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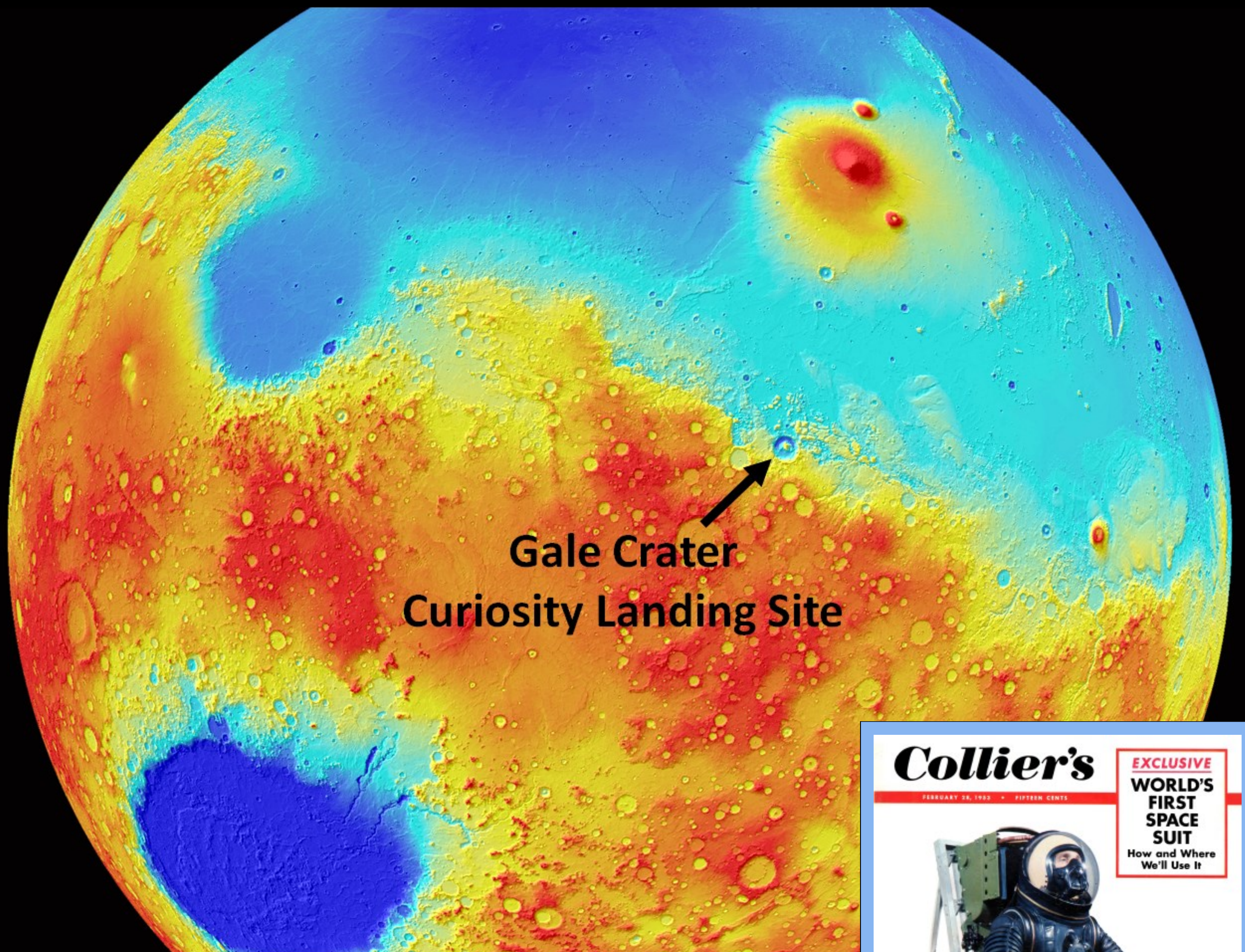
# A Geologist and Curiosity on Mars

*Interview with Dr. Dorothy Oehler*





**Also, Continuing in this Issue! Part 4 of 8:**

***Man Will Conquer Space Soon!***

**(Collier's 1952-54)**

# January / February 2013
# Horizons, Newsletter of AIAA Houston Section

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*Cover: Gale Crater context image, showing location of the crater on the dichotomy between the southern highlands and northern lowlands of Mars. Image is color-coded elevation from the Mars Orbiter Laser Altimeter (MOLA) that was on NASA's Mars Global Surveyor orbiter. Reds are elevations above 2600 m and dark blues are elevations below -5200 m, with respect to the Martian datum. North is up. Image created by D. Oehler. MOLA image data credit, NASA/ Goddard Space Flight Center. Table of contents page: part of Vincent van Gogh's 1889 painting The Starry Night.*

# A Geologist and Curiosity on Mars

Cover Story

DR. DOROTHY OEHLER, CURIOSITY PARTICIPATING SCIENTIST, INTERVIEWED BY DOUGLAS YAZELL, EDITOR

Dr. Oehler is a Senior Scientist in the Astromaterials Research and Exploration Science (ARES) Directorate at Johnson Space Center.

