MSL - SAM Science Reports
SAM Instrument Overview, MSL Section, Science Reports Home

MSL determines Age of Martian Rocks, reveals Surface Exposure Mechanism

December 11, 2013

The Curiosity mission has achieved another milestone as scientists have determined that the rocks inside Gale Crater that were analyzed by the rover are very old – even on geologic time scales, but were exposed very recently. The achievement of utilizing in-situ age-dating methods using radiogenic and cosmogenic noble gases marks a first in planetary exploration.

A scientific paper by Kenneth Farley and co-authors published on Monday presents the methods used to determine the age of the rocks itself and pin-point how long the rock has been exposed at the Martian surface.

The Cumberland mudstone was the second drill sample acquired by the MSL rover in May 2013 and underwent a number of analyses.

The SAM instrument performed a number of experiment runs using different settings, CheMin conducted multiple analyses of the sample and the APXS instrument was used to analyze the drilled sample that was distributed to the Observation Tray of the rover. All these measurements were combined to determine the age of the rock.

The K-Ar age-dating method is commonly used on Earth to determine the age of rock samples, but had never been used in space before. MSL used its APXS instrument to determine the elemental composition of the Cumberland rock. Cumberland is rich in potassium and thus includes potassium-40 which is a potassium isotope that spontaneously decays and produces argon-40 with a half life of 1.25 billion years.

In its initial state, the rock started out with no argon-40 (or a negligible abundance of argon-40). Over the evolution of the Cumberland rock, potassium-40 decayed and argon-40 was formed that accumulated in the material. Heating the rock allows the argon-40 to diffuse out.

When being delivered to the SAM oven, the sample was heated and the exact amount of argon-40 that was released was measured by the Quadrupole Mass Spectrometer of the instrument. Knowing the potassium abundance of the rock, the mass of the heated sample and the amount of argon-40 that is released allows a fairly accurate calculation of the age of the material.

Unfortunately, the SAM instrument can not measure the mass of a sample inside one of its sample cups and neither can the sample handling system of the rover. Ground testing has been used to determine the average sample mass that enters the SAM instrument, but that obviously comes with a relatively large error bar. It has been determined that SAM receives samples of 135 +/- 18 milligrams. This error bar can not be reduced which is the limiting factor for age-dating using the SAM instrument.
Nevertheless, the science team was able to determine that the Cumberland rock formed 3.86 to 4.56 billion years ago. This figure is in good agreement with the previous estimate of 3.6 to 4.1 billion years based on crater density measurements.

Previously, data from Curiosity was used to confirm that the material was of igneous origin. It is likely that the material formed on or outside the rim of Gale Crater and was transported to its current location by sedimentary processes, being washed down before being deposited inside Yellowknife Bay and forming the geological unit that has become known as Sheepbed.

Sediment transport at Gale Crater

The second part of the age-dating results presented in the paper is that the Cumberland site was just recently exposed (on a geologic time scale). Measuring the abundance of cosmogenic isotopes, scientists were able to pin-point how long ago the Cumberland site became exposed.

Cosmogenic isotopes are rare isotopes that are formed when a high-energy cosmic ray impacts with matter. As a result, a large number of nucleons are expelled from the object hit. This cosmic ray spallation creates rare isotopes that are not a part of the material in its original state.

On Mars, cosmic rays can penetrate as deep as two to three meters and create cosmogenic isotopes. Knowing the Galactic Cosmic Ray Dose at the surface and sub-surface and with that the formation rate of cosmogenic isotopes, allows scientists to deduce the amount of time a sample spent at or near the surface by measuring the abundance of a number of cosmogenic isotopes.

For the Cumberland sample the following isotopes were measured by SAM: argon-36, neon-21, and helium-3. As the samples were heated up, the isotopes were released as gases and the Quadrupole Mass Spectrometer precisely measured the individual abundance of the three gases. Argon-36 is generated through the capture of thermal neutrons by Chlorine while neon-21 is produced from spallation of Mg, Si and Al. Helium-3 is formed by spallation of O, Si and Mg. The depth-dependence curves of those three isotopes is also well understood – the two spallation isotopes have a maximum of production rate at a depth of 15 centimeters followed by an exponential decline. Argon-36 has a larger sub-surface maximum at a depth of about 60 centimeters. The depth-dependences are due to different formation processes and the nuclear cascade occurring in the uppermost rock regions.

To take advantage of the different production rates at the different depths for all three isotopes, the ratios of Ar/He, Ar/Ne and He/Ne are calculated. These ratios can be used to put together the story of how the rock became exposed, whether it occurred instantaneously or if a steady erosion caused a progressive downward migration of the surface. (Instantaneously refers to geological time scales.)

