

Color Images from Mars Rovers: Spirit and Opportunity

by Webster, Bob

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Subjects: Mars (Planet) -- Pictorial works

Color Images from Mars Rovers

by Bob Webster

Thanks to Bob Webster for making these images available. They are recombinations of images with different colored filters. All images are courtesy of NASA/JPL and in the public domain in the United States.

Mars Attacks!

I was browsing the NASA web site for photos from the Mars rovers, but most of them are black and white. Then I noticed they have the raw images posted that can be combined into color photos, so I combined a bunch of them into "living color." Here they are:

Mars in Color, from ?Opportunity?
Opportunity Photos
Mars in Color, from ?Spirit?
Spirit Photos

The color is not perfect on these, but it should be in the neighborhood. There are a lot of variables. The cameras are calibrated differently from time to time, there are different bandwidths available in different images, and the sun is at different angles.

In these photos, 3 to 6 images were taken, one after another, using different bandwidth filters. There may be 5 minutes pass from the first to the last image, so a shadow may move a little bit during that time. An interesting effect of this is an occasional rainbow strip on the edge of shadows.

The image file names include information such as camera type, time taken, location, etc. Here is the full info:

http://origin.mars5.jpl.nasa.gov/gallery/edr_filename_key.html

The image on this site have the filter and sometimes the Left or Right designator removed. If L or R is missing, then they were taken with the Left camera, which uses visible light filters.

These images were taken with the panoramic camera, because it's the one that uses color filters. The filters used vary from image to image. The available filters are:

Left Camera
Right Camera

1 = EMPTY (clear)
1 = 436nm (37nm Short-pass)

2 = 753nm (20nm bandpass)
2 = 754nm (20nm bandpass)

3 = 673nm (16nm bandpass)

3 = 803nm (20nm bandpass)

4 = 601nm (17nm bandpass)

4 = 864nm (17nm bandpass)

5 = 535nm (20nm bandpass)

5 = 904nm (26nm bandpass)

6 = 482nm (25nm bandpass)

6 = 934nm (25nm bandpass)

7 = 432nm (32nm Short-pass)

7 = 1009nm (38nm Long-pass)

8 = 440nm (20) Solar ND 5.0

8 = 880nm (20) Solar ND 5.0

Some bandwidths of visible light are:

red

650

orange

590

yellow

570

green

510

blue

475

indigo

445

violet

400

Everything gets kind of fuzzy from this point on. The visible light bandwidths are not even sharply delimited. The bandwidths in the Martian cameras don't necessarily match the color bandwidths on Earthling computers. In a lot of the images some of the bandwidths are missing. For example, this image:

only uses filters 4, 5, and 7, which more or less correspond to reddish-orange, yellow-green, and violet. There is a hole or two in the spectrum, notably red and blue, so it ends up looking a little weird. But it's still much better than black and white.

Some of the images from Mars use filters 2, 5, and 7, or some wide range like that. This provides more information for scientific

analysis, but it doesn't look normal when combined. That is, if there is a "normal" for pictures from Mars. I skipped most of these.

The right pan camera filters are mainly longer wavelength in the ultraviolet range. I only included one of those pictures, mostly because I wondered what it would look like:

I used Photo Mud to merge the separate images. In fact, I wrote the Merge Color Separation function in Photo Mud so I could do this. You can download a test version here:

<http://xpda.com/photomudsetup.exe>

When Photo Mud version 3.0 is released in a few days, I'll replace this file with a 30-day trial version. If you download the test version before then, you can have a free update to the release version without a 30-day limit. Let me know if you find any "design considerations" or other things that don't work.

Here's where to get the latest raw images from Mars:

<http://origin.mars5.jpl.nasa.gov/gallery/all>

Some of the NASA pictures show mainly red on Mars, such as this panorama:

But the colors in the corners of this sundial in the base of the photo from looks quite a bit different on earth than on the landscape photo. There is a lack of blue in the Mars photo, or maybe even a translation of blue to red. There's probably a good reason for this, since NASA has better software and spent more time on it.

