

## Supplementary Materials for

### Mars methane detection and variability at Gale crater

Christopher R. Webster,\* Paul R. Mahaffy, Sushil K. Atreya, Gregory J. Flesch, Michael A. Mischna, Pierre-Yves Meslin, Kenneth A. Farley, Pamela G. Conrad, Lance E. Christensen, Alexander A. Pavlov, Javier Martín-Torres, María-Paz Zorzano, Timothy H. McConnochie, Tobias Owen, Jennifer L. Eigenbrode, Daniel P. Glavin, Andrew Steele, Charles A. Malespin, P. Douglas Archer Jr., Brad Sutter, Patrice Coll, Caroline Freissinet, Christopher P. McKay, John E. Moores, Susanne P. Schwenger, John C. Bridges, Rafael Navarro-Gonzalez, Ralf Gellert, Mark T. Lemmon, the MSL Science Team

\*Corresponding author. E-mail: chris.r.webster@jpl.nasa.gov

Published 16 December 2014 on *Science* Express  
DOI: 10.1126/science.1261713

#### This PDF file includes:

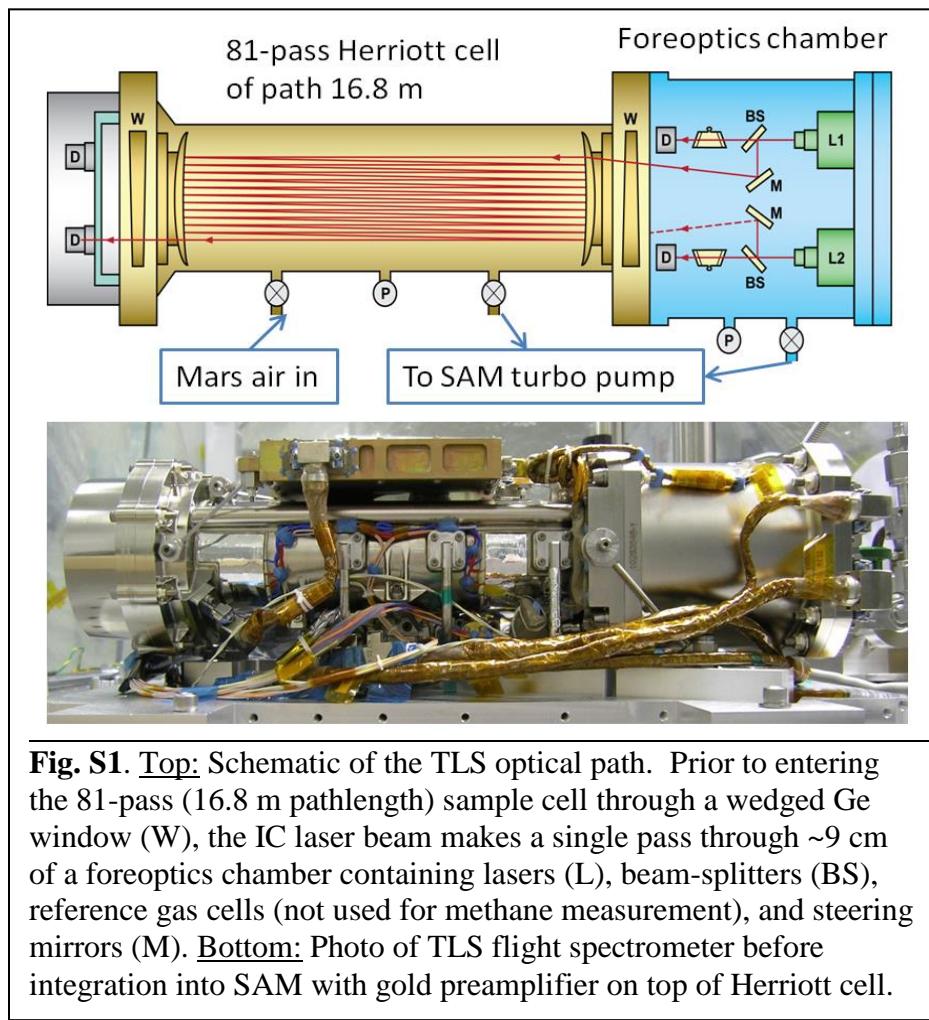
- Materials and Methods
- Supplementary Text
- Figs. S1 to S13
- Tables S1 and S2
- Full Reference List
- The MSL Science Team Author List

## Materials and Methods

This supplementary material repeats some of that published earlier (33) that is here updated and extended to include discussion of the enrichment experiments, spectral difference plots, correlation results of the TLS methane measurements with a variety of observed quantities like relative humidity, water abundance, ground and surface air temperatures, etc., and finally to present arguments for ruling out terrestrial contamination.