The Ar/He and Ar/Ne ratios are used to learn about the exposure time scale while the He/Ne ratio provides a cross-check as it was expected to be 8 for both scenarios (instantaneous exposure or steady erosion).

The Ar/He ratio was measured at 1.7 +/- 0.5, the Ar/Ne ratio was 12 +/- 5 and the He/Ne ratio was 7.5 +/- 2.6 which is close to the expected number. The determined Ar/He and Ar/Ne ratios correspond well to the predicted ratios of the no-erosion scenario of 1.5 and 13. Additionally, the measured ratios are very different from those calculated for the steady erosion scenario.

Using the cosmogenic isotopes, scientists concluded that the rock was exposed approximately 80 million years ago which is very recent. It is also possible that the figure represents the sum of multiple periods the rock spent on the surface, but that is highly unlikely.
Knowing that the rock was formed about 4 billion years ago and became exposed at the surface 80 million years ago, scientists also identified the mechanism that moved the rock to the surface. The Sheepbed layer is exposed by a quick erosion process that occurs between the different surface layers. Cumberland is part of the Sheepbed Unit that is located below the Gillespie layer and the Point Lake layer. Looking at images taken by Curiosity at Yellowknife Bay, it is obvious that the different geological layers erode at different speeds.

The weak mudstone of the Sheepbed unit is eroded very easily as it is slowly removed by Martian winds and dust. As Sheepbed is sandblasted by wind scouring, the harder layers such as Gillespie are undercut. As the scarp retreats, the Sheepbed unit becomes exposed. This erosion is quite fast and progresses at an average rate of about one meter per million years.

Assuming the scarp retreat is an ongoing and persistent process, it is very easy to find freshly exposed surface by locating the base of the downwind scarp. This will play a major role in the selection of future drill targets as teams seek to find out whether organic chemicals have been preserved in rocks. As rock is exposed at the surface, cosmic radiation causes the destruction of organic molecules. That is why teams search for freshly exposed material that did not experience the harsh surface radiation environment for long periods of time.

For more details on the Martian surface radiation environment, read our RAD science report from December 10, 2013.

The Yellowknife Bay site (left) and the KMS-9 site at Waypoint 4 (right) show similar signs of active scarp retreat.

No Methane on Mars - MSL SAM Data puts Previous Detections in Doubt

Data from NASA's Mars Science Laboratory rover and its Sample Analysis at Mars (SAM) Instrument revealed that the Martian Atmosphere lacks methane. This result is a surprise to scientists because there were previous detections of abundant methane on Mars. Using SAM data, scientists were able to issue a significantly lower upper limit of the methane abundance on Mars than expected.

Detecting methane on Mars remotely via orbiters or ground-based telescopes has been difficult in the past because methane is only abundant in trace amounts, if at all. Scientists have been debating over atmospheric methane for decades, but there has not been a definitive conclusion until now.
The SAM instrument performed a total of six atmospheric analyses between October 2012 when instrument commissioning was underway and June 2013. None of these sampling activities showed any signs of methane.

To perform atmospheric sampling, SAM directs atmospheric gas into the instrument package for analysis by the instrument's Tunable Laser Spectrometer. The TLS is a two-channel Herriott cell device to detect targeted species (carbon dioxide, water and methane) with high sensitivity. For methane detections, the 3.27 micrometer wavelength is used because Methane shows a characteristic band at ~3057cm⁻¹. Using TLS to perform a number of sampling runs has provided scientists with sufficient data to reduce the upper limit of atmospheric methane abundance on Mars. The methane concentration in the Martian atmosphere today must be no more than 1.3 parts per billion, MSL mission scientists concluded. That is about one-sixth as much as some earlier estimates.

"This important result will help direct our efforts to examine the possibility of life on Mars," said Michael Meyer, NASA's lead scientist for Mars exploration. "It reduces the probability of current methane-producing Martian microbes, but this addresses only one type of microbial metabolism. As we know, there are many types of terrestrial microbes that don't generate methane."

The Tunable Laser Spectrometer within SAM can also perform enrichment studies - directing atmospheric gas through scrubbers and cold traps to enrich it in methane - if any is present - for isotopic and abundance studies. This method can be used to determine the methane concentration well below 1 part per billion.

"It would have been exciting to find methane, but we have high confidence in our measurements, and the progress in expanding knowledge is what's really important," said Chris Webster of NASA's Jet Propulsion Laboratory. "We measured repeatedly from Martian spring to late summer, but with no detection of methane."

These new results are particular surprising when looking at previous detections of abundant methane on Mars. These detections made by Earth-based observatories and from Mars Orbit pointed to a methane concentration of up to 10ppb in the Martian Atmosphere with localized peaks of 60ppb.