It looks to me like NASA included filter 2, infrared light, in their red color composition. In this image with filter 2, you can see how bright the lower right color tab is:

This one is filter 3, is visible red. The blue tab in the lower right is not nearly as bright:

Here is a composition I did using infrared as red, and shifting the colors toward that end of the spectrum. This is kind of like the sundial in the color landscape.

Here's the image with "normal color" composition:

The second one looks a lot closer to the original photo above. In these two images, the background dirt looks about the same, but these settings make a big difference sometimes.

Photos Courtesy NASA/JPL-Caltech

Mars in Color, from ?Opportunity?

4/9/2004

4/8/2004

4/7/2004

4/6/2004

4/5/2004

4/5/2004

4/4/2004

4/4/2004

4/4/2004

4/3/2004

3/30/2004

3/28/2004

3/28/2004

3/27/2004

3/24/2004

3/23/2004

3/22/2004

3/22/2004

3/21/2004

Infrared used for red

3/20/2004

filter 2 (infrared) used for red

3/20/2004

filter 2 (infrared) used for red

3/20/2004

3/20/2004

3/20/2004

3/20/2004

3/19/2004

3/18/2004

3/18/2004

3/17/2004

3/17/2004

Dubbed "Carousel," the rock in this image was the target of the Mars Exploration Rover Opportunity science team's outcrop "scuff test." On sol 51 (March 15, 2004), Opportunity slowly rotated its left front wheel on the rock, abrading it in the same way that geology students use a scratch test to determine the hardness of minerals. The image on the right, taken by the rover's navigation camera on sol 51, shows the rock post-scuff. In this image, it is apparent that Opportunity scratched the surface of "Carousel" and deposited dirt that it was carrying in its wheel rims.

3/16/2004

3/16/2004

3/15/2004

3/15/2004

"Shoemaker's Patio" near the Mars Exploration Rover Opportunity's landing site, shows finely layered sediments, which have been accentuated by erosion. The sphere-like grains or "blueberries" distributed throughout the outcrop can be seen lining up with individual layers. This observation indicates that the spherules are geologic features called concretions, which form in pre-existing wet sediments. Other sphere-like grains, such as impact spherules or volcanic lapilli (fragments of material between 2 and 64 millimeters or .08 and 2.5 inches in maximum dimension that are ejected from a volcano) are thought to be deposited with sediments and thus would form layers distinct from those of the rocks. This image was captured by the rover's panoramic camera on the 50th martian day, or sol, of the mission.

3/15/2004

3/14/2004

3/14/2004

This image is of the exceptional rock called "Berry Bowl" in the "Eagle Crater" outcrop. The study of this "blueberry-strewn" area and the identification of hematite as the major iron-bearing element within these sphere-like grains helped scientists confirm their hypothesis that the hematite in these martian spherules was deposited in water. To separately analyze the mineralogical content of three main features

within this area -- blueberries, dust and rock -- it was important that the rock abrasion tool's brush was able to rest on a relatively berry-free spot. The rock's small size and crowd of berries made the 10-minute brushing a challenge to plan and execute. The successful brushing on the target whimsically referred to as "Near Empty" on the rover's 48th sol on Mars left a dust-free impression for subsequent examination by the rover's spectrometers. No grinding was necessary on the rock because spectral data obtained on the dust-free surface were sufficient to verify that the rock's chemical composition differs significantly from the hematite-rich berries.

3/13/2004

3/13/2004

3/12/2004

3/12/2004

The sphere-like grains or "blueberries" distributed throughout the outcrop can be seen lining up with individual layers. This observation indicates that the spherules are geologic features called concretions, which form in pre-existing wet sediments. Other sphere-like grains, such as impact spherules or volcanic lapilli (fragments of material between 2 and 64 millimeters or .08 and 2.5 inches in maximum dimension that are ejected from a volcano) are thought to be deposited with sediments and thus would form layers distinct from those of the rocks.

