# A Comparison of the Chesapeake Bay Impact Structure and the Arizona Barringer Crater

Determining the effects of velocity, composition, size, and location of impact on the crater of the meteorite

By: Matthew Albertson, Emma Booker, Jazmine Evans, and Rose Murphy

## Introduction

The crater formed by a meteorite is affected by all of the characteristics of the meteorite, including the velocity, composition, size, and location of impact. In order to determine the effects of a meteorite on its resulting crater, each element of the meteorite must be compared and combined with others to evaluate which characteristic has the strongest effect.

## Methodology

The team conducted a review of literature and a simulation to better understand how velocity, composition, size, and location of contact of a meteorite affects the surface of an impact crater. The team analyzed each of these factors in reference to the Chesapeake Bay Impact Structure and the Arizona Barringer Crater.

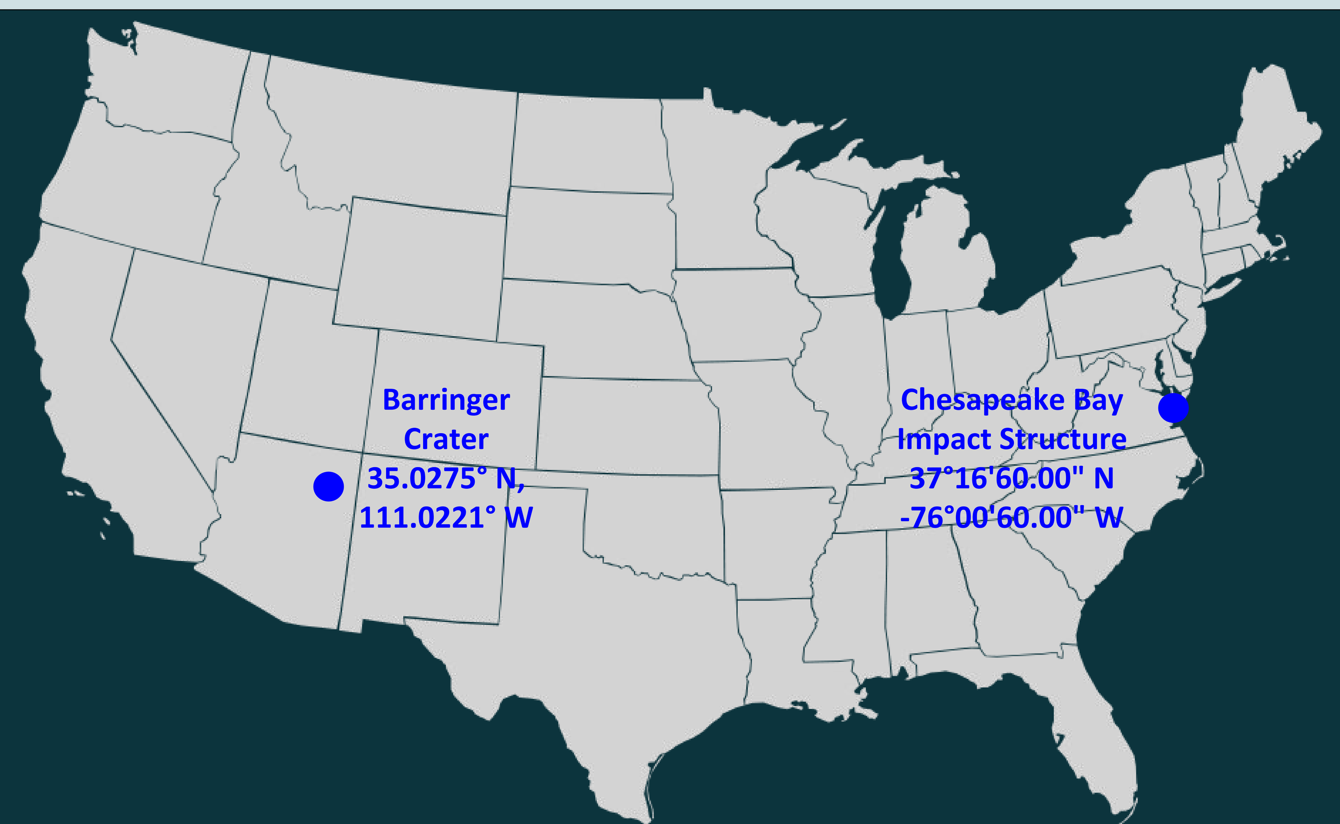
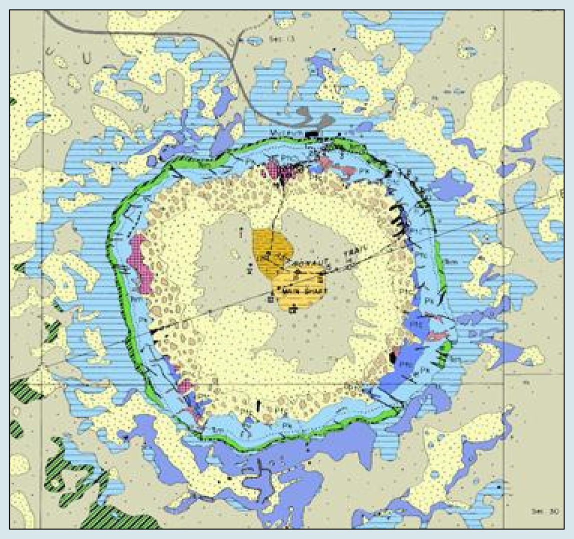



