NEAR-GROUND AIRBURST CRATERING: PETROGRAPHIC AND GROUND PENETRATING RADAR (GPR) EVIDENCE FOR A POSSIBLY ENLARGED CHIEMGAU IMPACT EVENT (BAVARIA, SE-GERMANY).

LPSC 2020

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Introduction

The asteroid impact near the Russian city of Chelyabinsk in 2013 was the largest airburst on Earth since the 1908 Tunguska event. Meanwhile, there are scientists who consider airburst as much more dangerous for mankind than direct projectile impacts to form meteorite craters [1]. In the geological past impact cratering accompanied by giant airbursts must have hit Earth periodically, whereby the term cratering refers to the fact that projectiles exploding in the atmosphere may leave their traces also on the ground to form shallow craters. Here we report on effects of a suspected large airburst event, the traces of which are documented by small craters, shock effects, an extended superficial melt rock sheet and significant evidence from GPR investigations.

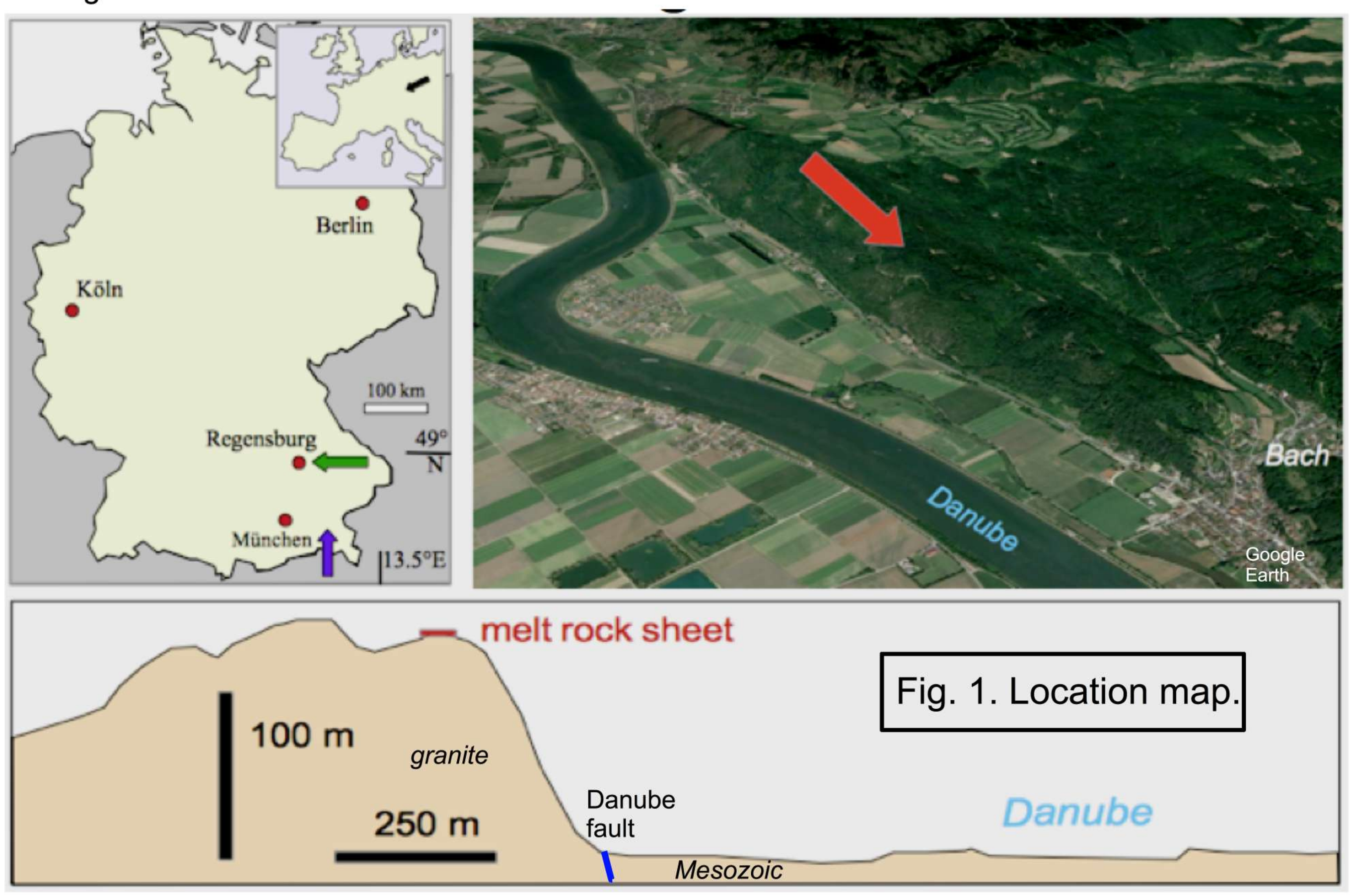


Fig. 1. Location map.

