IMPACT EARTH – A 2023 UPDATE ON THE TERRESTRIAL IMPACT RECORD. G. R. Osinski[1], R. A. F. Grieve[1], A. J. Cavosie[2], L. Ferrière[3], A. Losiak[4], [1]Dept. Earth Sciences, University of Western Ontario, London, Canada (gosinski@uwo.ca), [2]School of Earth and Planetary Sciences, Curtin University, Perth, Australia, [3]Natural History Museum Vienna, Vienna, Austria, [4]Institute of Geological Sciences, Polish Academy of Sciences, Wroclaw, Poland.

Introduction: During the second half of the 20th century, and into the 21st century, it has become increasingly clear that the impact of asteroids and comets with other planetary bodies is one of the most ubiquitous and important geological processes in the Solar System [1, 2]. It is now widely recognized that the impact process has played a fundamental role throughout the history of the Earth and other planetary bodies, resulting in both destructive [3] and beneficial effects, both for microbial life [4] and through the production of economic metal and hydrocarbon deposits [5]. While the impact record on Earth is incomplete, it offers the only opportunity to conduct comprehensive fieldwork, deep drilling, detailed geophysical surveys, and to obtain *in situ* samples that are essential not only to confirm an impact origin of a given structure or deposit, but also to characterize the nature and properties of the impactites.

The *Impact Earth* (www.impactearth.com) initiative aims to provide a holistic view of meteorite impacts, from fireballs, to meteorite falls, to the largest crater-forming events. The three main aims are to provide a resource for the research community by hosting an *Impact Earth Database*, to promote the public understanding and interest in impacts, and to provide resources for educators at both the school and university level. In this contribution, we provide a summary and overview of the current impact record on Earth based on a 2022 review [6] and subsequent recent discoveries. We note that there are likely omissions and errors in this database due to the diversity and breadth of the current literature on terrestrial impacts, and we welcome input from the entire community to ensure that this resource is an accurate and up-to-date as possible.

The Impact Earth Database – Impact Craters, Hypervelocity Impact Craters, and Impact Deposits: As presented in detail by Osinski et al. [6], the literature is not always clear in terms of what constitutes an impact site of extraterrestrial origin, with various terms having been used, such as "crater", "impact crater", "hypervelocity impact crater" and "meteorite impact crater". In addition, the terms "penetration crater", "penetration funnel", and "terminal pit" are also used to describe the small, often meter-deep holes formed when large meteorites impact with the Earth's surface. The following terminology and definitions are thus used in the *Impact Earth Database* to avoid any unwarranted confusion:

Impact crater: A general term for a topographic depression where either shock metamorphism did not occur or has not been recognized in the target materials.

Hypervelocity impact crater: This is what most people envisage when the term "crater" is used but it should be restricted to impacts where evidence of *shock metamorphism* in the target materials has been confirmed. Importantly, most hypervelocity impact craters are eroded such that the original crater-form is modified or no longer present. The term *hypervelocity impact structure* is thus more appropriate for most terrestrial hypervelocity impact craters, except in the rare cases where the original crater morphology is preserved.

