# Implication of stepwise heating and UV laser ablation $^{40}Ar$-$^{39}Ar$ and U-Pb data on the timing of ductile movement in the Irtysh Shear Zone and the Kalbinsky granite magmatism (East Kazakhstan)

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The NW-trending Irtysh Shear Zone (ISZ) separates two domains with different geotectonic settings (Fig. 1). To the NE, the Rudny Altay domain with a Middle Devonian to Lower Carboniferous island arc setting and to the SW, the Irtysh-Zaysan domain with pre-Middle Carboniferous accretional sequences and Middle-Upper Carboniferous collisional complexes. In the second domain, the Kalba-Narym batholith is NW-trending, elongated over more than 300 km (Lopatnikov *et al.*, 1982) and generally at about 20–30 km distance from the ISZ, although affected in some places by the shearing. The Kalbinsky granite complex, with rock varietyes showing S-features, represent the biggest volume inside the batholite. In the NE part, ductile deformation is often oveprinting rocks belonging to an earl phase of this complex while the latest granite-leucogranite veins, basic dikes and lamprophyres of the Mirolubovsky complex are not deformed. A better knowledge of time relations between ductile deformation and granitic magma emplacement is important for understanding the activation mechanism of the ISZ and the reconstruction of the regional geotectonic evolution.

In the present report new UV laser ablation and stepwise heating $^{40}Ar$-$^{39}Ar$ results on different minerals and U-Pb ages on zircon are presented for the ISZ and the Kalbinsky granite complex.

## Methods

$^{40}Ar$-$^{39}Ar$ experiments were performed in the laboratory of geochronology (Vrije Universiteit Brussel) on a static MAP-216 mass spectrometer with a Quantel quadrupled Nd-YAG UV laser for ablation and an induction system with Mo-crucible for stepwise heating. Samples were irradiated at the BR-2 reactor of the Belgian Nuclear Research Centre in Moll. Stepwise heating experiments were also performed at the UIGGM on 'MI 1201 V' mass spectrometer connected with a «double-vacuum oven». U-Pb data were obtained using isotope dilution techniques on TSN 206A CAMECA and MI-1320 mass spectrometers (Vladimirov *et al.* 1998). All results are shown on Fig. 1. Stated errors correspond to a $\pm 1\sigma$ interval.

## The ISZ cros sections

In the Predgornoe cross section (Fig. 1), two sheared metasedimentary rocks were analysed. For sample Ir10, a quartz-muscovite-chlorite shist with well established left-lateral movement, muscovite yielded an age spectra showing a plateau age of 281 ± 2.4 Ma. Sample Ir27, a quartz-muscovite-biotite-chlorite shist was analysed with the UV laser technique. Biotite spot ages with low $^{37}Ar/^{39}Ar$ ratios (corresponding to pure biotite) group around two different values 283 ± 7 Ma (4 spots) and 264 ± 3 Ma (9 spots). The lower ages correspond to chlorite zones. Laser shots on single K-feldspar grain yielded on average an age of 278 ± 1.7 Ma.

In the Buhtarma lake cross section shist samples have been subjected to stress-metamorphism and display various compositions. Ir91, a quartz-biotite-amphybole-plagioclase blasto-mylonite in the NE side has a marked left-lateral microtexture and was analysed with the laser ablation technique. This yielded on average ~277 ± 7 Ma for 10 shots on biotite. On the SW side of the cross section samples of a granite shist (Ir78), a granite mylonite from a 3-m wide shear zone (Ir80) and a cross-cutting unsheared late granite vein (Ir82) were analysed. Stepwise heating analyses on the sheared fabric represented by biotite in the samples Ir78 and Ir80 yielded plateau ages of 282 ± 1.5 Ma and 283 ± 1.6 Ma. Stepwise heating on a feldspar aliquot from sample Ir80 results in a staircase spectrum rising from 235–248 Ma to a plateau (42% of $^{39}Ar$ released) with an age of 275 ± 1 Ma. Step heating on Ir82 feldspar shows a staircase spectrum with a plateau age of 269 ± 2.3 Ma (63% of $^{39}Ar$ released).

Unsheared granite samples from different massifs (Proletarsky - Ir45, Kurchumsky - Ir132, Mirolyubovsky - T42, T437, Priirtyshsky - T368; Chebundinsky - T201) were studied using the $^{40}Ar$-$^{39}Ar$ techniques. Emplacement ages for some of them are based on U-Pb dating on zircon (Fig. 1).

## Discussion

Closure temperatures estimates for Ar in muscovite and biotite under moderate cooling rates (10°C/m.y.) are 350°C and 300°C. For more rapid cooling rates the closure temperature would be somewhat higher. Notice that this temperature interval (350–400°C) is likely to be important for weakening of quartz and feldspar in mylonites (O'Hara *et al.*, 1997). The similar temperature range (300–400°C) is thought to prevail within the brittle-ductile transition in the continental crust (Carter, Tsenn, 1986). While U-Pb data on zircon normally give an age for the emplacement of the granite body.

Laser and step heating data on sheared fabrics represented by fresh mica, for samples of different composition and selected in different cross sections at 150 km from each other belonging to the ISZ show within error limits similar ages (281 ± 2.4 Ma, 277 ± 7 Ma, 283 ± 7 Ma, 283 ± 1.6 Ma, 282 ± 1.5 Ma). Cooling of rocks belonging to the ISZ through temperature range 300–350°C could occur because of only exhumation to the depth with temperatures lower than closure temperature of Ar isotope system or because of only cessation of heating of rocks already uplifted to that depth some time before. We favour second possibility, because simultaneous cooling due to cessation of ductile deformation and related activity for both crossections of the ISZ distant to 150 km seems to be more probable than cooling due to erosion and uplift.

Additional information on the thermal history of the ISZ is obtained from $^{40}Ar$-$^{39}Ar$ data on feldspar that has an estimated closure temperature for Ar of 200°C to 300°C (Foland, 1994). Younger feldspar ages for both cross sections indicate that local thermal activity inside the ISZ still continued after sessation of intensive phase of ductile deformation. In the case of the mylonite sample Ir80, its relatively young feldspar $^{40}Ar$-$^{39}Ar$ age (275 ± 1 Ma) can be related to the emplacement of a late vein of the Kalbinsky granite (Ir82) cutting a 3-m wide shear zone from which Ir80 was sampled. A feldspar from sample Ir82 yielded a stepwise heating plateau age of 269 ± 2.3 Ma. It gives a lower limit for the emplacement age of this granite vein and confirms that ductile deformation was finished at that time.

$^{40}Ar$-$^{39}Ar$ stepwise heating data on mica formed during an early phase of Kalbinsky granite complex are not distinguishable within error limits from U-Pb data on zircon. It means that granite emplacement and cooling through 300°C occurred in a short time range: 280–294 Ma for Proletarsky massif, 274–282 Ma for Priirtyshsky massif, 268–281 Ma for Chebundinsky massif. Only $^{40}Ar$-$^{39}Ar$ data are available for Mirolubovsky massif (282–286 Ma on biotite) and Burobaysky massif (289–297 Ma on biotite).

Thus on the base of our data we constrain the time-span when the ductile deformation inside the ISZ ended, i.e. about 270 Ma ago. Note that the early phase of Kalbinsky granite emplacement is simultaneous (sintectonic) with the major phase of ductile deformation inside the ISZ.

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