*Please tells us about your travel to California from Houston and working there on Mars time.*

I went to Pasadena, California for the landing of Curiosity with my husband, John, and another couple from Houston. We were all at Caltech that evening where they had 3 huge screens set up outdoors for folks involved in Mars Science Laboratory (MSL) to watch the various events associated with the landing. There were several thousand people there. Shortly before the landing, the International Space Station passed overhead and was clearly visible. The crowd cheered. When the landing was taking place, you could hear a pin drop. After landing, there were tears in some eyes. Landing was around 10:30 pm, Pacific Daylight Time (PDT), and soon after that, I went to the Jet Propulsion Laboratory (JPL) (just a few miles away from Caltech) and began my first "day" on Mars Time. All the scientists were there and work proceeded immediately that evening. I finished that first "Mars Day" of work around 8:30 am PDT.

*What did you propose to win this role as a Participating Scientist?*

I proposed to help focus the search for ancient biosignatures (evidence of past life) in Gale crater.

Organic materials constitute some of the best preserved and least ambiguous remains of ancient life on Earth and it is thought that organic materials may also provide evidence of possible past life on Mars. However, because the surface of Mars appears to be oxidizing and destructive to organic compounds, it will be necessary to select areas in which to search for organic remains very carefully.

My background includes 20+ years of research and exploration in the petroleum industry where I studied organic materials in sedimentary rocks. That work included study of various types of biosignatures, the geologic contexts in which organic biosignatures occur, and the characteristics of organic biosignatures at microscopic scales (in thin section) and macroscopic scales (in outcrop). So I proposed to use my background to help identify optimum localities for biosignature exploration by Curiosity, by targeting specific portions of outcrops at MSL investigation sites for elemental, mineralogical, and chemical analyses and providing insight regarding geologic facies that can add to interpretation of MSL data throughout the mission.

*What is your role on the team? Geologist?*

As a Participating Scientist, I interact with other geologists and geochemists. We have divided ourselves into "theme" groups and I usually work within the group that assesses geologic and mineralogic data. We look at the images and spectroscopic data that come down each day, and we plan the next day's activities based on what we have seen. Our group is highly diverse and we have participants with expertise in many different areas (e.g., chemistry, biology, soil science, fluvial and aeolian geologic systems, igneous processes, clay mineralogy, glacial processes, various types of spectroscopy, etc.). We also discuss longer range plans and strategy for obtaining the best scientific results.

*Above: NASA Mars Science Laboratory (MSL) logo featuring the Curiosity rover. Image credit: NASA.*

At the end of most days, we have a 1.5 to 2 hour Science Discussion that is open to the entire team. We each give presentations at those Discussions, when we see areas in which we can contribute information relevant to current and planned activities. Some of those discussions are detailed with lengthy questions and follow-up. While we were all still in Pasadena at JPL and working on Mars Time, some of the most intense Science Discussions ended up being at 2 or 3 in the morning!

*How many Participating Scientists were selected?*

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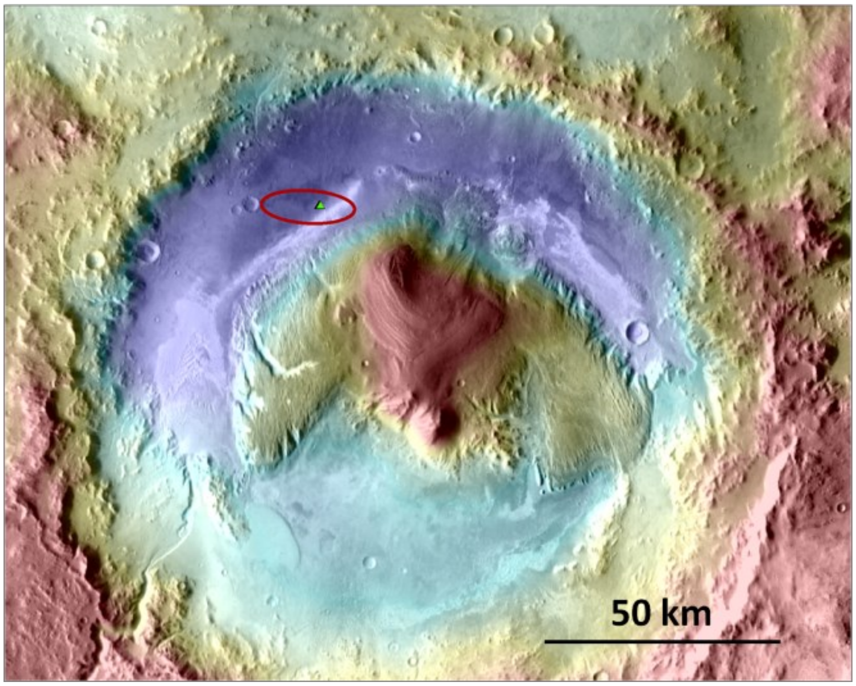


Fig. 1. Gale Crater showing landing ellipse (red oval) and Landing Site (green triangle). Image created by overlaying elevation data from the Mars Orbiter Laser Altimeter (MOLA) on Daytime Infrared Data from The Thermal Emission Imaging System (THEMIS). Red colors are elevations higher than about -1500 m while the dark blues indicate elevations below about -4200 m. North is up. MOLA image data credit: NASA/Goddard Space Flight Center. THEMIS image data: NASA/JPL-Caltech/Arizona State University.

