Institute of Rock Structure and Mechanics of the Czech Academy of Sciences
V Holešovičkách 41, 182 09 Praha 8

Czech-German workshop on tectonics and geothermochronology

15.9.2022 Conference centre IRSM CAS, Prague

11:00 Lucie Nováková (IRSM CAS, TUBAF) – Welcome and introduction talk

Session 1

11:15 Raymond Jonckheere (TUBAF) - *Tracks of time and the thermal histories of rocks*

11:40 Carolin Aslanian (TUBAF) - *Etching fission tracks in apatite to reconstruct their thermal histories*

12:05 Leila Sarkhosh (TUBAF) - *The thermal properties of partial annealed fission tracks in multiple etched Durango apatite*

12:30 Raymond Jonckheere (TUBAF) - *The ravages of time and the vibrations of zircon*

13:00 Lunch break

Session 2

13:45 Erhan Gulyuz (IRSM CAS) - *Integration of Paleomagnetic Data with Geo/Thermo-chronology*

14:05 Miroslav Coubal (IRSM, GLI CAS) - *The youngest tectonic crustal stresses in the Bohemian Massif inferred from the faulted lava flow of Komorní Hůrka Volcano (1,1 Ma)*

14:30 Lucie Nováková (IRSM CAS, TUBAF) – *Testing fission-track tectonics: A natural long-term, low-temperature annealing experiment in Palaeozoic basement*

14:55 Bastian Wauschkuhn (TUBAF) - *The Kontinentale Tiefbohrung: building on a firm foundation*

15:20 Coffee break

Session 3

15:50 Lothar Ratschbacher (TUBAF) - *Steady-state plate tectonics—unsteady orogeny: a view from Pamir-Tibet*

16:15 Nilay Gülyüz (IRSM CAS) - *Application of low temperature thermochronology to the exploration of porphyry copper deposits with case studies in Tethyan Metallogenic Belt, Turkey*

16:40 Florian Trilsch (TUBAF) - *Cenozoic Evolution of the SW-Tian Shan – a perspective from low-temperature thermochronology*

17:05 Chandreyee Goswami (IRSM CAS) - *Understanding the Neogene Uplift along the Eastern Himalayan Syntaxis: Importance of U-Th/He low temperature thermochronology*

17:30 Final word

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Session 1

Tracks of time and the thermal histories of rocks

Raymond Jonckheere[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

"… The accumulation of tracks left by the disintegration products of spontaneous nuclear fission is sometimes used to date those minerals; the method is known as fission-track dating, and it can be applied to rocks that are hundreds of thousands of years old. … The actual experiment could have been made by a cockroach or any other complex adaptive system". (M. Gell-Mann, The Quark and the Jaguar, 1994).

An important part of geological research is concerned with the architecture of the earth's crust and the processes that created it. The fission-track method is one of several geochronological methods that provide constraints on the timings, rates and magnitudes of these processes. The method is based on nuclear fission of uranium, but in contrast to other methods it does not rest on direct measurements of the parent and daughter concentrations but instead on counting and measuring the damage trails from fission of ^{238}U over geological time and fission of ^{235}U in a nuclear reactor. The damage along fission tracks is repaired at elevated temperatures. Thus the etchable length of a track depends on the temperature it has experienced, so that *"individual tracks can be thought of as maximum-reading thermometers, which are continually generated throughout [time], and allow the deciphering of the variation of temperature with time"* (Green et al., 1989). This is the aim of fission-track temperature-time-path modelling. It is performed by fission-track geochronologists and is applied to rocks that are a few to hundreds of millions of years old.

Etching fission tracks in apatite to reconstruct their thermal histories

Carolin Aslanian[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

The fission-track dating method is based on counting and measuring damage trails (tracks) produced from uranium fission in natural minerals. These tracks are too thin and too small to be seen. In order to observe them under the microscope, the samples are etched. Etching widens the tracks and therefore they become countable and measurable. Understanding the

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etching process is an important aspect in fission-track dating. The current models are derived from those for etching isotropic materials, based on a track-etch rate vT along the track axis and a bulk etch rate vB in all other directions. We formulated a different etch model, which accounts for the geometries and the dimensions of etched fission tracks and explains the different track shapes in different crystal faces.