The Regensburg/Bach melt rock sheet

In the early new millennium, a ca. 500 m x 50 m sheet of surficial melt rock granite with abundant glass formation down to a depth of roughly 1 m exposed along the highest point of the granite massif above the Danube valley (Fig. 1) was discovered by a local mineral collector, raised some interest of a geologist, initiated early unpublished mineralogical work and practically fell into oblivion. Man-made and volcanic activities can be (and were) absolutely excluded, and the phenomenon had obviously escaped geologic mapping in the forest.

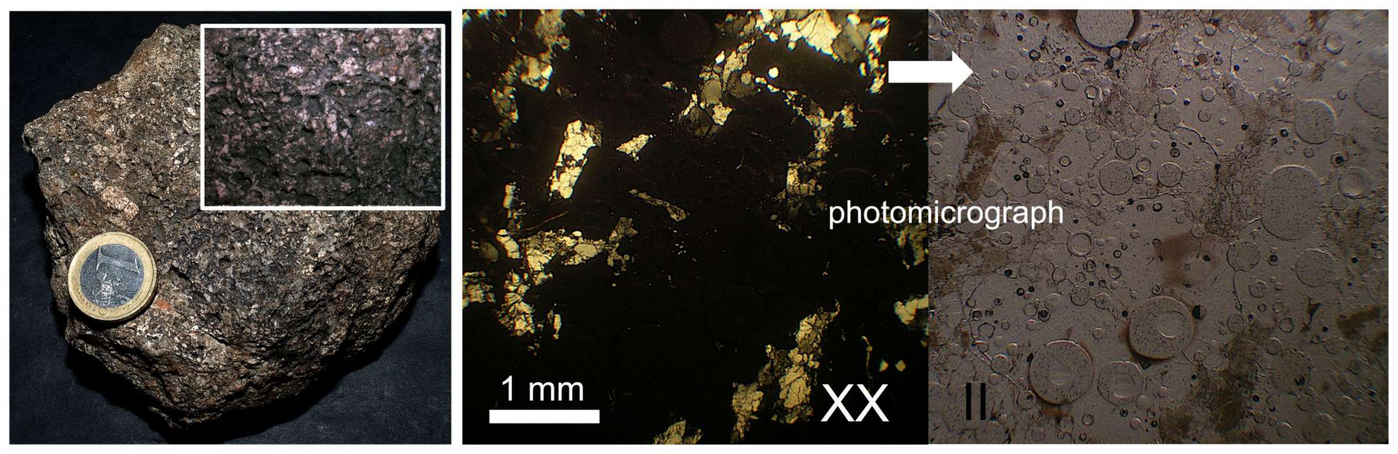


Fig. 2. Practically only quartz grains have survided in the glass matrix of the granitic melt rock.

In the absence of plausible anthropogenic or geological causes, a meteorite impact event was soon considered, and since no impact crater of some size was known far and wide, superficial melting of the granite by an airburst was discussed as a possible explanation. An extensive surface glass formation was considered in analogy to the formation of the famous Libyan desert glass and to the Trinity nuclear weapons experiment and the formation of the trinitite glass [2], and new petrographic analyses confirm an **impact shock event** as very likely cause for the granite melting (Fig. 2).

