KINKED BIOTITE AS A STRAIN MARKER IN EXPERIMENTAL IMPACT CRATERS IN GNEISS. A. Agarwal[1], M. H. Poelchau[1], T. Kenkmann[1], [1]Albert-Ludwigs-Universität Freiburg, Institut für Geo- und Umweltnaturwissenschaften, Geologie, 79104 Freiburg, Germany.

Introduction: Microanalysis of samples from impact craters tends to focus on shock effects related to the pressure of the shock wave, e.g., the formation of planar deformation features, mineral phase changes, etc., which are then employed as shock barometers [1]. From a structural standpoint, deformation within the shock wave is not only related to shock pressures but also the corresponding strain. Understanding how the two correlate can give insights into the stress-strain path of the shock wave and help to understand processes within the shock wave in more detail.

Biotite is a mineral that buckles or kinks under compression and is thus a useful strain marker in plate tectonic settings [2]. Biotite also kinks under shock compression, and the required shock pressures for the onset of kinking have been experimentally determined [3], with kinking occurring above ~1 GPa.

Two impact experiments were therefore performed within the MEMIN research unit [4] using biotite-rich gneiss targets, and subsurface deformation was mapped using kinked biotites as finite strain markers.

Impact experiments: The two impact experiments were carried out at the two-stage light-gas gun facilities of the Ernst-Mach Institute on Maggia gneiss. Spherical aluminum projectiles with diameters of 5 mm were accelerated to ~7 km/s. Targets were 25 cm edge length cubes. The target in the first experiment (A37) was set up with the gneiss layering parallel to the target surface; the second experiment (A38) had layering perpendicular to the target surface.

Maggia gneiss, a metamorphic gneiss from the Maggia valley in southern Switzerland, was chosen as a target material due to its fine interlayering of feldspar- and quartz-rich bands with biotite-rich mafic bands. The gneiss layers are 1-2 mm thick and thus both smaller than the diameter of the projectile. The banding is very homogeneous and planar throughout the target blocks.

Methods: The two cratered blocks were sawn in half and thin sections were made of the crater subsurfaces. Optical microscope investigation shows prevalent kinking of biotite close to the crater surface, with the intensity of kinking decreasing with distance from the impact point. High resolution BSE image maps were made of the subsurface.

Based on these maps, the amount of kinking in individual biotite grains was quantified. The length of kinked biotite c-axis planes l_0 was measured as well as the length of the shortened biotite l_1, giving a strain value $\varepsilon = (l_0 - l_1) / l_0$. A total of 1337 values were measured. Furthermore, the orientation of the kink plane, which is a hypothetical plane lying within the fold hinges of a kink, was measured relative to the foliation and relative to the impact point source. The interlimb angle, which is the opening angle of the two limbs of a kink, was also measured.

Results and Discussion: Kink and strain measurements were focused on several profiles within the thin sections. In A38 (foliation perpendicular to the target surface) the central or "vertical" profile beneath the impact point source (Fig. 1) shows strains in the biotites exceeding 10% shortening near the crater surface. With increasing depth beneath the surface, strain values decrease, and at 4 cm or 8 d_p (projectile diameters; 1 d_p = 5 mm) distance from the crater floor, shortening has decreased by almost 2 orders of magnitude to ~0.1% (Fig. 2).

These strain values show a clear correlation with the corresponding interlimb angles (Fig. 2). Higher amounts of shortening are reached through tighter folding in the kinks and narrower interlimb angles.

Note that for the vertical profile in A38, the shock wave front is perpendicular to the foliation and propagates parallel to it. This means that the principal axis of stress, σ_1, is also parallel to the biotite layering and compression is parallel to biotite c-axis planes.

Two "oblique" profiles were also measured in A38 (Fig. 1). Biotites were measured that had an oblique orientation to the shock front; angles between σ_1 and c-axis planes were ~30-45°. This led to a variation in the style of kinking. In particular, the orientation of kink planes varies based on their position to the left or right of the impact axis. When kink plane orientations are compared to their position relative to the point source it can be seen that kink planes are roughly perpendicular to the local propagation direction of the hemispherical shock wave and thus roughly perpendicular to σ_1.

In the oblique profiles of A38, strain values near the crater surface are slightly lower than the strain values of the vertical profile, and they decrease more rapidly with depth. Interlimb angle also show the same trend (Fig. 2). Kinking is thus less intense for increased angles between σ_1 and biotite c-axis planes.

In A37 (foliation parallel to the target surface), a vertical profile was also measured. Here, the angle between σ_1 and biotite c-axis planes is ~90°. Kinking occurs as conjugate sets, and most notably, the kink plane orientations are no longer perpendicular to the local propagation direction but at angles of ~40-50°.

