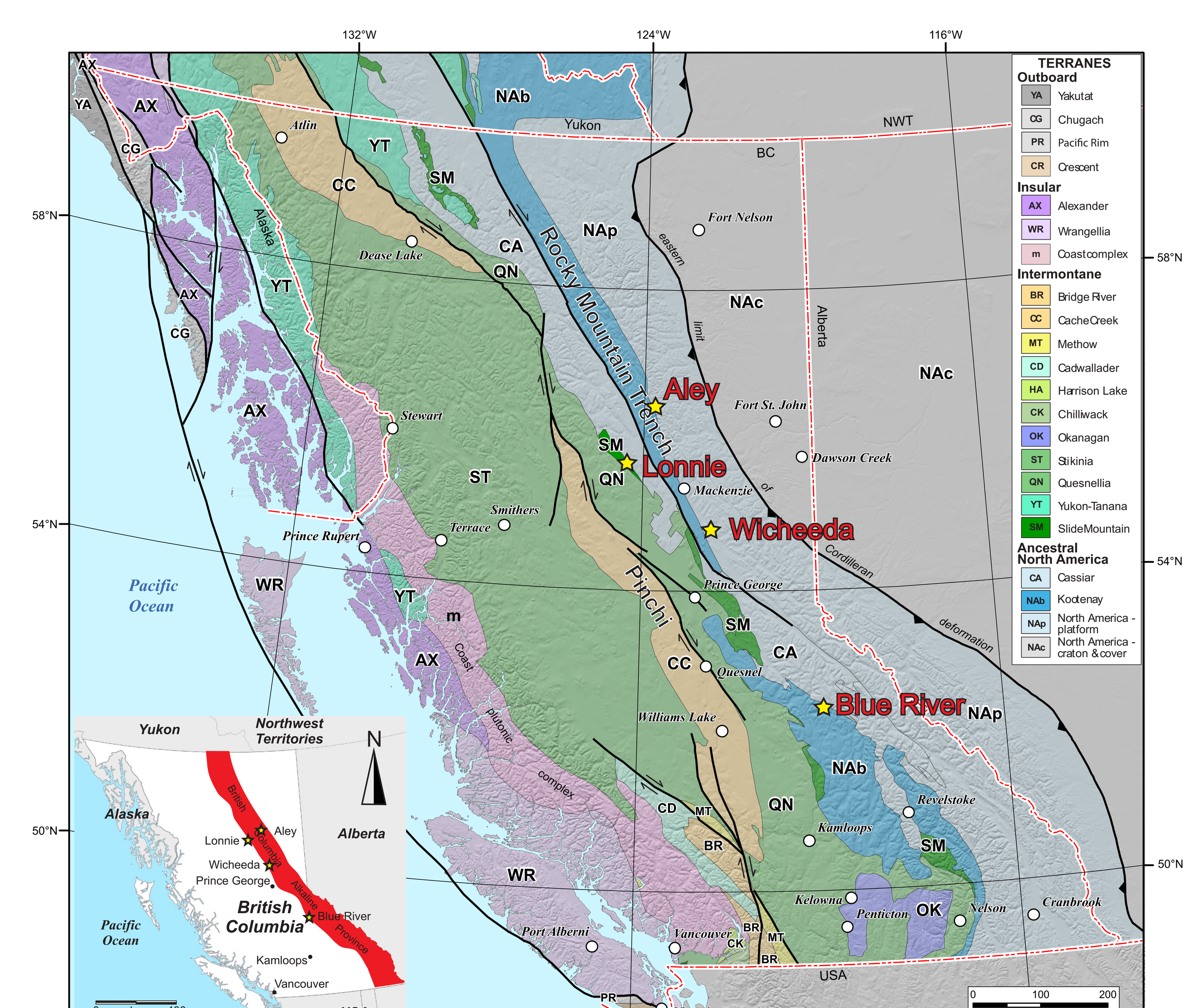

Fig. 1: Tectonic setting of selected British Columbia carbonatite complexes (yellow stars). British Columbia alkaline province shown in red (inset map). Municipalities are denoted by white circles. Modified after Colpron and Nelson (2011). Inset modified after Pell (1994).