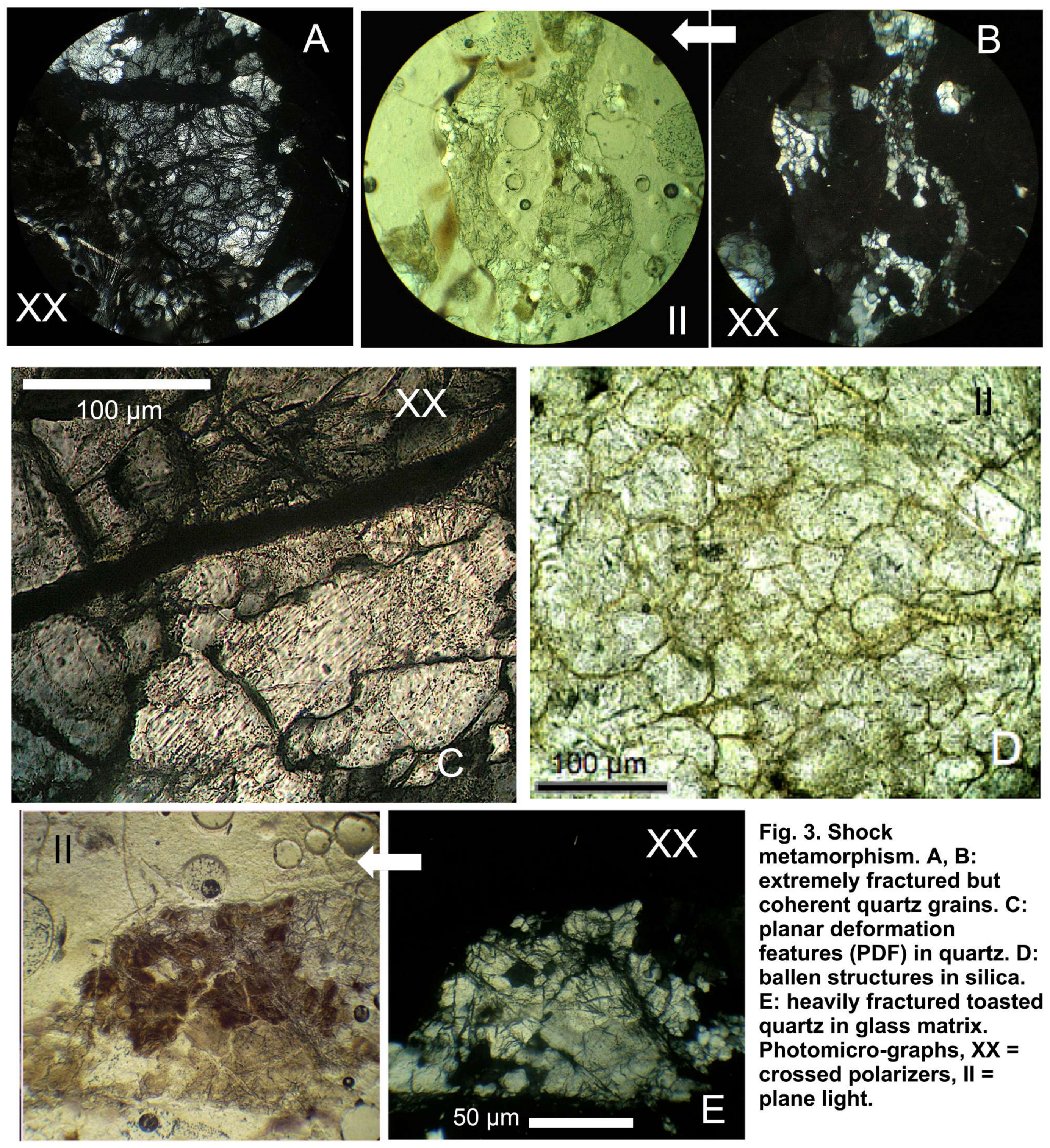
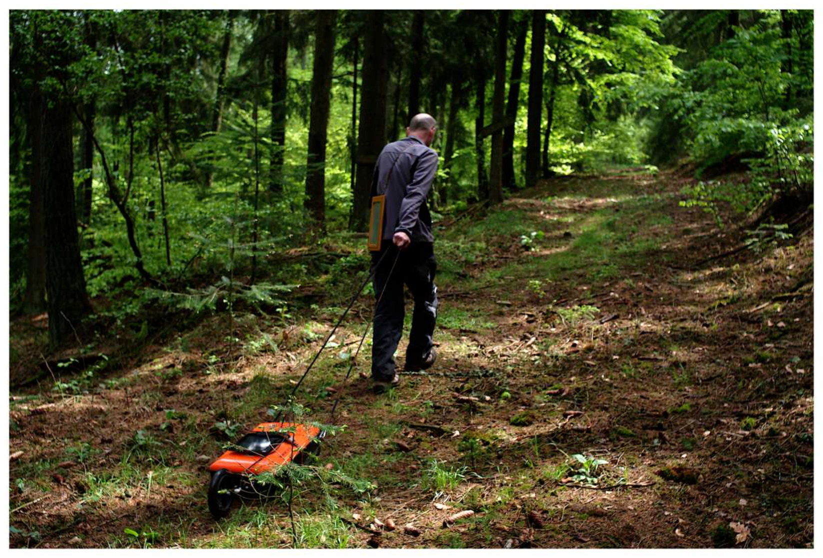


