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PSEUDOTACHYLYTES FROM THE TATRA MTS. – HOW MANY CRUSHING EVENTS ?

Abstract: Two generations of pseudotachylytes could be assigned to two sets of tectonic structures, differing in origin and age of formation. The older, subhorizontally running pseudotachylytes are characterised by a complex internal structure and were probably generated during Upper Cretaceous shearing (65-70 Ma) and regenerated during later, Miocene uplift movement (25-28 Ma).

Keywords: pseudotachylytes, Tatra Mts., fault zones, hematite.

INTRODUCTION

Pseudotachylytes are commonly found in the fault zones, as typical products of faulting process. According to the definition, pseudotachylyte is "a cohesive glassy or very fine grained fault-rock with very distinct fabric" (Passchier, Trouw 1998). There have been a long discussion if they originated by friction heating and melting on the fault plane during earthquake (Philpotts 1964; Maddock 1983) or by local cataclasis and clasts comminution (i.e. Wenk 1978). At present a consensus is usually presented that both processes could be active in various degrees (i.e. Wenk at al. 2000). In the Tatra Mountains pseudotachylytes have been found in the fault zones cutting granitoid pluton and are traditionally linked to the Miocene exhumation of the Tatra Mts. crystalline block (Gawęda, Piwkowski 2000; Petrik at al 2003). In the earlier papers, devoted to the problem of pseudotachylytes some contrasting features of these rocks are presented.

A. In the samples from Batižovecka Valley Petrik at al (2003) observed two types of pseudotachylytes light (older) and dark (younger) phases, differing in bulk composition and being an effect of friction melt differentiation during flow. The light matrix is believed to have the composition close to the original melt, while the dark matrix in the central parts of veins represents the less viscous, clasts-laden, Fe-rich melt. No presence of glass had been found, but cataclastic mineral assemblage recorded the temperature about 400^{o}C and 2.5-3 kbars of pressure. The possible friction melt, at present recrystallised, was highly oxidised and show high mobility in the open system, with meteoric waters introduced. The composition of matrix suggest the disequilibrium melting of a biotite-dominated assemblage but anyway, the high content of iron (about 45 wt % of Fe_2O_3) cannot be understood by any melting mechanism.

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B. In the Kończysta Peak and Pasternakowe Czuby area Gawęda & Piwkowski (2000) found the heterogenous pseudotachylyte veins composed of ultramylonite and discontinuous glass layer, with a composition similar to the minimum granite. The glass was younger than hematite-rich ultramylonite, in which the hematite-rich clasts and stripes were also present. That suggests the friction melting event which occur after the formation of differentiated Fe-rich pseudotachylytes.

The field investigations carried out by the present author allowed to conclude about time relations between the different stages of pseudotachylyte formation and preliminary characteristics of the process.

GEOLOGICAL SETTING, SAMPLING AND EXPERIMENTALS

The polygenetic granitoid body of the Tatra Mountains is composed of five petrographic types of granitoids, representing five Variscan intrusion stages (from 405 Ma to 314 Ma; Poller et al. 2001). The granitoid portions (except the westernmost part of the pluton, emplaced in the metamorphic envelope) are cut by the dark pseudotachylytic veins, connected to the flat, almost horizontal discontinuities (Gerlach, Zlomiskova Valley, Drača Valley, Mięguszowiecki Peak – Kazalnica Mieguszowiecka, Kończysta Peak, Štolska Dolina, Nižna Bystra) and also to the subvertical, north-south trending ones (Velicka Valley, Batizovecka Valley).

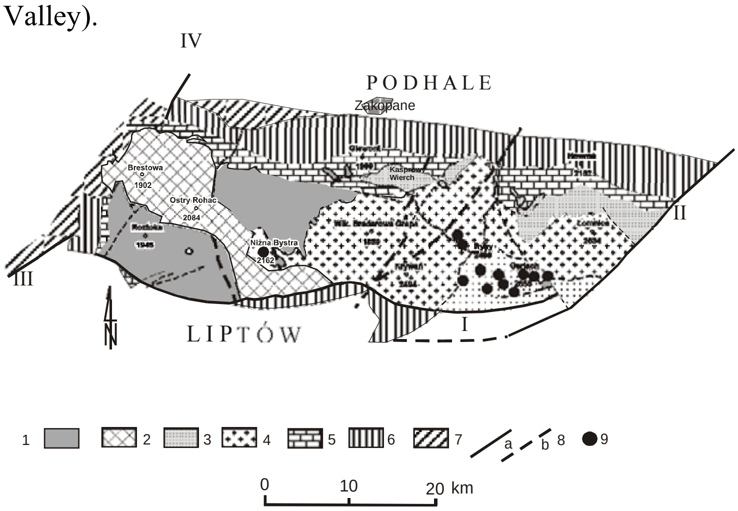

Fig. 1. The simplified geological sketch of the Tatra Mts. with the sampling points location. (1 –5) - crystalline basement: 1 - metamorphic envelope; 2 - Rohacze-type granite; 3 – Goryczkowa-type granite; 4 – common Tatra granite; 5 - High Tatra granite; 6 - mesozoic rocks of the sedimentary cover and Wierchy nappe ; 7 – Lower Regle nappe ; 8 – Upper Regle nappe ; 9 – faults: a – identified , b – assumpted; 10- sampling points; I - Podtatrzański fault ; II - Drużbaki fault ; III - Chocz fault ; IV - Krowiarki fault .