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There were 29 Participating Scientists selected to be on the mission. And there are thousands of people who have worked on Curiosity (if you count all the engineers who helped to design and develop Curiosity and who help with the day to day operations). I am part of the Science Team which includes the Participating Scientists as well as scientists who are members of the various Instrument Teams. The whole science group consists of about 400 members and includes representatives from the United States and many other countries including the United Kingdom, France, Spain, Denmark, Germany, Mexico,

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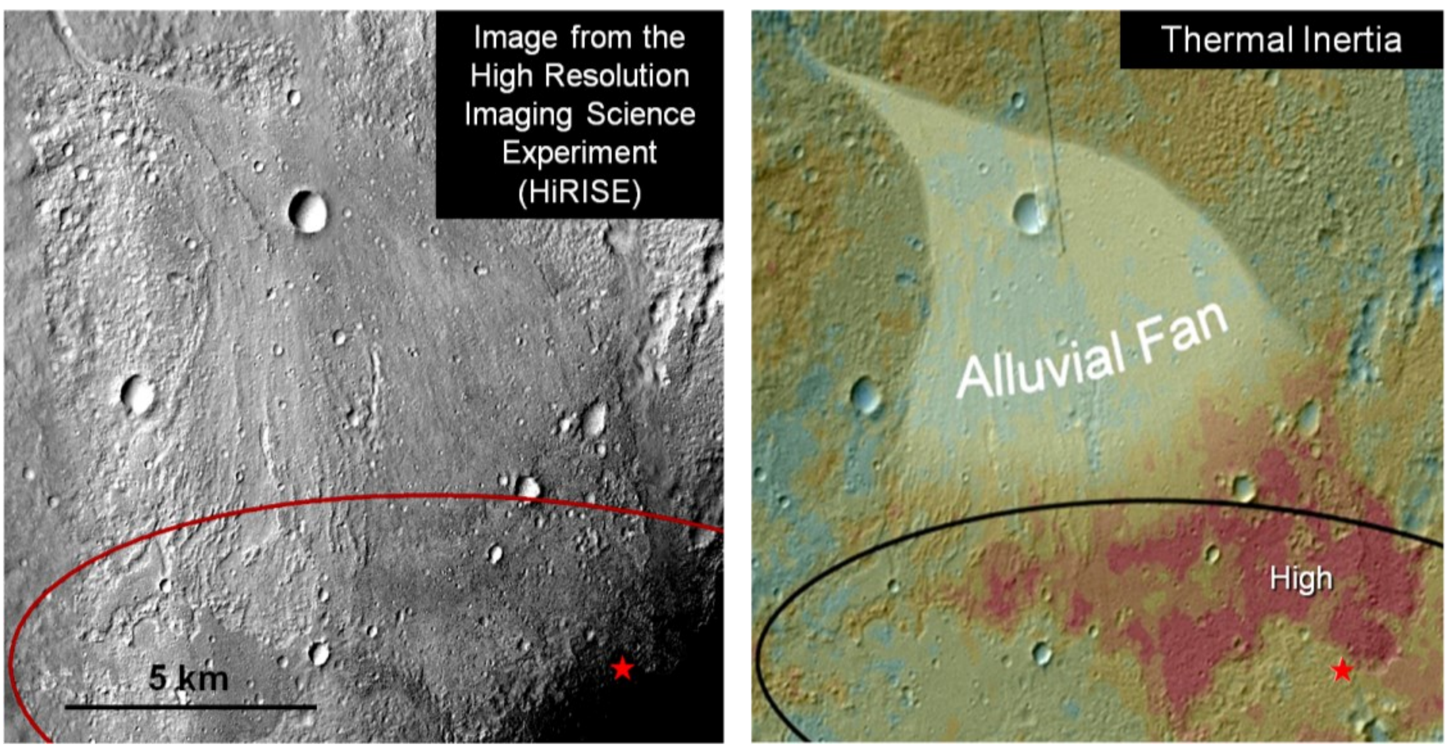


*Fig. 2. Alluvial fan (left) and high thermal inertia unit (right) in Curiosity's landing ellipse. Red star is Curiosity's landing site. Left panel: HiRISE image of the alluvial fan that originates from the NW rim of Gale crater and travels into the area of the landing ellipse (portion of red oval). HiRISE Image credit, NASA/JPL/University of Arizona. Right Panel: High thermal inertia unit. False-color map merging topographic MOLA data with thermal inertia data, and illustrating location of this unit distal to the alluvial fan. North is up. Thermal Inertia data obtained with THEMIS spectrometers on the Mars Odyssey spacecraft, colored so that reds are high thermal inertia. Image credit: NASA/JPL-Caltech/ASU.*

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Canada, Japan, Russia, and Australia.

*What is of note in Curiosity's results so far?*

Gale crater includes a 5.5 km high, central mound of sediments that is surrounded by a moat-like topographic low. MSL landed on the topographic low (Fig. 1), about 400 m from a region that had been of interest prior to landing because of its location distal to what appeared from orbital image data to be a cone-shaped feature that originated on the rim of crater and spread into the moat. This type of feature resembles those on Earth that are commonly deposited by streams (and called alluvial fans). In addition, that distal region was characterized by relatively high thermal inertia (also determined from orbital data). Thermal inertia is a material property that influences the slowness with which the temperature of a material approaches that of its surroundings. Thermal inertia can be influenced by grain size and mineralogy, among other factors, and the fact that the thermal inertia of the distal region appeared distinctive could have reflected unusual rock formations at that locality (Fig. 2). Since Curiosity landed so close to this unusual unit, the Science Team decided to travel there first. Curiosity has now arrived at that unit and is beginning to assess sediments in the part of it that has been called Yellowknife Bay (YKB).

During the traverse to YKB, Curiosity spent much of its time characterizing all of its different instruments - checking their health and performing First-Time-Activities (FTA) on each. Those activities are completed now. Everyone on the mission is pleased, as one by one each instrument has been tested and has performed excellently.