The thermal properties of partial annealed fission tracks in multiple etched Durango apatite

Leila Sarkhosh - TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology

Summary

There is an important defect in the current model of the fission-track method that has serious consequences for geological applications. Our assumption that it is related to etching of the tracks. This defines our research focus and determines our approach based on etching and measuring of tracks. Our aim is to compare the etching of fossil tracks in geological samples and that of induced tracks in lab-annealed and irradiated apatites. Our ultimate goal is to propose a practical solution for eliminating artefacts from geological fission-track studies. In addition, we aim to develop alternative methods for measuring fission tracks. It involves measuring the length and width of tracks. Track measurements are challenging due to their narrowness, but step-etching (etching solution: 5.5 M HNO3 at 21°C) increases their widths, which allows us to measure them using a suitable microscope. Analyzing the length distributions and numbers of tracks provides new information about experimental factors affecting thermal history modelling. We discuss the track etch rate, effective etch time and isotropic/anisotropic etching properties of the mineral in relation to the annealing temperature.

The ravages of time and the vibrations of zircon

Raymond Jonckheere[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

Joly and Rutherford (1913) reported radiohalos (pleochroic halos) around zircon inclusions in micas from Caledonian granites. Holmes (1913) proposed that radiohalos could provide a minimum age for the Earth. Houtermans (1951) related the age of pleochroic halos to cooling below 300-400 °C. Ages based on radiohalos were published well into the sixties before the method was abandoned. Holland and Kulp (1950) then proposed measuring the damage densities in the actinide-rich inclusions (zircons) themselves, instead of the enclosing mica; the measurements used DTA or XRD. Hurley and Fairbairn (1952) stressed the contribution of the recoil nucleus to

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the lattice damage and estimated the total number of atomic displacements per α-event at 4.5 · 10^3. Holland and Gottfried (1955) related changes in the densities, refractive indices, birefringence and unit-cell dimensions of Sri Lanka zircons to their estimated α-doses from self-irradiation. They proposed that radiation damage accumulation proceeds in three overlapping stages and concluded that the dated ~570 Ma zircon samples had experienced an episode of thermal annealing.

Following Raman investigations of radiation damage in zircon and their significance for geological dating (Nasdala et al. 2003; Geisler, 2003; Pidgeon, 2014), our lab explored the potential of zircon Raman dating. We carried out a multiband calibration based on age standards, annealing experiments for determining the closure temperatures associated with different bands, and developed techniques for assessing the extent of damage repair due to thermal annealing. Raman measurements are also important for assessing the effects of radiation damage in fission-track and He-dating.

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Session 2

Integration of Paleomagnetic Data with Geo/Thermo-chronology

Erhan Gülyüz[1]

[1] *Institute of Rock Structure and Mechanics of the Czech Academy of Science, Department of Neotectonics and Thermochronology*

Summary

The common point of paleomagnetic and geo/thermo-chronology records is being dependent on Currie or closure temperatures of various minerals. Basically, paleomagnetic records read from magnetic minerals with some specific currie temperatures gives information about rotation or inclination of geological units in the horizontal plane. On the other hand geo/thermo-choronolgy records solely give information about vertical movement of sampling points. A successful integration of the two disciplines has a potential to explain 4-D (x-y-z and time) movement of sampling points, hence geological units. Here, we present some test results of one of our new projects and discuss the advantages and problems regarding this new methodology.

