PSEUDOTACHYLITES FROM THE HIGH TATRA MTS. – EVIDENCES FOR LATE PALEOGENE SEISMIC/TECTONIC EVENTS.

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Abstract: The Tatra Mts. pseudotachylites from the foothill of Mount Gerlach and its host – granitic rocks have been dated by direct $^{40}Ar/^{39}Ar$ laser-probe. The laser spot analyses of biotites from biotite tonalite give an age of 325 ± 3 Ma. Majority of feldspar spot analyses of pseudotachylites fall within range 36 – 28 Ma, documenting Oligocene seismic activities reflecting the propagation of Sub-Tatra detachment fault that is connected with origin and subsidence of Central-Carpathian Paleogene Basin.

Key words: pseudotachylites, granitic rocks, $^{40}Ar/^{39}Ar$ dating, tectonic, Sub-Tatra fault, Tatra Mountains.

Introduction

Understanding of the tectonic evolution of orogenic belts and intracratonic areas depends on our ability to determine the age of tectonic features e.g. ductile shear zones and brittle faults on a variety of crustal scales. Generally, there is no problem with dating of ductile shear zones that experienced mid- to lower crustal conditions indeed technology of measurement in the isotope geochemistry was rapidly improved during the last twenty years. Combination of ion probe and/or laser with mass spectrometer enabled to measure isotopic ratios within one grain. In the crystalline basement areas, where any sedimentary or volcanic markers are lacking, it is difficult to determine the age of brittle faults. If differential vertical movements of crustal blocks exceed a few hundred meters it may be resolved by fission-track thermochronology. However, dating of brittle faults with small displacement without stratigraphic markers is still undetected in the basement areas besides of pseudotachylites that recorded sufficient high-temperature changes during their origin. Pseudotachylite is dark aphanitic fault related rock composed of friction-derived melt material interspersed with clasts and crystals from the host-rock, and is thought to be formed in response to seismic activity either meteorite impacts, rapid tectonic faulting or landslides (e.g. Philpotts, 1964; Sibson, 1975; Magloughlin & Spray, 1992; Reimold, 1995). This rock is found as distinctive veins and networks in its host-rock usually containing quartz. Tectonic pseudotachylites form during seismic events by cataclastic grain size reduction followed by friction-induced melting. They form along the so-called generation surfaces accommodating the seismic slip. Markedly planar fault veins, where the melt has been generated, can be distinguished from smaller, irregular injection veins where the pseudotachylite material was injected into tension fractures (Sibson, 1975). High potassium content of the melt material, derived from the host-rock micas and/or amphiboles makes pseudotachylite an ideal candidate for $^{40}Ar/^{39}Ar$ dating (Reimold, 1990; Kelley et al., 1994; Spray et al., 1995; Sherlock & Hetzel, 2001). Although recently were pseudotachylites described from the Tatra Mts. (Petrík & Reichwalder, 1996; Petrík & Janák, 2001) their age was still unknown. The aim of this contribution is to present a new direct laser-probe $^{40}Ar/^{39}Ar$ data from pseudotachylites their host-rock granites and discuss possible scenario of their tectonic origin in the crystalline basement of Tatra Mts.

Geological setting

The Tatra Mountains are located in the northern Slovakia area just on the border with Poland and represent so-called core mountains within Tatric superunit of the Central Western Carpathians (Andrusov, 1968; Maheľ, 1986). The crystalline basement of the Tatra Mts. is composed of pre-Mesozoic metamorphic and granitic rocks, overlain by Mesozoic and Cenozoic sedimentary cover sequences and nappes. Generally, the granitic rocks are dominated within basement rocks, whereas metamorphic rocks are abundant mainly in the western part (the Western Tatra Mts.) and in the eastern part (the High Tatra Mts.) they are presented only in the form of xenolithes within extensive granitic body. Based on the field relations, petrography and geochemistry following granitoid types have been distinguished (Kohút & Janák, 1994) in the Tatra Mts. pluton: *High Tatra type* – representing mainly by biotite tonalite and muscovite-biotite granodiorite (HTT) - which appears only in the central High Tatra Mts. part. *Common Tatra type* – consists of biotite and muscovite-biotite granodiorite to granite, slightly porphyric (CTGD) - this type is dominant in both parts of the massif - Western and High Tatra Mts. *Goryczkowa type* – porphyric granites to granodiorites with pinkish K-feldspar (GG) - appears mainly in the northernmost part of the Tatra pluton. There were described sporadically *biotite-amphibole quartz diorite* – forming only small bodies and lenses of several meters to tens of meters within the HTT and CTGD. Noteworthy, that all known occurrences of pseudotachylites are within HTT and CTGD.

Pseudotachylites were found at several places in the Tatra Mts. (e.g. Bystrá Valley in Western Tatra Mts., Velická Valley and Batizovské Lake just on the foothill of Mount Gerlach in the High Tatra Mts.). On the southern slope of Gerlach pseudotachylites are related to several NNE striking faults with a steep dip of 75-90° to ESE and WNW. Generally, thickness of principal - generation surface veins are within 1 – 10 cm, whereas branched dendritic injection ones are less than 0.5 cm thick. Pseudotachylite is composed of matrix (crystallised melt) consisting of hematite (5-40%), albite and K-feldspar, and clasts dominated by feldspars and quartz. The proportions of matrix minerals are highly variable which results in melt compositional trends apparently controlled by biotite or hematite. It is, inferred that primary melt originated by preferential dehydration melting of biotite (Petrík & Janák, 2001), whose proportion in melting was 20-50 wt.% (based on biotite and pseudotachylite melt FeO_{tot} contents). Water liberated into the melt enabled further melting of quartz and feldspars leaving 50-80% of restite represented mainly by plagioclase clasts. The P-T conditions were estimated from the retrograde cataclasite assemblage biotite-chlorite-albite-phengite-epidote-hematite (by THERMOCALC) and yield P = 350-400 MPa and T = 450 °C (Petrík & Janák, 2001).