3/11/2004

3/11/2004

3/11/2004

the 3.1 millimeter-deep (just over one-tenth of an inch) hole ground by the Mars Exploration Rover Opportunity's rock abrasion tool in the target called "Mojo 2" on "Flatrock" was taken on the 44th martian day, or sol, of the mission. It will help complete the chemical analysis of the lowest layer of the outcrop in the crater where the rover now resides. After a brief brushing on sol 45, the science team plans to place Opportunity's spectrometers on the hole to collect data vital to their understanding of this impressive outcrop.

Scientists believe that the spherule or "blueberry" in the upper right area of the circular impression was sliced in half by the rock abrasion tool. "Blueberries" are a known obstruction to the grinding tool that cause it to terminate its sequence. Despite the stall, the rock abrasion tool abraded "Flatrock" for one hour and five minutes, producing a cavity ripe for investigation.

3/10/2004

3/10/2004

3/9/2004

3/8/2004

3/7/2004

3/7/2004

This hole was made by the rover's rock abrasion tool, located on its instrument deployment device, or "arm." The hole is located on a target called "McKittrick" at the "El Capitan" region of the Meridiani Planum, Mars, rock outcrop. It was made on the 30th martian day, or sol, of Opportunity's journey.

The grinding process at has generated a significant amount of reddish dust. Color and spectral properties of the dust show that it may contain some fine-grained crystalline red hematite.

Courtesy NASA/JPL

3/1/2004

2/29/2004

This hole was made by the rover's rock abrasion tool, located on its instrument deployment device, or "arm." The hole is located on a target called "Guadalupe" at the "El Capitan" region of the Meridiani Planum, Mars, rock outcrop. It was made on the 30th martian day, or sol, of Opportunity's journey.

The grinding process at has generated a significant amount of reddish dust. Color and spectral properties of the dust show that it may contain some fine-grained crystalline red hematite.

2/29/2004

The silver colored metal of the ring on the solar abrasion tool is a reddish brown after the dust settled on it, probably from fine-grained hematite.

2/29/2004

2/28/2004

2/28/2004

2/27/2004

2/27/2004

2/22/2004

The image is from the right pan camera, made up of ultraviolet bandwidths.

2/20/2004

2/20/2004

The "El Capitan" region of the rock outcrop at Meridiani Planum, Mars. This image shows fine, parallel lamination in the upper area of the rock, which also contains scattered sphere-shaped objects ranging from 1 to 2 millimeters (.04 to .08 inches) in size. There are also more abundant, scattered vugs, or small cavities, that are shaped like discs. These are about 1 centimeter (0.4 inches) long.

2/20/2004

2/20/2004

The "El Capitan" region of the rock outcrop at Meridiani Planum, Mars.
2/20/2004

The "capture magnet," which attracts atmospheric dust particles from the front deck of the rover. The lighter-colored areas in the image are clean sections of the magnet virtually free of dust, and the dark areas are places where dust has collected. Dust particles in the martian atmosphere are estimated to be about 1 micrometer in size (1/1000th of a millimeter or 1/1000th of .04 inches).

The material below the magnet's aluminum surface is laid out in concentric rings, giving the image a bull's-eye appearance. The magnet was designed in this configuration to collect as much atmospheric dust as possible. Spirit and Opportunity each carry seven magnets.

2/19/2004

The Mars Exploration Rover Opportunity dragged one of its wheels back and forth across the sandy soil at Meridiani Planum to create a hole (bottom left corner) approximately 50 centimeters (19.7 inches) long by 20 centimeters (7.9 inches) wide by 9 centimeters (3.5 inches) deep. The rover's instrument deployment device, or arm, will begin studying the fresh soil at the bottom of this trench later today for clues to its mineral composition and history. Scientists chose this particular site for digging because previous data taken by the rover's miniature thermal emission spectrometer indicated that it contains crystalline hematite, a mineral that sometimes forms in the presence of water. The brightness of the newly-exposed soil is thought to be either intrinsic to the soil itself, or a reflection of the Sun.

2/19/2004

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2/19/2004

2/17/2004

2/17/2004

2/14/2004

2/12/2004

2/9/2004

2/8/2004

Rock abrasion tool, also known as "rat" (circular device in center), located on the rover's instrument deployment device, or "arm."

