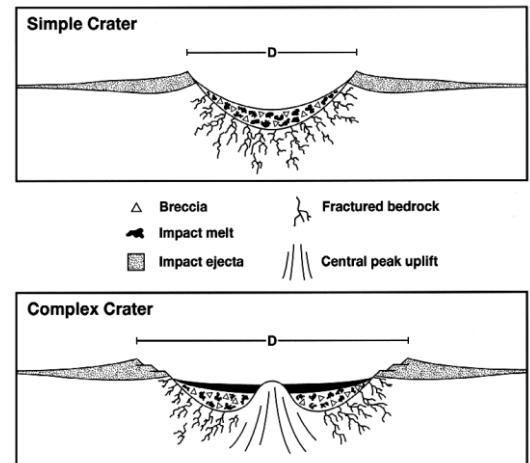


# Investigating Impacts

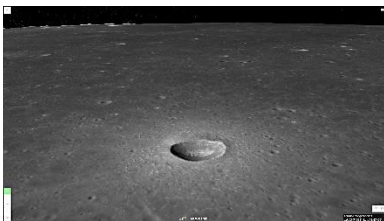
## Teacher Background

Crater formation on planetary bodies, including Earth, the Moon, and Mars, is primarily the result of impacts from meteoroids, asteroids, and comets. When these objects collide with a planetary surface, their kinetic energy is rapidly transferred to the target surface, resulting in an explosion and the creation of a crater. The size and shape of the crater depend on several factors: the speed and angle of impact, the mass and density of the impactor, and the geological characteristics of the surface itself.

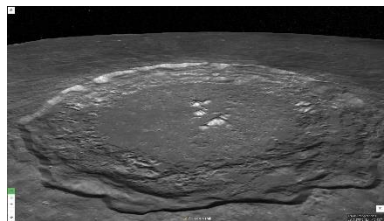
There are typically two main types of craters: simple and complex. Simple craters are smaller with a bowl-shaped depression, and they typically lack any central peaks. Complex craters are larger, often with **central peaks** that result from the gravitational collapse of the crater floor shortly after the impact. These peaks are essentially rebound features where the sudden compression from the impact is followed by an upward thrust of material. Complex craters may also display **terraced rims**, which are step-like structures caused by the slumping of the walls due to the collapse of the transient crater during crater formation.



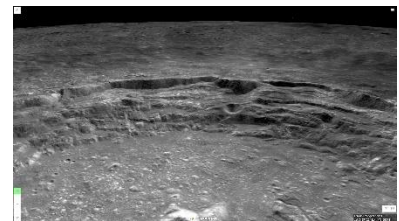
Credit: NASA



Linne', a simple crater



Copernicus, a complex crater

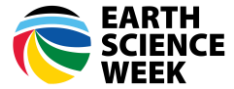
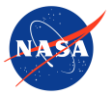


Terraces in the rim of Copernicus

Gravity has a lot to do with the final shape (**morphology**) of the crater. It influences the **trajectory** and speed of the impacting body and also affects the **ejection** of materials during the impact. For instance, gravity is weaker on the Moon and Mars compared to Earth. That means that for impacts of similar energy craters on the Moon and Mars will be larger and deeper than on Earth. As well, impact debris is more likely to travel further in lower gravity instead of falling back into the crater. Crater walls are less likely to collapse in the lower gravity of the Moon and Mars, too.

Exploring craters provides significant insights into the geologic history of a planet. Craters can reveal the age of surfaces (the more craters, the older the surface). They can also show the presence of water or ice if the crater is in a polar region or shows signs of erosion or sediment deposition.

Understanding these aspects is crucial for interpreting observational data, whether from experiments or maps.



## Standards

NGSS Performance Expectation 5-PS2-1: Support an argument that the gravitational force exerted by Earth on objects is directed down.

DCI: ESS1.C The History of Planet Earth; ESS1.B Earth and the Solar System; PS2.B Types of Interactions

SEP: Asking Questions and Defining Problems; Planning and Carrying Out Investigations; Analyzing and Interpreting Data

CCC: Patterns; Cause and Effect; Scale, Proportion, and Quantity

## Lesson Outline

Engage: View pictures of craters on the Earth and the Moon and discuss how they may have formed.

Explore: Plan and carry out an investigation to test variables affecting impact crater formation.

Explain: Analyze data to explain variability among craters.

Elaborate: Explore craters on the Moon and Mars using NASA Treks to infer how they formed.