### The Tunable Laser Spectrometer (TLS) in the Sample Analysis at Mars (SAM) instrument suite on the Curiosity Rover:

This instrument has been previously described in detail (29,33 and references therein). Fig. S1 below shows the optical layout for the methane measurement.



### Methane spectroscopy and laser parameters:

The TLS interband cascade (IC) laser scans through a unique fingerprint of seven spectral lines in the  $\nu_3$  band: three  $^{12}\text{CH}_4$  lines associated with R(3) and four subsequent  $^{13}\text{CH}_4$  lines associated with R(3) transitions. Table S1 below lists the three  $^{12}\text{CH}_4$  lines

used for this study, as identified by both the HITRAN data base (43) and laboratory measurements. We create the labels e, f, g for these three lines, where the g line is strongest, and both e and f are about half the intensity of the g line.

| <b>Table S1.</b> Spectral lines used to identify methane from HITRAN data base (43) |                                                                           |                                            |            |       |
|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------|------------|-------|
| Spectral line center<br>(cm <sup>-1</sup> )                                         | Line-strength at 296 K<br>(cm <sup>-1</sup> / molecule·cm <sup>-2</sup> ) | Ground-state<br>energy (cm <sup>-1</sup> ) | Assignment | Label |
| 3057.687285                                                                         | 2.085E-19                                                                 | 62.8781                                    | R(3)       | g     |
| 3057.726529                                                                         | 1.245E-19                                                                 | 62.8768                                    | R(3)       | f     |
| 3057.760524                                                                         | 1.245E-19                                                                 | 62.8757                                    | R(3)       | e     |

The IC laser was developed at JPL, and operated near 245 K stabilized by a two-stage thermoelectric cooler (TEC) producing single-mode (>99%) continuous-wave output power with a linewidth retrieved from low-pressure (Doppler limited) spectra of ~10 MHz. This light was collimated using an efficient triple-lens collimator to produce ~1 mW laser power that passes through the foreoptics chamber then into the sample (Herriott) cell. Prior to entering the Herriott cell, the beam was attenuated by a factor of ~20 by a thin mylar sheet (not shown in Fig. S1) to reduce optical fringing and detector non-linearity. We note that the pre-launch settings for the TEC and laser current scans (used for calibration also) have not been changed and the target spectral line positions remain in our scan window. Very small (~linewidth) variations in the spectral line position are seen depending on the Curiosity heat ramp behavior, but we observe and track the methane lines continually for each spectrum through the simultaneously-recorded reference cell detector; the tracked methane spectrum arises from residual methane gas in the foreoptics chamber.