Curiosity's new in-situ measurements are not consistent with those previous results - even if the methane of local hot spots was dispersed globally and loss processes were at work.

"There's no known way for methane to disappear quickly from the atmosphere," said Sushil Atreya of the University of Michigan.

"Methane is persistent. It would last for hundreds of years in the Martian atmosphere. Without a way to take it out of the atmosphere quicker, our measurements indicate there cannot be much methane being put into the atmosphere by any mechanism, whether biology, geology, or by ultraviolet degradation of organics delivered by the fall of meteorites or interplanetary dust particles."

**Methane on Mars**

Methane on Mars can have a number of origins. When methane was first discovered on Mars, many saw the presence of it as a clear indication of life or microbial activity, but aside from biological processes, methane can have a number of origins. Geological processes such as volcanism or reactions involving iron oxide, water and carbon dioxide can produce large amounts of the gas.

In addition to these two traditionally known origins on atmospheric methane, both, on Earth and on Mars, scientists have thrown a number of other theories on the table. In recent years, exogenous sources have been studied. Scientists at the Max Planck Institute for Chemistry in Mainz, Germany, and the universities in Utrecht and Edinburgh have published a theory on methane being produced by micro-meteorites and interplanetary dust particles that enter the thin Martian atmosphere and settle on the surface.

The researches have used meteorites that were found on Earth's surface and subjected those to conditions identical to those encountered on the surface of Mars. What they found was a large amount of methane being released by the meteorites under the influence of UV radiation levels that are present on Mars.
Another source of atmospheric Methane could be Martian Dust Devils, as a team of scientists at the Metropolitan Autonomous University, Azcapotzalco, Mexico found: "We propose a new production mechanism for methane based on the effect of electrical discharges over iced surfaces. The discharges, caused by electrification of dust devils and sand storms, ionize gaseous CO2 and water molecules and their byproducts recombine to produce methane." (A. Robledo-Martinez et al., Electrical discharges as a possible source of methane on Mars: Lab simulation, 2012)

Under the conditions on Mars, methane would quickly break down due to ultraviolet radiation coming from the Sun, interactions of the gas with the surface such as sinkage and oxidation, and chemical reactions with other gases in the Martian atmosphere, so for a permanent presence of methane on Mars, a continuous source would have to be present to replenish the atmospheric methane.

The processes of possible Methane storage and production of Mars as well as Methane destruction are not yet understood. In addition, the question whether methane, if present, is created by biological or geological processes, is still to be answered.

Past Methane Detections on Mars

The debate about methane on Mars started way back in 1969 when scientists working with the Mariner 7 Spacecraft announced that the spacecraft had likely detected Methane with its Infrared Spectrometer Instrument. This announcement was made just 48 hours after receiving data from the Spacecraft that recorded Infrared Spectra while performing its flyby of Mars. The spectra included bands that were not associated with carbon dioxide or other known substances on Mars and, after briefly performing lab tests, the team jumped to the conclusion of methane being present on Mars.

The announcement created a huge stir because of its implications to life on Mars, however, project scientists publicly retracted the finding several weeks later after completing additional analysis of the spectra acquired by Mariner 7 that revealed that the unexpected band at a wavelength of 3.3μm that was mistaken for methane was actually created by carbon dioxide ice in an unexpected configuration.

Several decades later, in 2003, a team at NASA's Goddard Space Flight Center that was studying the Martian atmosphere, announced that trace amounts of methane at the level of several parts per billion were found to be present in the atmosphere of the planet. In 2004, data from ESA's Mars Express Orbiter and ground-based telescope observations suggested even higher quantities of methane of up to 10ppb.

Data acquired by telescopes and Mars orbiters have led to new theories as a large variability of atmospheric methane in time and space was suggested. In a paper released in 2009, Michael Mumma of NASA's Goddard Space Flight Center presented a hotspot theory based on data acquired in 2003 and 2006. "Methane is quickly destroyed in the Martian atmosphere in a variety of ways, so our discovery of substantial plumes of methane in the northern hemisphere of Mars in 2003 indicates some ongoing process is releasing the gas," he said in 2009.

"When present, methane occurred in extended plumes and the maxima of latitudinal profiles imply that the methane was released from discrete regions. At northern mid-summer, the principal plume contained ~19,000 metric tons of methane." (Mumma et al., Strong Release of Methane on Mars in Northern Summer 2003; 2009) The localized hotspot peaked at about 60ppb, before the methane concentration started to decrease. The lifetime of the hotspot was under one year. Whether the methane plume was biological or geological in origin is unknown. "Right now, we don't have enough information to tell if biology or geology -- or both -- is producing the methane on Mars," said Mumma (2009). "But it does tell us that the planet is still alive, at least in a geologic sense. It's as if Mars is challenging us, saying, hey, find out what this means."

