

Peralkaline and metaluminous granitoids and volcanics of the Neoproterozoic rift-related Robertson River igneous suite, Northern Virginia, USA: Nb-Ta oxides and their alteration

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The Robertson River suite is the largest Neoproterozoic A-type granite body emplaced along the eastern Blue Ridge flank during regional Rodinia crustal extension. Eight plutons constitute the elongate (110 km by ≤ 5 km) Robertson River batholith (Tollo and Lowe 1994). U-Pb isotopic analyses of zircons indicate emplacement in two magmatic pulses: about 735–722 and 704–697 Ma. Metaluminous magmas were emplaced during both pulses and form most of the batholith. Peralkaline magmas constitute the Amissville granite and the Battle Mountain volcanic centre (Tollo 1994) that erupted unknown quantities of rhyolite during the final phase of activity. The igneous body appears to be a multiply intruded large dike-shaped sheet emplaced episodically into Mesoproterozoic basement during regional Rodinian crustal extension.

The first pulse rocks are metaluminous and includes the Rivanna granite, Laurel Mills granite, Arrington Mountain alkali feldspar granite, White Oak alkali feldspar granite, and the Cobbler Mountain alkali feldspar quartz syenite. The second pulse includes the metaluminous Hitt Mountain alkali feldspar syenite and the peralkaline Amissville alkali feldspar granite and the Battle Mountain feldspar granite, rhyolite, and felsite. The Robertson River plutons exhibit compositional and mineralogical characteristics typical of A-type granites. Composition variations include a striking enrichment in HFSE such as Zr, Nb, Y, and REE, high Ga/Al and FeO^T/MgO , and low Ba and Sr. Both metaluminous and peralkaline rocks have a plethora of accessory minerals such as Nb-Ta oxides, chevkinite mineral group, allanite, fluorcarbonates, gadolinite, zircon, monazite, apatite, calcite, siderite, and sphalerite; fluorite is ubiquitous. The major REE-bearing phases are fluorocarbonate, chevkinite group mineral, allanite, gadolinite, and a variety of Nb phases with variable REE content.

The Nb-Ta oxides occur in a wide variety of chemistry, habits, and typically show multiple generations, and alteration and deposition by late-stage fluids. To date, five major groups of Nb-Ta oxides have been identified by EPMA analysis; columbite group, fergusonite group, euxenite group, aeschynite group, and the pyrochlore super group. The nomenclature distinctions except columbite were based on the three-group model of Ercit (1995). No crystallographic investigations were attempted and we assume considering their U and Th content that most are metamict. The columbite group represented by columbite-(Fe) and columbite-(Mn) has been observed in both metaluminous and peralkaline units. $\text{Ta}/(\text{Ta}+\text{Nb})$ is very low, all below 0.06; TiO_2 averages 2.5 wt% and $\Sigma\text{REE}+\text{Y}$ is ≤ 1 wt%. Most columbite is in the range of 0.3 to 0.6 $\text{Mn}/(\text{Mn}+\text{Fe})$, however, the Rivanna granite columbite-(Fe) has $\text{MnO} \leq 0.1$ wt%. The fergusonite group is the most abundant Nb-Ta oxide and has been observed in most of the Robertson River suite. The only member, fergusonite-(Y) is HREE enriched, with FeO^T 0.1 to 4 wt%, TiO_2 0.2 to 3 wt%, PbO 0.3 to 0.5 wt%, CaO 0.1 to 1 wt%, ΣREE averages 16 wt%, Y_2O_3 averages 28 wt% with variable amounts of UO_2 and ThO_2 , usually ≤ 1 wt%. The aeschynite group, to

date, has been found only in the peralkaline granites. Three members, all LREE enriched, have been identified based on dominant cation in the A and B sites, aeschynite-(Nd), nioboaeschynite-(Ce), and nioboaeschynite-(Nd). All have CaO 1 to 3 wt%, FeO^T 1 to 2 wt%, ThO₂ 0.5 to 5 wt%, ΣREE averages 30 wt%, and Y₂O₃ averages 3 wt%. The euxenite group was recognized in both the metaluminous and peralkaline units; two members polycrase-(Y) and euxenite-(Y) were distinguished based on the dominant B-site cation. Both members have FeO^T 0.1 to 4 wt%, PbO 0.3 to 0.5 wt%, CaO 0.4 to 4 wt%, ΣREE averages 10 wt%, Y₂O₃ averages 20 wt% with variable amounts of UO₂ and ThO₂ that range from 0.2 to 4 wt%. Members of the pyrochlore super group have been identified in both the metaluminous and peralkaline units. This group is the most chemically variable; fluorcalciopyrochlore, calciopyrochlore, and a probable mixed pyrochlore species were observed. Nb is the dominant B-site cation in all analyses. In all members, TiO₂ ranges from 5 to 8 wt%, with variable UO₂ and ThO₂ 0.5 to 12 wt%, PbO 0.1 to 6 wt% and ΣREE ranges from 0.2 to 8 wt%.

The Robertson River suite is enriched in HFSE and Ga. The maximum values are as follows: Ga varies from 41 to 54 ppm in the metaluminous rocks and 58 and 87 ppm in the peralkaline Amissville and Battle Mountain units respectively, Zr ranges from 178 to 2402 ppm in the metaluminous suite and from 2469 to 4055 in the peralkaline rocks, Nb ranges from 47 to 97 ppm in the metaluminous units to 203 to 312 ppm in the two peralkaline units, and ΣREE+Y vary from 367 to 1685 ppm in metaluminous rocks to 1167 and 8253 ppm in the Amissville and Battle Mountain peralkaline units, respectively. The Nb/Ta w/w whole rock ratio varies from 7 to 30, however, most are below chondritic value of 19.9 and range from 10 to 18. This is in contrast to the Zr/Hf w/w whole rock values where most are superchondritic, >34.4. In both cases, their ratios are not correlated to abundance. The Nb/Ta w/w values of the Nb-Ta oxide minerals are far more varied than those in the host rocks, especially in the fergusonite and euxenite groups. The Nb/Ta w/w values in both fergusonite and euxenite groups vary from 11 to 300 with many with Ta analyses below the EPMA detection limit of 0.1 wt%.

Alteration in all the Nb-Ta groups except columbite is pervasive and can make interpretation of EPMA data sometimes difficult. The fergusonite, euxenite, and aeschynite groups appear to alter mainly by hydration with the addition and loss of major constituents. Si, Al, and Fe typically increase with Ti, Th, U and Pb increasing in some grains. Losses in Y and REE are major, although Nb tends to be less affected in some grains. The significant loss of Y and REE together with the identification of very late stage Y-REE phases suggest that using Y and REE related ratios to distinguish among magma sources may be questionable. Pyrochlore group alteration is by hydration and A-site cation loss and addition, especially Ca and Pb. The alteration systematics of the Nb-Ta minerals suggests that a late-stage, highly reactive aqueous fluid moved through the rock during the early cooling process. Ta appears to have been relatively mobile, although the details of its movement and precipitation are yet unknown.

References:

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