

Constructing the Solar System: A Smashing Success!

Lecture 8: Impact Earth — Chicxulub and other terrestrial impacts

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1 Introduction

Collisions are one of the most ubiquitous events in the Solar System. In most cases, the result is the formation of an impact crater on the surface of the larger body involved in the collision. All Solar System bodies show evidence of impacts throughout their lifetimes. However, Earth exhibits many fewer impact craters on its surface when compared to the other terrestrial planets (Mercury, Venus and Mars), and other rocky bodies such as the Moon and the asteroids.

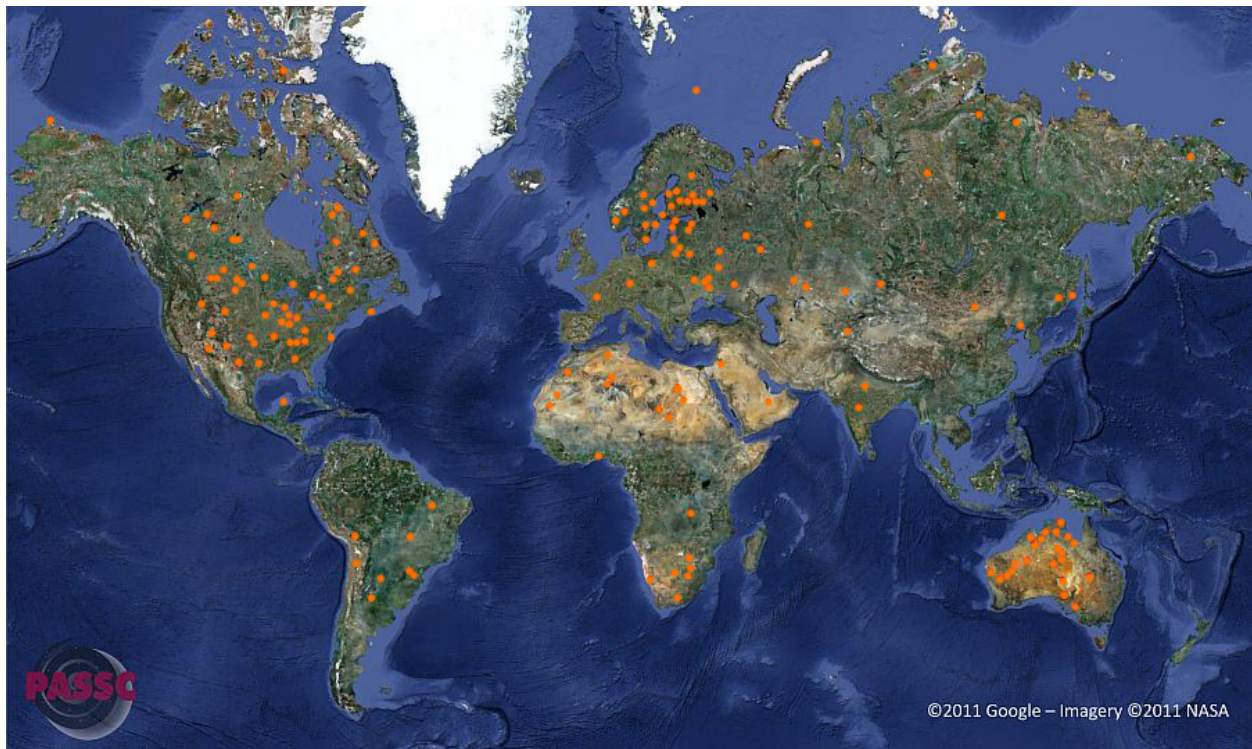
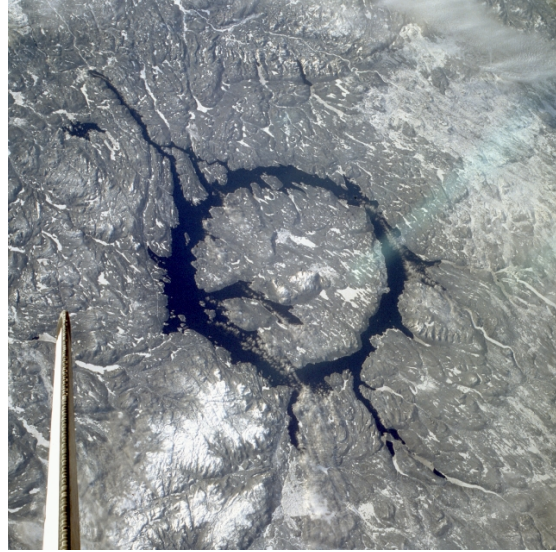


