SHOCK EXPERIMENTS WITH PREHEATED WITWATERSRAND QUARTZITE AND THE VREDEFORT MICRODEFORMATION CONTROVERSY. **W.U. Reimold,** Schonland Research Centre for Nuclear Sciences and Bernard Price Institute of Geophysical Research, University of the Witwatersrand, WITS 2050, Johannesburg, R.S.A.

Textures of Witwatersrand quartzite specimens experimentally shocked in the 5.1 - 35.5 GPa pressure range were presented by Reimold and Hoerz in 1986 (1,2). Those samples were shock-loaded while being kept at room temperature. The purpose for this study was two-fold: (i) to further study the influence of textural parameters and mineralogy on the formation of shock textures in polycrystalline materials, and (ii) to compare the experimentally produced deformation textures with natural deformation occuring in the same stratigraphic horizon (Hospital Hill quartzite) in the collar of the Vredefort structure, about 120 km away from the sampling site for the undeformed test specimens (sample mineralogy: ref (1)). The most important result of this first test series was, that while the experimentally produced progressive shock metamorphism is comparable to natural shock metamorphism as e.g. observed in Coconino sandstone from the Meteor Crater (3), it does not include the typical Vredefort microdeformation - i.e. multiple sets of planar fractures. It was concluded that the Vredefort-characteristic microcracks might have formed under shock compression at elevated temperatures and pressures (the present erosion level equals an original depth of 11-15 km).

A method was subsequently devised by F. Hoerz and co-workers at the experimental shock facility at Johnson Space Centre, Houston, to perform shock experiments on specimens held at elevated temperatures. Experimental details of the "hot-shock" technique will be presented elsewhere, but it should be indicated that a reusable (for economic reasons!) target-furnace assembly was designed that allowed to "shoot" at a desired temperature interval of + 5°C. Six experiments were performed at 2.9, 5.5, 8.1, 12.7, 17.5 and 27.6 GPa, respectively, and always at temperatures between 440 and 435°C (thought to correspond approximately to the temperature at depth at 2 AE ago of presently exposed Vredefort rocks).

Results of "hot-shock" tests (Fig.1): At low pressures (< 8.1 GPa) irregular fracturing is the dominant deformation phenomenon. Preferred sites for the formation of short (< 50 μm) microcracks - often in near-rectangular configuration - are grain margins and (probably) primary fractures. Fracturing can be so intense that thin breccia zones (< 150 μm) can develop. Undulatory extinction is rare in shots of pressures below 5.5 GPa. A series of radial cracks - in shape and length barely distinguishable from the above-described irregular fractures - was induced in shock-loading at low shock pressures. This effect is less evident in samples shocked at higher pressures. Comparing hot- and cold-shocked 5.5 GPa-specimens, a slightly higher fracturing degree is noted in the "hot"-shocked sample. Up to 5.5 GPa, incipient recrystallization of "breccia" zones can be observed. At intermediate pressures - 8.1 to 17.5 GPa - the degree of irregular microfracturing continues to evolve. Fracturing degrees are clearly higher than in cold-shocked equivalents (1). Brecciation along grain boundaries and major cracks becomes more prominent with increasing pressure as well. Mosaicism was first observed in the 8.1 GPa specimen. Recrystallization of breccia zones - and at 17.5 GPa also along intragranular cracks - progresses rapidly with pressure. As in the cold-shocked samples, no Vredefort-type planar fractures could be observed at low or intermediate shock stages in this study. Whereas planar elements (lamellae, features, Fig.1h) could be first detected in rare single sets at 16.8 GPa in a cold-shocked specimen, the 17.5 GPa hot-shocked sample is devoid of this deformation effect.

However, the high-pressure texture of the preheated 27.6 GPa-sample is very similar to the textures of cold-shocked samples at 28-29.7 GPa. Nearly all grains are "clouded" by a network of multiple sets of planar elements in multiple (>3) orientations. Locally, grains display beginning isotropization. Open, subplanar fractures, as described by (1; Fig.2B) in the cold-shocked 29.7 GPa specimen, can be also observed in the hot-shocked 27.6 GPa sample (Fig.1i). At this shock level, brecciation and recrystallization are virtually absent, and the degree of irregular fracturing has dropped far below that at 8.1 GPa.