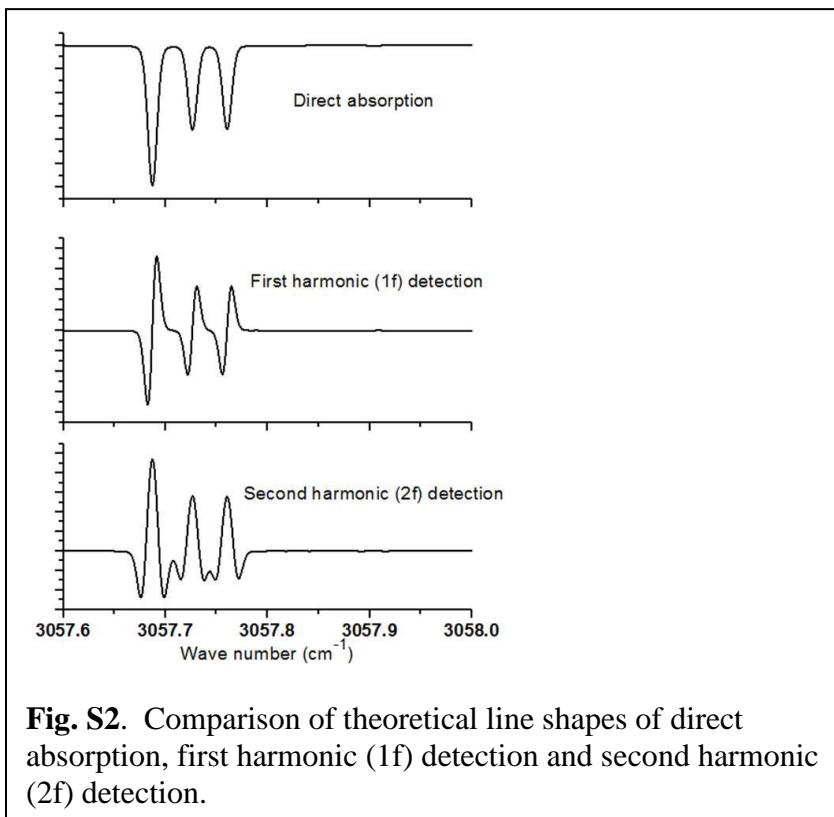
#### Description of the Difference Method:

We determine Mars methane abundances by differencing full cell and empty cell results (not spectra), as described below. In a typical run on one sol, we collect (downlink) 13 empty cell spectra (2 minutes on board averaged each) followed by 26 full cell, then followed by another 13 empty cell spectra for return-to-zero check. Cell temperatures and pressures are extremely stable during the complete sol run and contribute negligibly to our results (see later). We chose to record relatively long periods of continuous empty or full spectra to make sure that no drift (growth or loss) in retrieved methane abundance was observed during the run. We record sequential 2-minute empty cell spectra for ~1 hour followed by ~1 hour of sequential full cell spectra. We do not difference full-empty spectra before processing. Rather, with powerful computing resources now available, we process each of our 3 methane lines separately in each and all of our 2-minute spectra (by comparison with HITRAN calculations described below), then produce a combined efg-line average abundance for each spectrum that becomes a single raw 2-minute data point. Then, after applying common calibration factors and error contributions, we compare statistically the empty and full cell results for each measurement after normalizing to the empty cell mean values.

### Direct and Second-harmonic (2f) Spectra

TLS is designed to simultaneously produce both direct absorption and second harmonic (2f) spectra, as is standard for commercial and laboratory tunable laser spectrometers (44). Tunable laser spectrometers “scan” through spectral lines by applying a current ramp (usually saw-tooth) to the laser that through junction heating changes the wavelength by a small amount, the ramp repeated typically every one second (as done in TLS).

In direct absorption, absorption line depths that indicate gas abundance are measured as dips in the large light level on the detector as the laser is scanned. For very weak absorptions of ~1% or less (due to low gas amounts, too small path lengths or gas pressures, etc., and as expected for low methane (<20 ppbv) amounts) it is challenging for electronics and dynamic range to measure small changes in a large signal, and a “harmonic” detection is preferred. In harmonic detection, the very narrow laser linewidth (much narrower than the gas absorption line) is modulated (“dithered”) at high frequency (say 10 kHz) by applying a sinusoidal component to the laser current ramp (increasing laser current is the normal method of tuning the laser across the spectral scan) with an amplitude that is small compared to the gas linewidth. So, if we modulate at 10 kHz and look at only the component of the detector signal at 10 kHz (using phase-sensitive detection), we would record a first-harmonic or first-derivative (1f) spectrum as shown in Fig. S2. Outside the spectral line and at the line center, the laser is jiggling left and right where no difference exists, so it records zero in these places, but has its maximum signals (negative and positive) at the side of the line where the slope is maximum.



**Fig. S2.** Comparison of theoretical line shapes of direct absorption, first harmonic (1f) detection and second harmonic (2f) detection.

If we now modulate at 10 kHz, but look at the component of the laser light on the detector that is at 20 kHz, we would record (as we do on TLS) the second-harmonic or second-derivative (2f) spectrum seen in Fig. S2. Both 1f and 2f spectral signals are zero-based in amplitude and move the detection frequency to higher frequency (kHz) compared to the direct (DC) spectrum, where 1/f noise is lower. Thus the harmonic method produces higher signal-to-noise spectra. The 1f spectrum is not usually used since it can have small vertical offsets and the line center position is a zero-crossing rather than a peak. The 2f spectrum is preferred since it has its peak in the same place as the direct absorption spectrum, and moves the detection regime to the higher (20 kHz) frequency.

