Mineral chemistry and U-Pb geochronology of columbite group mineral, cassiterite and monazite indicate mutiple stage mineralization in the Zhaojinggou rare metal deposit, Central Inner Mongolia, North China

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The Zhaojinggou rare metal (Nb,Ta,Rb) deposit, located in the western segment of Inner Mongolian Axis, belongs to the gold and rare-metal metallogenic belt in the northern margin of North China Craton. Among the Zhaojinggou highly evolved granite to pegmatite complex, three major granites containing Nb-Ta oxides are albite granite (AG), aplite (AP) and biotite alkali-feldspar granite (BG). Nb-Ta oxides in AG present in anhedral granular texture and belong to columbite-(Mn) end member, showing oscillatory and normal zoning and with $Mn^{\#}$ (0.480-0.897) and $Ta^{\#}$ (0.043-0.601) increasing from core to rim. Nb-Ta oxides in AP display fine grain texture and homogeneous composition, with narrow $Mn^{\#}$ (0.157-0370) and $Ta^{\#}$ (0.154-0.196) range, falling into columbite-(Fe) field. Nb-Ta oxides of BG occur in euhedral granular aggregate or columnar texture and belong to columbite-(Fe) end member, showing normal zoning and with elevated $Mn^{\#}$ (0.349-0.390) and $Ta^{\#}$ (0.056-0.228) from core to rim. Laser ablation-inductively coupled plasma-mass spectrometry U-Pb dating of columbite-(Mn) from AG and columbite-(Fe) from BG yielded distinct Tera-Wasserburg lower intercept age of 133.4 ± 2.6 Ma and 121.2 ± 2.6 Ma, respectively. Cassiterite from AG yielded weighted mean $^{206}Pb/^{238}U$ age of 130.4 ± 0.8 Ma, similar to the age dated by columbite-(Mn). Monazite from AP with hematitization and amazonitization yielded consistent weighted $^{208}Pb/^{232}Th$ age of 132.4 ± 0.9 Ma and 132.2 ± 0.6 Ma, respectively. On the basis of these results, we propose that there are two-stage Nb-Ta mineralization episodes in the Zhaojinggou deposit during the Early Cretaceous, showing different Nb-Ta mineral chemistry, and the first-stage Nb-Ta mineralization related to AG and AP at 130 Ma and second-stage linked with BG at 120 Ma. The granitic intrutions formed both at 130 and 120 Ma might be new potential candidates for rare metal exploration in this region.