2/8/2004

2/7/2004

2/7/2004

2/7/2004

A region at the end of the rock outcrop lining the small crater, called "Eagle Crater." The sphere-like grains or "blueberries" dotting the rocks in the outcrop can also be seen above the rocks, suggesting that these geologic features have origins beyond Eagle Crater.

2/7/2004

2/3/2004

1/28/2004

1/28/2004

1/28/2004

1/28/2004

1/28/2004

1/28/2004

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1/28/2004

1/28/2004

These layered rocks measure only 10 centimeters (4 inches) tall and are thought to be either volcanic ash deposits or sediments carried by water or wind.

1/27/2004

1/26/2004

Opportunity Photos

Mars in Color, from ?Spirit?

4/11/2004

4/11/2004

4/11/2004

4/11/2004

4/11/2004

4/11/2004

4/11/2004

4/11/2004

4/7/2004

4/7/2004

4/7/2004

4/6/2004

4/5/2004

4/5/2004

4/5/2004

4/5/2004

4/5/2004

no violet/indigo

4/5/2004

4/5/2004

4/4/2004

4/4/2004

4/3/2004

4/3/2004

4/3/2004

4/1/2004

3/31/2004

3/30/2004

3/29/2004

3/29/2004

3/27/2004

This image was taken by NASA's Mars Exploration Rover Spirit on sol 79 after completing a two-location brushing on the rock dubbed "Mazatzal." A coating of fine, dust-like material was successfully removed from targets named "Illinois" (right) and "New York" (left), revealing clean rock underneath. The center of the two brushed spots are approximately 10 centimeters (3.9 inches) apart and were aggressively analyzed by the instruments on the robotic arm on sol 80. On sol 81, the rover drilled into the New York target to expose the original rock underneath.

3/26/2004

3/25/2004

3/25/2004

3/25/2004

This hazard-avoidance camera image was taken by NASA's Mars Exploration Rover Spirit on sol 79 after completing a two-location brushing on the rock dubbed "Mazatzal." A coating of fine, dust-like material was successfully removed from targets named "Illinois" (right) and "New York" (left), revealing clean rock underneath. In this image, Spirit's panoramic camera mast assembly, or camera head, can be seen shadowing Mazatzal's surface. The center of the two brushed spots are approximately 10 centimeters (3.9 inches) apart and were aggressively analyzed by the instruments on the robotic arm on sol 80. On sol 81, the rover drilled into the New York target to expose the original rock underneath.

Note: The raw images are under the pan camera with color filters. ???

3/24/2004

NASA's Mars Exploration Rover Spirit took this panoramic camera image of the rock target named "Mazatzal" on sol 77 (March 22, 2004). It is a close-up look at the rock face and the targets that will be brushed and ground by the rock abrasion tool in upcoming sols.

Mazatzal, like most rocks on Earth and Mars, has layers of material near its surface that provide clues about the history of the rock. Scientists believe that the top layer of Mazatzal is actually a coating of dust and possibly even salts. Under this light coating may be a more solid portion of the rock that has been chemically altered by weathering. Past this layer is the unaltered rock, which may give scientists the best information about how Mazatzal was formed. Because each layer reveals information about the formation and subsequent history of Mazatzal, it is important that scientists get a

look at each of them. For this reason, they have developed a multi-part strategy to use the rock abrasion tool to systematically peel back Mazatzal's layers and analyze what's underneath with the rover's microscopic imager, and its Moessbauer and alpha particle X-ray spectrometers.

The strategy began on sol 77 when scientists used the microscopic imager to get a closer look at targets on Mazatzal named "New York," "Illinois" and "Arizona." These rock areas were targeted because they posed the best opportunity for successfully using the rock abrasion tool; Arizona also allowed for a close-up look at a range of tones. On sol 78, Spirit's rock abrasion tool will do a light brushing on the Illinois target to preserve some of the surface layers. Then, a brushing of the New York target should remove the top coating of any dust and salts and perhaps reveal the chemically altered rock underneath. Finally, on sol 79, the rock abrasion tool will be commanded to grind into the New York target, which will give scientists the best chance of observing Mazatzal's interior.