#### Spectral Data Processing:

The Beer-Lambert law models the optical transmission of light through an absorbing medium (44):

$$I_v = I_0 e^{-k(v)\rho l}$$

where  $I_v$  is the transmitted light intensity at frequency  $v$ ,  $I_0$  is the incident light intensity,  $k(v)$  is a line shaping function that may be Doppler, Lorenzian, or Voigt, although the Doppler lineshape is a close approximation at Mars atmospheric pressures.  $\rho$  is the molecular number density and  $l$  is the path length in cm. We use this model to determine the abundances of individual absorption lines present in our sampled measurements. The model needs many input spectral parameters for temperature dependence, air broadening, ground state energy, etc., and we use the HITRAN database for this information (43). Direct absorption spectra produce good results for gases that have line center absorption depths of ~1% or greater. For higher sensitivity, we add a modulation to the laser current and then demodulate the returning detector signal at twice that frequency. This effectively gives us a second harmonic or 2f spectrum in which sensitivities of up to 2 parts in  $10^5$  are possible. See the section above and also Webster et al. (44) for a complete discussion.

#### **Laser Power Normalization and Wave Number Scale**

For a given channel (either CH<sub>4</sub> or CO<sub>2</sub>/H<sub>2</sub>O), TLS returns 3 spectra from the Herriott cell “science” detector, and 3 spectra from the reference channel detector. For both the Herriott cell and reference channel spectra, these 3 spectra are the direct absorption spectrum, the 2f spectrum, and a high-gain 2f spectrum. Our methane analysis is done using the 2f spectrum that is normalized to laser power from the direct absorption spectrum and mapped to a wave number scale using the reference detector signals. The high-gain 2f spectrum is not used since with only moderate gain increase (x16) it duplicates the 2f spectrum in signal-to-noise ratio but suffers from dynamic range restriction.

The TLS instrument also returns reference detector spectra recorded simultaneously with those from the science detector, and these are used to track the methane lines to provide the wave number scale for later processing. The methane signal (spectra)

detected by the reference detector (located inside the foreoptics, as shown in Fig. S1) is due to residual methane in the foreoptics. The foreoptics contribution to the science spectrum is equivalent to about 90 ppbv for sols 79-292 and much lower for subsequent runs. The 2-stage thermoelectric cooler on the IC laser keeps the lines in the same position during the scans, with drifts in line positions over all sols of only about 1-2 linewidths that are tracked successfully.

For an amount of gas at a given pressure and temperature, calculations using the HITRAN data base parameters (43) will predict the depth and width (distribution in wave number) of the absorption by the gas sample for all sampled frequencies, allowing us to then compare our recorded spectra to the spectra produced by the model. But, in order to make this comparison, we must first normalize the recorded data. This process that takes level 0 data (spectra) and produces level 1 data (spectra) entails:

Removing a “null pulse” which is a measurement of the background light taken with the laser off, and recorded during every one second spectrum that is averaged on board for our 2-minute downlinked spectrum. This allows us to determine the direct absorption with respect to a percentage of transmitted light (i.e. 1% absorption: 99% transmission).