Figure 1: A map of the United States of America showing GPS coordinates and relative locations of the craters.

## Arizona Barringer Crater

Created approximately 50,000 years ago, the Barringer Crater is located at the edge of the Colorado Plateau (U.S. Geological Survey, n.d.). The crater is about 1.2 km wide and 180 m deep (U.S. Geologic Survey, n.d.). Because it is fairly young in geological terms, little erosion has taken place, resulting in preservation of much of the original ejecta blanket (Lunar and Planetary Institute, 2009). From this debris, the original composition of both the meteor and the initial Earth crust are determined. Much of the ejecta is composed of shock-melted limestone, sandstone from the crust, and metallic droplets from the iron-based meteor (U.S. Geologic Survey, n.d.). The explosion from the impact of the Canyon Diablo meteorite contained the force of over 150 times the power of the nuclear bomb used at Hiroshima or 1.7 megatons of dynamite (U.S. Geologic Survey, n.d.). This caused a great amount of stress on the local geology, as shown by melted quartz, which has a melting point that is significantly higher than most elements (Shoemaker, E. M., 1959).



http://www.lpi.usra.edu/publications/books/barringer_crater_guidebook/craterMap/

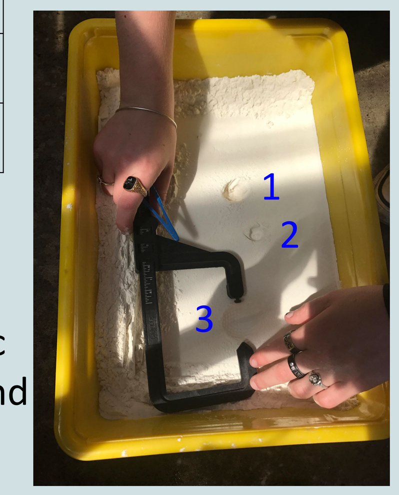
- Velocity: 12-20 km/sec towards Earth (U.S. Geologic Survey, n.d.)
- Composition: Nickel-Iron rich (U.S. Geologic Survey, n.d.)
- Size of Meteorite: 30 m in diameter and 90,700 tons (U.S. Geologic Survey, n.d.)
- Size of Crater: 1.2 km in diameter and 180 m deep (U.S. Geologic Survey, n.d.)
- Location: Northern Arizona, Desert ecosystem, thin soil, exposed bedrock, low relief (Roddy et al., 1975)

## Comparison

Both meteorites had similar velocities; however, that is the only similarity observed. The meteorite that formed the Barringer Crater was Nickel-Iron rich, making it more dense than the siliceous meteorite that formed the Chesapeake Bay Impact Structure. The meteorite that formed the Barringer Crater was approximately 30 m in diameter and 90,700 metric tons in mass, while the meteorite that formed the Chesapeake Bay Impact Structure was approximately $1.2 \times 10^9$ metric tons in mass (Edwards, 2009). The Barringer Crater is located in northwestern Arizona, in a rocky environment while the meteorite that created the Chesapeake Bay Impact Structure impacted shallow water over a large area.

