

## WORLDS OF CHANGE

Name(s) \_\_\_\_\_

With the possible exception of a few captured satellites, the planets and moons of our solar system formed about 4.5 billion years ago. Age differences among these various bodies refer to their surface areas. Those that are geologically active may [a] resurface due to volcanism, thus erasing much of their early history or [b] shift along faults, thus disrupting previously existing features. Those planets and satellites that are geologically dead retain the scars of volcanism, tectonics, and numerous encounters with meteorites.

Imagine the newly formed planets and their satellites during those early days. Gravitational attraction lured untold numbers of meteoroids toward their surfaces. Many of these massive rocks struck so forcefully that surfaces literally cracked upon impact. Magma from beneath oozed upward through the resulting cracks, or fissures, re-surfacing huge areas. Pressures from deep within caused tremendous surface upheaval as huge chunks of surface area pulled apart, slid in opposing directions, or buckled upward. What chaotic worlds these infant bodies must have been!

After millions upon millions of years, the numbers of meteoroids floating freely about the solar system correspondingly decreased significantly reducing the number of impacts. The surfaces of geologically inactive bodies, strewn with craters, ancient lava flows and faults, eventually came to be frozen in time.

You may wonder whether the planets and satellites of our solar system are still vulnerable to meteoritic impact today. If there ever was a doubt, that doubt was erased in 1993-94 when a comet was drawn into the gravitational field of Jupiter and broke up into a nuclear train striking Jupiter in a series of cataclysmic impacts. Photos showing this explosive event have been reproduced on the following page.

1. Why does evidence of this nuclear train impact not exist on Jupiter today?

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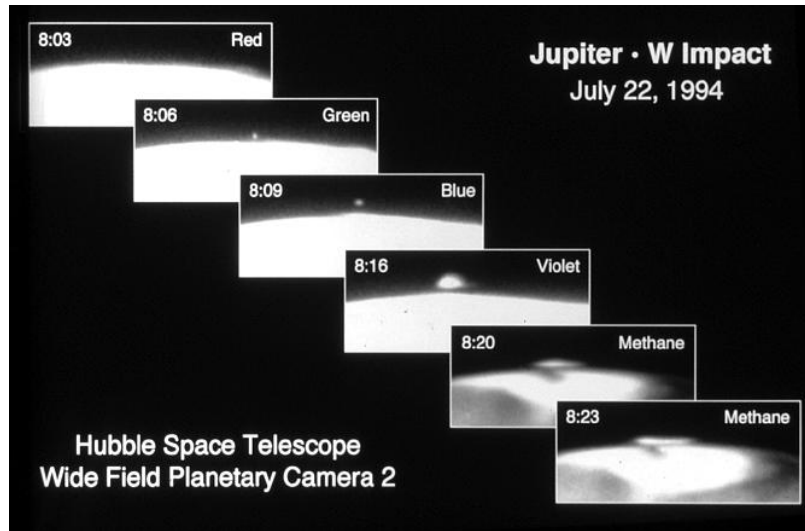
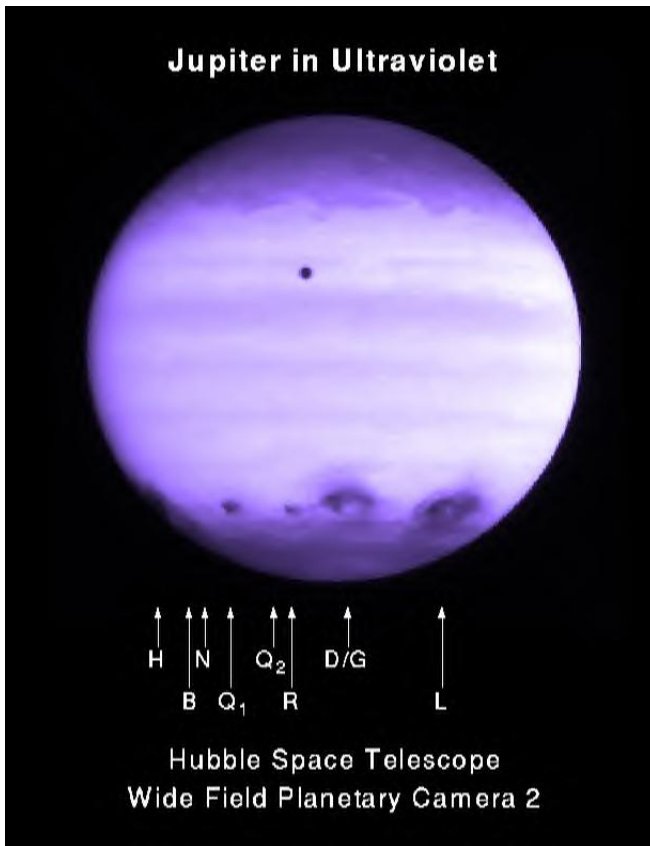


Photo credit directly above and below: Hubble Space Telescope Comet Team.