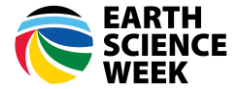
Evaluate: Describe crater formation including how different shapes and sizes may form.

## Notes

- Content details and suggested responses to the lesson questions and activities are provided in the [Teacher Notes and Suggested Responses](#) section beginning on page 11.
- Modify the format of the Elaborate section as needed, considering the technological proficiency of the students and computer availability.



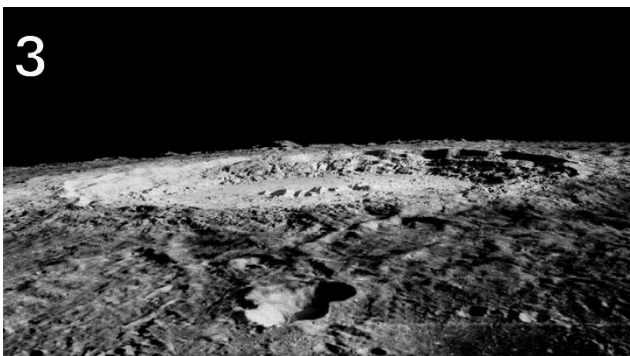
Name: \_\_\_\_\_



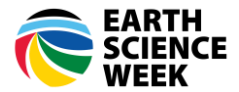
# Investigating Impacts

## Engage

Examine the pictures of different craters on the Earth and Moon.



1. How do you think each of these craters formed?
  
  
  
  
  
  
  
  
  
  
2. What variables might affect the shape and size of a crater that formed and that we see today?
  
  
  
  
  
  
  
  
  
  
3. What could planetary scientists learn by studying craters on the Earth, Moon, or other planetary bodies?



## Explore

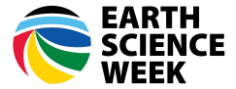
Plan and carry out an impact investigation using flour or corn starch, cocoa powder, a large pan, hard objects of various sizes, masses, densities, and shapes (marbles, washers, rocks, etc.), string, ruler, and/or measuring tape, and a scale. Consider how you will explore the variables, such as those listed in the table below, that affect crater formation using your plan. Make observations of the different shapes and sizes of the craters that form. Also, measure and record the diameter and depth of the craters, noting the differences caused by changing variables.

Write down your plan for how to set up your model and your procedure for investigating impacts.

Also, create a table like the one below. Adapt it to include the variables you are testing.

Object	Mass (g)	Drop Height	Crater Description (shape, features, etc.)	Crater Diameter	Crater Depth

At the end of your investigation, also draw the surface of your model after completing all the impacts.

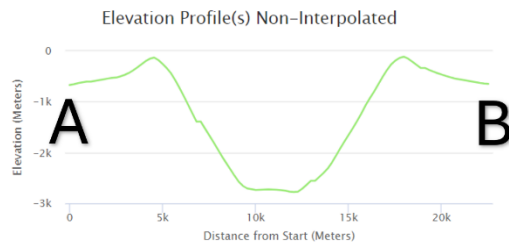
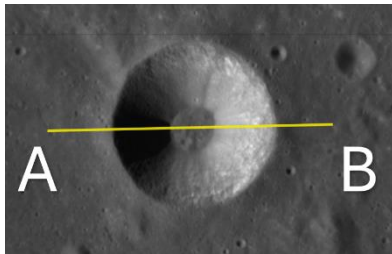


## Explain

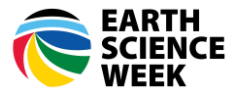
Now that you have created many impact craters, answer and discuss the following:

1. Explain how impact craters are formed. Include the word “gravity” in your explanation.
2. How did crater size change when items of different mass (i.e., weight) were dropped from the same height?
3. How would you state the general relationship between an item’s mass and the crater size?
4. How did the size of the items affect the crater sizes?
5. How would you state the general relationship between an item’s size and the crater size?
6. What are some ways your model is similar and what are some ways your model is different than real impact processes?

7. How might the craters be different if we were to conduct this experiment on the Moon? Explain your thinking.
  
8. How might the craters be different if you threw the objects (which would likely result in the objects traveling faster) rather than dropping them?
  
9. It is helpful to graph the height of craters by creating an elevation profile. Below is an example of an elevation profile along the yellow line.







