Description of samples from the Hohentwiel, Germany

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Samples

7 samples of potential shatter cones have been evaluated, of which 4 were available as physical samples, the rest as high resolution photographs. The physical samples were photographed as well.
These samples have been investigated with regard to their shape and form to be able to confirm or discard them as shatter cones. For that, an attempt was made to outline typical striated bodies on their surfaces and to measure the angles between striations.
The investigation of striation has been carried out on photographs of individual samples.

Macroscopic observations

On all samples with the exception of one, striated, conical bodies could be observed without any doubt. The exception is strongly weathered and hardly any surface structures are visible.
On all other samples, all striations merge in an apex and are not parallel to each other which is the typical appearance of shatter cones (Fig. XX). Also, the samples show various forms and shapes of the surfaces, e.g., undulating to convex or concave, which is very common for shatter cones and have been described already by several authors (e.g., Melosh 1990, French, 1998, Wieland et al. 2007). This, however, could also be attributed to the composition of the rock and the orientation of fractures. This relationship is unknown due to the lack of evidence from the field. In the more fine-grained rock types, such as limestones, the striations and imprint of a concave or convex surface is much more pronounced than in more coarse-grained rocks or rocks with inclusions or with large pore space, such as tuffs.

Measurements

An attempt was made to measure as many striation angles as possible for each sample, and determine an apex orientation, but the number of measured striations differs from sample to sample. This is due to the different quality of samples.
Although the angles do vary on individual samples from between 12-64°, they are in general very consistent on the rest of the samples, i.e., the majority of measurements revealed angles between 30 and 45°. This consistency persists on samples of different rock types.
It is clear from the observations and measurements that the orientation of the apeces does not scatter on individual samples, but do point in a uniform direction. This direction, however, can vary from sample to sample.

The relationship to bedding and fractures or the centre of a possible impact crater is difficult to determine due to insufficient data from the field.

Interpretation

Striation angles

The range of striation angles is wider on samples of a fine grained rock type, such as limestone. This could be due to the increased number of small heterogeneities in the rock, such as grains, minerals, but also structural elements, e.g., bedding and fracture surfaces which occur on a much smaller spacing. If these samples will be confirmed shatter cones, this supports the theory by French (1998) and Wieland et al. (2007) that the shock wave is reflected on such heterogeneities in the rock and which is responsible for the development of striations. The apex of these striations then must point towards the centre point where the reflection occurred, i.e. grains, minerals, surfaces, and not to the centre of a possible impact crater after a back rotation of strata to its pre-impact orientation (see Wieland et al. 2007).

Striation orientations

The striation orientation is uniform on individual samples. No samples are available which are lying on top of each other and display shatter cone characteristics with different general apex orientations as described by Wieland et al. (2007). This may be caused by the size of samples or the preservation of those in the field. As a result, it can only be stated, and confirmed, that the consistent apex orientations on individual samples are, however, conform to observations from confirmed shatter cones of other impact sites by previous authors (e.g., Melosh, 1990, French 1998, Wieland et al. 2007).
As a result, no statement can be made whether a back rotation of strata to its pre-impact position would result in shatter cone apeces pointing towards an impact centre, as stated by French (1998), or whether the apeces orientation scatter after the back rotation with respect to the centre of the impact crater as postulated by Wieland et al. (2007). In addition, the in situ measurements of shatter cone and bedding orientations in the field are lacking in order to make a qualitative statement on this matter.

Conclusions

Although no microscopic observations have been carried out, it can be said that these samples resemble shatter cones. Typical conical shapes and concave and convex surfaces as well as striations which merge are indicative for shatter cones (see also e.g., Melosh, 1990, French 1998) and do not correspond to tectonic fault patterns, such as slickensides, which are usually parallel to each other.
However, striated surfaces in volcanic settings can be misleading and it needs to be made sure that they are not linked to the volcanic event itself (e.g., explosive breccias) or through other man-made events using explosive forces (such as road cutting).
Although, the investigated samples do show close resemblance to shatter cones derived by an impact, it cannot be ruled out that the striated surfaces are linked to a volcanic event in the Hohentwiel.
The striated surface which have been evaluated cannot be used alone to determine an

impact origin of the Hohentwiel and further studies are needed.
In order to constraint their true origin better, more detailed field work and more samples are required. Furthermore, additional work needs to be carried out on impact related features, such as shocked quartz and pseudotachylitic breccias.

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