Are There Floods on Mars

Overview:

Students examine images of Martian flood channels, focusing especially on Ares Vallis, the landing site of the *Mars Pathfinder* spacecraft. They will analyze the surface features around the landing site and discover that it is located at the mouth of a large channel. Tracing this channel towards its origin, students will determine its dimensions and see how the channel flows from several areas of chaotic terrain. They will then use crater densities to determine that Ares Vallis crosses a variety of terrains formed at different times in Martian geologic history. Next, students consider the types of rocks and sediments that *Pathfinder* found at the mouth of this large flood channel, as it crosses a landscape with considerable geological diversity. Finally, students write a story explaining features in Ares Vallis supporting the idea that there were mammoth floods on Mars and how *Pathfinder* used flood debris to shed light on Martian geologic history.

National Science Education Standards:

Standard A: Understanding about scientific inquiry
Standard B: Motions and forces
Standard F: Natural hazards

Time:

Approximately 3 - 45 minute class periods.

Grade Levels:

Grades 8^{th} - 12^{th}

Materials:

- Image set
- Clear plastic overlays
- Washable markers

Background:

Ares Vallis is one of a series of channels that descend from a highland plateau into the low-lying Chryse Planitia (plain). Ares Vallis originates in three large areas of chaotic terrain, follows a 1,800 km (1,170 mi) course and terminates in the Chryse Planitita, approximately 2.5 km (1.6 mi) below its source. The channel is 25 km (16 mi) wide, about 1 km (0.65 mi) deep, and many of its features lend strong support to the idea that Ares Vallis is an immense flood channel. For example, the scour marks and longitudinal grooving seen in Martian outflow channels were most likely produced by high-volume, deep, high-velocity flows. While scientists have proposed ice, lava, mud flows and wind as possible methods that might have excavated the channels, water is considered the most likely agent.

How much water did Ares Vallis carry? Discharge created can be inferred by determining the volume of material the flood removed. Scientists estimate that the floods removed 200,000 km^3 (50,000 mi^3) of material (the approximate land area of Alabama, one-mile deep) from the chaotic terrain and channel bed. This would require a discharge rate in the range of 10 million to a billion m^3 per second. Ares Vallis' estimated peak discharge rate is 70 million m^3 per second. If the floods were 100 m deep, they would have lasted an estimated 50 days. If they were 200 m deep, as some researchers speculate, they would have lasted nine days. These figures compare to the Scabland flood, the largest known terrestrial flood, whose peak discharge rate is estimated to be 10 million m^3 per second. Additional comparisons can be made width the Amazon's mean annual discharge rate of 100,000 m^3 per second, and the 1993 Mississippi's flood peak discharge rate of roughly 30,000 m^3 per second.

Where might the water have come from?

Several hypotheses have been proposed:

- Rising magma may have melted large areas of ice and permafrost, thus releasing huge amounts of water suddenly.

- The chaotic terrain, often located near the head of the channels, testifies to the release of vast quantities of fluid material from subsurface sources. However, some researchers feel the areas of chaotic terrain seem too small to account for the amount of water required to fill and erode such large channels.

- Authorities on Martian flood channels discuss the possibility of there being impounded lakes just prior to the Martian flooding. There is evidence for lake sediments, and perhaps lakes formed by the release of groundwater. Because of low temperatures and low atmospheric pressure which would make the long-term existence of liquid water unlikely, it is thought that lakes could only exist if the surface of the water had been stabilized by a thick ice cover. Since ice tends to insulate the water beneath it and retard its freezing, a thick ice cover may have allowed water to remain in liquid state. Lake size and depth would be determined by the difference in the rate at which water seeped out of the ground and the rate at which the ice layer sublimated.

- Water may have been confined under pressure beneath a layer of permafrost. For example, a high core pressure could have been achieved if groundwater percolated down the eastern slope of the Tharsis Rise. This gravity-driven groundwater would pool at the eastern end of Valles Marineris and create an aquifer. There, a permafrost cap would confine the aquifer and, as more water collected, the water pressure would rise. If the permafrost cap fractured or melted, the pressurized aquifer would release its water catastrophically. Interestingly, the eastern end of Valles Marineris is, indeed, a vast area of chaotic terrain, roughly the size of Montana, and large channels lead away from it.

Where might all the water gone after it reached the Chryse Planitia?

All traces of the channels are gone between latitudes 45 N to 65 N. The mud-flow-like ejecta blankets around impact craters on the Chryse Planitia strongly suggest the presence of ground ice there. Several other striking features of the Chryse

Planitia (polygonal fracture patterns and bright-colored crater ejecta superimposed on the dark surface) suggest that these distinctive features are caused by the presence of sedimentary deposits from large floods. The floodwaters must have pooled in the low areas at the ends of the channels. These lakes would have frozen over immediately. If the ice was continually swept free of debris by wind, it would slowly sublime into the atmosphere. If, on the other hand, the lakes became permanently stable they would remain that way for the life of the planet. The frequent dust storms, the high-sediment load of the flood waters, and images of debris deposits at the poles all suggest that the ice deposits would have quickly become covered with debris and have stabilized.