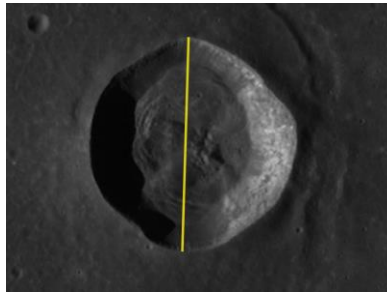
Explain what would happen to the elevation if you were walking along the yellow line starting from the left at point “A” to point “B.”



## Elaborate

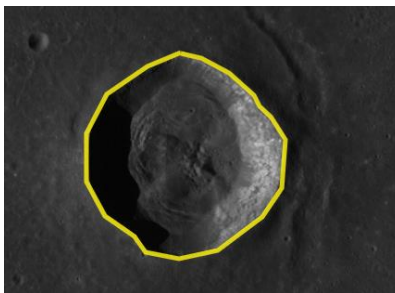
Use the NASA Moon Trek application to apply what you have learned so far about impact craters to real craters on the Moon and other planetary bodies.

1. Either visit <https://trek.nasa.gov/moon/> on your own computer or follow along with your teacher to travel around the Moon.
2. Explore the surface of the Moon using the following functions:
  - a. Zoom in and out using your mouse, or the plus and minus sign on the bottom left toolbar.
  - b. Hold and drag the map to move around.
  - c. Explore different types of maps you can view. Use the Projection button (  ) on the bottom left toolbar to change between 3D Globe, North Pole Map, Global Map, and South Pole Map.
  - d. Turn on the Nomenclature function on the bottom right within the Basemaps toolbar (  ). This will show you the names of the lunar features, including crater names.
3. From your general exploration of the surface of the moon, write down five observations related to the craters you see on the NASA Moon Trek application. What are some things you can say for sure about the craters? What are some things you have questions about regarding those craters?
  
4. Explore specific craters on the moon to learn more about the different shapes of craters (also called crater morphology). Use the Global Map Projection and turn on the Nomenclature feature.
  - a. Select the Fly To button (  ) in the bottom right side of the screen and type in “Dawes.”
  - b. Use the + button or your mouse to zoom in to see the edges of the crater clearly.
  - c. Fill in the table, Exploring Craters on the Moon with NASA Moon Trek, about the crater.
  - d. Use the menu button (  ) on the top right to select “Calculate Distance.” Select “Line” and draw a line across the largest part of the crater, from rim to rim. The line may need to be drawn diagonally to do this.



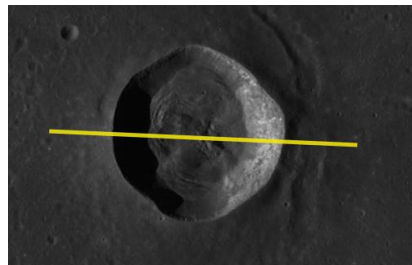
**Figure 1** Example of using the line tool to calculate the diameter of Dawes crater

- e. To remove the line, click on the line and select “remove marker.”
- f. Use the menu button (☰) on the top right to select “Calculate Distance.” Select “Polyline” and click around the crater to calculate the circumference.



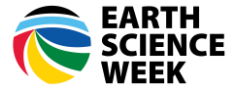
**Figure 2** Example of using the polyline tool to calculate the circumference of Dawes crater

- g. To remove the circle, click on the line and select “remove marker.”
- h. Use the menu button (☰) on the top right to select “Crater Elevation Profile” and “Line.” Draw a line from outside the crater rim, across the crater, to the other side of the crater.



**Figure 3** Example of the Calculate Elevation Profile to view the cross section of Dawes crater

- i. Explore the elevation profile that is shown and explain the shape in the table. Remember, the elevation profile shows the height of the crater along the yellow line.
  - j. To remove the line, click on the line and select “remove marker.”
5. Repeat step 4 for all the craters listed in the table.
  6. You examined two types of craters so far, simple and complex.
    - a. Based on your observations, infer which types of craters are simple craters and which are complex.



- b. Come up with your own definitions for each type of crater based on your inferences.  
Simple crater

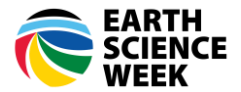
Complex crater

7. Explore the surface of the moon and find one other example of each type of crater. Write the name and make observations in the table for each one.
8. Now explore craters on Mars using: <https://trek.nasa.gov/mars/>
9. Use the same procedure as step 4 to fill in the table, Exploring Craters on Mars with NASA Mars Trek, about the craters listed.
10. Based on your definitions earlier, draw conclusions about the type of crater each of the three Martian craters listed in the table represents.