Strain values in the vertical profile are ~10% at the crater surface but decrease much more rapidly than A38, reaching values of in the order of ~0.1% after only 2 d_p. This is likely related to a different deformation style in horizontal biotites, where shear faulting induces kinks, as opposed to the “buckling” style of deformation in subvertical biotites. Additional “horizontal” profiles were measured near the target surface. For these profiles, the shock wave propagation direction should again be roughly parallel to biotite layering. Surprisingly, strain values here are reduced by roughly an order of magnitude compared to the vertical profiles of A38. This may be due to interaction of the shock wave with the target surface leading to reduced shock pressures.

Outlook: Biotites are useful strain markers and can be used within an experimental impact setting to map out strain gradients (Fig. 3). Care needs to be taken when calibrating biotites of variable orientation, and in a next step, strain ellipses for kinking at different distances to the point source will be constructed. A detailed understanding of strain in relation to corresponding shock pressures derived either from numerical models of from sample shock barometry has the potential to yield new insights into shock deformation processes.

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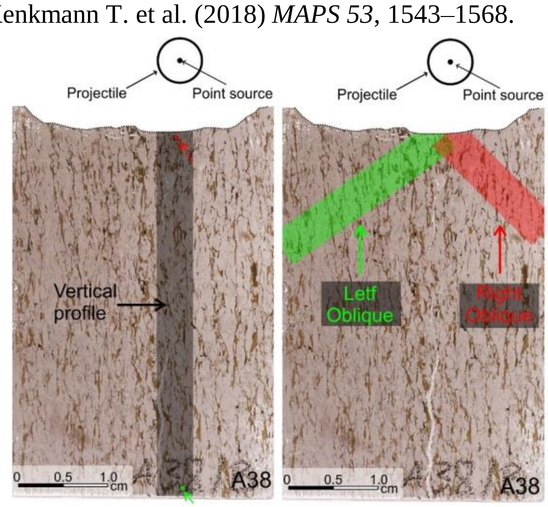

Fig. 1. Thin section scan of the crater subsurface from experiment A38, showing the orientation of profiles in which strain in kinked biotite was measured.

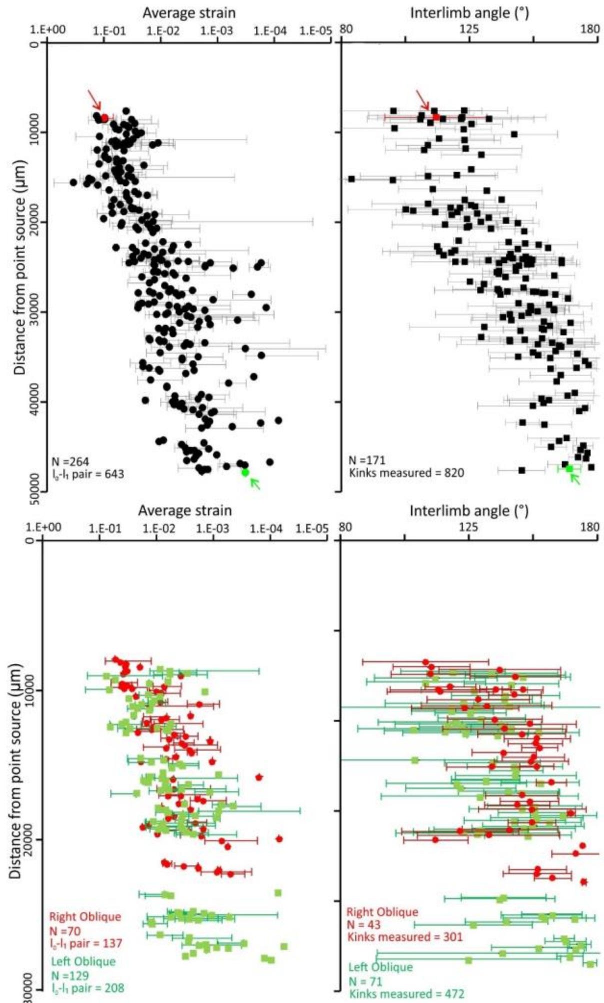

Fig. 2. Strain values and interlimb angles measured in profiles from experiment A38. Top: vertical profile, Bottom: right (red) and left (green) oblique profiles.

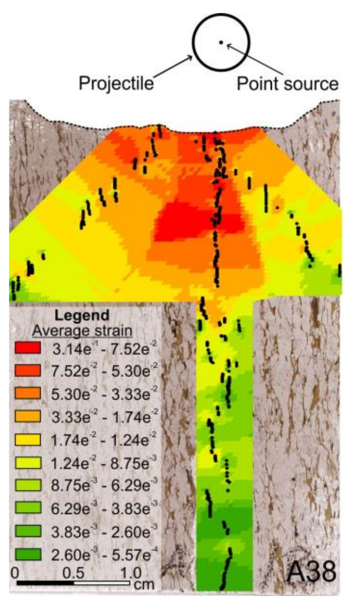

Fig. 3. Strain values from three profiles of A38 were interpolated to generate a preliminary strain map. Highest intensity of strain is directly beneath the point source.