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Ar/Ar geochronology in the western Tianshan (northwestern China):

from Carboniferous (ultra)high-pressure metamorphism and thrusting to Permian strike-slip deformation and fluid ingress

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BACKGROUND

The Tianshan large-scale tectonic system

The Palaeozoic tectonic systems of Tianshan comprises a number of belts with ophiolitic mélanges and (ultra)high-pressure metamorphic rocks. These formed after closure of oceanic and back-arc basins that resulted in terrane collisions. We studied one of them: the Changawuzi-Kekesu metamorphic complex that comprises metagraywacke-like metasediments that contain lenses and blocks of ultramafic rocks, marbles and eclogites with blueschist layers.

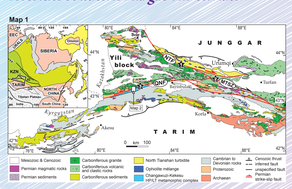
Our Ar/Ar laser-probe data show that (ultra)high-pressure metamorphism is of Late Palaeozoic age, not of Triassic, as suggested by some SHRIMP zircon ages in recent literature.

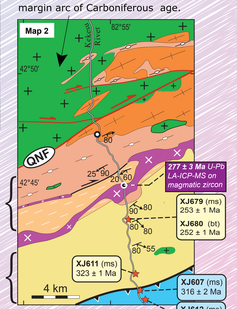
Our combined Ar/Ar, structural and geochemical multi-disciplinary approach revealed that tectonism evolved from overthrusting in Late Carboniferous time, producing (ultra)high-pressure metamorphism, to large-scale strike-slip faulting in the Permian [*1; 2*]. During this period, the magmatism compositionally changed from highly fractionated calc-alkaline (Late Carboniferous) to alkaline (Permian) [*3*]. The transition took place around Carboniferous-Permian boundary time, i.e. ca. 300 Ma. This suggests that the conditions for dehydration melting of the mantle wedge ceased to exist. Permian bimodal magmatic activity was concentrated in brittle-ductile strike-slip fault zones, and thus post-collisional with respect to docking of terrains.

$^{40}Ar/^{39}Ar$ Dating of White Micas and Biotite

Instead of trying to date the peak pressure conditions we focus on Ar/Ar analysis of white mica formed during retrograde recrystallisation when the (ultra)high-pressure metamorphic rocks were exhumed. Single grains that were separated from rocks were step-heated with a defocussed laser beam. Plateau ages were calculated if >70% of the $^{39}Ar_k$ was released in at least three or more contiguous steps, the apparent ages of which agreeing to within 1σ of the integrated age of the plateau segment. Pseudo-plateau ages meet these criteria for segments representing <70% of the ^{39}Ar released. All errors are quoted at 1σ level.

Tectonics southern margin Yili terrane

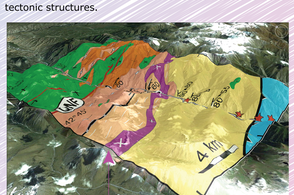




The Yili terrane formed part of a continental margin arc of Carboniferous age.

Ductile deformation fabrics with weakly plunging lineations related to movement along the dextral Permian Qingbulak-Nalati strike-slip fault (QNF).

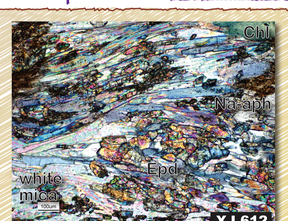
The Yili terrane's southern margin is overthrust by (ultra)high-pressure metamorphic rocks, producing steeply southward plunging stretching lineations and top-to-the-north shear. This event produced main phase tectonic structures.



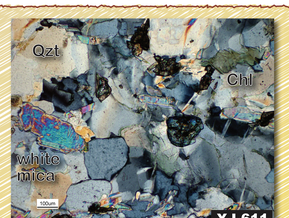
The synkinematic Kekesu K-granite (LA-ICPMS U-Pb zircon age: 277 ± 3 Ma [*3*]) intruded the ductile QNF strike-fault zone close the basement-cover contact.

Partially retrogressed blueschists and metasediment samples

XJ607 is a foliated and lineated garnet-bearing blueschist that contains substantial amounts of chlorite and white mica. White mica generally occurs in chlorite-rich layers as 500-1500 µm long tabular strain-free crystals, or as aggregates, and may be intergrown with chlorite along their basal cleavages.



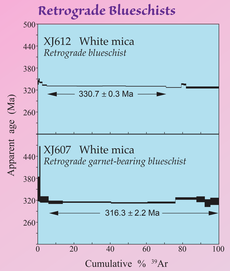
XJ612 a lineated blueschist with a principal foliation that is defined by differences in modal amounts of preferentially orientated blue amphibole and epidote, along which green chlorite and white mica (150-1500 µm long) have grown, which are in part intergrown along their basal cleavage.



XJ611 is an inequigranular garnet-bearing chlorite-mica quartzite with an ill-defined foliation. White mica occurs as 100-1000-µm-long and strain free crystals in the quartz matrix. In contrast to XJ607 and XJ612, garnet in this sample is devoid of glaucophane inclusions, and not chloritized.