Fig. 3. Shock metamorphism. A, B: extremely fractured but coherent quartz grains. C: planar deformation features (PDF) in quartz. D: ballen structures in silica. E: heavily fractured toasted quartz in glass matrix. Photomicro-graphs, XX = crossed polarizers, II = plane light.

Shock metamorphism in the melt rock sheet

In terms of impact nomenclature the material of the melt rock sheet may be considered impact melt rocks, in which relics of granites coexist with a strongly vesicular glass matrix (Fig. 2 A, B). The granite must obviously have been heated to such a degree that only quartz grains could survive (Fig. 2). These quartz grains must have experienced extreme shattering (Fig. 2 C,), possibly from thermal shock (see below). Shock effects like those well-known in quartz from impact cratering are observed throughout analyzed samples, and we state planar deformation features (PDF, Fig. 2 C), diaplectic glass passing over to ballen structures (Fig. 2 D) and so-called toasted quartz (Fig. 2 E).

The GPR measurements



The GPR survey of the melt rock sheet and a peripheral zone comprised about 3 km profile length. Reciprocating a lot of lines was performed to prove reproducibility of the data. Registration depth was 8 m and sampling rate on the profiles 3 cm. Data processing used Sandmeier Reflex GPR software.

Fig. 4. The GPR equipment: Transient Technologies VIY3-300 with a 300 MHz antenna. The photo was taken from the top of the melt rock sheet.