Notable results on the way to YKB include

1) Identification with images from the Mast camera (Mastcam) of a rock outcrop that appears to be a pebble conglomerate. Because this rock includes fairly large rounded pebbles, it is likely that the conglomerate was formed as a result of a major and vigorous stream that flowed into the crater.
2) Analysis of various ejecta clasts by the Chemistry and Camera (ChemCam) laser instrument and the Alpha Particle X-Ray Spectrometer (APXS). Both instruments give indications of elemental composition. Results suggested that these ejecta blocks are alkali basalts, a type of igneous rock not yet seen on Mars. These data suggest that igneous processes on Mars have been more complex and dynamic than had previously been considered.
3) Analysis of the Mars atmosphere by the Sample Analysis at Mars (SAM) instrument. This showed atmospheric enrichment in the heavy isotopes of argon and of carbon in carbon dioxide; these results support theories of atmospheric loss on Mars and confirm connection to Mars of gases in Martian meteorites, where the measured Ar-40/Ar-36 ratio is 7 times more enriched in Ar-40 than on Earth.
4) Acquisition of the first X-ray diffraction pattern of minerals from another planet, using the Chemistry and Mineralogy (CheMin) instrument. This information allowed identification of a variety of minerals in the sand scooped at a site called Rocknest (Fig. 3).

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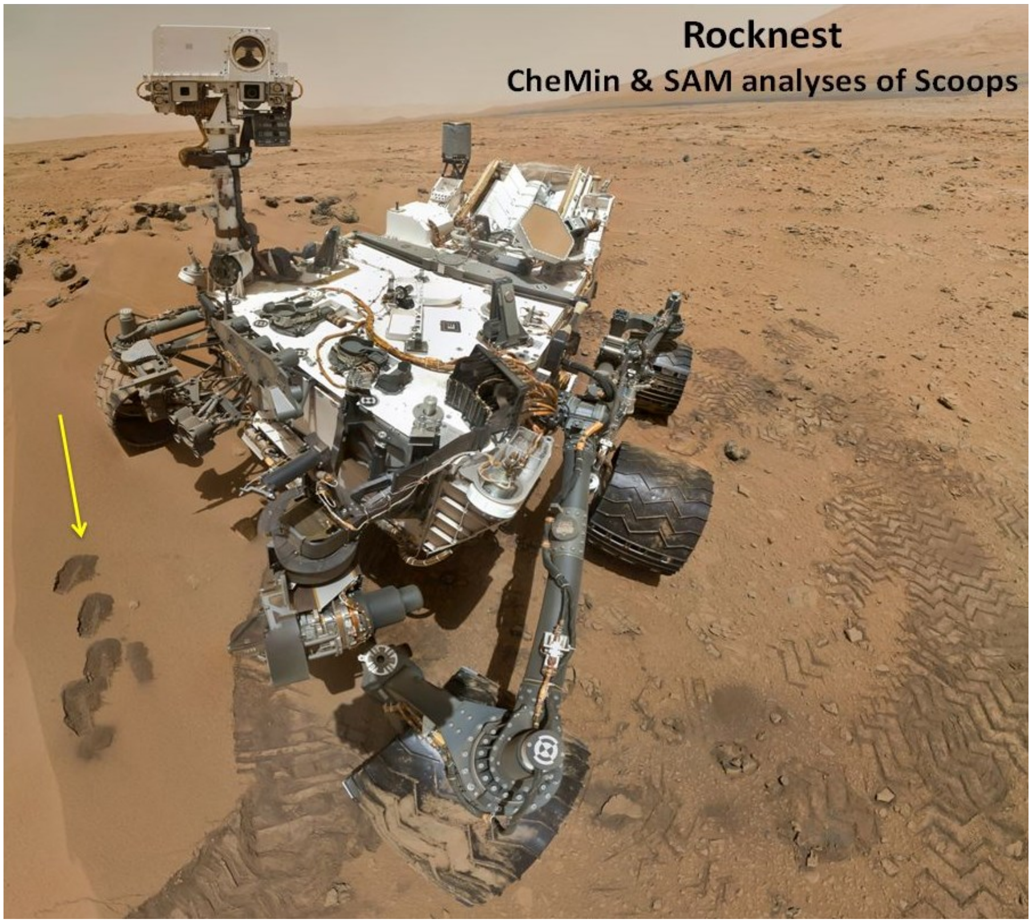


*Fig. 3. Self-Portrait of Curiosity taken by Mars Hand Lens Imager (MAHLI) on Curiosity at Rocknest Site where scoop first used for CheMin and SAM analyses. Arrow points to scoop sites. Image is a mosaic of 55 individual MAHLI images. Image Credit, Malin Space Science Systems.*

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*What is Curiosity's mission and mission duration?*

The primary mission duration is two years. The main objective of the mission is to assess Gale crater's past habitability. That means we are evaluating the potential of regions in Gale to have supported life. While we are considering an array of physical, chemical, and geological parameters, major variables include long-lived water as well as the potential for concentrating and preserving organic materials. Our main objective is the 5.5 km mound of sediments in the center of the crater. That mound, officially Aeolis Mons, is unofficially called Mt. Sharp. There is a canyon that goes up Mt. Sharp (Fig. 4) and we will likely be traversing that canyon, looking at rocks in the canyon walls (just as one can do in the Grand Canyon of the United States). The rocks in the lower part of the mound are thought to have formed about 3.6 to 3.8 billion years ago.