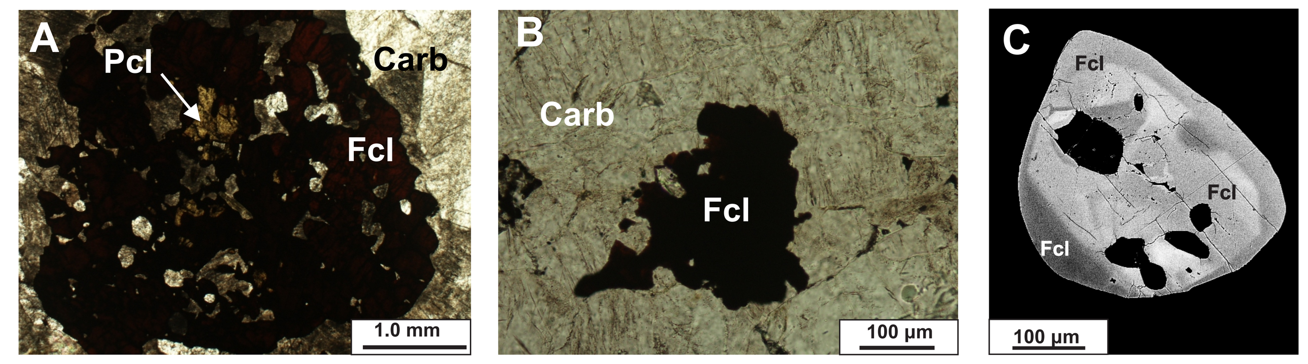

Fig. 2: Columbite-tantalite mineralisation in British Columbia carbonatites. (A) Columbite-(Fe) forming a corona around metamict pyrochlore, Lower Fir carbonatite, Blue River (plane polarised light [ppl]). (B) Columbite-(Fe) enclosed in carbonate, Lonnie carbonatite (ppl). (C) Compositional zonation of columbite-(Fe), Fir carbonatite, Blue River (Scanning Electron Microscope [SEM] backscatter image). Pcl = pyrochlore; Fcl = columbite-(Fe); Carb = carbonate; Fe-Ox = Fe oxide.

