GENESIS OF PSEUDOTACHYLITIC BRECCIAS FROM THE VREDEFORT DOME, SOUTH AFRICA: NEW MICROCHEMICAL AND PETROGRAPHIC FINDINGS.

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Introduction: "Pseudotachylite" is generally considered friction melt formed along faults or shear zones. The melt is produced by friction heating, which generally requires sliding velocities consistent with seismic slip. The distinction between "impact" and "tectonic" "pseudotachylite" plays an important role in impact settings, as melt breccias in impact structures often closely resemble tectonic friction melt but may have been formed by different processes. Controversy remains about the genesis of these melt breccias, with the most popular hypotheses being genesis by (1) shearing (friction melting); (2) shock compression melting (with or without a shear component); (3) decompression melting immediately after shock propagation through the target / related to rapid uplift of crustal material due to central uplift formation; (4) combinations of these processes, or even (5) intrusion of allochthonous impact melt. Resolving this problem requires detailed multidisciplinary analysis in order to comprehensively characterize the nature of these breccias and to identify the exact melt-forming process(es). In order to distinguish between bona fide "pseudotachylite" and similar breccias in impact structures of still debated origin we refer in this latter case to "pseudotachylitic breccia".

Pseudotachylitic breccias (PTB) are the most prominent impact-induced deformation in the central uplift of the Vredefort Impact Structure [1, 2], and similar breccias occur in abundance in another very large and ancient impact structure, Sudbury in Canada [e.g., 3,4]. In this study major and trace element data for newly analysed small-scale pseudotachylitic breccias from Vredefort, from mafic (dioritic) and granitic host rocks, are presented and compared with the chemical compositions of their respective host rocks. Finally, the entire new micro-chemical database for granitic and dioritic pseudotachylitic breccias is considered with respect to genetic implications.

Methodology: Detailed bulk and micro-chemical analyses, and micro-petrographic and textural observations on the matrices of pseudotachylitic breccias and respective host rock samples from 8 locations - 1-10 mm wide mafic PTB in mafic host rock (UP-5, farm Sandspruit 1182, outer core of the SW sector of the Dome; UP-32, farm Kopjeskraal 517IQ, inner NW collar; UP-54, farm Tweelingkop 388, outer W collar; UP-69, farm Rietpoort 518 IQ, 4 km N of Parys; UP-73, farm Boomplaas 1005, NW collar), and various samples from massive PTB occurrences in the National Sun, Kudu and Leeukop quarries, have been collected. PTB matrices were analysed in polished thin sections by image analysis, optical and scanning electron microscopy (SEM), and electron microprobe analysis (EPMA). Selected bulk samples of pseudotachylitic breccia and of host rock were analyzed by X-ray fluorescence spectrometry for major and trace element abundances, and selected samples are still being analysed by INAA.

Results: The mafic host rocks, which are all metamorphosed (i.e., *epi*diorite), consist essentially of Ca-amphibole and plagioclase, together with epidote, biotite, relics of the original clinopyroxene, and titanomagnetite. Based on major element abundances, especially TiO_2 < 1wt%,, all 5 samples can be classified according to Pybus [5] and Reimold et al. [6] as epidiorites of Type 2 – thought to represent feeder dikes for Ventersdorp Supergroup extrusives. The groundmass of PTB veins is very fine-grained crystalline comprising mostly feldspar and amphibole, as well as some minor pyroxene) and seems to have experienced post-impact metamorphism [e.g., 8]. The clast population of mafic PTB comprises ca. 25 vol% and consists mostly of feldspar, some quartz, and generally minor pyroxene and iron-titanium oxides. Only PTB sample UP-32, where PTB are preferentially developed in amphibole-rich areas (compare Fig. 1) contains a sizable amphibole clast component. Otherwise amphibole clasts entrained in breccia matrix occur mostly as small-sized particles. Some alteration (rarely exceeding 5 vol%) comprises local replacement of mafic clasts (biotite, amphibole, pyroxene) by chlorite and partial replacement of plagioclase by sericite. Lithic fragments entrained in breccia matrix are generally at least partially annealed, indicating the high level of thermal overprint related to formation of these melt breccias and/or post-impact metamorphism. The commonly observed rounding of clasts seems to be related to thermal abrasion. Some of the clasts are partially or wholly (ghost clasts) assimilated by melt.