And that is what Curiosity and SAM set out to do. Using TLS to determine whether trace amounts of methane are present, MSL provides conclusive evidence to support the search for methane. By determining isotope ratios of methane, if found, SAM would provide insight into its formation and point to geological or biological origins.
Curiosity Rover traces major Atmospheric Loss on Mars

The Sample Analysis at Mars Instrument of the Mars Science Laboratory Rover has continued examinations of the Martian atmosphere to provide more data on the phenomenon of atmospheric loss that formed today’s thin Martian Atmosphere that results in a surface pressure of only 0.6% of that of the Earth.

“Evidence has strengthened this month that Mars lost much of its original atmosphere by a process of gas escaping from the top of the atmosphere,” NASA said in a statement. The new data was acquired by SAM early in April and represents the most precise measurements ever made of isotopes of argon in the Martian atmosphere. "We found arguably the clearest and most robust signature of atmospheric loss on Mars,” said Sushil Atreya, a SAM co-investigator at the University of Michigan, Ann Arbor.

Argon, one of the noble gases, accounts for 1.6 percent of the Martian atmosphere. The ratio of two isotopes of Argon, the heavier Ar38 and the lighter Ar36 provided additional data on the atmospheric loss suffered by Mars. Earlier, the ratio of Deuterium and Hydrogen was determined and also provided evidence for a major atmospheric loss.

Because Argon is a non-reactive gas, its isotope ratio provides more robust data as Argon is not involved in any chemical reactions that could change the isotope ratios. Also, because of its higher atomic weight, Argon ratios represent more conclusive evidence for atmospheric escape than the D/H ratio.

SAM found that a significant amount of Ar36 was missing which supports the theory of atmospheric loss that favors lighter elements. The Ar36/Ar38 ratio as determined by SAM is 4.19 (+/- 0.035). This Argon ratio is much lower than the solar system’s original ratio of 5.5 that was determined through measurements of the sun and Jupiter as well as Earth. SAM also analyzed Carbon and Oxygen isotope ratios and concluded that these elements are also rich in heavy isotopes.

Although the processes that might have caused atmospheric loss are not fully understood, it is known that if atmosphere is lost due to physical processes, lighter elements/isotopes are favored while heavier elements are retained because of gravity. This produces a difference in isotope abundances is over large time scales of hundreds of millions of years.

Currently, scientists believe that the majority of the Martian Atmosphere was lost due to direct interaction of the atmosphere with the solar wind after Mars lost its protective magnetic field. This and other physical processes caused around 85 to 95% of the Martian Atmosphere to escape into deep space. The original atmosphere would have been warmer and it would have provided a substantially higher surface pressure which would have created an environment suitable for sustaining liquid water – a requirement for life as we know it.

Curiosity’s SAM quadrupole mass spectrometer is the first instrument to precisely detect the Ar36/Ar38 ratio of Mars. Previous measurements made by the Viking mission in 1976 and data collected from tiny amounts of Argon found in Mars meteorites were of high uncertainty levels.

Scientists hope that the MAVEN mission (Mars Atmosphere and Volatile EvolutionN) set for launch later this year will provide more data on the Martian Atmospheric loss as well as the current rates of escape of neutral gases and ions to space and the processes controlling them.

The SAM QMS also analyzed another solid sample before Mars headed into solar conjunction, giving scientists some more data to look at during the break in communications. In the image to the right, the major volatiles released from the 4th powdered rock sample analyzed from the John Klein Drilling site are shown as a function of temperature. As the sample is heated in SAM’s oven, the different gases evolve at characteristic temperatures which provide data on the composition of the sample.

In the image, each mass spectrometer signal is scaled separately to illustrate the patterns for various gases showing what temperatures caused the gas to be released. SAM data suggests the presence of hydrated minerals, carbonates, perchlorates, sulfates and sulfides. The second water peak representing a high-temperature water release indicates the presence of clays.

The SAM team also continued to analyze previous data that focused on the search for Methane. So far, the SAM data suggests a Methane abundance of 0.4 +/-1.1ppbv with an upper limit of 2.7ppbv at a 95% certainty level. A definitive Methane measurement has yet to be made and for that, SAM will be performing Methane Enrichment Experiments in the future to increase its sensitivity in order to detect Methane and possibly its isotopes.
Curiosity discovers Evidence for Habitable Environment in Distant Martian Past

The Mars Science Laboratory Science Team has presented the first results of the analysis of drilled rock samples performed by the Curiosity Rover and its SAM and CheMin Instruments.