The youngest tectonic crustal stresses in the Bohemian Massif inferred from the faulted lava flow of Komorní Hůrka Volcano (1,1 Ma)

Miroslav Coubal[1,2], Martin Šťastný[2], Jakub Stemberk[1], Jana Schweigstillová[1], Petra Štěpančíková[1], Dagmar Kořínková[2], Vladimír Prouza[2]

[1] *Institute of Rock Structure and Mechanics of the Czech Academy of Science, Department of Neotectonics and Thermochronology*

[2] *Geological Institute of the Czech Academy of Science, Department of Geological Processes*

Summary

In order to expand the range of knowledge about the youngest tectonic stresses that acted in the Bohemian Massif, the brittle deformation of the lava flow of one of the youngest volcanoes Komorní Hůrka Volcano (0.7 - 1.01 Ma), was studied. Within the observations and measurements, we have identified several generations of striations differing in (their) morphology, which successively formed and superimposed one over the other during the last ca. 1 Ma. The measured heterogeneous set of fault slip data was separated into the homogeneous sub-sets using the automatic procedure of Málek, Fischer and Coubal (1991), extended in addition by an original technique based on recording the mutual loading of

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striation populations. Both optical microscopy and SEM were used to estimate the original conditions of the individual populations of striations.

The older generation of striations (represented by two similar homogeneous sub-sets) is interpreted to be the record of mutual collision of the semi-solidified blocks of (or within?) the lava flow during the effusion process.

The younger generation of striations was produced in already solidified rocks by tectonic stress with parameters very close to the present crustal stress as identified from earthquake focal mechanisms in Western Bohemia (c.f. Vavryčuk et al., 2013).

The youngest homogeneous sub-set was reactivated by vertically oriented, nearly uniaxial compression. Due to the low number of assigned/analyzed fault-slip data, it is considered a not yet particular indication of the action of pressurized fluids.

Testing fission-track tectonics: A natural long-term, low-temperature annealing experiment in Palaeozoic basement

Lucie Novakova[1,2], Raymond Jonckheere[2], Bastian Wauschkuhn[2], Lothar Ratschbacher[2], Carolin Aslanian[2]

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[2] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

Fission tracks in apatite are ~20 µm long and ~10 nm wide, too thin to observe with an optical microscope. Polished grain mounts must therefore be etched to make them visible. It is generally taken for granted that factors related to polishing, etching, counting and measuring the etched tracks are inconsequential. We believe that, from lack of investigation, there persist certain misconceptions regarding these issues, which lead researchers to overestimate the accuracy of the track counts and length measurements. Knowledge of the true effective time of confined tracks based on measurements of their widths presents a potential improvement in modelling the thermochronological conditions of the studied samples.

It is nevertheless not certain that reliable tectono-thermal histories are obtained with this development. This must be established based on well-constrained field data. The 9.1 km KTB borehole drilled into the western border of the Bohemian Massif is an ideal test site for temperatures up to 265 °C. The Naab Mountains, 40 km to the south, were exhumed in the Variscan and never covered by more than 1 ¼ km of sediments since the beginning of the Permian (Vercoutere 1994). Samples from the Palaeozoic basement, again exposed at the surface, have thus never experienced temperatures in excess of ~40°C. This makes the Naab

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area (Western part of the Bohemian Massif) a perfect testing ground for the low-temperature predictions of fission-track modelling.

The Kontinentale Tiefbohrung: building on a firm foundation

Bastian Wauschkuhn[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

Deep boreholes are natural laboratories for testing geothermochronometers under geological conditions. There is good evidence that samples from the upper section of the *Kontinentale Tiefbohrung* remained at constant temperatures since their last documented exhumation in the Late Cretaceous to Palaeocene. We measured the apatite fission-track ages and mean confined-track lengths on drill cores from the 4 km pilot hole. Both standardless and standard-based ages are consistent with population ages from earlier studies and together define a clear age profile. The measured age and length profiles are compared with predictions of twenty-four annealing models for isothermal holding. There are clear discrepancies between the measured and calculated profiles. Tectonic, volcanic and even climate factors have been suggested to be responsible for the discrepancies. We maintain instead that the predictions of lab-based annealing models are inaccurate at geological timescales. Our group is compiling images and measurements of confined tracks in the KTB apatites for constructing a public reference database for geological annealing of fission-tracks.

Raman measurements on zircons from the *Kontinentale Tiefbohrung* allow investigating the accumulation and repair of irradiation damage under geological conditions. Uniform Raman values close to those of undamaged zircon below 5 km depth are interpreted as due to residual damage predating exhumation. A superimposed post-exhumation signal indicates full retention down to 3 km depth, partial annealing between 3 and 5 km, and zero retention at greater depth. Our provisional interpretation is that this refers to repair of the least resistant damage component.