*Table 1: Comparing Depth and Diameter of Simulated Craters*

| | Magnetic Rock (1) | Marble (2) | Golf Ball (3) |
|---|---|---|---|
| Depth | 21 mm | 10 mm | 6 mm |
| Diameter | 20.63 mm | 12.7 mm | 31.75 mm |


The team tested how different factors such as velocity, composition, and size of a meteorite affect the shape of the crater. The team used three different "meteors": a hollow plastic golf ball, a marble, and an irregularly shaped magnetic rock. The objects were dropped from a height of 2.5 meters and the diameters of the resulting craters were measured with calipers. The team concluded that denser objects created deeper holes though larger objects created craters with larger diameters.

## Chesapeake Bay Impact Structure

Formed over 35 million years ago, the Chesapeake Bay Impact Structure (CBIS) is the largest crater in North America (Shirley et al., 2016). The crater formed around what is now the Eastern Shore of Virginia and the Chesapeake Bay (Shirley et al., 2016). The crater has been mostly covered by Cenozoic post-impact sediments, making obtaining samples only possible by drilling (Edwards et al., 2009). The meteorite had a velocity of 17.8 km/s before it entered the earth's atmosphere. The crater has a maximum depth of approximately 1,766 meters and is 85 kilometers wide, making it about 70 times larger than the Barringer Crater (Edwards et al., 2009). The crater was formed by an S-type asteroid, which implies that the meteorite had a stony and siliceous composition (Edwards et al., 2009). The crater is also believed to be responsible for the North American Tektite field which covers most of the Atlantic Ocean (Poag et al., 1994). The tektite is glass formed from the high temperature impact in the ocean. Remnants from the Chesapeake Bay impact have been found as far away as the continental shelf off the coast of New Jersey (Poag et al., 1994).


https://geology.usgs.gov/postdoc/profiles/malinconico/index.html

- Velocity: 17.8 km/s towards Earth (Collins et al., 2005)
- Composition: Siliceous (S-type)
- Size of Meteorite: approximately $1.2 \times 10^9$ metric tons in mass (Edwards et al., 2009)
- Size of Crater: 85 km in diameter (Edwards et al., 2009)
- Location: Eastern Shore, VA, shallow water, sand and soil

## Velocity

The speed of each meteorite affects the size and complexity of the crater. Higher speed meteorites create larger craters with more profound effects than slower meteorites of the same size. The meteorite that created the Chesapeake Bay Impact Structure reached an estimated speed of 17.8 km/s, and the meteorite that formed the Barringer Crater was estimated to have accelerated to about 20 km/s (Collins et al., 2005). Even though the Canyon Diablo meteorite had a higher velocity than the meteorite that formed the CBIS, the Barringer Crater is much smaller than the Chesapeake Bay Impact Structure. This is because the Canyon Diablo meteorite had so much less mass than the meteorite that created the CBIS that the effects of increased mass outweighed the effects of a decreased velocity. The amount of energy released during the Barringer Crater was about 1.7 Mt, while about $1.75 \times 10^6$ Mt was released during the formation of the CBIS, which is over a million times more energy than the amount released by the Canyon Diablo meteorite (Collins et al., 2005).

## Composition & Size

An increase in density of a similar sized meteorite will cause an increase in energy released in an impact because of the resulting increase in mass of the meteorite. The Canyon Diablo was nickel-iron rich, which is much denser than the Chesapeake Bay asteroid, which is an S-type, or stony siliceous composition. The amount of energy released in an impact dramatically affects the shape of the crater. The relatively low-energy impact that created the Barringer Crater formed a simple bowl-shaped crater. The Chesapeake Bay Impact Structure is a complex crater with a central, crystalline peak surrounded by breccia from the impact, and a wide, shallower outer brim surrounding the deeper inner crater so that the whole Chesapeake Bay Impact Structure resembles an inverted sombrero. The Barringer Crater is about 1.2 km in diameter, making it much smaller than the Chesapeake Bay Impact Structure, which is around 90 km in diameter.