Curiosity completed its first full drilling operation on Sol 182, February 9, 2013 at the John Klein site inside Yellowknife Bay which is a depression in the Glenelg area of Gale Crater where an ancient layer of bedrock was exposed - making this location suitable for Curiosity's first use of its hammering drill.

Curiosity drilled a 6.4-centimeter hole and acquired the rock tailings that were generated by the drill. After spending several Sols processing the gray sample material that was collected by the drill, Curiosity distributed sample material to its two Laboratory Instruments, SAM - Sample Analysis at Mars, and CheMin - Chemistry and Mineralogy.

The two instruments performed detailed analyses to determine the precise composition of the rock material that holds a record of an ancient Martian environment.

Even before starting chemical analysis, teams were surprised by the appearance of the drilled sample which was gray-green in color. This color suggests that the material found in the rock was not highly oxidized, unlike the majority of the highly oxidized, red Martian surface.

Left: Opportunity Photo of the well known red, oxidized Mars - Right: MSL image of the “new” gray Mars

SAM and CheMin confirmed that the environment in which the rock was formed was unlike the harshly oxidizing, acidic or extremely salty environments that are known to have existed on Mars. Science teams found sulfur, nitrogen, hydrogen, oxygen, phosphorus and carbon - elements that are key ingredients for life. The rock that was drilled is made up of a fine-grained mudstone containing clay minerals, sulfate minerals and other chemicals.

The rock layer formed in an intermittently wet environment that deposited and cemented fine-grained sediments. Subsequently, the rock was fractured and veins were generated by flowing water that caused minerals to precipitate in the fractures. For concretions (spherules of minerals) to form, a rock has to be surrounded by fluid containing minerals, flowing through pore spaces in the grains of the rock. Both, veins and concretions, were found in the Sheepbed layer that was the subject of drilling operations. Data from several instruments of Curiosity, MAHLI, ChemCam, APXS, MastCam and now SAM & CheMin support these characteristics of the ancient environment present at Yellowknife Bay.
The two CheMin X-Ray diffraction spectra shown above represent the two CheMin Analysis that were conducted on Mars. The image to the left represents data acquired during analysis of windblown dust that was sampled earlier in the mission at the Rocknest Target. The right image represents the CheMin data taken during powdered rock sample analysis.

The two spectra show similar signatures of feldspar, pyroxene, magnetite and olivine minerals. Rocknest's composition also showed that the dust consists of 25 to 35 percent amorphous material. The Rocknest data suggests that the material was formed in a dry, wind-shaped environment with low-water activity, while the John Klein site shows the complete opposite, a lakebed environment with high water activity.

The center of the spectrum to the right shows higher intensity near the center which is indicative of abundant phyllosilicate, particularly clay minerals called smectites that are known to form in the presence by pH-neutral water on source minerals in an environment that lacks abundant salts. Igneous minerals that could form these clay minerals, such as olivine, were found in the rock sample. The data also show minor amounts of anhydrite and bassanite. Evidence for a pH-neutral or slightly alkaline environment can be found in the presence of calcium sulfate along with the clay.

"Clay minerals make up at least 20 percent of the composition of this sample," said David Blake, principal investigator for the CheMin instrument. These findings are different from those made by the Mars Exploration Rovers that found evidence of an ancient environment that formed sulfate-rich sandstones in an environment that likely was not habitable due to the extremely high acidity of the water, high salinity and limited chemical gradients that would have restricted energy available to microorganisms.

In contrast, the ancient environment found inside Yellowknife Bay would have been supportive of life - an environment characterized by neutral pH-levels, chemical gradients that would have created energy for basic forms of life, and a low salinity that would have helped microbial metabolism.

The image to the right shows data collected by SAM when analyzing the powdered rock sample. The sample was heated in the instrument's oven to 853 degrees Celsius and allowed gases to be released by the material which were then analyzed by SAM using its quadrupole mass spectrometer (QMS). Signatures of more than 500 mass values were detected and analyzed by QMS. Five of those are shown in the graph. The data shows an abundance of water, carbon dioxide, oxygen as well as sulfur dioxide and hydrogen sulfide.

The gas chromatograph of SAM was able to determine the ratio of reduced species to oxidized species released by the material which was significantly higher in the powdered rock sample from the Sheepbed layer when comparing it to the Rocknest sample.

This indicates a significant amount of available chemical energy because of the presence of oxidized, less-oxidized, and even non-oxidized chemicals. These chemical gradients are exploited by microorganisms living on Earth and are a strong indication of a habitable environment, when paired with water.