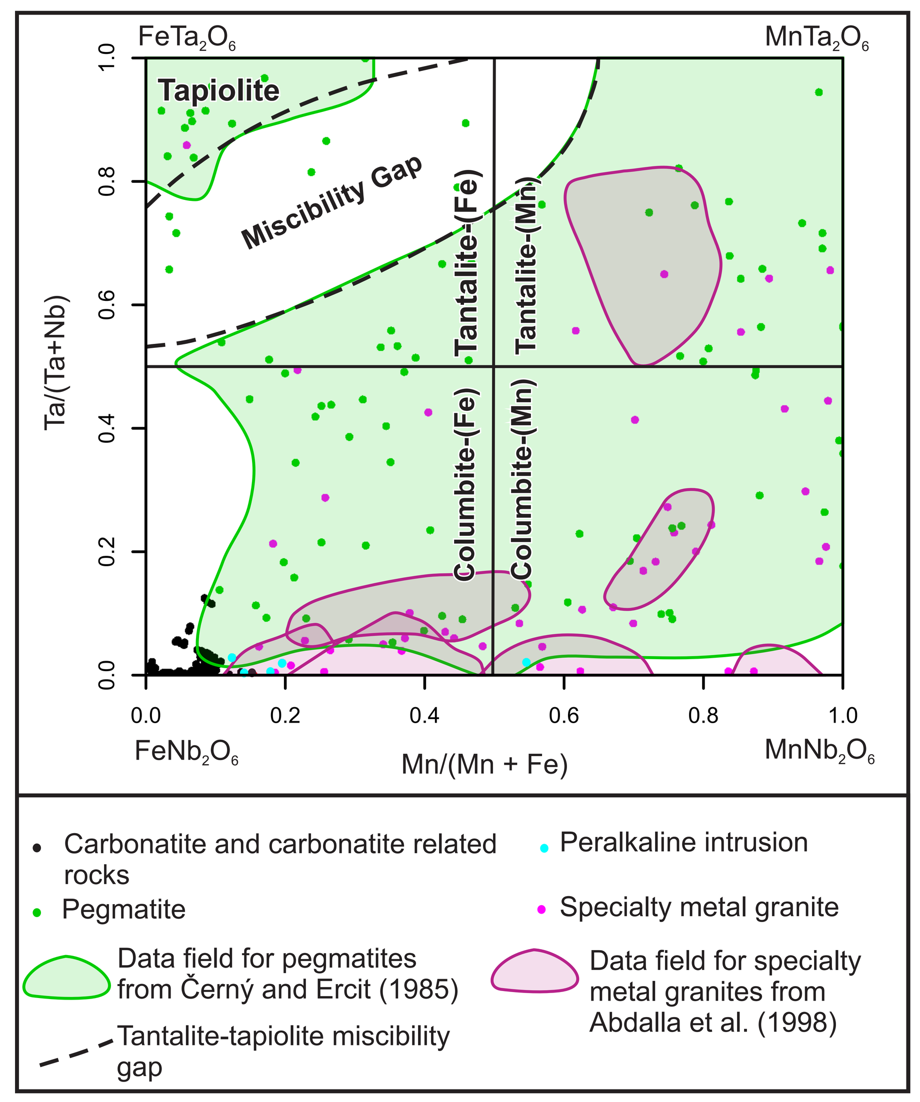

Fig. 3: Data for British Columbia carbonatites obtained by electron microprobe analysis of in situ grains, supplemented by data available in the literature from other carbonatites, pegmatites, peralkaline intrusions and specialty metal granites. Mineral classification from Černý and Ercit (1985) and Černý and Ercit (1989). The empirically derived tantalite-tapiolite miscibility gap from Černý et al. (1992) is denoted by dotted black lines.

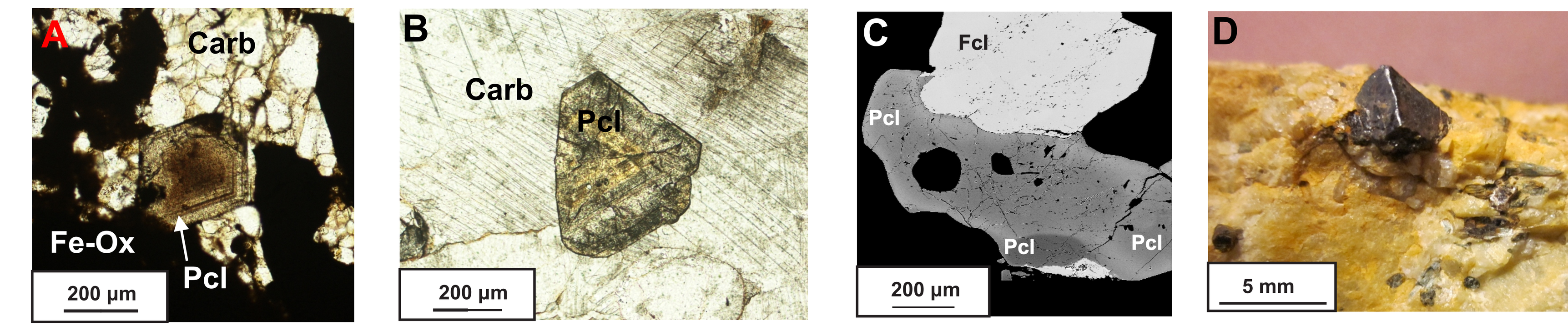

Fig. 4: Pyrochlore supergroup minerals from British Columbia carbonatites. (A) Euhedral oscillatory zoned pyrochlore, associated with Fe-oxide, surrounded by carbonate material, Aley carbonatite (ppl). (B) Subhedral oscillatory zoned pyrochlore surrounded by carbonate, Lonnie carbonatite (ppl). (C) Anhedral pyrochlore grain displaying resorption texture, in association with columbite-(Fe), Fir carbonatite, Blue River (SEM backscatter image). (D) euhedral pyrochlore, Verity carbonatite, Blue River. Abbreviations are the same as in Fig. 2.

