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Crustal transtension and associated high-T/low-P metamorphism in the North Tianshan Arc, NW China

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The crustal evolution of the North Tianshan during the late Paleozoic remains controversial due to the lack of structural and metamorphic constraints. We present new structural, petrological and geochronological data of the Xiaopu metamorphic complex (XMC) to address this issue. The XMC shows a well-preserved Buchan-type metamorphic sequence made of garnet, andalusite-staurolite and sillimanite zones. Structural observations indicate that garnet, sillimanite, andalusite and staurolite grew syn-kinematically during a transtensional event (D2). Inclusion trails in garnet cores oriented at high angle with the external foliation probably record an earlier deformation stage (D1). Synchronous ductile normal faults and thrusts (D3) overprinted previous structures and control the exhumation of the metamorphic complex. LA-ICP-MS zircon U-Pb ages of pre-D2 gneissic granodiorite, syn-D2 granitic dikes and post-D2 diorites constrain the occurrence of D2 between 332 and 305 Ma. Apatite U-Pb ages of mylonitic rocks from the ductile fault indicate that D3 occurred at ~285 Ma. Phase modelling and geothermobarometers were used to estimate the pressure-temperature (P-T) conditions of the XMC. Peak conditions show progressive temperature increase from andalusite-staurolite schists (~580 °C) to sillimanite migmatites (~680 °C) at nearly constant pressure (~4 kbar), suggesting a significant thermal effect of nearby large intrusive bodies. The schists display a pre-peak heating with slight decompression and the migmatites show retrograde cooling and decompression to ~600 °C and ~3 kbar. Their P-T paths and high/T and low/P thermal regimes are in line with an extensional setting. Monazite U/Th-Pb ages of 313-311 Ma for sillimanite-bearing schists and migmatites suggest monazite growth during the retrogression. ⁴⁰Ar/³⁹Ar ages of mica from sillimanite schists are in the range of 298-275 Ma, consistent with a later cooling and exhumation associated with D3. These data reveal the crustal transtension during the middle to late Carboniferous (~330-310 Ma) and cooling and exhumation during the early Permian (~285 Ma) of the North Tianshan arc. Such transtensional tectonics probably facilitated decompression melting of the lower crust and lithospheric mantle of the arc. Subsequent ascent and emplacement of the resulting melt could yield high thermal gradient, produce partial melting of the mid-crustal rocks and promote crustal exhumation.