11. Discuss your results and crater definitions with classmates.

- a. How are your results similar and how are they different?

- b. If your results differ widely, go back and explore the craters together and come to a consensus.
- c. As a class, decide upon definitions of each crater type and corresponding examples of each.



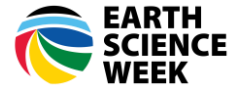
### Exploring Craters on the Moon with NASA Moon Trek

Crater Name	Crater Shape Description	Crater Diameter	Crater Circumference	Draw the elevation profile
Dawes				
Moltke				
Tycho				
Copernicus				
Clavius				
Theophilus				

### Exploring Craters on Mars with NASA Mars Trek

Crater Name	Crater Shape Description	Crater Diameter	Crater Circumference	Draw the elevation profile
Gale				
Zunil				
Cassini				





## Teacher Notes and Suggested Responses

Details and suggested responses are ideal responses and will likely include more detail than students are expected to answer in order to provide the most information and support possible.

### Engage

**Image 1:** Meteor Crater in Winslow, Arizona, United States.

*Image credit: Steve Jurvetson*

Meteor Crater, also known as Barringer Crater, spans approximately 1.2 kilometers in diameter and is about 170 meters deep. It was formed roughly 50,000 years ago by the impact of a nickel-iron meteorite weighing about 300,000 tons. This simple crater is one of the best-preserved impact sites on Earth, offering invaluable insights into planetary science and impact dynamics.

**Image 2:** Pingualuit crater in Nunavik, northern Quebec, Canada

*Image credit: NASA/Jesse Allen*

Pingualuit Crater, nestled in Nunavik, Northern Quebec, Canada, measures about 3.4 kilometers across. Formed about 1.4 million years ago, this young and remarkably circular simple crater houses a deep lake, approximately 267 meters deep, making it one of North America's deepest lakes. The impact occurred in a region of crystalline rocks, and the crater's pristine preservation makes it a significant geological site.

**Image 3:** Copernicus crater in the Mare Imbrium Basin, Moon

*Image credit NASA/JPL/USGS*

Situated on the Moon's near side, Copernicus Crater is an iconic lunar feature with a diameter of about 93 kilometers. Estimated to be around 800 million years old, this complex crater is distinguished by its extensive ray system, terraced walls, and a central peak complex. These features make it a striking example of lunar geology and are easily visible from Earth, highlighting its relative youth in lunar terms.

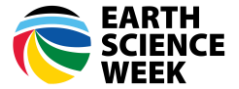
**Image 4:** Wetumpka crater in Wetumpka, Alabama, United States

*Image credit: Alabamadem*

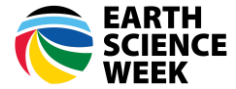
Wetumpka Crater in Alabama, USA, has a diameter of approximately 7.6 kilometers and dates back about 83 million years. This complex crater was formed by a marine impact and has since been largely eroded and buried under newer sediment layers. Its geological significance lies in its pattern of disturbed formations and the presence of shatter cones, confirming its origins from an ancient marine impact event.

1. How do you think each of these craters formed?

*All of the craters shown on this page were formed by impact events. Students might suggest other ways craters can be formed, such as volcanoes, subsidence (like sink holes), or explosions.*



2. What variables might affect the shape and size of a crater that formed and that we see today?
  - *Impactor characteristics, such as size, speed, and density*
  - *Angle of impact*
  - *Surface characteristics of planetary body that was impacted, such as type of surface material, layering of surface material, geological features*
  - *Gravity*
  - *Atmospheric conditions*
  
3. What could planetary scientists learn by studying craters on the Earth, Moon, or other planetary bodies?
  - *Age of the surface*
  - *Impact processes and material behavior*
  - *Planetary composition and structure*
  - *Geologic and environmental history*



## Explore

**Suggested experiment set up** from [NASA's Impact Craters activity](#):

1. Fill the pan with your chosen material to about 2.5 cm and smooth the surface so it settles evenly.
2. Sprinkle a fine layer of a dark, contrasting material evenly until it completely covers the surface.

**Suggested cratering process procedure**, modified from [NASA's Impact Craters activity](#):

1. Measure the mass of each impactor. Record the mass on the data chart.
2. Drop impactor #1 from a height of 30 cm onto the prepared surface.
3. Remove the impactor carefully from the model using tweezers, tongs, a magnet, or fingers depending on the size and material of the impactor.
4. Measure the diameter and depth of the resulting crater.
5. Note the presence of ejecta (rays). Count the rays, measure and determine the average length of all the rays.
6. Record measurements and any other observations you have about the appearance of the crater on the data chart. Complete three trials and compute the average values.
7. Repeat steps 2 through 5 for impactor #1, increasing the drop heights to 60 cm, 90 cm and 2 meters. Complete the data chart for these as well.
8. Now repeat steps 1 through 6 for two more impactors.