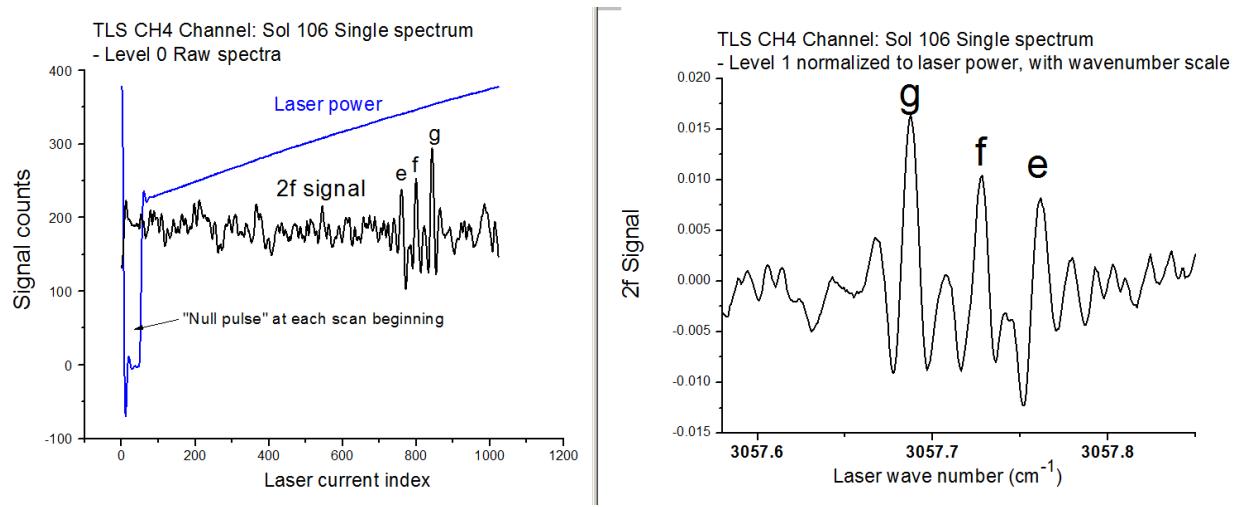
Removing any DC offsets in the harmonic spectra (described below).

Fit the baseline of the spectra. This sloping baseline results from the fact that the laser output power increases as it tunes through different wave numbers.

Divide 2f spectra by DC baseline.

Assign a wave number ( $\text{cm}^{-1}$ ) scale to the real spectra. We do this by using easily identifiable peaks of known wave number.

Once the raw spectra (level 0 data) are normalized (Fig. S3) as level 1 data, we can then use the HITRAN model to scale our real world data.



**Fig. S3.** Example of normalization of a real single spectrum (2 min.) downloaded for sol 106. The methane triplet lines e, f, g can be identified from Table S1 above. The left panel is the complete level 0 spectra, whereas the right panel that shows level 1 data (same 2-min. spectrum normalized to power and given wave number scale) has been expanded in wave number to show the methane lines used and the occurrence of optical interference fringes that limit the detection method for a single 2-min. spectrum.

### ***Producing Abundances***

Using temperatures and pressures from our instrument for input, we iteratively run the model, varying the abundance in a converging algorithm until the synthetic spectra for the single line is the same size as our real spectrum (within some determined threshold). The convergence criteria are set to optimize for the 2f spectra.

For the methane analysis, we generate two results, one named “peak-to-peak” that returns the peak-to-peak signal amplitude (actually central peak to lobe-average) values, and a second named “integral” that returns the area of the 2f line between and above the bottom lobe minima positions (wave number). The peak-to-peak method finds the signal amplitude of the 2f maximum and lobe minima average, and is our preferred method since it produces somewhat lower scatter in our data, although results for either method are very close. The integral method, which is used for retrieving H, C, O isotope ratios (31) uses the following algorithm:

Find the global max of the 2f absorption spectra (peak)

Find the two local minima (2f lobes)

Fit a line between the two lobes

Using the lobes as integration boundaries, find the area between the fitted line and the spectra for both the direct and 2f spectra. Ratio this area between real and synthetic spectra and if ratio is outside the convergence threshold, iterate with new abundance.

Once the measurements converge, we ratio the resulting areas of the real spectra to the synthetic spectra which has a known abundance. For both methods, using the same laser modulation and gain throughout (pre-launch calibration and all Mars measurements), we relate the 2f signal size to the direct absorption size through calibration as described below, and like any flight project, we rigorously run our experiment as tested and calibrated pre-launch.