The samples were collected from all the mentioned places and are presented on the Fig. 1.

The microscopic observations and modal analyses were carried out in the faculty of Earth Sciences, University of Silesia using the Olympus BX-60 and James & Swift microscopes, microprobe analyses were at CAMECA SX 100 at the University of Warsaw, using both natural and standards. The help of Dr Martin Chovan and MSc Roman Hanes (University of Bratislava) during field works is highly appreciated.

RESULTS

Pseudotachylytes were found both in subhorizontal and subvertical fault zones.

A. Pseudotachylytes in subhorizontal discontinuities (Kończysta, Pasternakowe Czuby, Mieguszowiecki, Niźna Bystra, Zlomiskowa Valley, Dračia Valley, Štolska Valley, Gerlach), are heterogenous and composed of two or three distinct portions: external light, internal dark, and axial:

1.Ultramylonite composed of clasts cemented by light fine grained matrix. The clasts are crushed granitic minerals, matrix is formed by comminuted, but distinguishable minerals. No melt is present. High feldspars content (Q/Fs = 0.29-0.48) suggest the preservation of original granitic proportions in clast population, no matter how big they are. No distinct orientation is observed in this part of the vein.

2.Dark pseudotachylyte composed of hematite-rich matrix and high proportion of clasts, with a domination of quartz (Q/Fs = 1.25-2.66). Flow orientation of both clasts and matrix minerals is observed. Among the clasts quartz predominates, but the fragments of ultramylonite are also present.

3.Internal dark-violet or dark green homogeneous, extremely hematite-rich axial zone, with small proportion of microscopically visible clasts, predominantly quartz (Q/Fs = 3.6-4.0).

In some cases there is no zonation but weak orientation of stripes and irregular portions of dark and light material, suggesting the presence of tectonic activity which caused physical mingling of the original zonation. In such pseudotachylytes one can observe the common transformation of magmatic assemblage ulvöspinel ($Fe^{+3}_{1.86}Fe^{+2}_{0.4}Ti_{0.404}Mn_{0.004}O_4$) + Mn-ilmentite ($Fe_{0.841}Mn_{0.115}Ti_{1.007}O_3$) into rutile and then into titanite ($Ca_{0.9}Al_{0.12}Ti_{0.79}Fe_{0.02}Si_{0.99}O_4OH$). Titanite is commonly associated with zoned epidote, enriched in LREE. The latest mineral is idiomorphic hematite up to 30 μm in diameter. Stripes of ultra-finegrained aggregates of quartz + feldspars + rare hematite (recrystallised melt?) with the granite-like composition could be also found, similar to that described from Kończysta Mt. (Gawęda, Piwkowski 2000). Zoned, undisturbed pseudotachylytes dip 10-35^o to S, while disturbed, re-melted pseudotachylytes dip 5-15^o to N.

B. Pseudotachylytes in subvertical (NE-SW to NNE-SSW running and 75-90^o dipping) **discontinuities,** found in Batižovecka Valley, Velicka Valley and on the S-slopes of Gerlach are composed of two distinct parts: light and dark. They are fully adequate to these described by Petrik et al. (2003). It is a problem for further discussion if these two parts are product of differentiation or two crushing events: some microscopical observations show tectonic relations between these two zones.

In case of Velicka Valley small horizontal faults (A = 1 – 5 cm) perpendicular to the main subvertical zone were also noted, cutting both light and dark.

DISCUSSION AND CONCLUSIONS

Two sets of faults are filled by pseudotachylytes differing is structure and order of evolution. In the subhorizontal faults at least three (or four ?) tectonic episodes are recorded. The last episode caused mingling of the earlier zones and sporadically formation of melt. The lack of field relations of both types of pseudotachylytes makes impossible to decide about their relative age.

Taking into account the geological history of the Inner Carpathians one can suppose that the subhorizontal faults (and pseudotachylytes) are partly connected to the Upper Cretaceous overthrusting and nappe formation process (^{40}Ar-^{39}Ar ages in the range 75-66 Ma - Maluski et al. 1993 and 65-70 Ma – Kohut, Sherlock 2002). The later Miocene uplift formed the Subtatric Fault on the south and a flexure on the north, causing also the formation of NE-SW trending subvertical discontinuities coupled with the gravitational (?) shift of some rock-portions to the north . That could cause the rejuvenation of the older subhorizontal structures almost simultaneously with the vertical movements and formation of pseudotachylyte in subvertical zones (25-28 Ma; Kohut, Sherlock 2002) as well as the re-melting of the early-formed pseudotachylytes. Because the Subtatric Fault was reactivated several times during the Neogene it is possible that the faulting and thrusting processes and pseudotachylyte formations events took place many times during the Alpine history of the crystalline basement of the Tatra Mts.

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