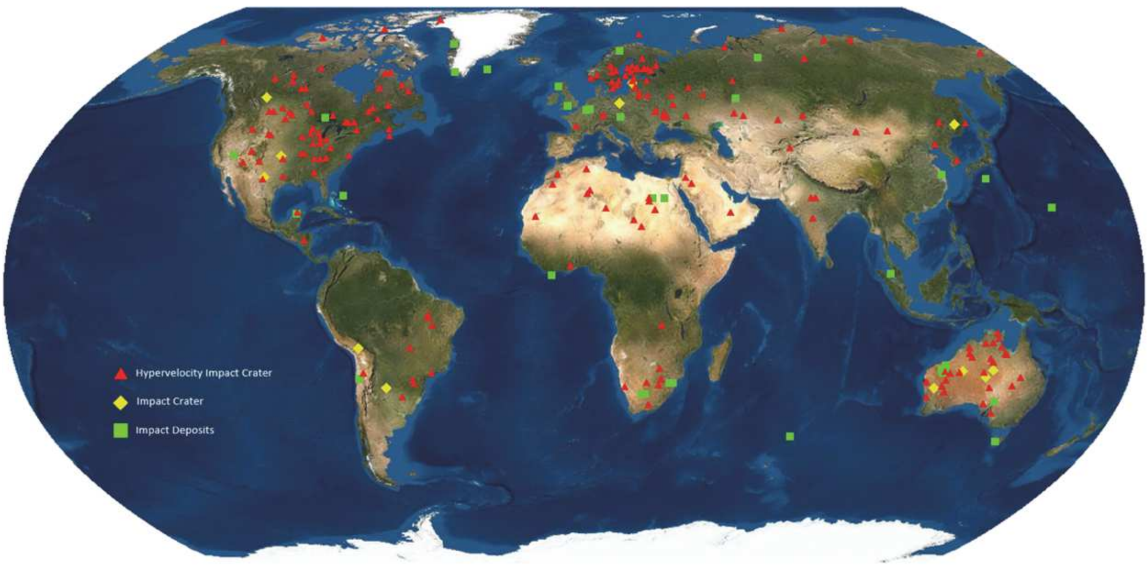

Fig. 1. Location of confirmed impact craters, hypervelocity impact craters, and impact deposits on Earth.

Impact deposit: This is a deposit with evidence of impact via extraterrestrial materials and/or shock metamorphism. The source crater may or may not be known. Common examples of impact deposits are tektite strewn fields, impact spherule layers, etc.

Impact craters: The *Impact Earth Database* lists **12** impact craters. Many of these are well-known and were discovered in the 1920s and 1930s (e.g., Henbury, Odessa); more recently confirmed examples include Carancas [7], Peru, and Whitecourt [8], Canada. At present, unambiguous evidence for shock metamorphism has not been documented at these sites, often despite significant efforts. Indeed, the recognition of small "craters" is very difficult because of the coupled challenges of a very small zone of target material being subjected to shock metamorphism and melting (and then being subsequently dispersed) and the nature of the target, which is typically unconsolidated sediment, where the recognition of shock metamorphic effects can be challenging. Two notable examples are the Ilumetsa [9] and Sobolev [10] structures that have properties consistent with them being formed by an impact, but where no clear signs of extraterrestrial material has been identified to date. They are, thus, not listed in the *Impact Earth Database*.

Hypervelocity impact craters: As noted above, to be classed and listed in the *Impact Earth Database* as a hypervelocity impact crater, a structure must have confirmed evidence of *shock metamorphism* in the target materials. Osinski et al. [6] listed 188 confirmed hypervelocity impact craters. Since then, 3 new hypervelocity impact structures have been confirmed, bringing the total to **191**: Nova Colinas, Brazil [11] – confirmed by the presence of feather features and planar deformation features (PDFs) in quartz – Ora Banda, Australia [12] – where shatter cones and PDFs in quartz have been identified – and Ilkurlka, Australia [13] – also confirmed by the presence of PDFs in quartz.

In terms of the identification of hypervelocity impact craters, it is notable that all three of these new structures were confirmed by the presence of PDFs in quartz, with the addition of feather features in quartz at Nova Colinas and shatter cones at Ora Banda. This should not be surprising given all but one of the previously identified hypervelocity impact craters listed in Osinski et al. [6] were confirmed based on the finding of PDFs in quartz and/or shatter cones. The one current exception is the Pantasma impact structure, Nicaragua, where the confirmation came from the identification of FRIGN zircon and an extraterrestrial Cr isotopic signature in impactites [14]. The lack of PDFs in quartz can be ascribed to quartz-poor and fine-grained largely volcanic target rocks and the tropical rainforest setting, where outcrops are sparse and heavily weathered, making the identification of shatter cones challenging.

Impact deposits: In addition to the impact craters and hypervelocity impact craters discussed above, there are a large number of examples of what we have termed *impact deposits* that contain material with a confirmed impact origin, but for which most have no known source crater. Osinski et al. [6] classified such impact deposits into five main categories: (1) tektite strewn fields, (2) spherule layers, (3) occurrences of other types of impact glasses, (4) impact breccias, and (5) detrital shocked minerals. In summary, the *Impact Earth Database* currently lists **6** tektite strewn fields, **27** spherule layers, **7** occurrences of other types of impact glasses, **5** impact breccia occurrences, and a number of detrital shocked mineral deposits derived from the Santa Fe, Sudbury, and Vredefort impact structures.

Ongoing work: For the interested reader, a live and continually updated version of the *Impact Earth Database* is available via the Impact Earth website (www.impactearth.com). As we noted at the outset, given the shear breadth of the literature on terrestrial impacts, we acknowledge that there will be omissions and likely errors in this database and we welcome input from the community to ensure that this resource is kept as accurate and up-to-date as possible.

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