$^{40}Ar/^{39}Ar$ Age Spectra

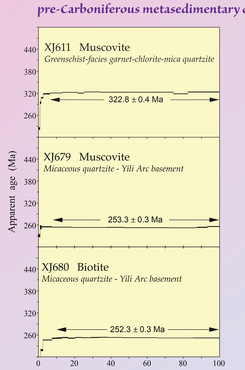
Retrograde Blueschists



White mica from the strongest retrogressed blueschist (**XJ607**) taken immediately above the basal thrust fault of the Changawuzi-Kekesu belt gave the youngest Ar/Ar plateau age of 316 ± 2 Ma (94% ^{39}Ar release). White mica from a more moderately retrogressed blueschist (**XJ612**), at a structurally higher tectonic position, yielded a slightly older pseudo-plateau age of 331 ± 1 Ma (66% ^{39}Ar release).

Changawuzi-Kekesu thrust fault

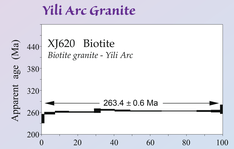
pre-Carboniferous metasedimentary cover of Proterozoic basement Yili terrane



Quartzite **XJ611** was taken at about 1 km below the thrust contact with the overriding Changawuzi-Kekesu belt. White mica gave a plateau age of 323 ± 1 Ma (96% ^{39}Ar release).

Two quartzites from deeper levels in the metasedimentary cover series were taken at less than 2 km from an over 20 km long sill of the massive Early Permian Kekesu granite. Strain-free crystals (at least 500 µm long) of muscovite (**XJ679**) and biotite (**XJ680**) yielded much younger concordant plateau ages of 253 ± 1 and 252 ± 1 Ma, respectively, over virtually the entire gas release. Muscovite XJ679 has a subtle saddle shaped age spectrum.

Yili Arc Granite



Sample **XJ620** (Map 1; star 3) is from an unfoliated, biotite granite (LA-ICPMS U-Pb zircon age 313 ± 4Ma [*3*]). The huge pluton pluton is located at about 5 km across strike from the Qingbulak-Nalati strike-slip fault, within the 15-20 km wide zone with steeply dipping tectonic fabrics bordering the fault. Biotite in this strain-free magmatic rock occurs as ca. 500 µm long equidimensional grains, and yielded a plateau age of 263 ± 1 Ma over almost the entire gas release.

Interpretation

The age of the (ultra)high-pressure metamorphism

The (ultra)high-pressure metamorphism in the Tianshan is generally regarded to have occurred in the Early Carboniferous based on multi-method isotopic ages of 345-350 Ma. This is about 100 Ma older than recently published SHRIMP ages on zircon for this event, see [*1, 2*] for a review. These Permian and Triassic ages would imply that this early orogenic event is as young as the final stages of gold mineralisations, which occurred by convective fluids channeled in Permian strike-slip fault, associated with post-suturing alkaline magmatic activity.

The saddle shape of the age spectrum of white mica XJ607 from a retrograde blueschist suggests chemical heterogeneities at the grain scale. This can be assigned to the observed partial recrystallisation of older phengite and/or new growth of more muscovite-rich mica during re-eqilibration when the (ultra)high-pressure metamorphic rocks were exhumed. This mechanism is discussed in detail in a separate poster A254 EGU2012-5231 [*5*].

Exhumation of the (ultra)high-pressure metamorphic rocks was coeval with their northward thrusting over the southern margin of the Yili terrane. The ages obtained for the thrusting coincide with a Late Carboniferous timing of the waning stages of calc-alkaline magmatic activity in the Yili continental margin arc.

Meaning of Permian $^{40}Ar/^{39}Ar$ ages

The granite that yielded 263 Ma-old biotite XJ620 lacks deformation fabrics that may be related to the tectonic imprint of the nearby Permian Qingbulak-Nalati strike-slip fault. This date is much younger than the 313 Ma intrusion age, and the age difference too large to be explained by slow cooling. Ca. 252 Ma-old white mica XJ679 and biotite XJ680 are from metasediments that have a steeply plunging lineation. This shows that these rocks too are not affected by dynamic recrystallisation related to ductile strike-slip deformation.

The youngest micas are about 25 Ma older than a 277 Ma-old K-granite that occurs less than 2 km across strike and intruded a splay of the Qingbulak-Nalati strike-slip fault. Thus, we do not interpret the ca. 250-265 Ma mica ages by the direct thermal effect of intruding granite, but by recrystallisation of the mica by fluid flow, which may be late magmatic, channelled into these steep zones. The slight saddle shape of the muscovite age spectrum, indicative of minor chemical heterogeneities of mica due to new growth and/or its partial recrystallisation, agrees with interpretation. See separate poster A254 EGU2012-5231 for a detailed discussion of this mechanism [*5*].

Take home messages

- Fluid-mediated recrystallisation of mica may lie behind our finding of young (Permian) $^{40}Ar/^{39}Ar$ ages.
- Our Late Carboniferous $^{40}Ar/^{39}Ar$ age for northward thrusting of the (ultra)high-pressure metamorphic complex over the Yili arc's southern margin coincides with the waning stages of calc-alkaline magmatic activity in the arc.
- Unrealistically young isotopic ages for early orogenic eclogites also relate to fluid-mediated recrystallisation processes that occurred well after Late Carboniferous suturing.
- The saddle shape of some white mica age spectra suggests minor chemical heterogeneities at the grain scale, which are due to partial recrystallisation or new growth of the mineral.

MORE TO EXPLORE

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