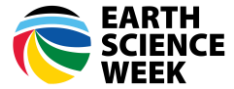
### Optional Data Extension

Have students graph their data by graphing the average crater diameter vs. impactor height, and average ejecta (ray) length vs. impactor height. On the graphs, students can use different symbols to represent different impactors.

### Surface of the Model After the Experiment

The surface of the pan will have a variety of craters with different characteristics. As more impacts occur during the experiment, the surface will increasingly resemble the heavily cratered landscape on planetary bodies like the Moon.

Each impact will create a new crater, and with successive impacts, some of these craters will overlap with others. This overlapping is common on the Moon, where older craters often show signs of disturbance due to subsequent impacts. In the experiment, older craters may appear more eroded or partially obliterated by newer craters, which will generally have sharper, more defined edges and a more pristine appearance. The distribution and ejecta patterns (rays) around craters can also vary depending on the size and density of the projectiles used.



## Explain

1. Explain how impact craters are formed. Include the word “gravity” in your explanation.

*Impact craters are formed when an object, such as a meteoroid or asteroid, collides with a planetary surface. The kinetic energy from the impactor is transferred to the surface, causing an explosion of material and creating a crater. Gravity plays a critical role in this process by pulling the impactor towards the surface with increasing speed, enhancing the impact force when it strikes. Additionally, gravity helps to pull the ejected material back down around the crater, shaping its final structure.*

2. How did crater size change when items of different mass (i.e., weight) were dropped from the same height?

*When items of different mass were dropped from the same height, the heavier items generally created larger craters. This is because heavier items have more mass and thus more gravitational potential energy when raised to a certain height. When this energy converts to kinetic energy during the fall, it results in a greater impact force upon collision, leading to larger craters.*

3. How would you state the general relationship between an item’s mass and the crater size?

*As the mass of the impacting item increases, the size of the crater also increases.*

4. How did the size of the items affect the crater sizes?

*The size of the items affected the crater sizes such that larger items tended to produce larger craters. This outcome is primarily because larger items present a greater surface area upon impact, distributing the force over a wider area of the surface and displacing more material.*

5. How would you state the general relationship between an item’s size and the crater size?

*Larger items typically create larger craters.*

6. What are some ways your model is similar and what are some ways your model is different than real impact processes?

*Similarities include the basic principles of physics involved—gravity, impact energy, and material displacement.*

*Differences include the scale, environmental conditions, and varying angles and speeds of impactors.*

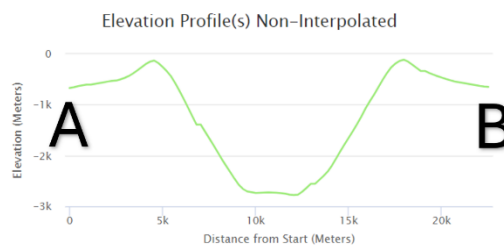
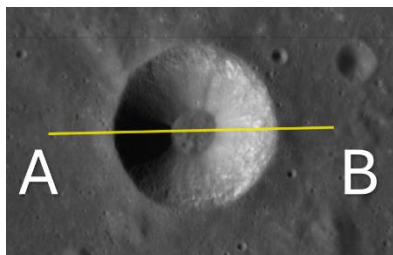
7. How might the craters be different if we were to conduct this experiment on the Moon? Explain your thinking.

*If this experiment were conducted on the Moon, the craters might be larger and deeper. This difference would be due to the Moon's weaker gravity, which would result in less deceleration of the impactor as it falls and less force pulling the ejected material back to the surface. Consequently, material can be thrown further away from the impact site, potentially leading to a wider and deeper crater formation.*

8. How might the craters be different if you threw the objects (which would likely result in the objects traveling faster) rather than dropping them?

*If the objects were thrown rather than dropped, the resulting craters might exhibit more elongated shapes and have more dispersed ejecta patterns. Throwing the objects introduces variations in angle and speed, leading to impacts at oblique angles and potentially higher velocities. This can cause the craters to be oval-shaped and the ejecta to be thrown asymmetrically, differing significantly from the more symmetrical craters formed by dropping objects vertically.*

9. It is helpful to graph the height of craters by creating an elevation profile. Below is an example of an elevation profile along the yellow line.