Comet Shoemaker-Levy heading for Jupiter  
Nuclear train photo credit: D. Jewitt and J. Luu

## “Worlds of Change”

When viewing photos of planetary and lunar surfaces, attempt to determine which in a series of events occurred most recently. A crater embedded upon another crater’s rim is sure to be younger than the one whose rim was altered. A fault passing through a crater may have caused portions of that crater to shift in opposite directions indicating that the fault is the more recent of the two events. An impact crater embedded in the surface of a lava flow is almost certain to be younger than the flow itself. A surface covered with numerous craters, both large and small, is generally much older than a surface with fewer craters. Aging by comparing a sequence of events that occurred at different times is referred to as **relative dating**.

Careful study may reveal many clues as to the relative ages of lunar features. Recently formed impact craters display steep and well-defined slopes whereas older ones display rounded and indistinct slopes. As these craters age, gravity slowly and gradually pulls them downward resulting in a flattened or subdued appearance. This flattening occurs at a more rapid pace on those bodies composed of ice or ice and rock mixtures than those composed of rock only. **Lava flows** may spread over large areas covering previously exposed features, stopping at the edges of large cliffs or highlands. Flowing lava may carve out channels and valleys as it rushes toward lower elevations. Rays of debris, ejected during meteorite impact, gradually disappear over the course of millions of years. Craters surrounded by rays, therefore, are much younger than those without.

Internal pressures may cause large **faults**, or cracks, to form at the surface. These faults mark the edges of crustal plates that slide past, under, and over each other. This surface break-up into large plates and the interactions between them is called **tectonics**.

Carefully study the photos of the near and far sides of Earth’s Moon found on the following page. Note the two very distinct areas – dark and light – on the Moon’s near side. Although only a portion of the Moon’s far side is shown on the second photo, the terrain shown is quite representative of the entire surface on that side of the Moon.

2. Which surface areas – **dark** or **light** – were the most recently formed? \_\_\_\_\_

How do you know? \_\_\_\_\_

3. Which side of the Moon displays the greatest contrast in age – the **near** or **far** side?

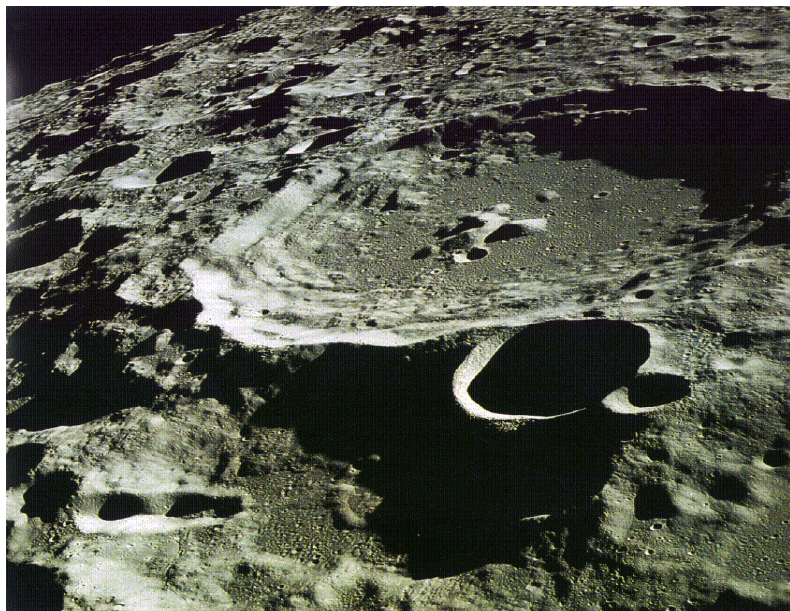
\_\_\_\_\_ Explain. \_\_\_\_\_

4. List two sources of the material of which lunar rays are composed? \_\_\_\_\_

5. What do lunar rays reveal about the relative age of those craters that have them versus those that do not? \_\_\_\_\_



Near Side of Earth's Moon



Far Side of Earth's Moon. Photo courtesy of NASA



6. Hadley Rille, a long, winding lunar valley is featured in the photo above. Explain how this valley most likely formed? \_\_\_\_\_
- \_\_\_\_\_
7. Locate Hadley Crater straddling Hadley Rill. Which feature, the **crater** or the **rill**, is older? \_\_\_\_\_ How do you know? \_\_\_\_\_
- \_\_\_\_\_