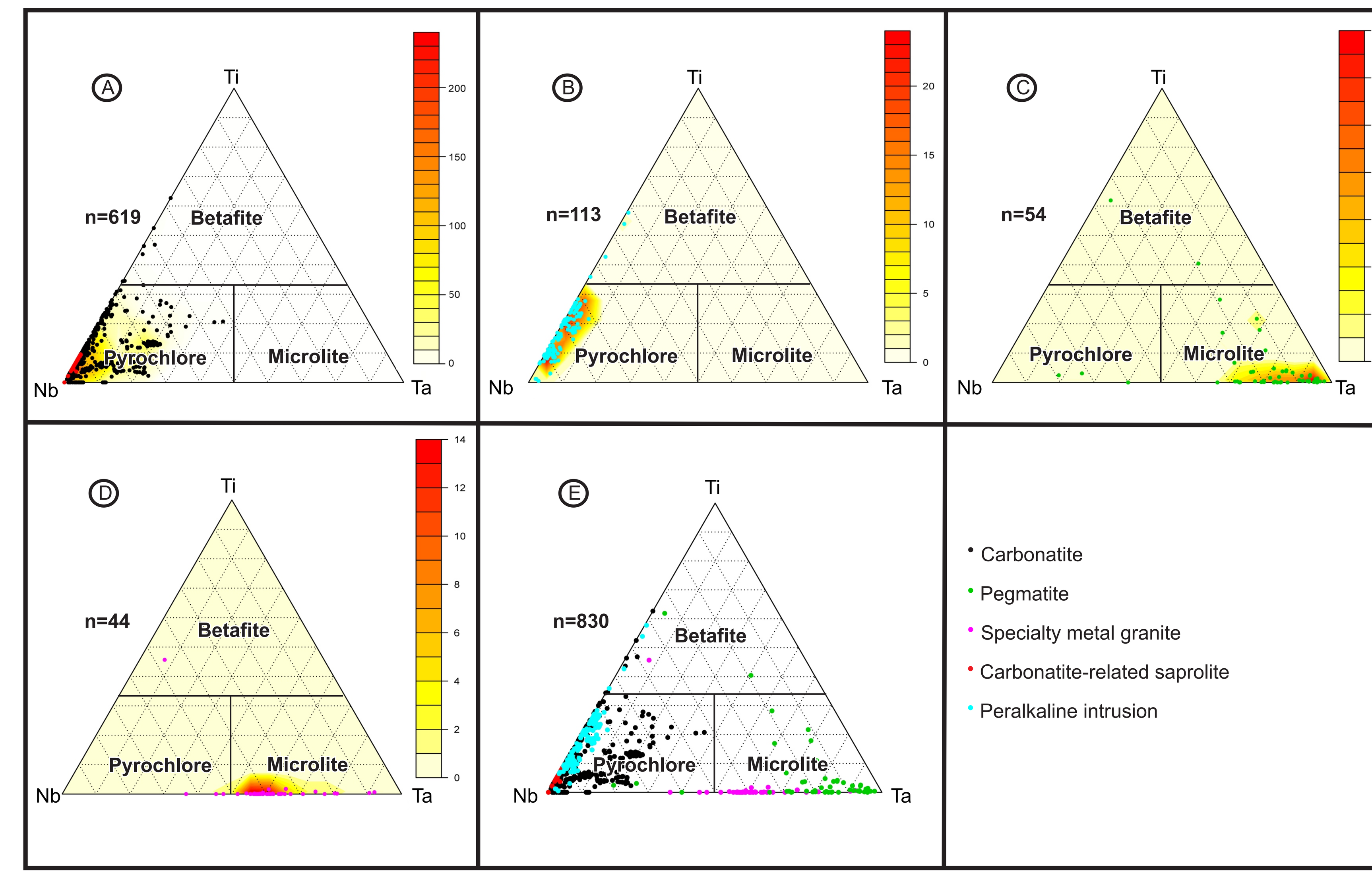

Fig. 5: Chemical compositions of pyrochlore supergroup minerals from (A) British Columbia carbonatites supplemented by that of pyrochlore supergroup minerals from other carbonatite complexes and related saprolites, (B) peralkaline intrusions, (C) pegmatites, (D) specialty metal granites, and (E) a combination of all of the above. Mineral classification from Hogarth (1977) and Atencio et al. (2010).