For comparison, on Earth, we know that microbial life was abundant and diverse by 3.5 billion years ago (from morphological and geochemical fossils that are preserved in ancient sedimentary rocks). Because of that abundance and diversity, it is reasonable to assume that microbial life was present on Earth before 3.5 billion years ago. Many think that the early histories of Mars and Earth were similar and so it makes sense to consider the possibility that microbial life may have been present on early Mars, as well. Curiosity will be able to analyze sediments in sequence, starting with some of the oldest in Gale. And then, we will be able to "read" the history of the crater in changes in the rock types as we proceed up the canyon to investigate the progressively younger sediments, higher in the mound. In this way, we will learn about the geologic history that spans the change from the early, relatively wet period on Mars to the later, drier and colder time.

*Who else in Houston works on Curiosity?*

Eleven people in the Clear Lake area work on Curiosity. Of those, ten people work on MSL at Johnson Space Center, in the Astromaterials Research and Exploration

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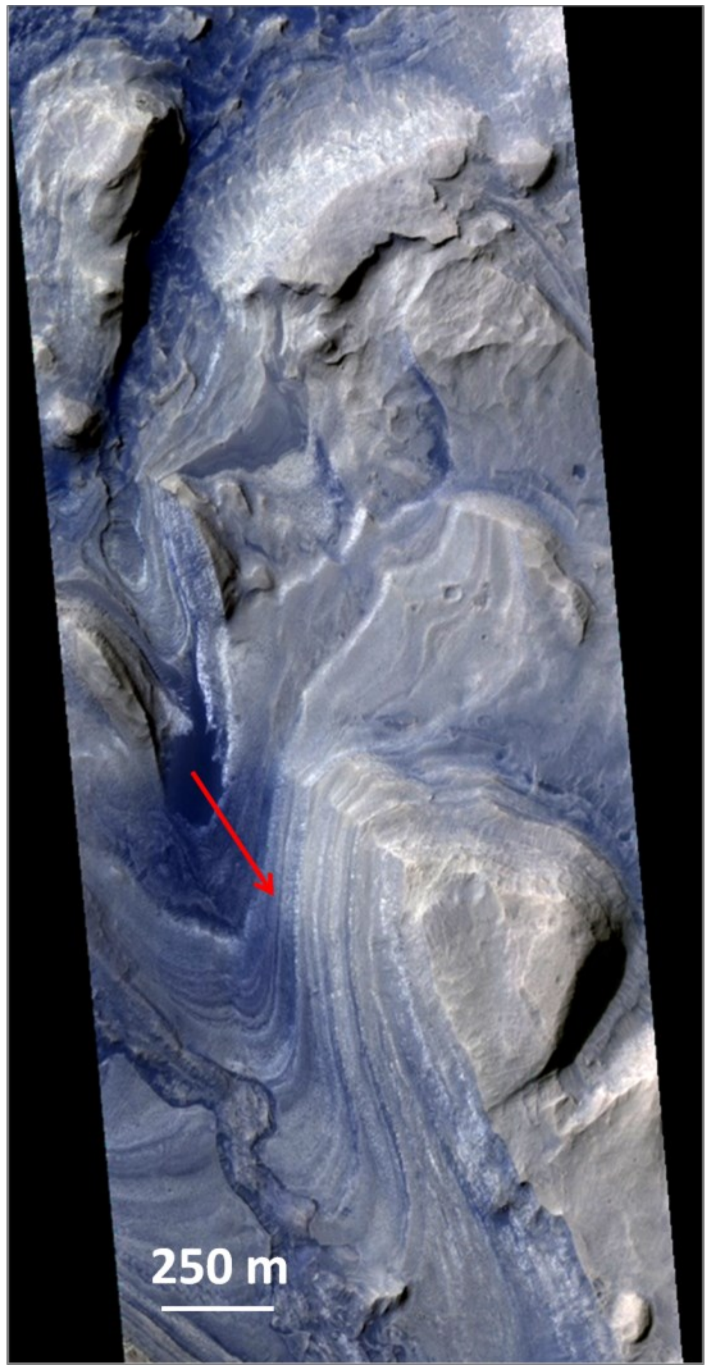


*Figure 4. HiRISE image PSP_009149_1750_COLOR, showing the canyon in the mound of sediments at Mt. Sharp that Curiosity will traverse. Red arrow indicates stratified sediment layers in the canyon walls. North is up. Image credit: NASA/JPL/ University of Arizona.*

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Science (ARES) Directorate. This group includes two Participating Scientists, myself and Dr. Paul Niles; Dr. Douglas Ming, who acts as a Chairman of the MSL Science Operations Working Group and is also a Co-Investigator (Co-I) on CheMin and SAM; Dr. Richard Morris, a Co-I on CheMin and SAM; Dr. John Jones, a Co-I on SAM; Mr. Trevor Graff, who provides data analysis for CheMin; Dr. Brad Sutter, a collaborator on SAM; and Ms. Cherie Achilles who provides Payload Upload and Payload Download support. In addition we have two Post-Doctoral Associates in ARES who are MSL instrument collaborators, Dr. Elizabeth Rampe for CheMin and Dr. Doug Archer for SAM. From the Lunar and Planetary Institute, Dr. Allan Treiman serves as an MSL Long Term Planner and Co-I on CheMin.

