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Fission-track dating using LA-ICP-MS – a case study of tectonic structures from Western Balkanides, Bulgaria

Датиране по метода на следите, използвайки лазерна аблация – изследване на тектонски структури от Западна Стара планина

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Introduction

Fission-track (FT) dating is a low-temperature geochronological method applied for analysis of the thermal and tectonic evolution of rocks from the Upper crust. The conventional FT dating method requires a thermal neutron irradiation of the samples to produce induced fission tracks of ^{235}U used as a proxy for ^{238}U contents (Tagami, Sullivan, 2005 and references therein). FT dating using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) has been successfully applied the last 10 years in order to determine directly the ^{238}U content in the studied zircon and apatite grains (Svojtka, Kosler, 2002; Hasebe et al., 2004) and thus to avoid the neutron irradiation as well as the handling of radioactive materials.

For the present study we have sampled both the hanging wall and the footwall of 3 regional tectonic structures in the Western Balkanides, part of the Alpine-Himalayan orogenic belt. Two of the structures are Vratsa and Vidlich thrusts of presumable Late Alpine age, whereas the third one is the neotectonic normal fault that bounds the Sofia basin to the north (Fig. 1). We have collected 12 samples from magmatic and sedimentary rocks at different altitude and tectonic position in order to reveal the time of activities and the temperature conditions during Alpine tectonic events in this area.

Sample preparation and analytical methods

Sample preparation and counting of fission tracks were processed at Kyoto University, Japan, following the procedures described in Tagami et al. (1988). The separated apatites were arranged and mounted in epoxy resin and consequently dried for more than 24 hours at room temperature, whereas the zircons were embedded in teflon on a hotplate at about 345 °C. After mounting, pre-grinding, grinding and polishing of mounts was performed in order to remove at least 8 μm for apatite and 6 μm for zircon from the surface to expose

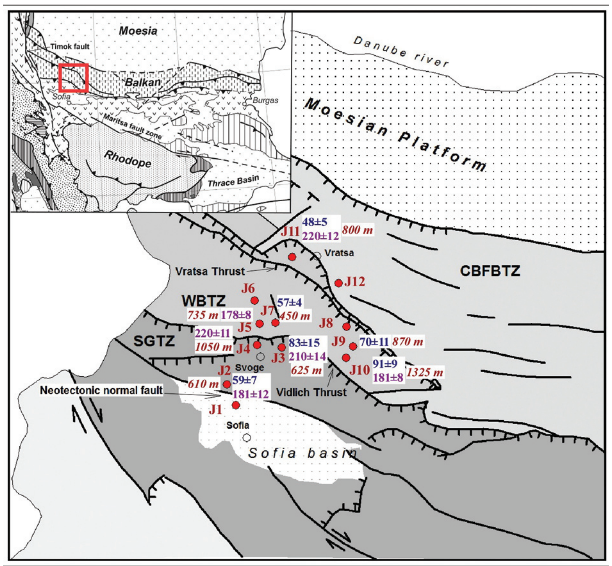

Fig. 1. Position of the sampled rocks on the schematic tectonic map of Western Balkanides (tectonic zones: *SGTZ*, Srednogorie; *WBTZ*, Western Balkan; *CBFBTZ*, Central Balkan–Fore-Balkan). The obtained apatite FT ages (in Ma) are given in blue and the zircon FT ages in violet; the altitude of the samples is given in red.

4π geometry. For pre-grinding and grinding 1200 μm silicon carbide paper was used. Polishing was done using 15 and 2.5 μm diamond pastes.

In order to reveal the fission tracks and made them visible under optical microscope chemical etching of the samples was performed. Apatite mounts were etched in 5.5 N HNO_3 for 20 s. at temperature of 21 °C (Donelick et al., 2005). Zircons were etched on an electric hot plate using the eutectic NaOH:KOH (1:1) etchant at 252 °C for at least 20 hours. Spontaneous tracks were counted under a Nikon ECLIPSE E600 optical microscope using 100x dry objective lens and 10x ocular lens. Durango and Fish Canyon Tuff age standards were used for the apatites and Fish Canyon Tuff and BM4 for the zircons analysis.

After counting of fission tracks in the single apatite and zircon grains, uranium concentration was directly measured on the same grains using an Agilent 7500 instrument (ICP-MS) equipped with a 193 nm Microlas Excimer laser ablation system at Kanazawa University (Hasebe et al., 2004). The laser ablation pit diameter usually is 20 μm (when the counted area is larger a grid of pits is made to cover it), the laser frequency is 4–5 Hz and the time duration of the measurement 10 s. with 15 s. background. ^{238}U concentrations were calibrated against NIST 610 and NIST 612 standard glasses. ^{238}U content (needed for calculation of the single-grain fission-track ages) was calculated by converting the counts per seconds (cps) using the measured ^{43}Ca cps for apatite and ^{29}Si cps for zircon from the mineral stoichiometry. FT ages and errors were calculated using the equations of Hasebe et al. (2004).

Preliminary results

Zircon and apatite ages were calculated only for 8 samples as the others did not yield enough good quality grains (Fig. 1). Problems like zonation of zircons and abundance of fractures and inclusions in the grains hampered the possibility of obtaining reliable age results for some of the analyzed samples. Most of the zircons show high uranium content which leads to very high track density (more than 20 per 100 μm^2) that impede the track counting.

The obtained from the analyzed samples zircon ages between 181.4±7.6 Ma and 220.4±11.3 Ma (Fig. 1) most probably do not represent the age of any particular tectonic event. No significant tectonic or magmatic events have been reported for the study area during the Late Triassic and the Early Jurassic. The relatively large spread of single grain ages of these samples suggest that most probably they have undergone partial resetting (at temperatures lower than 250 °C) during a thermal event of Alpine age.

The obtained apatite FT ages are between 47.8 ±4.7 Ma and 91.2±9.3 Ma. Apatite FT ages between 70 and 91 Ma (samples J3, J9 and J10) from different elevations in the eastern part of the study area are more likely to be related to cooling after the Late Cretaceous magmatic event (at ~92–91 Ma in the region of Balkanides, von Quadt et al., 2005). Modelling of the apatite FT data was hampered due to the lack of enough track lengths measurements in the analyzed samples. Nevertheless the 20 measured confined tracks in sample J7 from the autochthon of the Vidlich thrust, which yield age of 56.8±3.6 Ma give mean track value of 14.9 μm that suggests relatively fast cooling at this time. This Early Eocene cooling corresponds to the time of the pre-Priabonian (Late Alpine, Illyrian phase) thrusting in the Balkanides. Clearly the thrusting along the Vidlich thrust could not be related to this tectonic phase as its footwall experienced cooling at that time. Therefore the thrusting is most probably of Early Alpine (Austrian) age. The younger apatite FT age from the study area of sample J11 (47.8±4.7 Ma, Triassic sandstones from the hanging wall of Vratsa thrust) could be related to cooling after Late Alpine thrusting in this region.

Additional fission-track dating and eventual modelling of the apatite ages and track lengths distribution will be necessary for a better constrain of the tectonic and thermal evolution of the Western Balkanides.

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