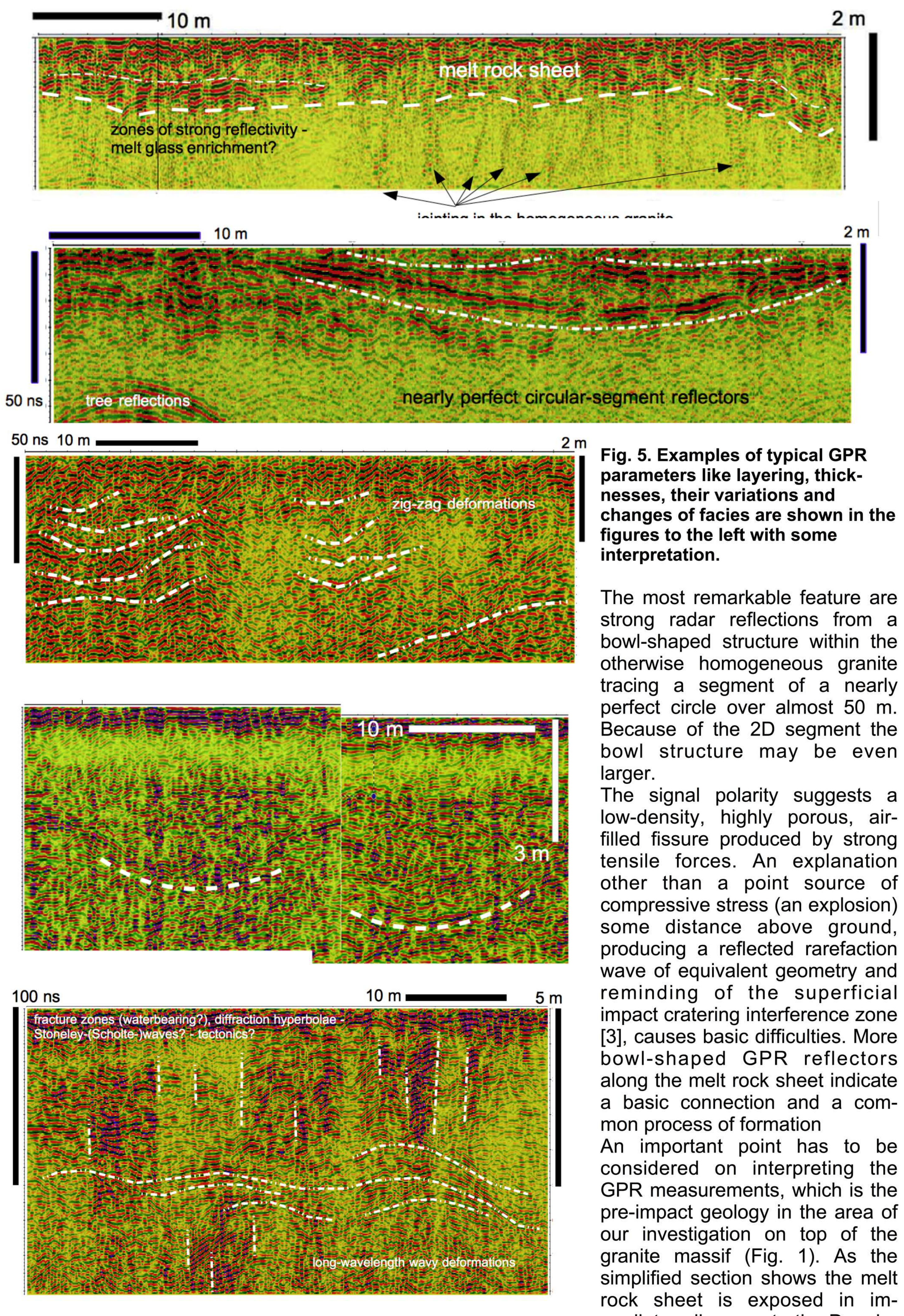


Fig. 5. Examples of typical GPR parameters like layering, thicknesses, their variations and changes of facies are shown in the figures to the left with some interpretation.

The most remarkable feature are strong radar reflections from a bowl-shaped structure within the otherwise homogeneous granite tracing a segment of a nearly perfect circle over almost 50 m. Because of the 2D segment the bowl structure may be even larger.

The signal polarity suggests a low-density, highly porous, air-filled fissure produced by strong tensile forces. An explanation other than a point source of compressive stress (an explosion) some distance above ground, producing a reflected rarefaction wave of equivalent geometry and reminding of the superficial impact cratering interference zone [3], causes basic difficulties. More bowl-shaped GPR reflectors along the melt rock sheet indicate a basic connection and a common process of formation

An important point has to be considered on interpreting the GPR measurements, which is the pre-impact geology in the area of our investigation on top of the granite massif (Fig. 1). As the simplified section shows the melt rock sheet is exposed in immediate adjacency to the Danube fault, and tectonics along this very prominent fault is expected to have not spared the granite in the area of our investigations from more or less significant deformations. Hence, GPR radargrams shown here may well reflect such deformations in the form of fracture zones and folding as is exemplarily shown in the lowermost image. Since the profile is running far outside the melt sheet, we are probably seeing "normal" tectonics instead of impact features. Also fluorite dikes that have been exploited in the Bach environs, may be seen in GPR anomalies.

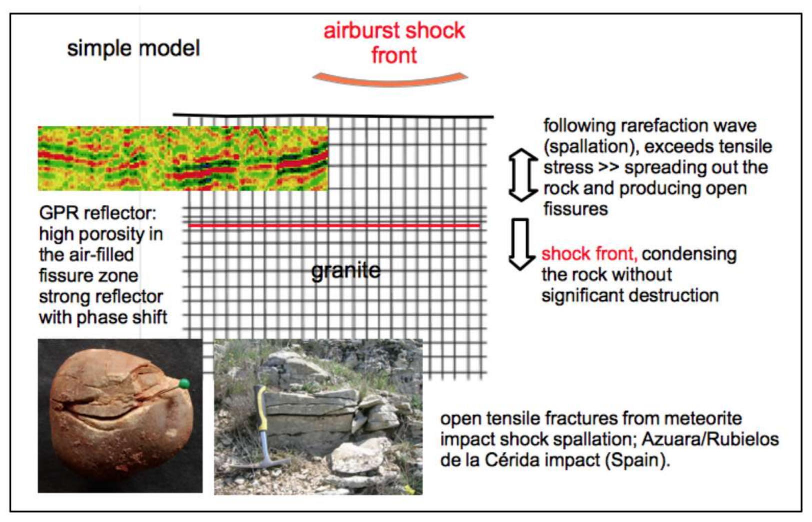


Fig. 6. Impat shock spallation: Rarefaction tensile waves follow shock compressional waves. In impact cratering the spall plate model [3] has gained some application, and meanwhile the rarefaction is generally considered the most destructive process.