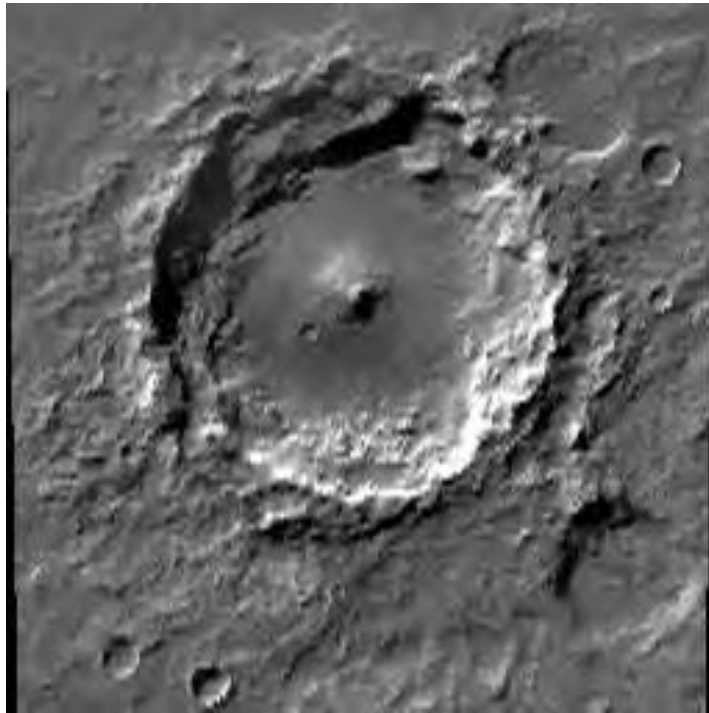
8. This series of impact craters is found on the surface of Ganymede, Jupiter’s largest satellite. This feature was formed as individual members of a nuclear train, traveling in the very same direction, struck in succession, i.e. a brief interval of time separated the impact of each individual meteorite impact.
- a. What is the most likely origin of this series of meteorites? \_\_\_\_\_
- b. How does the impact of this nuclear train prove that Ganymede rotates on its axis?  
\_\_\_\_\_
- c. How does the relative age of this series of craters compare with that of other craters on Ganymede’s surface? \_\_\_\_\_

Craters may be formed in two ways: by volcanic action or meteorite impact. Two Martian craters are featured in the next two photos. The one directly below is atop our solar system’s largest volcano, Olympus Mons.



This irregularly shaped crater at the summit of Olympus Mons is a caldera, formed as the summit of this giant volcano collapsed. This collapse may have occurred due to lava flowing outward, creating an internal cavity beneath the summit that could no longer withstand the weight above.

9. What evidence supports the theory that Olympus Mons is younger than most features on Earth’s Moon? \_\_\_\_\_  
\_\_\_\_\_
10. Given the fact that gravitational attraction is directly related to the mass of a body, explain why Martian volcanoes can grow to a much larger size than volcanoes on Earth.  
\_\_\_\_\_  
\_\_\_\_\_

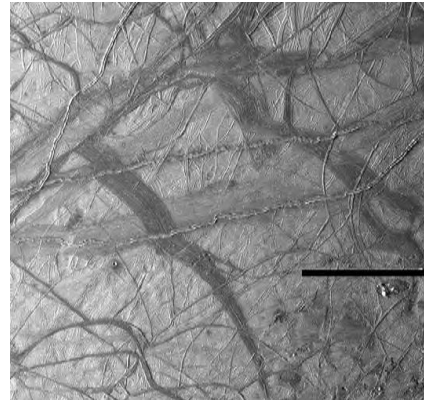


The Martian crater in the photo above displays a central peak formed due to rebound of the crater floor immediately following impact. Whether a central peak forms depends upon its diameter, surface gravity, and the type of surface material.

11. List two clues that would be useful in determining the relative age of the large crater compared to the craters surrounding it.
  - a. \_\_\_\_\_  
\_\_\_\_\_
  - b. \_\_\_\_\_  
\_\_\_\_\_
12. List two clues that would be useful in determining the relative age of the two middle-sized craters located in the upper right and lower right of the photo.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
13. Locate and draw a circle around a crater that is, without a doubt, younger than the large crater displaying a central peak.