Summary:

Ares Vallis is believed to be a channel, formed over 3 billion years ago, when a large volume of subsurface water broke through the surface and flowed to the Chryse Basin. The plain at the mouth of Ares Vallis is the designated landing site for *Mars Pathfinder*, and it was selected partly for engineering reasons such as having a relatively smooth surface to minimize landing problems. Another selection criteria was that this landing site promises to provide scientists an unusual opportunity to look into the geological history of Mars. Scientists expect that the flood presumes to have created Ares Vallis eroded rocks and sediments from along its course. Ares Vallis traverses a range of rock types dating from different periods in the planet's history. The estimated scale of the floods - the largest know in the Solar System - would easily carry an enormous variety of rocks and sediments down from the ancient southern highlands to the mouth of Ares Vallis.

Exploration:

Investigation #1: Looking at the Landing Site

1. Refer to Image 3, the close-up of the *Pathfinder* landing site. Have the class (or groups) discuss the landing site in terms of the surface features. The goal of the discussion is to engage students rather than to learn facts. Questions might include:

1a. How big is this landing site? What state is approximately this size?

- Rhode Island.

1b. What features stand out?

- These might include: a smooth surface, streamlined land forms, craters with mud flow ejecta blankets, small secondary craters without ejecta blankets that were created by material blasted out when the large craters were formed, and channel beds.

1c. How might such a landscape have formed?

1d. Why might scientists have selected this area as the *Pathfinder* landing site?

- Because they have has little information related to this question, student responses will vary. The geological reason is that there is a good sampling of rocks available. The engineering reasons are : a smooth surface; a low elevation which gives the parachute more time to slow the spacecraft; and lots of direct sunlight at this latitude for the solar panels.

1e. What instruments are on the lander?

- The lander has a camera, a weather station, and a rover which can move independently over the surface. The rover has its own camera and an APXS to examine rocks near the lander.

2. Refer to Image 5 showing the broader view of the landing site including the mouth of the Ares Vallis channel. Have the class (or groups) consider questions such as:

2a. What do you notice in this larger perspective?

- The channel and more streamlined features.

2b. Is there anything in this image that furthers our understanding of why this area was chosen as a landing site?

- Few craters, flood plain.

2c. Is there anything in this image that was not visible on Image 3 that helps us understand some of the features pictured in Image 3?

- A channel.

2d. What do you think shaped most of these surface features? Find three pieces of evidence to support your answer.

- Water. Streamlined landforms, channels, possible wet ground shown by the mud flow-like ejecta blankets around the large craters, smooth surface with grooves running parallel to presumed water flow direction.

2e. What direction did the water seem to come from?

- The southeast.

2f. Look at the area around where the Tui Vallis joins the plain. Did the Ares or Tui channel occur first? How do you know?

- Ares first because Tui flow marks eroded the earlier Ares flow marks.

2g. If the surface of Mars is now dry, how could water have flowed?

- It is believed that Mars had flowing surface water early in its development.

Investigation #2: Looking at Ares Vallis

1. Refer to Image 1, the broadest view of the Ares Vallis region. Have students trace Ares Vallis back to its source. You might distribute clear plastic overlays and marker pens and have students outline Ares Vallis and the key landforms surrounding it.

1a. Where does Ares Vallis start?

- In the regions of Lani and Margaritifer chaos.

1b. How long is it? What does this correspond to on Earth?

- 1,800 km (1,170 mi).

1c. How does its width change from source to mouth? Is this typical of channels on Earth?

- Ares Vallis has a consistent width for much of its length. On Earth, channels are often small and narrow near the source and often start in deep V-shaped valleys. Near their mouths, channels on Earth widen and the valleys containing them become broader and shallower.

1d. What landforms are visible near where Ares Vallis originates?

- Craters and four areas of chaotic terrain: Margaritifer, Lani, Hydaspis, and Aram.

1e. What additional features suggest water flow?

- A channel enters a crater due east of the Aram Chaos. It breaches the downhill side and enters another crater. A channel leaves this second crater to reconnect with Ares Vallis.

Investigation #3: Looking at Chaotic Terrain Around the Chryse Basin

1. Image 7 highlights two large areas of chaotic terrain at the head of the two outflow channels just west of Ares Vallis (the mouth of Ares Vallis is visible in the upper right corner of the image). The Simud Vallis emanates from the Hydrotes Chaos and flows northwest from the lower center of the image. The Tui Vallis emanates from the Hydaspis Chaos and flows from the southeast corner to the upper center of the image.

1a. What features are associated with chaotic terrain?

- Collapsed ground, outflow channels.

1b. How does the size of the chaotic terrain to the head of the Tui and Simud Vallis compare to the size of the chaotic terrain at the head of Ares Vallis? What consequences might such differences have?

- There is more chaotic terrain at the head of Ares Vallis. This could have supplied large quantities of water intermittently or all at once, creating large floods in either case.

1c. How many different chaotic terrains drain into the Ares Vallis?