More impact evidence

The Sünching crater

In connection with the Bach melt sheet campaign and with regard to the absence of a larger crater, field inspection focused on possible nearby impact signature, and in fact from studying the high-resolution Digital Terrain Model two interesting locations could be identified: Sünching and Sulzbach.

Fig. 7. The Sünching crater with a distinct rim wall is considered by the monument office to be a medieval tower hill. Note the similarity to the Chiemgau craters (Fig.11).

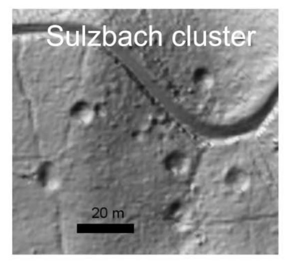


Fig. 8. Close to the Bach melt rock sheet a cluster of several small, slightly rimmed craters was identified in the Digital Terrain Model shadowed relief map. A closer inspection is outstanding

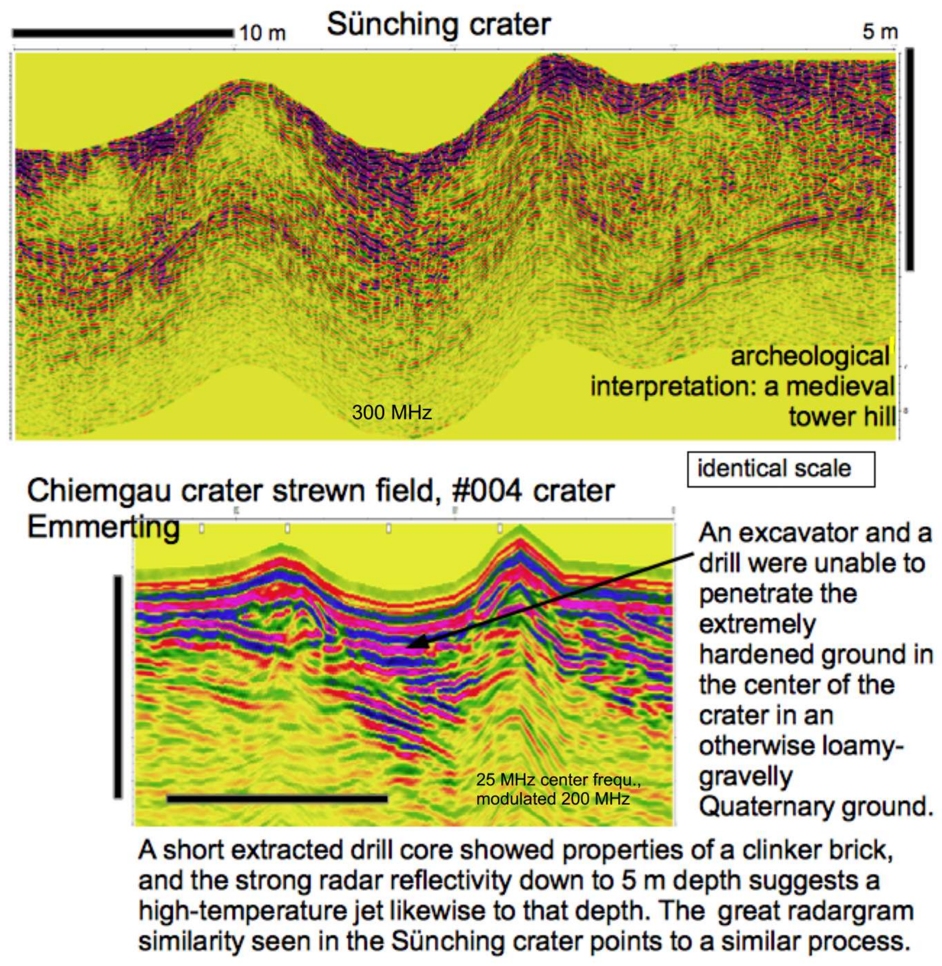


Fig. 9. GPR for comparison: The Sünching crater and the #004 Emmerting crater in the Chiemgau impact strewn field suggest the same formation process.

Fig. 10 Location map for the Bach melt rock sheet, the Sünching and Sulzbach craters and the Chiemgau impact crater strewn field.