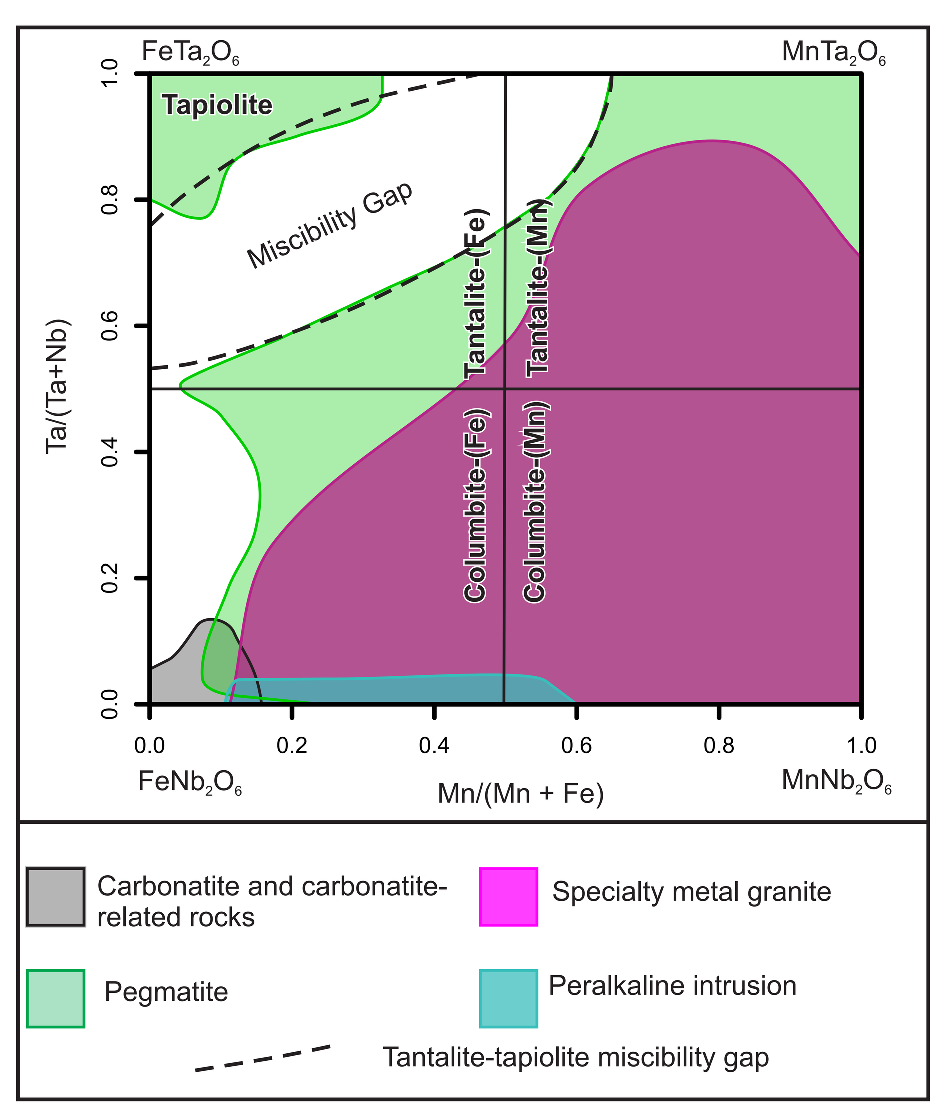

Fig. 6: Discrimination diagrams for columbite-tantalite series. Minerals from carbonatite rocks plot near the columbite-(Fe) corner of the quadrilateral with Mn/(Mn+Fe) and Ta/(Ta+Nb) ratios ≤ 0.15. Columbite from peralkaline intrusions plot along the $FeNb_2O_6$–$MnNb_2O_6$ side of the quadrilateral and have Mn/(Mn+Fe) ratios ≤ 0.6. There is overlap between columbite from specialty metal granites and pegmatites. The tapiolite field is restricted to minerals from pegmatites.