"This result, combined with suitable aqueous conditions at this site in the distant past, made this a potentially habitable environment," NASA said in a statement.

"The range of chemical ingredients we have identified in the sample is impressive, and it suggests pairings such as sulfates and sulfides that indicate a possible chemical energy source for micro-organisms," said Paul Mahaffy, principal investigator of the SAM suite of instruments.
SAM’s tunable laser spectrometer (TLS) also analyzed the gases to examine isotopes of carbon, oxygen and hydrogen, in both water and carbon dioxide.

One item of special interest is the ratio of Deuterium and Hydrogen. Deuterium, also known as heavy hydrogen, is one of two stable isotopes of hydrogen, and contains one proton and one neutron in its nucleus while the common hydrogen isotope (Protium) has no neutron in the nucleus. The deuterium-to-hydrogen ratio measured in the rock sample from John Klein was lower than that measured at Rocknest, meaning that the sampled material at John Klein was older than that at Rocknest.

Determining the D/H ratio of water bound in minerals allows scientists to learn more about the past atmospheric environments on Mars with a special focus on atmospheric loss. As physical processes cause atmospheric loss, heavier isotopes of gases are retained so that a difference in isotope abundances is produced over large time scales. Atmospheric loss at the top of the atmosphere to interplanetary space favors lighter isotopes.

As MSL begins to drill into more and more rocks, SAM might be able to examine the D/H ratio of past Martian environments to assess the process of atmospheric escape over time.

SAM also continued its ongoing search for organics on Mars using the gas chromatograph mass spectrometer (GCMS). The instruments detected the simple carbon-containing compounds chloro- and dichloromethane in the John Klein sample. The results are shown in the graphic to the left.

The large blue peak on the left shows the presence of chloromethane and the two red peaks represent dichloromethane. To put these measurements in context, data from ‘blank runs’ is also shown. These runs were performed before samples were delivered to SAM to make sure the signals from the actual sample were above the background levels detected in blank runs.

Similar detections were also made at the Rocknest side, indicating the possibility that these simple compounds were formed by the reaction between Martian carbon and chlorine released when the sample was heated inside the SAM instrument. Another analysis of a drilled sample is required to provide data that will help scientists understand whether terrestrial carbon on the drill, or residual chlorine from the Rocknest sample are responsible for these results.

Curiosity will continue working inside Yellowknife Bay and perform more drill sample analyses to gather more information on this site’s environment in a distant past that is so different from the ancient environments that were already known.

“We have characterized a very ancient, but strangely new ‘gray Mars’ where conditions once were favorable for life,” said John Grotzinger, Mars Science Laboratory project scientist. “Curiosity is on a mission of discovery and exploration, and as a team we feel there are many more exciting discoveries ahead of us in the months and years to come.”

**MSL Science Team presents SAM Results of Rocknest Soil Analysis**

The Mars Science Laboratory Science Team has presented the first results of soil analysis performed by the Curiosity Rover on Monday, December 3, 2012 as part of the fall meeting of the American Geophysical Union. Curiosity used all of its instruments at Rocknest to support scientific activities, but SAM, the Sample Analysis at Mars Instrument aboard Curiosity, was a key player in regolith analysis.

Early in October, Curiosity arrived at Rocknest, a drift of wind-deposited soil about 2.5 by 5 meters in size, for what would be a long stop to perform initial scoop sampling and subsequent analysis by the two laboratory instruments, SAM and CheMin. Before any soil was distributed to the instruments, the Rover had to go through a lengthy process of decontaminating the sample handling and processing systems. This was needed to remove any residual substances that were left inside the system from Curiosity’s stay on Earth.
Curiosity used its 4.5 by 7 centimeter scoop to acquire soil samples and deliver the material to CHIMRA, the Collection and Handling for In-Situ Martian Rock Analysis device. The first two samples were used to scrub the internal surfaces of CHIMRA to remove any leftover substances by using purely Martian material. After sending the samples through all chambers and labyrinths of the system, the material was discarded. The third sample was examined by CheMin and the Alpha Particle X-Ray Spectrometer for initial analysis while SAM had to wait until the fourth sample was scooped up and processed. SAM received sample material from the fourth and fifth Rocknest scoop sampling procedure, for a total of three sample analysis runs of the instrument.

To better characterize SAM measurements, the instrument performed empty cell runs to see whether any terrestrial compounds are being measured. For all details on MSL operations including sampling, visit the MSL Mission Updates Pages 4 & 5. For more on SAM, visit the instrument overview site.

After SAM data was carefully checked and teams determined that the instrument was performing flawlessly, scientists were able to get busy and start piling through the data to perform thorough and careful analysis.