### **Calibration:**

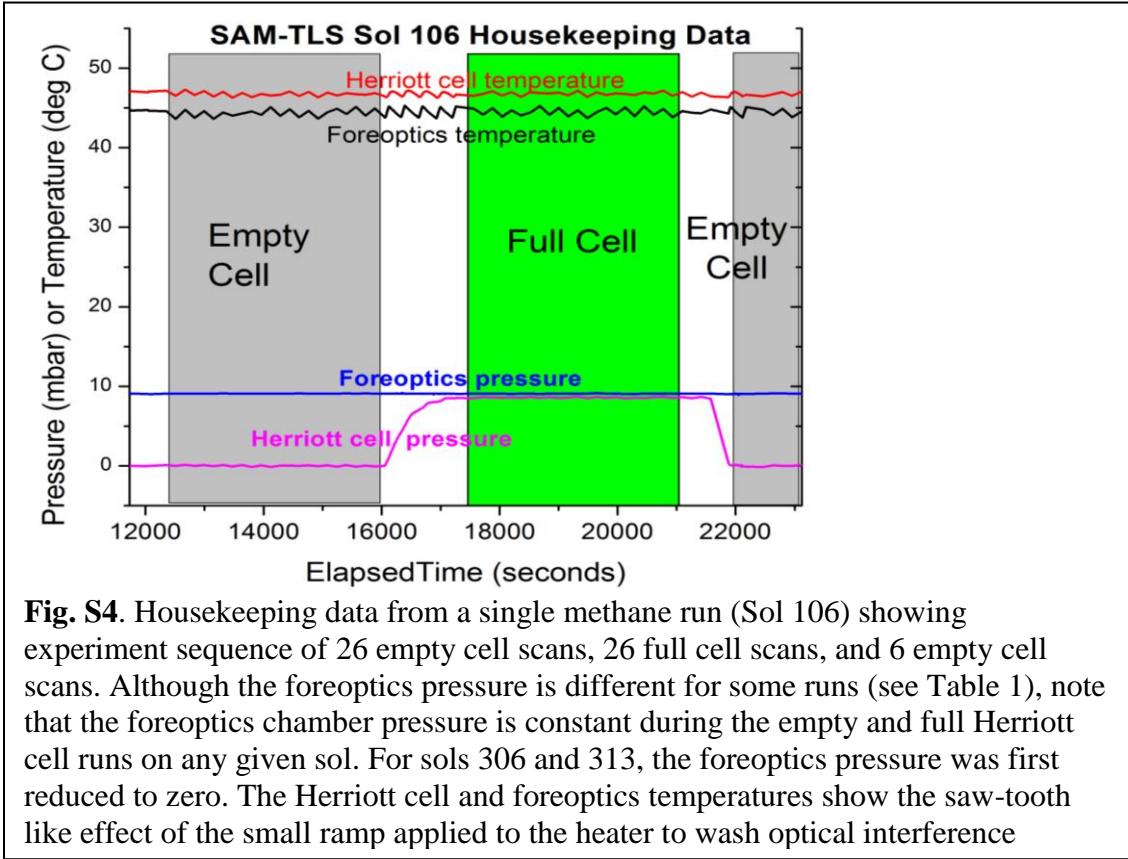
When analyzing direct absorption spectra with known pressure, temperature and path length, a Beer’s law calculation using spectral line parameters from HITRAN (43) can in theory provide the gas abundance without the need for calibration gases (i.e. someone else did the work when they created the data-base). However, calibration gases serve the dual purpose of verifying the spectrometer response (a check of pathlength or number of passes in a cell, laser linewidth, pressure, mode purity, temperature, saturation, etc.) and also giving a direct calibration (relationship) between the direct absorption and the 2f channel with its various different gain stages.

The relative methane abundances reported here are calibrated using NIST-traceable methane in air provided by the NOAA-CMDL laboratory (provided by Jim Elkins group) specified to contain  $88 \pm 0.5$  ppbv. By injecting this gas into the TLS Herriott cell during pre-launch calibration runs of TLS and SAM in the NASA GSFC environmental chamber, we record both direct absorption and 2f signal sizes using the same conditions (e.g. laser scan, modulation, flight electronics and software, Herriott cell temperature and pressure, ramp heater) used on Mars. During the calibration run, the foreoptics is pumped

out so that there is no contribution from foreoptics gas. The path length of the Herriott cell was verified to be 81 passes based on direct absorption measurements of these same methane lines using a second calibration cylinder (same provider) at 1800 ppbv. In addition, by adding pure methane gas at low pressures so that the lines are bleached to zero light transmission at line centers, the mode purity during the scan is verified. No change in alignment or detector signal sizes has been detected since pre-launch. Normalizing the mean value retrieved to 88 ppbv gives us a calibration result and uncertainty of  $88.0 \pm 1.13$  ppbv. We note that this absolute uncertainty of  $\pm 1.13$  ppbv does not carry forward in our difference method described below, since it would only serve to change the mean value and upper limit slightly (by ~1 part in 88).