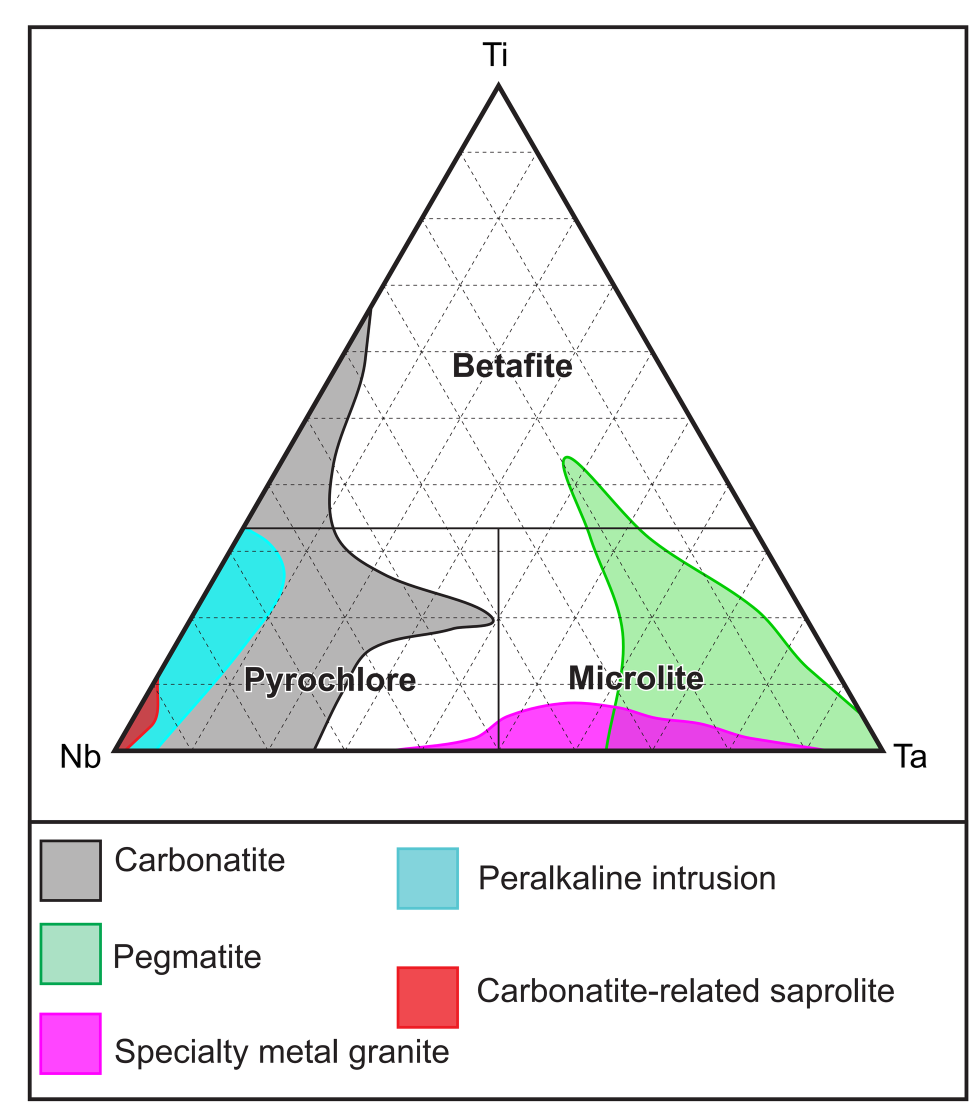

Fig. 7: Discrimination diagrams for the pyrochlore supergroup. Minerals from carbonatite-hosted pyrochlore supergroup minerals extends from Nb-rich pyrochlore to betafite. Pyrochlore from peralkaline intrusions are constrained to a narrow zone paralleling the Nb-Ti join; those from saprolites have a higher Nb content. Pyrochlore from pegmatites occupy the microlite field and extend into the betafite field. Pyrochlore from specialty metal granites occupy a narrow area of the microlite field along the Nb-Ta join and extend slightly into the pyrochlore field.

Summary:

1. The discrimination diagram for the columbite-tantalite series (Fig. 6) shows that columbite-tantalite series minerals from carbonatite-hosted deposits plot near the columbite-(Fe) corner of the quadrilateral with Mn/(Mn+Fe) and Ta/(Ta+Nb) ratios ≤ 0.15. Columbite from peralkaline intrusions plot along the $FeNb_2O_6$–$MnNb_2O_6$ join of the quadrilateral and have Mn/(Mn+Fe) ratios ≤ 0.6. There is overlap between columbite from specialty metal granites and pegmatites; however, the tapiolite field is restricted to minerals from pegmatites. There is a minor overlap of all four discrimination fields near the columbite-(Fe) corner of the quadrilateral.
2. The discrimination diagram for pyrochlore supergroup minerals (Fig. 7) shows that carbonatite-hosted deposits mainly contain pyrochlore and less commonly betafite group minerals. Pyrochlore from peralkaline intrusions are constrained to a narrow zone parallelling the Nb-Ti join; saprolites have a higher Nb content. Pyrochlore from pegmatites occupy the microlite field and extend into the betafite field. Pyrochlore from specialty metal granites occupy a narrow area of the microlite field along the Nb-Ta join and extend slightly into the pyrochlore field.
3. Ideally, both discrimination diagrams would be used together to improve their effectiveness in predictive targeting of specialty metal deposits. For example, a population of columbite-(Fe) grains plotting in the overlap between pegmatites and carbonatite (Fig. 6) does not provide a definitive answer regarding their deposit type; however, presence of pyrochlore with a carbonatite signature (Fig. 7) in the same sample will. We are currently working on binary discrimination diagrams involving a variety of trace elements. The determinative power of these diagrams remains to be tested.

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