In conclusion, in cold- and hot-shocked specimens the same deformation effects are found; however, fracturing, brecciation, and mosaicism are more strongly developed and occur at comparatively lower shock pressures in preheated shock-loaded specimens. A thermal effect - recrystallization - is important at low and intermediate shock pressures, but is absent at high pressures. As previously reported for cold-shocked Witwatersrand quartzite, Vredefort-type planar fractures could not be observed in this study either. The textures depicted in Fig.1 do not resemble natural deformation textures observed in Vredefort quartzite. This may be a vital observation, but the interpreter should remain conscious of the limits of experimental shock work - especially when comparing with deformation effects in gigantic natural structures, such as the Vredefort Dome.

On the Vredefort problem: The nature and formation of Vredefort-type planar microdeformation structures has become controversial since they were recently reexamined by Robertson et al.(4), Grieve et al.(5) and Reimold (6,7). Whereas the Ottawa group regards Vredefort microdeformations as diagnostic shock-produced planar features, this author has recognised open planar fractures similar to those found in tectonic settings (8). Orientations and distributions of planar microdeformations from Vredefort were determined by (4,5) and are described as "anomalous compared to that at other large terrestrial impact structures", and shock pressures calculated on the basis of planar feature orientation were "not regularly decreasing outward at Vredefort". Assuming that post-shock recrystallization - strongest near the centre of the Dome - had changed the distribution of planar "features", the Ottawa colleagues nevertheless favour an impact origin for the Vredefort structure.

This author determined the orientations of planar microdeformations in several Vredefort specimens, and the results are presented in Fig.2. Shock-characteristic ω,π and ε orientations were measured in each case, but the frequency distributions for annealed (fluid inclusion trails) and unannealed planar microdeformations are equally different from those associated with recognised shock levels A-D after (9)-Fig.2. As was already pointed out previously (2) and is being discussed in detail by (8), the orientation patterns of planar fractures associated with pseudotachylite -

determined for Vredefort, Witwatersrand, Johannesburg Dome, Northern Transvaal and Sudbury occurrences - are very similar. It is concluded that planar fractures of the Vredefort-type in quartz represent a typical microdeformation phenomenon associated with pseudotachylite formation (or - formed under stress-strain conditions found near or beyond the transition from brittle to ductile deformation regimes). At Vredefort the abundance of planar fractures along radial traverses though the granitic basement was shown to increase with increasing amount of pseudotachylite at given sampling sites (6).

The appr. orientations of subplanar to irregular fractures in a specimen from the Johannesburg Dome were also determined to be partially subparallel to ω or π orientations. Obviously the direction of tectonic stress as well as microtextural parameters are important factors determining the orientation of microdeformations. Thus ω or π–orientations are not unique to shock metamorphic deformation, whereas a predominance of ω, π and ε orientations in the case of planar elements appears to be a characteristic of shock metamorphism.

References: (1) Reimold , W.U. and Hoerz, F. (1986) LPS XVII, 703 -704; (2) Reimold, W.U. and Hoerz, F (1986) Geocongress '86, Ext. Abstr., Johannesburg, GSSA, 53 - 57; (3) Kieffer, S.W. et al. (1976) Contr. Mineral.Petrol. 59, 41 - 93; (4) Robertson, P.B. et al. (1987) LPS XVIII, 840 -841; (5) Grieve, R.A.F. et al. (Subm. to Proc. Int. Works. Cryptoexpl. Catastr. in the Geol. Rec., spec. issue Tectonoph., to appear 1988); (6) Reimold, W.U. (1987) LPS XVIII, 826 - 827; (7) Reimold, W.U. (1987) Is there evidence for shock metamorphism in the Vred. Struct.? Working paper, Int. Works. Cryptoexpl. and Catastr., Parys, July 1987; (8) Brandl, G. and Reimold, W.U. (as (5)); (9) Robertson, P.B. et al. (1968) in Shock metamorphism of Natural Materials (BM. French and N.M. Short, eds.), 433 - 452; (10) Reimold, W.U. et al. (1987) LPS XVIII, 830 - 831; (11) Reimold, W.U. et al. (as (5)).