#### The foreoptics contribution to the difference method:

The difference method is described in the body of the main paper, and the sequence shown in Fig. S4 below. During the empty or full cell periods, the foreoptics and Herriott cell pressures are very stable; during a typical run (Sol 106) the temperatures and foreoptics pressure are stable to 0.02%, and the Herriott cell pressure during the full cell section is stable to 0.1%.



During the long pre-launch activities in Florida, the foreoptics chamber leaked up to a significant pressure (~76 mbar) by the time we arrived at Mars. This pressure included terrestrial “Florida air” from the launch site that contained significant terrestrial methane gas (~10 ppmv) that showed up as a large methane signal (spectrum) on the Herriott cell science detector for both “empty” and “full” Herriott cell data, since the beam made one

pass through the 9-cm length of the foreoptics. Results from these runs made before sol 79 were discarded and not included in the analysis. To reduce the foreoptics contribution, we pumped down the foreoptics chamber in a series of steps for subsequent sol runs (80, 33, 11.5 mbar) until at 11.5 mbar we observed no detectable increase (or reduction) in the empty or full cell spectra with time over the run, so that we were confident that the leakage was negligible during the runs to follow. To eliminate any residual concerns regarding possible leaks between the foreoptics and Herriott cell during the run, for sols 306 and 313 we further reduced the foreoptics pressure to close to zero by pumping on the chamber.

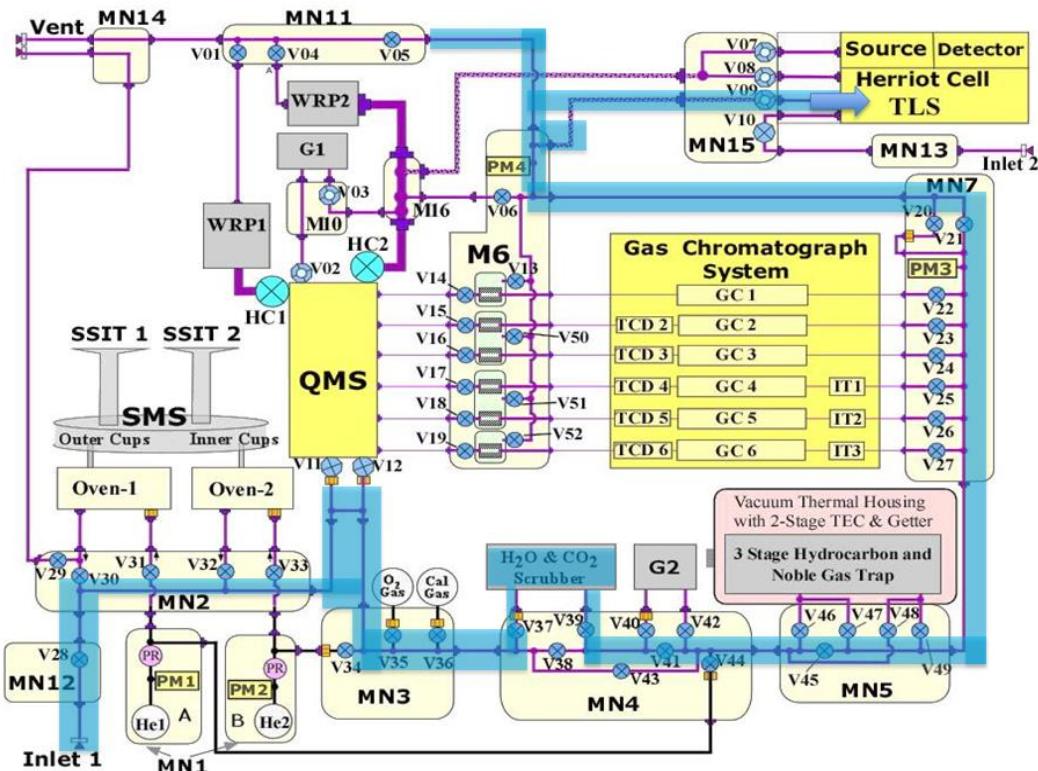
Because of the foreoptics contribution, all of our spectra (empty and full Herriott cell) look somewhat like those in Fig. S3 since (in the absence of significant Martian methane) they are dominated by the foreoptics contribution. We then process them as described above, and then look for differences in the empty and full cell results. Specifically, the “full” cell methane spectra are first processed as if the observed methane spectrum came only from the Herriott cell, that is, we use the measured Herriott cell pressure and temperature to retrieve a “full cell” methane mixing ratio by comparison with HITRAN. Then for the “empty” cell spectra, we use the same mean temperatures and pressures of the full cell and process the empty cell spectra to reveal the “empty cell” methane mixing ratio. This method makes the difference method most sensitive to Herriott cell methane from Mars, should it be there. If there were no methane on Mars, the empty and full cell results would be identical. If there were 20 ppbv methane on Mars, the full cell result would be 20 ppbv larger than the empty cell result. For sols 79-292, for example, both the empty and full cell results are close to 90 ppbv, and for sols 306 and 313 it is <20 ppbv. For the difference data given in Table 1, the mean empty cell values for that specific run have been subtracted from the mean full cell values to provide the resulting Martian methane mixing ratio.