*What is expected of Curiosity in the coming months?*

Curiosity has just used the drill for the first time. We will take that drilled sediment and begin to analyze it in both the CheMin and the SAM instruments. We anticipate that these analyses will provide information regarding the mineralogical composition of the sediments at YKB as well as potential inclusion of organic compounds, light elements, and isotopic tracers that can add insight into our assessment of the history and habitability of this important part of Mars. When those analyses are completed, Curiosity will turn around and begin the long trip to Mt. Sharp (Fig. 5). It is expected that the trip could take 6 or more months. But once there, Curiosity will traverse up a canyon like that shown in Fig. 4 to evaluate strata of rocks that are exposed in the canyon walls. Scientists will use all the data to select best areas for potential biosignature preservation, and samples from those areas will be analyzed with the full

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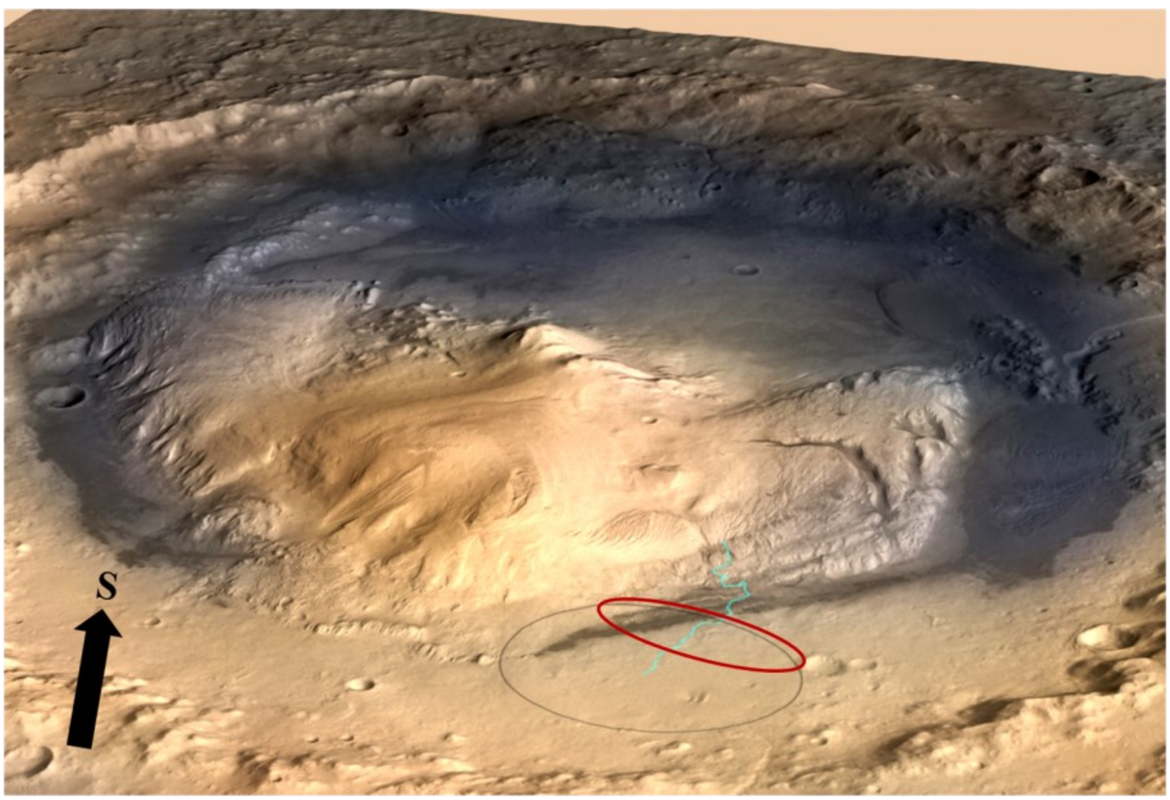


*Fig. 5. Oblique view of Gale Crater from a combination of elevation from the High Resolution Stereo Camera on the European Space Agency's Mars Express orbiter, image data from the Context Camera on NASA's Mars Reconnaissance Orbiter, and color information from Viking Orbiter image data. Final landing ellipse, red oval. Earlier landing ellipse, black oval. Green line is approximate route to canyon in Mt. Sharp. Image credit: NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS.*

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suite of instruments on board (Fig. 6). The rover will additionally look at seasonal variations in atmospheric composition and radiation, in preparation for future exploration.

*What do you hope to find on Mars? Lake sediments?*

Lake sediments, of course, would be very exciting. But anything that gives us more concrete information about the early history of Mars will be fascinating. Some think that there were abundant lakes on early Mars and some even think there might have been an early ocean in the northern Martian lowlands (see cover image). So data from the MSL mission may provide more insight into this early part of Martian history.

In this regard, Gale crater is a terrific site to be exploring. While the sediments in the upper part of the central mound are thought to have been deposited in a more recent, colder and drier period on Mars, the sediments in the lower part of the mound are thought to have been deposited in the earlier time that was wetter. That early time could have been the most habitable period on Mars. Moreover, because those lower mound strata are buried beneath a 5.5 km high pile of sediments, those strata will have been compacted by the weight of the overlying rock column. That compaction should help to minimize exposure to processes of oxidation on the surface of Mars, and as a result, the preservation potential for organics in these compacted sediments may be enhanced. In addition, Gale sits on the dichotomy that separates the southern highlands from the northern lowlands. That location could have received runoff from surface rivers that might have existed south of Gale and, of course, if there were an early ocean, Gale might have seen some influence of that because of its position on the dichotomy. Finally, the accessible canyon that cuts the mound will provide an unprecedented opportunity to sample the stratified sediments exposed in the canyon walls, allowing investigation of the deposits that span the wet to dry transition on Mars.