Figure 1: Map of the known impacts on Earth. Image courtesy of Planetary and Space Science Centre, University of New Brunswick/NASA/Google.



(a) Barringer Crater (Meteor Crater), Arizona. Image courtesy of Shane Torgerson/Wikimedia Commons.



(b) Manicouagan Crater, Canada. Image courtesy of Image Science & Analysis Laboratory, NASA Johnson Space Center.

Figure 2: Some examples of impact craters on Earth

2 What affects the cratering record on Earth?

Several factors are at play that limit the number of observable impact craters on Earth:

Atmosphere: Many of the smaller meteoroids that collide with Earth are filtered out by Earth's atmosphere. Heating is caused by the ram pressure generated as the fast-moving meteoroid compresses air in front of it as it passes through the atmosphere. Evidence of this is seen as fireballs in the night sky (e.g. the Geminids shower over the last two nights). One famous impact event that was stopped by the atmosphere was the Tunguska event in Siberia, Russia in 1908.

Oceans: Approximately 70% of the Earth's surface is covered by oceans, but of the 183 known impact structures on Earth, only one deep sea crater is known (the Eltanin structure in the South-East Pacific Ocean). When an impact hits the oceans (approximately two out of every three impacts will fall in the ocean), much of the impact energy is absorbed by the water layer. In some cases, this decreases the size of the crater that ultimately forms on the ocean floor. In other cases, a short-lived crater will open in the water layer, but no lasting effects will remain on the sea floor.

Weathering/Erosion: In some cases, craters which formed on land may be removed over time by the actions of wind and rain.

Tectonics: Probably the most important reason for the paucity of impact structures on Earth is plate tectonics. Sea floor spreading and subduction processes mean that the oldest seafloor is less than 200 million years old. Compared to the Moon, for example, which has some surfaces older than four billion years old, it becomes obvious why there are so many fewer craters on Earth: many that did form on the young Earth have been recycled as the plate they formed on was either subducted into the mantle or destroyed as part of a mountain building event.

3 Chicxulub

One of the most interesting craters on Earth from a geologic perspective is the Chicxulub crater, buried beneath the Yucatán Peninsula in Mexico. Despite Chicxulub crater being one of the largest on Earth (110 miles in diameter), it wasn't discovered until the late 1970s because of its burial hundreds to thousands of meters beneath the surface. During a search for petroleum by geologists, the unique features of the crater were spotted in the subsurface, and subsequently identified as an impact structure. As well as being interesting because of its size, Chicxulub is of importance for its consequences on life on Earth. It is thought that the mass extinction of prehistoric life was a direct result of the Chicxulub impact event 65.5 million years ago.

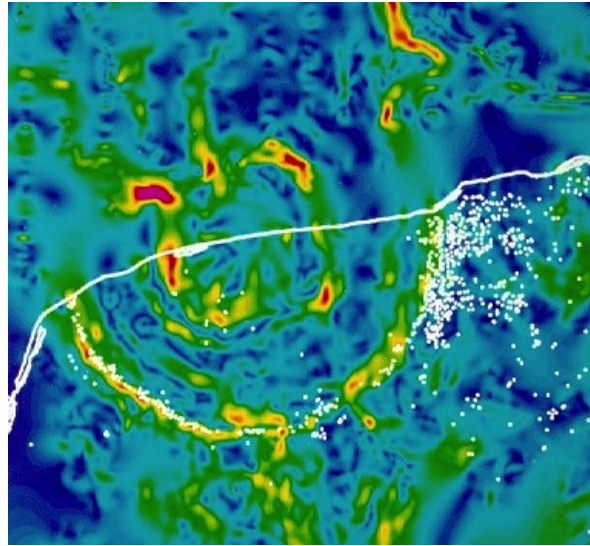


Figure 3: A map of the Bouguer gravity anomaly over the Chicxulub crater. The white line shows the coastline. The concentric circles are indicative of an impact event. Image courtesy of the Canadian Geological Survey.