The main groundmass minerals of PTBs in granitic host rock are plagioclase, K-feldspar, quartz, amphibole, and biotite. Accessory zircon, sphene, magnetite, and other iron and iron-titanium oxides are recognized within the melts. Clasts in the granitic PTB comprise ca. 20-25 vol% and are mostly quartz with subordinate feldspar. Feldspar in clasts is more extensively melted and/or shows stronger recrystallization than quartz grains. Commonly marginal clast melting is still visible in the form of haloes around molten clasts. Some granite, as well as some quartz and feldspar, clasts show shock effects (e.g., quartz and feldspar grains show one – rarely two - sets of PDF).

For pseudotachylitic breccias in granitic host rock the PTB matrix resembles the composition of the adjacent host rock but is generally slightly depleted in SiO_2 which is directly related to the observed volume percentages of quartz clasts. Mafic PTB matrices display depletion in Al_2O_3 and CaO and enrichment in FeO and MgO, in comparison to the bulk host rock compositions. Host rock major element compositions from XRF are: SiO_2 (50-53.6 wt%), TiO_2 (0.29-0.56 wt %), Al_2O_3 (9.3 – 15.7 wt%), Fe_2O_3 (7.49-12.7 wt%), MnO (0.13-0.19 wt%), MgO (6.39-14.5 wt%), CaO (9.89-13.3 wt%), Na_2O (1.03-2.36 wt%), K_2O (0.16-0.51 wt%), and P_2O_5 (0.03-0.07 wt%). Some analytical work (especially the INAA) is still in progress – the full results will be presented and discussed at the conference.

Conclusions: In this study electron microprobe in situ PTB groundmass and XRF bulk chemical analysis of both pseudotachylitic breccias and their host rocks revealed that pseudotachylitic breccia generally displays a close chemical relationship to the host rock sampled directly adjacent.. This confirms that melt was formed from material of the same composition and, with respect to mm to cm wide veinlets of breccia, of local origin. This is in agreement with our previous structural-chemical analysis that has shown that melt in cm to several dm wide veins was emplaced with at most 25 cm mobility [7]. In granitic environments, the refractory behavior of quartz seems to be the main reason for the chemical differences between PTB and host rock. Our first chemical investigations of PTBs in mafic host rock compositions revealed that the elements associated with plagioclase and/or hydrous ferromagnesian minerals are enriched in PTB veins. First order observations have shown that PTB seemingly occur preferentially in amphibole-rich host rock portions – an observation that confirms the macroscopic observations of [8,9]. Thus, PTB genesis in mafic host rock seems to be controlled by the mineralogical composition of the target rock. A further factor is likely the melting temperature involved – as this is a critical factor determining at which ratio feldspar and mafic minerals will go into the liquid state.

None of the analyzed veinlets has yielded any textural evidence supporting a significant influence of shearing/faulting. Our PTB's of different sizes (mm – m) all contain clast populations that represent locally occurring lithologies only, with distinct differences between clast population and host rock mineral abundances likely the result of different mechanical behavior and different melting temperatures of these various mineral phases. Overall, the findings of this latest work are in agreement with our already published observations on Archean gneiss-hosted PTB from Vredefort [7,10].

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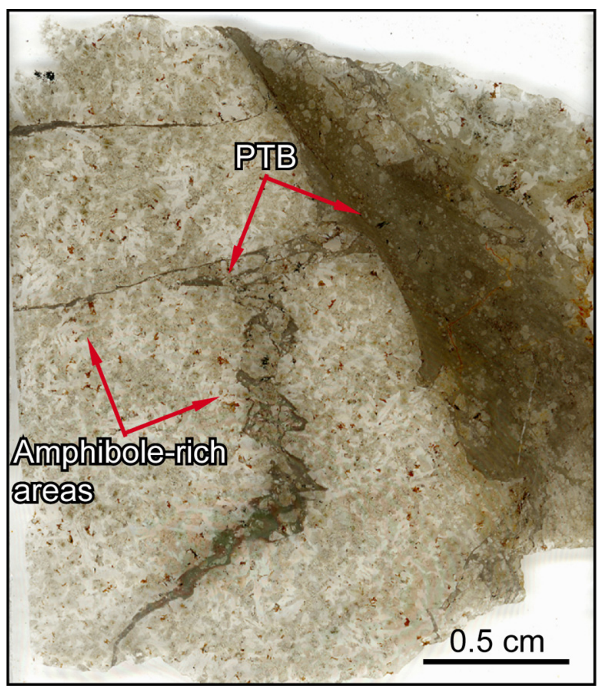

Fig. 1: Small-scale PTB (Sample UP-32) in mafic host rock. Note that PTB veins occur preferentially in amphibole-rich areas of the host rock.