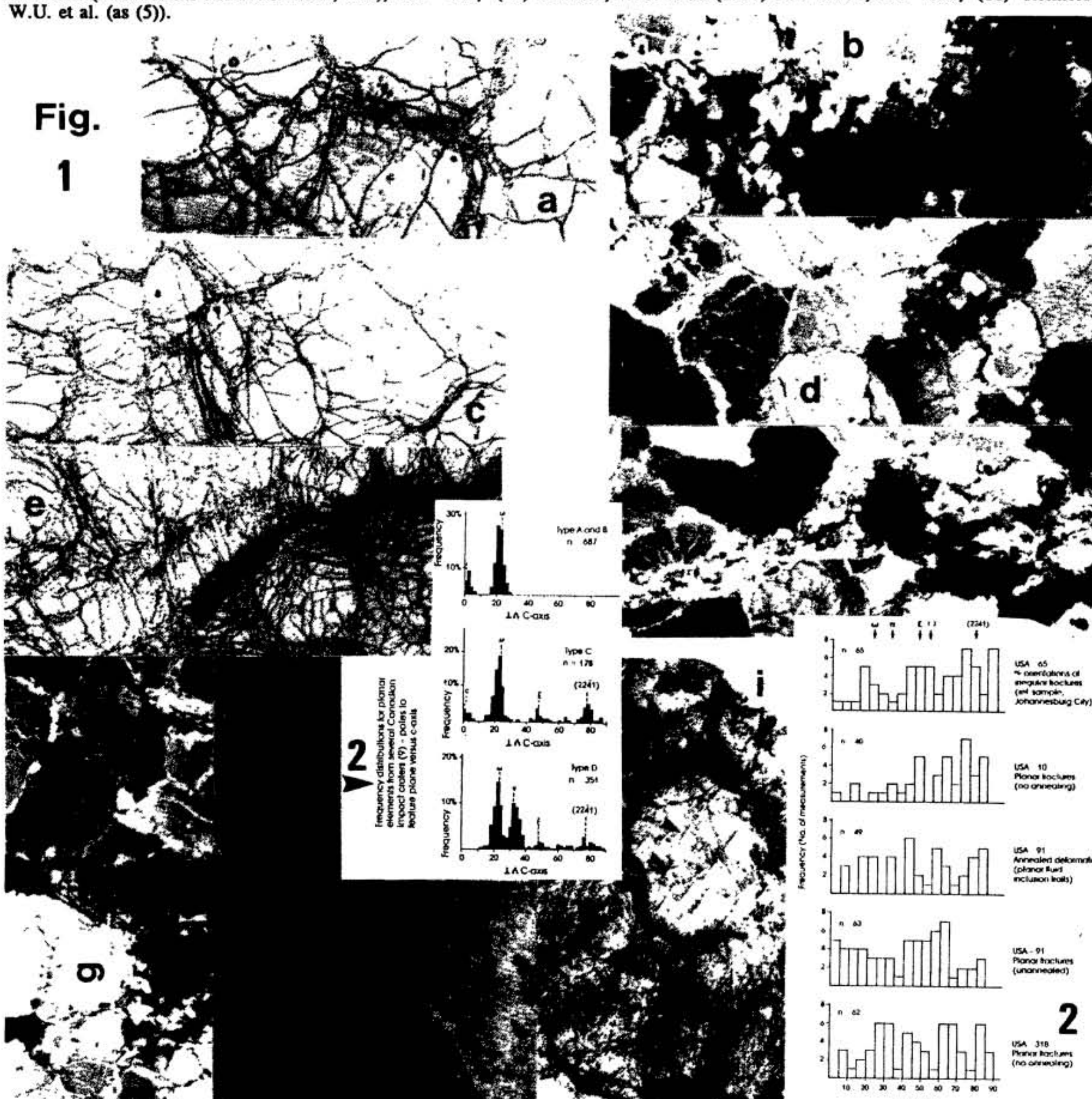

Fig.1 (a) 2.9 GPa, refl. light; (b) as (a), crossed pols.; (c) 5.5 GPa, refl. light; (d) as (c), crossed pols.; (e) 8.1 GPa, refl. light; (f) as (e), crossed pols; (g) 17.5 GPa, crossed pols.; (h,i) 27.6 GPa, par. pols.; widths : a,b,g - 1.1 mm, c,d,e,f,i - 2.2 mm, h -200 μm.

Fig.2 Comparison of orientations of pseudotachylite-related planar fractures and impact crater-related planar elements.