The Chiemgau impact possible airburst scenario

After the discovery of the melt rock sheet near Bach and a presumed formation by an impact airburst, a connection with the now established Chiemgau multiple impact event ([4, 5], and references therein) with the 120 - 130 km distant crater strewn field (Fig. 1) was soon seen, because the role of strong airbursts in the Chiemgau impact in addition to crater formation (Tüttensee crater, Chiemsee double crater, etc.) became more and more evident. Considering effects of plasma formation and neutron radiation obviously being well observed and discussed in the crater strewn field, we moreover mention widespread effects of extreme heating of the ground ([5, 6], and references therein): Halos of strongly enhanced temperatures (>1,500°C) around smaller craters (e.g. #004 Emmerting Fig. 11) are observed, and anomalous distinct magnetic susceptibility peaks measured over large areas at some depth in the soil excluding industrial or geogenic origin could well be explained by an impact remagnetization due to strong temperature overprint. Unusually strongly magnetized limestone cobbles and boulders from some of the smaller craters (e.g. Mauerkirchen, Kaltenbach), containing superparamagnetic nanoparticles, point to short-term high *PT* conditions [7, 8]. In particular, the formation of the chiemite carbon impactite containing diamonds and carbynes are reasonably explained by instantaneous shock carbonization/coalification of the target vegetation [6]. Hence, one or several airbursts in the Chiemgau area could well explain these observations, in particular with view to the low-density disintegrated, loosely bound asteroid or disintegrated comet proposed for the Chiemgau impact event [4, 5].

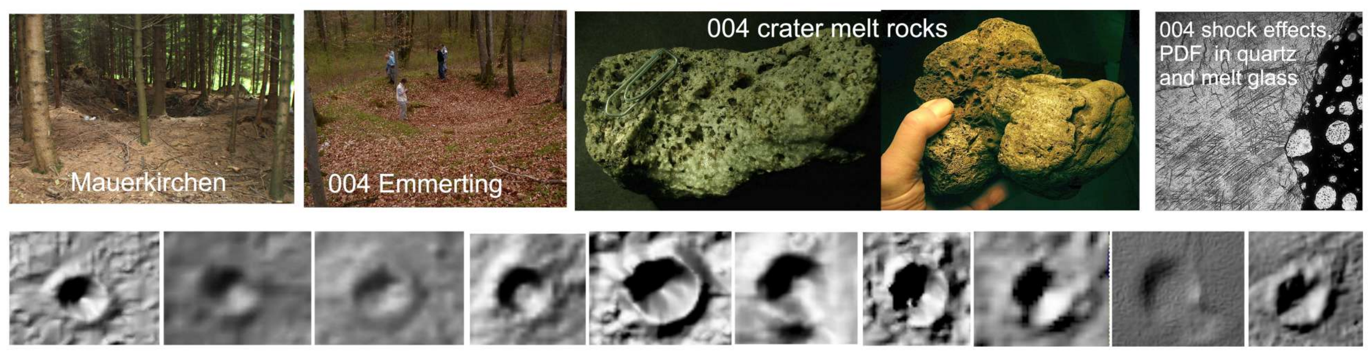


Fig. 11. Examples of smaller craters (diameter 10 - 20 m) in the Chiemgau impact strewn field. The Mauerkirchen and #004 craters are typical examples of accumulations of melt rocks with shock effects and abnormally magnetized limestone cobbles. Below: Digital Terrain Model shadowed relief.

Conclusions:

While impact airbursts and their threat to mankind are generally discussed for asteroids or meteoroids exploding high in the atmosphere, we present evidence that a larger dimensioned airburst was triggered close to the earth's surface, whereby not only noticeable craters were formed (Chiemgau impact, Sünching crater, possibly Sulzbach craters), but obviously strong shock could be produced without crater formation (Bach). To our knowledge, no comparable event has yet been proven on Earth. It also puts into perspective the recent discussion about the formation of the Libyan desert glass, for which an airburst formation is once again ruled out in favor of a hitherto not found impact crater, and the above-mentioned danger from airbursts is considered exaggerated [9]. This view is contrasted by our now presented research. While the Chiemgau impact is fairly well dated between 900 and 600 B.C. [10], no dating is available for the melt rock sheet, although due to the low soil formation and the freshness of the glasses, a very young age is likely and a synchronous impact event must be seriously considered. Otherwise, it must be assumed that airbursts near the ground were much more frequent than expected.

References

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