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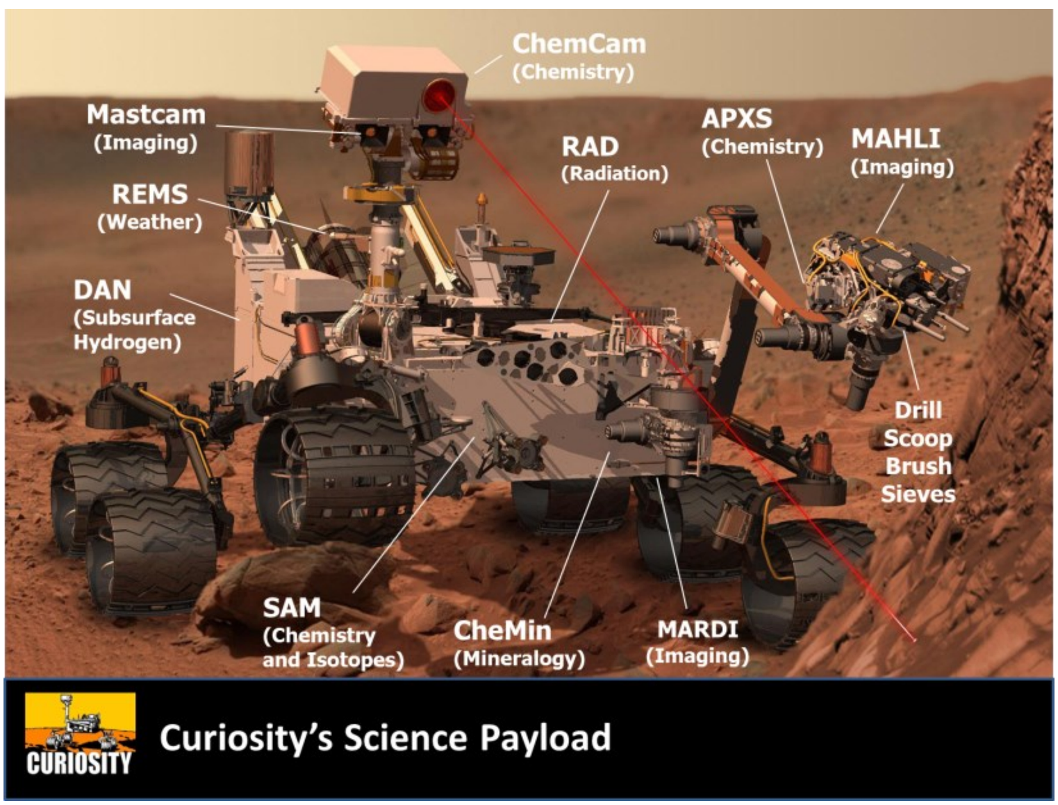


*Fig. 6. Curiosity Rover, showing full suite of scientific instruments. For scale, Curiosity is often compared to a Mini Cooper. Curiosity is about twice as long and five times as heavy as each of the previous two rovers on Mars, Opportunity and Spirit. Image credit: NASA/JPL.*

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Cover Story

The rover is currently at YKB, the part of the high thermal inertia unit that is distal to the alluvial fan shown in Fig. 2. The sediments in YKB are diverse and unlike anything we saw on the way there from the landing site. The YKB sediments show polygonal fractures, veins of white material that appear to be a calcium sulfate mineral, and potential evidence for fluid interaction with the rocks (Figs. 7 and 8). This is the site where

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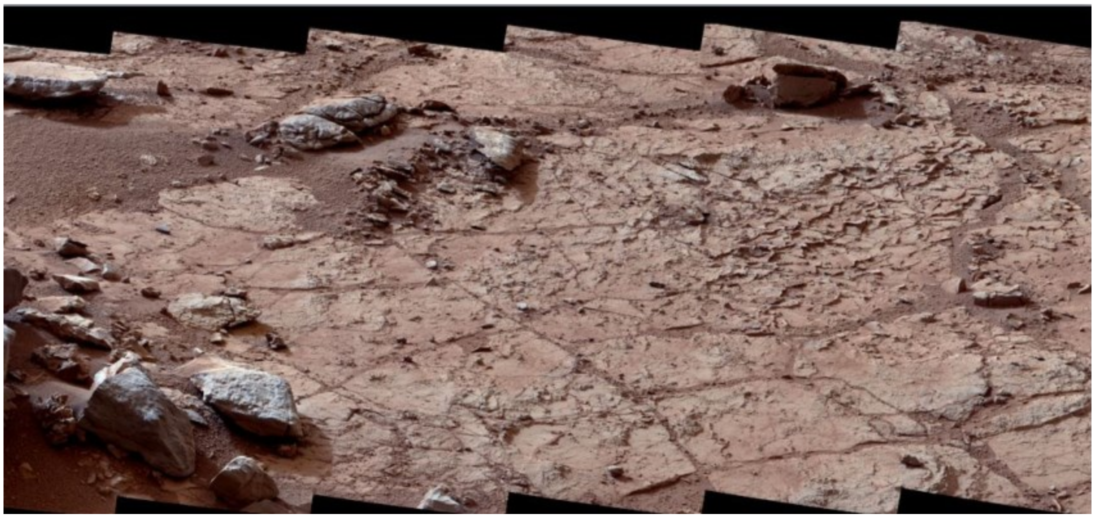

