WHY TO SEARCH FOR NEW IMPACT CRATERS ON EARTH? EXAMPLE OF THE RECENTLY CONFIRMED HUMMELN IMPACT STRUCTURE (SWEDEN). L. Ferrière[1], C. Alwmark[2], and S. Holm-Alwmark[2], [1]Natural History Museum, Burgring 7, A-1010 Vienna, Austria (ludovic.ferriere@nhm-wien.ac.at), [2]Department of Geology, Lund University, Sölvegatan 12, SE-223 62 Lund, Sweden.

Introduction: New impact craters, in fact mainly impact structures (i.e., the original crater is generally partially or largely eroded) are discovered/confirmed on Earth almost each year, but why should we continue to search for new ones? Currently, only 187 impact structures are definitively recognized on Earth, the last one being the Hummeln structure (Sweden, [1]), but many other impact structures that must exist have not yet been discovered/confirmed. Some more or less circular structures are presently considered to be of "uncertain origin" (see e.g., [2-4]); however, their recognition and confirmation as impact structures will need to be supported by evidence of unambiguous shock-deformations in minerals (e.g., planar deformation features [PDFs] in quartz), or traces of extraterrestrial matter (e.g., siderophile-element anomalies) [5]. The process of recognition of a new impact structure can be long and tedious; first a candidate structure should be identified, then it should be visited, and then samples should be collected and finally carefully investigated in the laboratory. The confirmation is a good first step but it then needs to be completed with a detailed investigation of the entire structure, including the conduction of proper geological, structural, and geophysical mapping. A large number of the 187 confirmed impact structures have merely only been identified, but not studied in detail. Even the age and the diameter of these structures are in many cases not well constrained, which can potentially strongly alter our understanding of the bombardment rate of the Earth by asteroids and comets. Knowing that large impacts can be globally destructive, potentially resulting in extinction events, the study of impact craters on Earth is essential. Furthermore, these structures also offer unique opportunities to better understand the impact cratering process.

Here we report on the confirmation of the impact origin of the Hummeln structure and the implications of such a confirmation, together with a more general discussion on recently confirmed impact structures.

Results and discussion: The Hummeln structure (57°22'N, 16°15'E) is located in the Småland province, in southern Sweden. It consists of an over 160 m deep and 1.2 km wide depression in the Precambrian crystalline basement, within Lake Hummeln. The origin of this circular depression has puzzled the geological community for nearly 200 years [1]. After the collection of breccia samples at the Hummeln structure (Fig. 1) and careful examination of dozens of polished thin sections, we were able to identify and to characterize shocked quartz grains (Fig. 2), first using the polarizing microscope, and then using scanning (SEM), and transmission electron microscopy (TEM), as well as the universal stage (U-stage).

Fig. 1: Macrophotograph of a (crystalline) polymict impact breccia from the Hummeln impact structure (sample HUM14_HS_11).

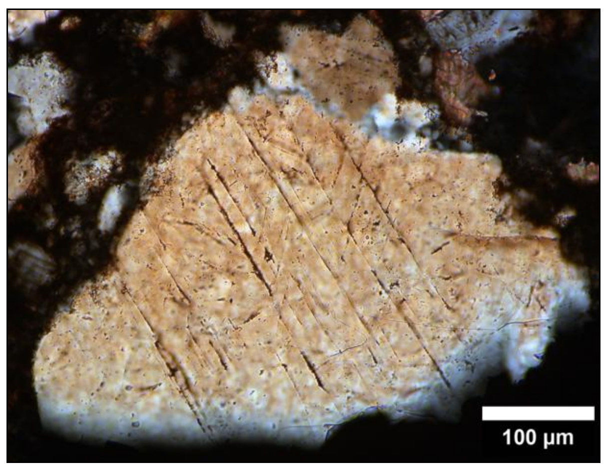

Fig. 2: Photomicrograph (crossed polars) of a quartz grain with two sets of PDFs (PTS HUM14_HS_01).

The documentation of unambiguous shock deformation features demonstrates that the Hummeln structure was formed by a hypervelocity impact event. This result have not only solved an almost 200-year old enigma, but it also strengthens the hypothesis that the cratering rate was increased during the Middle Ordovician as a consequence of the L-chondrite parent body

(LCPB) break-up event (i.e., the age of formation of the Hummeln structure is roughly coeval with that of the Granby impact structure, i.e., ~467 Ma [1, 6-8]). In addition, despite its relatively small size and its old age, the Hummeln structure is remarkably well preserved. This shows, contrary to the general assumption, that under specific conditions, i.e., a marine target environment with continued sedimentation, a small impact crater can survive more or less unaffected for hundreds of million years.

According to the recent work by [9] many more impact craters/structures in the size range of the Hummeln structure are still to be discovered. Based on probability calculations they estimate that ~90 craters with a diameter of 1 to 6 km and a further 250 with a diameter of 0.25 to 1 km are still awaiting discovery [9]. Furthermore these authors estimate that all craters larger than about 6 km in diameter exposed at the surface have already been discovered. We generally agree with their conclusions that many small exposed impact structures still remain to be discovered/confirmed, however, the recent findings of large impact structures, such as the Tunnunik structure (in Canada, ~25 km in diameter [10]), the Luizi structure (in DRCongo, 17 km in diameter [11]), and the Santa Marta structure (in Brazil, ~10 km in diameter [12]), illustrate that some medium to large exposed impact structures are still awaiting discovery/confirmation. The extended lists of structures presently considered to be of "uncertain origin" (see [2-4]) also support our opinion that a good number of medium to large, more or less eroded, exposed, impact structures await to be discovered/confirmed. This being said, the search should definitely continue, especially considering that some parts of the world – in particular Africa and South America – have been poorly explored because of the instable political situation and/or due to the difficult logistics. Asia should also not be neglected as a good number of impact structures are still awaiting discovery in this part of the world. All new discoveries bring new interesting observations and evidences that are very helpful to further our understanding of the crater-formation process. A good exemple is the recently discovered Kamil crater (in Egypt; [13]), 45 m in diameter, with a pristine ejecta ray structure. Such well-preserved craters were previously only observed on asteroid or planetary surfaces and, thus, the possibility to perform ground survey provides unique observations of small-scale hypervelocity impacts on Earth. These new observations can then be compared with laboratory impact cratering experiments results, and are thus complimentary. Our knowledge of the behavior of rocks and minerals subjected to hypervelocity impact was also furthered by some recent discoveries of new impact structures, for instance the response of sedimentary rocks to hypervelocity impact (see recent observations at the Luizi structure [14]). Of importance is not only to confirm the impact origin of a structure, but to provide detailed and intelligible observations that can then be used by modelers to better constrain their calculations.

Concluding remarks: A large number of impact structures still remain to be discovered/confirmed on Earth, but as said by [15]: "the “glory” of discovery of a new impact structure cannot subjugate good scientific practice". To be able to confirm the hypervelocity impact origin of a structure, proper, unique and unambiguous, evidence should be presented, although this is unfortunately not always the case. Here are only a few examples of recently claimed "impact structures" that are totally unsupported by the reported observations but that were, unfortunately, published in peer review journals: the Maniitsoq structure (in Greenland, [16]), the Warburton Basin structure(s) (in Australia, [17]), the Bajada del Diablo crater-strewn field (in Argentina, [18]), etc.

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