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Session 3

Steady-state plate tectonics—unsteady orogeny: a view from Pamir-Tibet

Lothar Ratschbacher[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

With geophysical-geological-geo/thermochronological data, I will discuss two hypotheses: i) Large orogens are governed by 'catastrophic' events that rule their *P-T-d*-states & potential-every equilibria, ii) these events are triggered by mantle processes. My goal is to trace mantle-crustal-surface and hinterland-foreland interactions on the hand of the Tian Shan-Pamir-Tibet orogen.

Application of low temperature thermochronology to the exploration of porphyry copper deposits with case studies in Tethyan Metallogenic Belt, Turkey

Nilay Gülyüz[1]

[1] *Institute of Rock Structure and Mechanics of the Czech Academy of Science, Department of Neotectonics and Thermochronology*

Summary

Copper is one of many "mineral" resources needed to support the world's increasing needs for energy production, storage and transport. Porphyry Cu ±(Au-Mo) deposits are the world's most important Cu resource, representing ~70% of world Cu production. These deposits form in the upper brittle crust, typically at depths of about 1-5 km, in relation with the continental magmatic arcs. Besides the importance of their genesis, understanding their exhumation and ore preservation at the stage of post-mineralization is very crucial for their exploration due to their formation at shallow depth. In this context, low temperatuere thermochronological methods (apatite fission track-AFT, apatite helium-AHe, zircon helium-ZHe)-corresponding to upper crustal processes could provide important information about the post-mineralization exhumation (burial, uplift and erosion) histories of the porphyry copper deposits.

The main aim of this talk is to provide two different case studies in Tethyan Metallogenic Belt, Turkey about the application of low-T thermochronological tools for exploration implications of porphyry copper deposits: (i) determining the current geometry of the Halilağa porphyry Cu-Au deposit (Çanakkale, Western Turkey), and (ii) determination of exhumation and

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preservation evolutions of Elbeyli, Güzelyayla, and İspir-Ulutaş porphyry Cu-Mo deposits (Eastern Pontides, NE Turkey).

Cenozoic Evolution of the SW-Tian Shan – a perspective from low-temperature thermochronology

Florian Trilsch[1]

[1] *TU Bergakademie Freiberg, Department of Tectonics/Geo-Thermochronology*

Summary

Summary: New low-temperature thermochronologic data, i.e., AFT and AHe data, reveal the exhumation history of the SW-Tajik Tian Shan along two N-S-transects. They highlight a rather simultaneous onset of uplift across the range, facilitated by the inherited character of major thrust systems. Additionally, for a few selected Tian Shan samples, I highlight the potential of apatite Raman measurements as a new kinematic parameter for AFT thermochronology, aiding the geologic interpretation of chemically complex detrital samples.

Understanding the Neogene Uplift along the Eastern Himalayan Syntaxis: Importance of U-Th/He low temperature thermochronology

Chandreyee Goswami[1]

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Summary

Understanding the collisional tectonics involves both the spatial and vertical movement of crust over time. The Eastern Himalayan Syntaxis (EHS) can be defined as the juncture between the E-W-trending Himalayas and the NNE-SSW-trending Naga Schuppen belt with very scanty data about crustal movement. The Mishmi block is described as a possible tectonic roof or a linkage between the Eastern Himalaya and Naga-Schuppen belt in the southeast.

Presently we are working on the area at southwest part of the Mishmi hills along with its Quaternary-Holocene foreland within the Upper Assam Basin. Our work focuses on the upliftment history along the Mishmi thrust during Neogene and Quaternary time and how it is responsible for the formation of present-day landform. We are using the apatite and zircon mineral grains from the metamorphic rocks across the Mishmi thrust to identify the time of the uplift during Neogene time. We also use the single sample dating of both zircon and

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apatite to understand the uplift rate. We are getting the Quaternary uplift history from OSL dates.

We will expand our work further in a wide area of Eastern Himalayas to understand the upliftment scenario along the major orogenic thrusts during Neogene time.

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