Gases released from the soil samples that were heated up inside SAM included a large amount of water vapor as well as smaller amounts of other gases including carbon dioxide, oxygen and sulfur dioxide, as the slide to the right shows. The data presented in the chart comes from three separate experiments which are indicated by the bars below the chart. The blue bars show the temperatures of the samples analyzed by the Tunable Laser Spectrometer of SAM while the red bars represent temperatures of gas sent to the Gas Chromatograph.

With abundant amounts of water being detected in the regolith samples, SAM was able to detect the Deuterium/Hydrogen ratio in the Martian Soil. Deuterium, also known as heavy hydrogen, is one of two stable isotopes of hydrogen, and contains one proton and one neutron in its nucleus while the common hydrogen isotope (Protium) has no neutron in the nucleus.

SAM provided the first ever data on D/H ratios from the Martian surface while previous data was only available via Mars Orbiters.

The D/H ratio is used along with other isotope ratios to assess the evolution of the Martian atmosphere over time, in particular the known phenomenon of atmospheric escape which has occurred on Mars (see SAM Science Update of November 2, 2012).

As physical processes cause atmospheric loss, heavier isotopes of gases are retained so that a difference in isotope abundances is produced over large time scales. Atmospheric loss at the top of the atmosphere to interplanetary space favors lighter isotopes. One of the predominate processes that involves water is the dissociation of water in the Martian atmosphere caused by ultraviolet radiation. As a result, hydrogen is formed and lighter hydrogen molecules containing protium escape into interplanetary space much faster than heavy hydrogen.

SAM results have shown that water vapor on Mars contains more Deuterium than that of terrestrial water. As MSL begins to drill into rocks, SAM might be able to examine the D/H ratio of past Martian environments to assess the process of atmospheric escape over time. Hydrogen released from samples at higher temperatures is believed to be older than hydrogen released at lower temperatures.
At higher temperatures, SAM also detected oxygen and sulfur compounds as well as chlorine compounds. The signatures detected by SAM are consistent with measurements made by the Phoenix Lander. The oxygen release might be the result of decomposition of perchlorates while the release of sulfur compounds released at high temperatures suggests the presence of sulfates or sulfides.

SAM detected simple chlorinated carbon compounds such as chloromethane, dichloromethane, chloroform and a 4 carbon chlorine containing compound that has yet to be identified. The chlorine in these organic compounds is of Martian origin, but it is still unclear whether the carbon is Martian or terrestrial. The chlorine compounds mentioned above could have formed in a reaction of a perchlorate or a peroxide-like phase and carbon containing molecules that could represent contaminants brought to Mars from planet Earth. The story of perchlorates on Mars began back in 2008 when the Phoenix Lander detected perchlorates at about 0.6wt % in Martian soil samples.

Further analysis and experiments are needed to definitively determine the origin of the carbon and to further examine the abundance of perchlorates inside Gale Crater.

“We have no definitive detection of Martian organics at this point, but we will keep looking in the diverse environments of Gale Crater,” said SAM Principal Investigator Paul Mahaffy of NASA’s Goddard Space Flight Center.

Curiosity and its science team will patiently continue the search for organics in different locations along the rover's path as the MSL mission continues. These are only the first results of SAM sample analysis and only mark the beginning of unprecedented measurements on the Martian surface to assess the planet’s past and present habitability. These first measurements have also shown that SAM is replicating results when being fed identical samples – showing that the instrument is operating flawlessly which is a big relief for scientists that have put years of hard work into sending this instrument to Mars.

Although the Cl in these organic compounds is Martian, it is presently unclear whether the carbon is Martian or terrestrial. This remains to be established with ongoing analysis, future laboratory work, and experiments on Mars.

The Curiosity search for organics in other environments and samples will continue.
Scientists present first MSL Data on Martian Atmosphere

The Sample Analysis at Mars (SAM) Instrument of NASA’s Mars Science Laboratory Rover has successfully started to perform chemical analyses of the Martian Atmosphere. The SAM Science Team presented its first findings in a teleconference on Friday.

Suspense had been building ever since SAM took its first sniff of the Martian Atmosphere earlier in the landed mission as the press and public were eager to get confirmation of a possible methane detection, but scientists are taking a careful approach and require multiple analyses and extensive data reviews before announcing their detailed findings on atmospheric methane on Mars. The initial runs of SAM have not revealed conclusive confirmation of methane on Mars.

SAM is a state-of-the-art chemical analyzer consisting of three components: a Quadrupole Mass Spectrometer (QMS), a Gas Chromatograph (GC) and a Tunable Laser Spectrometer (TLS).