It is predicted that the impactor would have had to be approximately 10 km in size to form a crater the size of Chicxulub. Impact simulations show that an impactor of that size would have generated earthquakes of magnitude 11 or greater and tsunamis affecting the coastal zones of the surrounding oceans. Also, it is expected that material could have been ejected and distributed around the globe by the impact. There is evidence to support this in the geologic record: in rock deposits from 65.5 million years ago from all over the world a spike in the iridium concentration can be found. Iridium is an element that is much more abundant in meteorites than in the Earth's crust, so the spike is interpreted as being meteoritic in origin. The dust cloud generated by the impact would have blocked out sunlight and inhibited photosynthesis for up to a year. For a further 10 years or so, sulfuric acid aerosols in the stratosphere could have reduced the sunlight at Earth's surface by $\sim 10\text{--}20\%$, accounting for the extinction of plants, and the organisms dependent on them for food. Another consequence of the falling ejecta material would be infrared radiation, which could kill exposed organisms, and also induce widespread wildfires, leading to further extinctions.

4 Future impacts on Earth?

Impacts on Earth are ongoing; however, most meteoroids are too small to cause any significant damage, or are burnt up in the atmosphere. In recorded history, the largest impact event was the Tunguska event in 1908, which did not even form a crater. However, there is of course the chance of a larger body striking the Earth. Impactors large enough to cause a global disaster would need to be around half a mile in diameter, and are estimated to fall only once every million years, or so. There is an excellent calculator available online called **Impact Earth**, hosted by Purdue University and Imperial College London, which is free to use. It will calculate the collateral effects of any impact event (you provide the impact parameters), and can be accessed at:

<http://www.purdue.edu/impacearth>



Figure 4: Artist's impression of a giant impact on Earth. Image courtesy of Don Dixon/NASA.

However, should we discover a large asteroid on collision course with the Earth, what could we do? Several techniques have been suggested. In general, the strategy is to detect potential threat early, and then use one of the following techniques to gradually shift the asteroid off course, until it is no longer on a collision course with Earth. Some examples include:

Nuclear weapons Use the blast from a nuclear explosion to vaporize part of the surface of the asteroid, and thus alter the course of its orbit

Kinetic impact Collide a heavy unmanned spacecraft with the asteroid to change its orbit

Gravity tractor With a long enough lead time, a high-mass unmanned spacecraft could be positioned in an orbit near to the asteroid, to slowly alter its orbit by gravitational attraction

Focused solar energy Use a lens on a spacecraft to focus the Sun's energy onto the asteroid and vaporize material — pushing it slowly off its collision course

5 Further reading

Should you be interested in reading more about any of the topics I have discussed throughout the lecture series, some of the following references may be of interest.

1. *The Astrophysics of Planet Formation* by Philip J. Armitage (2010) — See also, notes by Armitage at <http://arxiv.org/abs/astro-ph/0701485>
2. *Meteorites and the Early Solar System II*, edited by Dante S. Lauretta and Harry Y. McSween (2006)
3. *Impact Cratering: A Geologic Process* by H. Jay Melosh (1989)
4. *Planetary Surface Processes* by H. Jay Melosh (2011)
5. *Traces of Catastrophe: A Handbook of Shock-Metamorphic Effects in Terrestrial Meteorite Impact Structures* by B.M. French (1998)
6. *The Cambridge guide to the Solar System* by Kenneth R. Lang (2011)
7. *Impact Cratering: Processes and Products* edited by Gordon Osinski and Elisabetta Pierazzo (Available January 2013)

And remember, all the slides and handouts from the lecture series are available at the website listed at the bottom of this page.