IMPACT EARTH – A RESOURCE FOR PUBLIC OUTREACH AND TEACHING AT THE K-12, UNDERGRADUATE, AND GRADUATE LEVEL. G. R. Osinski[1], R. A. F. Grieve[1], P. J. A. Hill[1,2], J. D. Newman[1], P. Patel[1], G. D. Tolometti[1], [1]Institute for Earth and Space Exploration / Dept. Earth Sciences, University of Western Ontario, London, ON, Canada, [2]Department of Earth and Atmosphere, University of Alberta, Edmonton, AB, Canada (gosinski@uwo.ca).

Introduction: The collision of asteroids and comets with planetary objects is one of the most important and fundamental geological processes in the Solar System [1, 2]. A consequence of this is that meteorite impact craters are one of the most common geological landforms on the majority of the rocky planets, asteroids, and many of the rocky and icy moons of the inner and outer Solar System. Earth has not escaped this process and it has become increasingly well accepted that impact events have profoundly affected the origin and evolution of Earth [3]; from its environment (e.g., [4, 5]) and habitability [6–8] to the production of economic resources [9]. The fireball event of February 15th 2013 in Chelyabinsk, Russia [10], also served as a wakeup call that impact events are not a thing of the past and can still occur at any time.

With the ever expanding robotic exploration of the Solar System and the near-term likelihood of seeing humans return to the surface of the Moon, it is clear that there is a need for a greater understanding of impact cratering processes and products within the Earth and planetary science communities. From Hollywood movies such as Deep Impact, to the extinction of the dinosaurs, it is also apparent that impacts are of interest to the broader public and can spark the interest of K-12 students in various Science, Technology, Engineering and Math (STEM) disciplines.

Fig. 1. Landing page for the Impact Earth database.

In this contribution, we provide an overview of the *Impact Earth* initiative. *Impact Earth* has the twin goals of increasing public awareness and interest, and of encouraging the teaching and research on meteorite impacts and the closely related themes of meteors and fireballs themselves, meteorite falls, and crater-forming events. For further background of the *Impact Earth* initiative and the research aspects see Osinski and Grieve [11] and Osinski et al. [12]. Here, we focus on the outreach and teaching aspects of *Impact Earth*.

Impact Earth Website: At the core of the *Impact Earth* initiative is the website www.impactearth.com. It features background information on the threat of meteorite impacts on Earth, the detection of meteors and fireballs, an introduction to meteorites, and an overview of the formation and recognition of meteorite impact craters. A central feature of the website is a new searchable database of all confirmed impact craters on Earth and many of their most salient attributes, such as age, size, year of discovery, etc. (Fig. 1). This database provides an exploratory portal through which anyone can tour the Earth through a Google Map interface and check out craters around the world.

Fig. 2. Elementary school students making craters in mixtures of flour and cocoa powder.

K-12 Resources and Activities: As part of the *Impact Earth* initiative we have designed an Impact Cratering Activity. This has designed using an inquiry-based learning approach where students develop their own experiment while working through the steps of the scientific method. The aim of this activity is for the students to gain an understanding of the basic

characteristics of impact craters and how they form. The core of this activity is where the students create their own craters – and make a mess (!) – in layered mixtures of flour and cocoa powder (Fig. 2). A presentation, student worksheets, and notes for educators are freely available for download on the *Impact Earth* website www.impactearth.com.

This activity can be modified for students from Grades 6 to 12; although we have also done this activity for younger students with less structure. If time allows, a further unique aspect of this activity is the availability of rock kits (Fig. 3) that can be requested for loan through a simple online form. The foundation rock kits contain a variety of rocks from several impact craters around the world and notes and worksheets are available for teachers to guide them and their students through the use of the kits.

Fig. 3. *Impact Earth* rock kit.

Resources for Undergraduate and Graduate Students and Instructors: A major inhibitor to teaching students about meteorite impacts at the undergraduate and graduate level is the scarcity of materials. There is not an Earth science department in the world that doesn't have hand samples of igneous, sedimentary, and metamorphic rocks, but very few have impactites – the products of meteorite impact. As such, the *Impact Earth* rock kits mentioned above are also available for loan to university and college instructors. For these more advanced levels, a selection of petrographic thin sections is also available, as are more specialized rock kits featuring the products of individual craters as well as a collection specifically focused on impact melt rocks. At present, kits are available for the Gow Lake, Haughton, Mistastin Lake, Sudbury and West Clearwater Lake impact structures in Canada, and the Ries and Rochechouart impact structures in Germany and France, respectively.

Impact Cratering Short Course and Field School: For graduate students wishing to take a course focused on impact cratering, the Institute of Earth and Space Exploration (http://space.uwo.ca) in conjunction with the Canadian Lunar Research Network (http://clrn.uwo.ca) offers a 1-week long short course and field school based in Sudbury, Canada, the site of a ~250 km diameter, 1.85 billion year old meteorite impact crater. The Sudbury structure offers an exceptional opportunity to study impact melt rocks, various types of impact breccias, shatter cones, impact-induced hydrothermal alteration, and much more. This course introduces students to the processes and products of impact cratering on Earth and throughout the Solar System. The first 3 days feature 3 hours of lecture material in the morning, followed by field excursions and/or hands on laboratory sessions in the afternoons. A research project carried out in teams provides students with a hands-on immersive experience for the remainder of the week.

This course typically runs every 2 summers, always in late September or early October. It last ran in September 2019 and is scheduled to be run again in 2021. Interested students should contact the lead author (GRO). Students of any nationality and institute are welcome to take this course. Historically, several U.S. students have been financially supported to attend this course by the Solar System Exploration Research Virtual Institute, through the Center for Lunar Science and Exploration (CLSE) based at the Lunar and Planetary Institute.

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