Ganymede



Europa



Callisto



Io

Surface areas of Jupiter’s four large satellites are shown in the photos above. On the lines provided, write the name of each moon matching the description given.

14. \_\_\_\_\_ most similar to that of Earth’s moon
15. \_\_\_\_\_ is continually being resurfaced by volcanic eruptions
16. \_\_\_\_\_ most tectonically active surface
17. \_\_\_\_\_ large amounts of water are quite likely found beneath its surface
18. \_\_\_\_\_ its geologically active surface may be due in part to the gravitational tug of Jupiter and its largest satellite
19. \_\_\_\_\_ its surface suggests both tectonic and meteoritic impacts in its distant past



**Table I: Satellite Statistics**

Satellite	Comp.	Atmo. Pressure	Winds	Water	Int. Temp	Volcanoes	Tectonics
I	Rocky	1000 mb	Moderate	Lots	Hot	Active	Moderate
II	Icy	Tenuous	None	Ice	Hot	None	Active
III	Rocky	92,000 mb	Weak	None	Hot	Active	None
IV	Rocky	Tenuous	None	None	Cold	Extinct	None
V	Rocky	Tenuous	None	None	Hot	Numerous	None
VI	Rocky	6.8 to 9 mb	Mild	None	Warm	Extinct	None

The year is 2230 A.D. Three years and two months ago, SETI finally received intelligent radio transmissions from Itania, a planet in orbit about the star Altair, 16.5 light years from Earth. Due to its close proximity to Earth, plus its having only three times the mass and 1.6 times the radius of our own Sun, it had been long suspected that intelligent life might likely be found on one of the many planets in orbit about this star.

After several long years of agonizing frustration, SETI has finally decoded the transmissions. The Itanians have provided detailed information about the satellites within their own solar system. As experts in the fields of extraterrestrial geology and climatology, you and your team have been called upon to interpret the information gleaned from those transmissions. You have explained to your team that “tenuous” translates into “having very little”, “comp” refers to surface composition, or what the surface is composed of,” and “int. temp” refers to the “internal temperature” of the satellite.

20. \_\_\_\_\_ Which satellite would be considered geologically dead?
21. \_\_\_\_\_ Which satellite’s craters would be eroded during planet-wide dust storms?
22. \_\_\_\_\_ Which satellite would be the best candidate for human colonization?
23. \_\_\_\_\_ Which satellite is the best candidate for harboring only simple forms of life?
24. \_\_\_\_\_ Which satellite would erase scars of an impact crater most quickly?
25. \_\_\_\_\_ Which satellite would be most inhospitable to human colonization?

Match each of the satellites in orbit about Altair with its “twin” satellite within in our own solar system.

- |                |                   |                  |
|----------------|-------------------|------------------|
| 26. _____ Mars | 28. _____ Mercury | 30. _____ Europa |
| 27. _____ Io   | 29. _____ Earth   | 31. _____ Venus  |

## “Worlds of Change”

## Answer Key

1. [2] Jupiter is a gaseous planet and therefore has no solid surface.
2. [3] Dark. Fewer impact craters. Lava flows butted against features with higher elevations.
3. [3] Near. Older highlands and younger maria on the near side. Far side is heavily cratered.
4. [2] Ejected surface material and fragments of the meteorite itself.
5. [2] Those with rays are younger [or] those without rays are older.
6. [2] By a lava flow.
7. [2] Rille. Hadley crater is embedded upon the rille.
- 8a. [1] A “shattered” comet
- 8b. [2] For these fragments to impact in a straight line, the satellite had to be rotating.
- 8c. [1] They are the youngest features on Ganymede.
9. [2] So few impact craters on Mars as compared to the number on the Moon.
10. [3] Mars has much less mass than Earth, therefore it has less gravity thus permitting volcanoes to grow to a much larger size.
- 11a. [2] Steep, well-defined slopes
- 11b. [2] Very few craters have impacted upon this larger crater as compared to the area surrounding the crater. [Responses to 11a and 11b may be reversed.]
12. [4] Two points each for any two of the following: they’re flattened; they display rounded and indistinct slopes; the larger crater partially covers the crater in the upper right; and there are smaller craters within them.
13. [2] The small impact crater located down and to the left of the central peak should be circled on the photo.
14. [1] Callisto      19. [1] Ganymede      24. [1] V      29. [1] I
15. [1] Io      20. [1] IV      25. [1] III      30. [1] II
16. [1] Europa      21. [1] VI      26. [1] VI      31. [1] III
17. [1] Europa      22. [1] I      27. [1] V
18. [1] Io      23. [1] II      28. [1] IV