Explain what would happen to the elevation if you were walking along the yellow line starting from the left at point “A” to point “B.”

*Starting at point A, I walk uphill for approximately 5 kilometers. The incline gradually becomes steeper, with the final kilometer increasing noticeably in steepness. At the 5 kilometers mark, I would reach the crater's rim, where the terrain shifts to a very steep decline that continues for about 4.5 kilometers. This descent leads directly to the crater's base, where the ground levels out for a stretch of about 3 kilometers. After crossing the flat basin, the path ascends again, climbing up the opposite side of the crater over a distance of about 5 kilometers until reaching the summit of the far rim. From there, the terrain gradually slopes downward for an additional 5 kilometers, ending at point B.*



## Elaborate

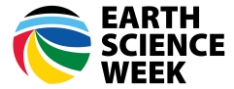
3. From your general exploration of the surface of the moon, write down five observations related to craters.
  - *The moon has a lot of craters, much more than Earth.*
  - *Craters vary in size.*
  - *Some craters have rays of ejecta around them – some evenly and some only on certain sides.*
  - *Some craters have features in the middle of the crater.*
  - *Some craters have craters within other craters, or overlapping craters.*
  - *Some crater rims are more clear/pristine than others.*
  - *Some craters look like they have smooth floors while others look fractured or broken up.*
  
6. You examined two types of craters so far, simple and complex.
  - a. Based on your observations, infer which types of craters are simple craters and which are complex.

*Simple craters = Dawes and Moltke*  
*Complex = Tycho, Copernicus, Clavius, and Theophilus*
  
  - b. Come up with your own definitions for each type of crater based on your inferences.

*Simple crater: Smaller, shallower, bowl-shaped depressions with smooth, rounded interiors and raised rims without any central peaks.*  
*Complex crater: Larger, more complex structures with flat floors, central peaks, and uneven (or terraced) rims.*
  
7. Explore the surface of the moon and find one other example of each type of crater. Write the name and make observations in the table for each one.

*Five other examples of simple craters: Linne', Bessel, Anaximenes, Torricelli, and Censorinus.*  
*Five other examples of complex craters: Aristarchus, Bailly, Schickard, Kepler, and Langrenus.*
  
10. Based on your definitions earlier, draw conclusions about the type of crater each of the three Martian craters listed in the table represents.

*Gale crater – complex*  
*Zunil crater – simple*  
*Cassini crater – complex*



## Evaluate

Answers to 1, 2, and 5 will vary.

3. Use evidence from your observations to argue if craters on the Moon are more similar to those on Earth or those on Mars. Why do you think craters on these two surfaces more similar?

*Craters on the Moon are more similar to craters on Mars. Craters seem to be more preserved on both planetary bodies compared to Earth as evidenced by the lack of craters in satellite images. Craters also seem more well preserved on the Moon and Mars compared to Earth. Craters features seem similar as well.*

4. Imagine an asteroid hits Earth and creates a simple crater. Now imagine this same asteroid instead hits Mars, which has about one-third of Earth's gravity and a much thinner atmosphere. How might the crater differ on Mars compared to Earth? Consider factors such as the size and depth of the crater, the ejection of materials, and the appearance of the crater rim. Explain your thinking.

*The crater would likely be larger and deeper with more widespread ejecta if the same asteroid impacted Mars in comparison to it impacting Earth.*

*On Earth, the asteroid would face significant atmospheric resistance as it enters. This resistance can cause the asteroid to lose some of its speed and even break apart before hitting the ground, depending on its size and composition. Therefore, the crater on Earth might not be as deep or large because the asteroid's velocity would decrease significantly upon entry. Additionally, Earth's stronger gravity would pull ejected materials back to the surface more quickly and closely around the crater, making the crater appear more compact with a well-defined rim.*

*Conversely, on Mars, the same asteroid would encounter much less atmospheric drag due to the thin atmosphere, allowing it to maintain more of its original speed and kinetic energy right up to the impact. This means the asteroid could hit the surface with greater force, potentially creating a deeper and wider crater. Mars' lower gravity would also influence the ejection of materials during the impact. The ejected materials could travel further away from the point of impact before settling, resulting in a more dispersed ejecta pattern around the crater. The crater rim on Mars might therefore appear less defined and more spread out compared to that on Earth.*