The Mazatzal targets were named after the home states of some of the rock abrasion tool and science team members.

3/23/2004

used violet for blue

3/22/2004

3/22/2004

3/22/2004

3/22/2004

3/22/2004

This image of the rock called "Mazatzal" was taken by the Mars Exploration Rover Spirit. It reveals some interesting features on this future rock abrasion tool target, including variants in tone, a sugary surface texture and scalloped areas where parts of the rock seem to have been worn away. Mazatzal's uniqueness is made even more obvious when it is compared to the more typical, basaltic rock in the lower right of the image.

3/21/2004

3/17/2004

3/17/2004

The Mars Exploration Rover Spirit acquired this navigation camera image on the 72nd martian day, or sol, of its mission (March 15, 2004), after digging its wheel into the drift dubbed "Serpent." Creating the commands that would generate this "scar" was not an easy task for rover controllers. Essentially, they had to choreograph an intricate dance for Spirit, maneuvering it up the side of the dune, shimmying its left front wheel a number of times to create the scuff, and then reversing to attain proper positioning for miniature thermal emission spectrometer observations. Before the task was finished, Spirit moved

forward to put the scuff within proper reach of the rover's arm. This scar allows the rover's instruments to see below the drift surface, to determine the composition of the materials. Initial results indicate that the drift material is similar to the basaltic sands that have been seen throughout Spirit's journey to the large crater dubbed "Bonneville." The material does not seem to be the same as that inside the crater.

Scientists are now looking to answer two questions: Why is the dark sand in the crater not the same as the dark sand in the drift? And why are there two different dark soil-type deposits in such a small place?

3/17/2004

3/17/2004

3/15/2004

3/15/2004

3/14/2004

3/14/2004

3/12/2004

3/11/2004

3/9/2004

3/9/2004

2/28/2004

2/27/2004

"Humphrey" at Gusev Crater, Mars, the Mars Exploration Rover Spirit's landing site. Spirit examined the lumpy rock with its suite of scientific instruments both before and after it drilled a hole into the rock surface on the 60th martian day, or sol, of its mission.

"Humphrey" was one of several stops on the rover's way to the large crater dubbed "Bonneville."

2/27/2004

2/27/2004

The large, shadowed rock in the foreground is nicknamed "Sandia" for a mountain range in New Mexico. An imposing rock, "Sandia" is about 33 centimeters high and about 1.7 meters long. When lightened, this image reveals much about the pictured rocks, which the science team believes are ejected material, or ejecta, from the nearby crater called "Bonneville." Scientists believe "Sandia" is a basaltic rock that landed on its side after being ejected from the crater. The vertical lines on the side of the rock facing the camera are known by geologists as "flow banding" and typically run horizontally, indicating that "Sandia" is on its side. What look like small holes on the two visible

sides of the rock are called vesicles; they were probably once gas bubbles within the lava. Many smaller rocks can be seen in the background of the image. Some rocks are completely exposed, while others are only peeking out of the surface. Scientists believe that two processes might be at work here: accretion, which occurs when winds deposit material that slowly buries many of the rocks; and deflation, which occurs when surface material is removed by wind, exposing more and more of the rocks.

2/26/2004

2/18/2004

2/18/2004

2/17/2004

2/14/2004

2/14/2004

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2/14/2004

2/13/2004

2/13/2004

2/13/2004

2/13/2004

2/13/2004

2/13/2004

2/13/2004

2/13/2004

Magnetic dust collector

2/12/2004

2/10/2004

White Boat is the first rock target that Spirit drove to after finishing a series of investigations on the rock Adirondack. White Boat stood out to scientists due to its light color and more tabular shape compared to the dark, rounded rocks that surround it.

2/9/2004

This is the Spirit's arm that does brushing, grinding, and drilling.

2/6/2004

This is the Spirit's arm that does brushing, grinding, and drilling.
2/2/2004

Spirit Photos

*** END OF THE PROJECT GUTENBERG EBOOK COLOR IMAGES FROM MARS ROVERS ***

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