## Location

The depth of penetration of the meteorite, before it loses its integrity as a single body, is a function primarily of the velocity and shape of the meteorite and the densities of the meteorite and target. The Chesapeake Bay asteroid impacted shallow water and the impact crater was flooded by surrounding rivers due to the topographic depression, forming the Chesapeake Bay. The Barringer Crater was formed in bedrock covered by a thin layer of topsoil. It has been hypothesized that if the meteorite that created the Chesapeake Bay Impact Structure had impacted lithified sediment similar to the sediments the Canyon Diablo meteorite impacted, the Chesapeake Bay Impact Structure would have only been 40-45 km in diameter (Plescia et al., 2009).

## Conclusion

As inferred from literature review and simulation, the Chesapeake Bay Impact Structure is much larger than the Barringer Crater because of the large size of the meteorite and the softer ground the meteorite impacted, not the velocity and composition of the meteorite that formed the crater.


Catchings, R. D., Powars, D. S., Gohn, G. S., Horton, J. W., Goldman, M. R., & Hole, J. A. (2008). Anatomy of the Chesapeake Bay impact structure revealed by seismic imaging, Delmarva Peninsula, Virginia, USA. *Journal of Geophysical Research,113*(B8). doi:10.1029/2007jb005421

Collins, G. S., & Wünnemann, K. (2005). Geological Society of America. *How big was the Chesapeake Bay impact? Insight from numerical modeling,33*(12), 925-928. doi:10.1130/g21854.1

Edwards, L., Powars, D., Browning, J., Mclaughlin, P., Miller, K., Self-Trail, J., . . . Elbra, T. (2009). Geologic columns for the ICDP-USGS Eyreville A and C cores, Chesapeake Bay impact structure: Post impact sediments, 444 to 0 m depth. *Geological Society of America Special Papers The ICDP-USGS Deep Drilling Project in the Chesapeake Bay Impact Structure: Results from the Eyreville Core Holes,* 91-114. doi:10.1130/2009.2458(04)

Lunar and Planetary Institute. (2009, May 28). Shaping the Planets. Retrieved April 18, 2017, from http://www.lpi.usra.edu/education/explore/shaping_the_planets/impact_cratering.shtml

Roddy, D.J., Boyce, J.M., Colton, G.W., & Dial, A.L.Jr. (1975). Meteor Crater, Arizona, rim drilling with thickness, structural uplift, diameter, depth, volume, and mass-balance calculations. *Lunar Science Conference, 6th, Houston, Tex., March 17-21, 1975, Proceedings. Volume 3*, 2621-2644, 1975LPSC...6.2621R

Plescia, J., Daniels, D., & Shah, A. (2009). Gravity investigations of the Chesapeake Bay impact structure. *Geological Society of America Special Papers The ICDP-USGS Deep Drilling Project in the Chesapeake Bay Impact Structure: Results from the Eyreville Core Holes,* 181-193. doi:10.1130/2009.2458(09)

Poag, C. (1997). The Chesapeake Bay bolide impact: a convulsive event in Atlantic Coastal Plain evolution. *Sedimentary Geology, 108*(1-4), 45-90. doi:10.1016/s0037-0738(96)00048-6

Shirley, J. S. (2016, November 29). The Chesapeake Bay Bolide Impact: A New View of Coastal Plain Evolution. Retrieved March 14, 2017, from https://pubs.usgs.gov/fs/fs49-98/

Shoemaker, E. M. (1959). USGS. *IMPACT MECHANICS AT METEOR CRATER, ARIZONA,* 1-44. doi:59-108

United States Geologic Survey. (n.d.). Astrogeology Science Center. Retrieved March 01, 2017, from https://astrogeology.usgs.gov/facilities/meteor-crater-sample-collection