These highly sensitive instruments are used to assess elemental, molecular and isotopic chemistry of solid and atmospheric samples in order to examine the present and past habitability of the planet by looking at chemistry that is relevant to life. A detailed SAM Instrument Overview is available here.

The QMS was used to determine the abundance of different gases in the Martian Atmosphere. To the right is a graph showing the major constituents of the atmosphere as measured by SAM. It uses a logarithmic scale so that all these gases with very different concentrations could be plotted.

Carbon dioxide is making up 95.9 percent of the atmosphere's volume, which is no surprise as CO2 is known to be the major atmospheric gas present on Mars. The next four most abundant gases are argon, nitrogen, oxygen and carbon monoxide. These numbers are in agreement with previous publications.

"The SAM measurements are rock solid from one run to another, they have a high precision," Sushil Atreya, SAM Co-Investigator, said. Now, teams will use SAM on a regular basis to monitor changes of these numbers as the Martian atmosphere evolves over the course of a Martian year.

A known phenomenon on Mars is a large dynamic in atmospheric pressures as well as composition of the atmosphere.

Atmospheric carbon dioxide freezes out during Martian Winter causing atmospheric pressure to decrease. About 35 percent of the total carbon dioxide is estimated to freeze out in Winter.

SAM has also started isotope measurements using atmospheric samples. These examinations are important to scientists because they give insight into the evolution of the Martian atmosphere. In the case of Mars, a large portion of the atmosphere is suspected to have been lost over the course of the planet’s history. As physical processes cause atmospheric loss, heavier isotopes of gases are retained so that a difference in isotope abundances is produced over large time scales. Atmospheric loss at the top of the atmosphere to interplanetary space favors lighter isotopes.

"Initial SAM results show an increase of five percent in heavier isotopes of carbon in the atmospheric carbon dioxide compared to estimates of the isotopic ratios present when Mars formed," NASA said in a news release. The abundances of the two major Argon isotopes, argon-36 and argon-40, have been determined by SAM in late-October. SAM detected about 2,000 times as much argon-40 as argon-36 which also supports theories on atmospheric loss.

This was the most precise measurement of argon isotope ratios on Mars and it confirms the connection between Mars and atmospheric gases that came to Earth trapped inside Martian Meteorites. The dark blobs that can be seen on the meteorite shown in the image to the right held a small amount of atmospheric gas that was trapped when the meteorite was ejected from Mars. Analysis of argon isotope of these samples have shown the same ratios that were determined by SAM.

These argon measurements also show that Martian isotopic ratio is about 7 times enriched in the heavier isotope compared to Earth which is suggestive of atmospheric loss.
The plot also contains different carbon dioxide peaks that are created by CO2 containing different isotopes of carbon and oxygen. The largest peak, at a mass of 44, contains the most abundant isotopes of both elements.

Obviously, the big question was about methane. Detecting methane on Mars remotely via Orbiters or ground-based telescopes has been difficult in the past because methane is only abundant in trace amounts, if at all. Scientists have been debating over atmospheric methane for decades, but there has not been a definitive conclusion yet. With SAM starting operations on Mars, a new chapter in the search of methane on Mars begins as SAM's TLS is the first instrument on the Martian surface that supports the search.

The first TLS measurements place an upper limit on methane abundance at just a few parts per billion with enough uncertainty that the methane level could be anywhere between 0ppb and 5ppb. Over the course of the mission, the SAM instrument will be calibrated and characterized so that the uncertainty of the instrument will be reduced and more accurate measurements can be made.

"Methane is clearly not an abundant gas at the Gale Crater site, if it is there at all. At this point in the mission we're just excited to be searching for it," said SAM TLS lead Chris Webster of NASA's Jet Propulsion Laboratory. "While we determine upper limits on low values, atmospheric variability in the Martian atmosphere could yet hold surprises for us."

**SAM TLS Methane Detection Method and possible Signatures**

**SAM Tunable Laser Spectrometer (TLS)**

The results presented by the SAM science team on Friday only mark the beginning of a suite of highly-anticipated measurements that include the search of methane, the analysis of atmospheric gas by the Gas Chromatograph and Mass Spectrometer, assessments of solid samples, starting to measure concentrated samples and more types of science measurement sequences that SAM is capable of.

"With these first atmospheric measurements we already can see the power of having a complex chemical laboratory like SAM on the surface of Mars," said SAM Principal Investigator Paul Mahaffy of NASA's Goddard Space Flight Center. "Both atmospheric and solid sample analyses are crucial for understanding Mars' habitability."

© 2011-13 www.spaceflight101.com - Patrick Blau
Spaceflight101 content can be shared/reproduced for non-commercial or informational purposes. Appropriate crediting is appreciated.