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Mineralogy and geochemistry of the Late Neoproterozoic rare metal granitoids of Gabal El-Ineigi pluton, Northern Arabian-Nubian Shield, Egypt

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Gabal El-Ineigi granitoid pluton is situated in the Central Eastern Desert of Egypt and is considered as one of the good examples of the fluorite bearing rare metal granites in the Arabian Nubian Shield (ANS). It constitutes a multiphase pluton consists of porphyritic syenogranites (SG) and coarse to medium grained highly evolved alkali-feldspar granites (AFG) intruded into the older granodiorites and metagabbro-diorite rocks. Petrographic features indicate that quartz, K-feldspar (perthite, Or_{97-99}), plagioclase (albite, An_{0-6}) and biotite are the major mineral phases of both granitic types with subordinate muscovite that is observed only in the AFG. Columbite, rutile, fluorite, zircon and thorite are the significant accessory minerals in the AFG while, allanite is exclusively encountered in the SG. Mineral chemistry study reveals that Nb-Ta-Ti-bearing oxides [columbite-group minerals (CGM)] and Nb-bearing oxides (ilmenorutile) represent the most common Nb-Ta host in the AFG. The CGM are represented mostly by complex zoned columbite-(Fe) and rarely by yttrocolumbite-(Y), with Mn/(Mn+Fe) ratios ranging from 0.17 to 0.31. Xenomorphic fluorite (F=46-51 wt%) is commonly filling the spaces between the major mineral phases and sometimes host rare metal minerals, e.g. columbite and thorite. Euhedral zoned allanite (Ce-Nd) is the common REE bearing mineral encountered in the SG. Geochemically, Gabal El-Ineigi granitoids are metaluminous (A/CNK= 0.95-0.99) related to post-collosional A2-type granites. The late phase AFG have distinctive geochemical features typical of rare-metal granites. They are highly fractionated calc-alkaline granitoids characterized by high Rb, Nb, Y, U and many HFSE contents, and extremely low Sr and Ba contents (4-35 and 13-18 ppm, respectively). Moreover, their REE patterns show pronounced negative Eu anomalies (Eu/Eu*=0.03 - 0.05) and tetrad effect (TE1,3=1.16 and 1.42), implying extensive fractionation via fluid-rock interaction that characterize the late magmatic stage differentiation. On the other hand, the SG are remarkably enriched in Sr and Ba (58-76 and 299-422 ppm, respectively) and show a relatively invariable enrichment in light rare earth elements (LREEs). The extremely high $^{87}Sr/^{86}Sr$ (1.7491-2.5376) ratios of the AFG is almost related to the disturbance in the Rb-Sr isotope system at the proposed high temperature magma-fluid interaction. On the other hand, the Sr-Nd isotope systematics of the SG are characterized by a high initial $^{87}Sr/^{86}Sr$ ratios of 0.7087-0.7109 and εNd(t) values of +4.7 to +5.8, with depleted mantle model ages (t_{DM}) between 0.82 and 0.98 Ga, implying a juvenile magma source of Neoproterozoic age, typical of other granitoids from the ANS continental crust.