- Four: Aram, Lani and Margaritifer are the main sources, and there is a small drainage from the Hydaspis chaos.

1d. Which outflow channel in this area is the longest? What is the significance of this?

- Ares Vallis is the longest and consequently cuts across a greater variety of geological formations.

2. Refer to Image 16 showing the regions that drain into the Chryse Basin.

2a. Approximately how many channels flow into Chryse Basin? Where are they located?

2b. What does that imply about the topography of the region?

- The Chryse Basin is surrounded by elevated plateaus to the south, east and west.

2c. Trace the flow of Ares Vallis from chaotic terrain through the channel to Chryse Basin. Where did the water flow after reaching the basin? Where are signs such as flow lines and teardrop islands no longer evident?

- The water appears to have spread out and either evaporated, sublimated or gone underground.

2d. What might explain why the Chryse basin looks so smooth?

- Because the Martian gravity is 4/10 that of Earth's, features commonly associated with sediment deposition on Earth are likely quite different on Mars. It may be that sediments of all sizes were kept in suspension long enough to deposit themselves fairly evenly over much of the Chryse Planitia without forming a delta.

Investigation #4: How Old Is the Martian Surface Around Ares Vallis?

1. Unlike Earth, the Martian crust is not active and does not constantly degrade and renew itself. Consequently, one can find parts of the Martian crust preserved from every phase

of the planet's history starting over four billion years ago. Since meteors continuously fall on a planet's surface and create craters, craters can be used to help determine the age of the surface. In general, the greater the crater density, the older the terrain. Mars has had two major cratering periods, one about four billion years ago and another about three billion years ago. By having students look at relative crater densities along Ares Vallis, they can appreciate that the geologic formations it flows over were formed at different times during Mars' history.

1a. Do the crater densities in the areas surrounding Ares Vallis change? If so, how?

1b. Using crater density, estimate which parts of the surface are the youngest and oldest.

1c. Construct a reasonable sequence for the following events: Ares Vallis forms, the highland plateau (at the head of Ares Vallis) forms, Chryse Planitia forms, chaotic terrain develops, and the ridged plains (the heavily cratered area northeast of Ares Vallis in the Arabia Terra) form.

- From oldest to youngest: Highland Plateau, Ridged Plains, Chaotic terrain, Ares Vallis, Chryse Planitia).

Investigation #5: Looking at Sediment Transport

1. Refer to Image 13, the delta formed where the Mississippi River flows into the Gulf of Mexico.

1a. What do students notice?

- A delta, deposition, islands, silt flowing into ocean.

1b. How might this example of sediment transport relate to Ares Vallis?

- Deposits at the mouth of a river will likely contain sediments from along its entire length.

1c. Why is this important piece of information in the *Pathfinder* mission?

- Scientists expect that analyzing samples in an outwash plain will enable them to study rocks from the entire Ares Vallis drainage. This concept is called a grab-bag site.

1d. How does one find an area that has rocks from a lot of different places?

- Look for outwash plains at the mouth of channels.

1e. How large an area might the rocks and soil found at the Mississippi delta or on the Chryse Planitia have come from?

- Have students look at maps showing the drainage basin of the Mississippi delta and Ares Vallis.

Investigation #6: Ares Vallis and the Pathfinder Mission

1. Why did scientists choose Ares Vallis?

- Your students should be able to explain that a wide variety of rocks probably were deposited near the proposed landing site. This will enable *Pathfinder* to find a wider than normal variety of rocks. Other advantages of this landing site include: a relatively smooth surface to minimize landing problems, a mid-latitude location for more direct sunlight for solar power, and a low elevation to allow more time for deceleration.

2. Remind students that no one knows for sure what caused Ares Vallis and the other features in this area. The flows may have been lava, mud or ice. Maybe fractures created the channel before water flowed down it. Remaining questions include: what caused the water to break through to the surface and why is there no alluvial fan where the Ares Vallis flows into Chryse Basin? Mars research is an on-going process. Data from the *Mars Pathfinder* and *Mars Global Surveyor* missions, in addition to future Mars mission scheduled to launch from Earth every 26 months will answer some questions and very likely raise some new ones.

Investigation #7: What is the Significance of the Martian Floods to the Pathfinder Landing Site?

1. Based on their experiences in the module, students should now be able to write a story explaining how features in Ares Vallis support the idea that there were mammoth floods on Mars and how *Pathfinder* intended to use flood debris to shed light on Martian geologic history. Since many aspects of the channels are poorly understood, the focus is on having students develop hypotheses, identify evidence to supports those hypotheses and synthesize the concepts to which they have been introduced. A thorough discussion would mention the evidence for cataclysmic floods. In addition, it would discuss the significance of the regional topography, the relationship of the regional topography, the relationship between channels and chaotic terrain, and the different time periods represented in the geology over which Ares Vallis flows. Finally, a complete story would mention how these elements bear on the geologic and engineering reasons for selecting the *Pathfinder* landing site. Consider having students use alternate formats such as multimedia presentations or poster reports.

Name ________________________

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