Results

There were collected seven pseudotachylite samples hosted by biotite tonalite (HTT) and biotite granodiorite (CTGD) from the Tatra Mts. Five of them were selected for laser-probe $^{40}Ar/^{39}Ar$ study together with two samples of host-rock granitic rocks. The samples were analysed at The Open University Milton Keynes (UK) using a focused CW Nd-Yag infrared laser combined with noble gas mass spectrometer MAP 215-50, according analytical procedure Sherlock & Hetzel (2001).

Host rock:

Sample TL-10 – biotite tonalite, that was collected 500 metres from the pseudotachylite vein TL-9, yielded a narrow range of ages (322 ± 2 to 331 ± 2 Ma, mostly between 322 and 327 Ma). These ages are derived from laser spot analyses of biotite only. Weighted mean of spot analyses give an age 325 ±3 Ma This age determination is in good agreement to previous assumption of magmatic age of this type of granitic rocks done by $^{40}Ar/^{39}Ar$ – 330 ± 3 Ma (Maluski et al., 1993), and/or CLC single grain zircon U-Pb data 311 ±16 Ma respectively 314 ± 4 Ma (Poller & Todt, 2001) from the High Tatra Mts. Indeed, the emplacement ages are comparable with the granitic argon ages, taking into account the rate of cooling for the intrusion, it should be noted that the granitic rocks have not experienced any sufficient argon-loss subsequent to their formation.

Pseudotachylite:

Ages for the pseudotachylite samples range from 28 to 164 Ma although ages greater than 65 Ma are restricted due to heterogeneous ^{37}Ar distribution, very variable atmospheric argon component and/or very low in potassium (^{39}Ar) content. When these high ages were removed following age ranges yield individual samples: TL-9 – 32 to 63 Ma; TT5a-97 – 37 to 65 Ma; TT5b-97 – 29 to 65 Ma; TT6a-97 – 28 to 42 Ma. However, host-rock Variscan tonalites did not show any post-crystallisation argon loss due to regional reheating (including Neo-Alpine period) we suppose that pseudotachylites similarly did not suffered argon loss therefore we prefer the lowest ages for their origin. The age of pseudotachylite formation is most likely connected with Late Paleogene – Oligocene (36 – 28 Ma) seismic events.

Discussion and conclusion

Hence the age of the Tatra Mts. pseudotachylite formation was unknown, there were only "scientific guess" for time of its origin. Commonly its generation is connected with Tatra Mts. uplift and/or propagation of Sub-Tatra fault e.g. Janák et al. (2001). Authors suggested Miocene age of its origin on the base of existing apatite fission-track data from the Tatra Mts. granitic rocks yielding age between 20 – 10 Ma (Burchart, 1972; Kráľ, 1977). Assuming the total thickness of the Mesozoic cover and nappe complexes reached at least 3.5 – 4 km, and the Paleogene sediments may have had about 3.5 – 4 km in thickness (Janočko & Jacko, 2001), the inferred pre-Miocene burial of pseudotachylite-hosting granitic rocks amounts approximately 10 – 11 km. Accordingly, the studied pseudotachylites were probably generated by seismic slip along subsidiary tear faults that accompanied foundation and early stages of development of this large-scale Sub-Tatra detachment fault in the proximity of the ductile/brittle transition. Propagation of the Sub-Tatra fault is connected with origin and subsidence of Central-Carpathian Paleogene Basin in area eastern from the Tatra Mts. We suppose that our dating of the Tatra Mts. pseudotachylite veins enabled identified early stages of the Tatra Mts. uplift and/or formation Sub-Tatra fault.

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Kohút & Sherlock Figs.

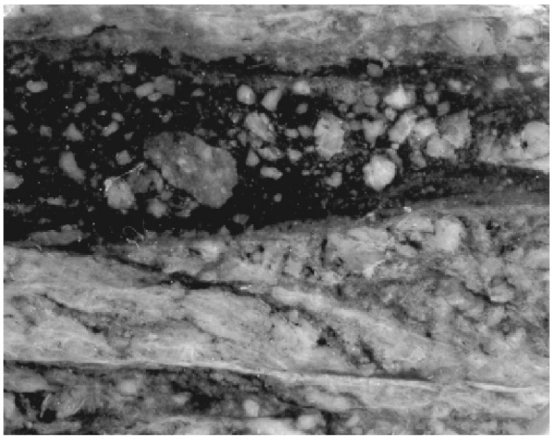

Fig. 1 Typical pseudotachylite vein sample TT-5b, width of view - 2.5 cm

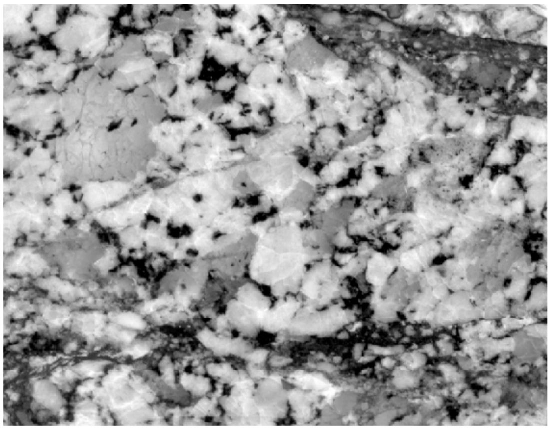

Fig. 2 Host rock biotite tonalite with small injection vein, sample TT-6a, w. - 2.5cm