*Fig. 7. Sediments at Yellowknife Bay (YKB). Mastcam image credit: Malin Space Science Systems.*

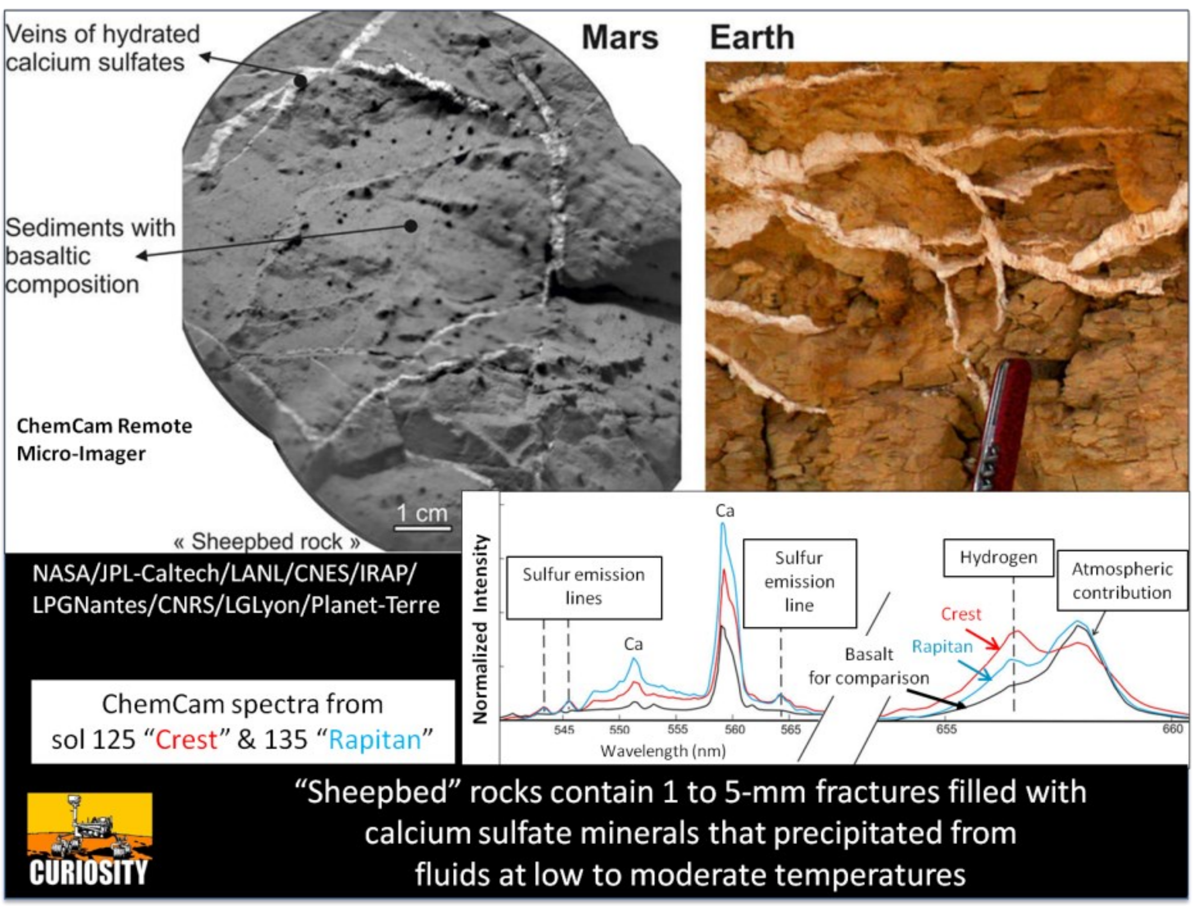


*Fig. 8. Veins of hydrated calcium sulfates in sediments at Yellowknife Bay (YKB). Image credit: NASA/JPL-Caltech/LANL/CNES/IRAP/LPGNantes/CNRS/LGLyon/Planet-Terre.*

## Cover Story

*Fig. 9.* ***Curiosity's first sample drilling.*** *At the center of this image is the hole in a rock called "John Klein" where Curiosity conducted its first sample drilling on Mars. The drilling took place on February 8, 2013, or Sol 182, Curiosity's 182nd Martian day of operations. A preparatory, test shallower hole (the one on the right) was drilled two days earlier, but the deeper hole resulted from the first use of the drill for rock sample collection. The image was obtained by Curiosity's MAHLI camera on Sol 182. The sample-collection hole is 0.63 inch (1.6 centimeters) in diameter and 2.5 inches (6.4 centimeters) deep. The "mini drill" test hole near it is the same diameter, with a depth of 0.8 inch (2 centimeters). Image credit:* ***NASA/JPL-Caltech/MSSS.***

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we just used the drill (Fig. 9) and will proceed to use the full capability of the instruments on Curiosity to help us to understand the history of this fascinating part of Mars.

**Biography**

Dr. Oehler received her Ph.D. from the University of California at Los Angeles (UCLA) and worked for 20+ years in the international petroleum industry as a geologist/geochemist. After that, she began work at NASA, investigating earliest life forms on Earth as well as applying techniques of predictive geology to questions of Mars habitability. This past November, she was awarded the 2012 Distinguished Alumni Award from UCLA. She lives in Houston with her husband, John Oehler, who has recently published his first novel, **Aphrodesia**, to wide acclaim.

*Above: Dr. Dorothy Oehler. Image credit: Dr. John Oehler.*