#### The “methane enrichment” and “hybrid” experiments:

For direct ingest runs (lower precision), inlet 2 (see top right corner of Fig. S5) is used. It is a 3/16” internal diameter stainless steel tube heated to 50°C containing a dust filter of sintered Inconel 0.5 micron particles that is located on the rover side ~1 m above the Martian surface, and was pointed at a variety of directions relative to the nominal wind direction.

On two occasions we conducted “methane enrichment” experiments that effectively increase the methane abundance in the Herriott cell by removing (“scrubbing out”) a large part of the main atmospheric component, carbon dioxide. In these runs, the Mars atmosphere is ingested through a second inlet (Inlet 1 in Figure S5 below) and led to the TLS Herriott cell by passing over a CO<sub>2</sub> scrubber cell filled with Linde 13X molecular sieve material. Once the Herriott cell is pumped out, the Mars atmosphere is ingested along the path shown in Fig. S5 until the TLS cell is either at 90% of the Mars ambient pressure of ~7 mbar, or two hours have gone by. For the two enrichment runs, we typically produced 4-5 mbar of enriched atmosphere in the Herriott cell after the two-hour limit. The script for the enrichment runs was thoroughly tested in the SAM test-bed at NASA GSFC in a series of 3 runs aimed at determining “the enrichment factor (EF)”, during which a “Mars mix” of known abundances (50 ppbv methane in this case) was used, where TLS measured the methane abundance before and after the enrichment, and

for the “empty cell”. Using an N<sub>2</sub>/Ar ratio approximating that expected on Mars, a value for EF of  $24 \pm 2$  (95% CI) was first obtained, modified to  $22 \pm 2$  (95% CI) with a more accurate N<sub>2</sub>/Ar ratio from a separate gas mixture in a subsequent run.



**Fig. S5.** The SAM gas handling and routing schematic. V=valve, MN=manifold, SMS=sample manipulation system, WRP=wide range turbomolecular pump. The broad blue highlight shows the path taken by the ingested Mars atmosphere during the enrichment experiments. The lower precision “direct ingest” runs ingest Mars atmosphere through the shorter path from Inlet 2 and manifold MN13 into the Herriott cell.

Because our first enrichment run on Sol 573 produces a very low value for methane in contrast to the earlier “high methane” runs, we modified the methane enrichment script to append a direct ingest run immediately after it, and called this our “hybrid methane” script. This was also tested in the SAM test bed at NASA GSFC, and produced consistent enrichment factor of  $23 \pm 1$  (95% CI) even though it was conducted months after the first run with many other test-bed studies in EGA mode done in between.

## Data Analysis:

Through the SAM central data handler (CDH), the Curiosity rover returns two-minute averaged spectra from TLS (direct absorption and 2f spectrum for both Herriott cell and reference gas cell) that show the three spectral absorption lines given in Table S1. We treat each of these lines as a separate estimate of the absorption attributable to methane somewhere along the optical path. These absorptions were converted into an apparent methane mixing ratio in the Herriott cell by assuming that this is the only region in which methane occurs.

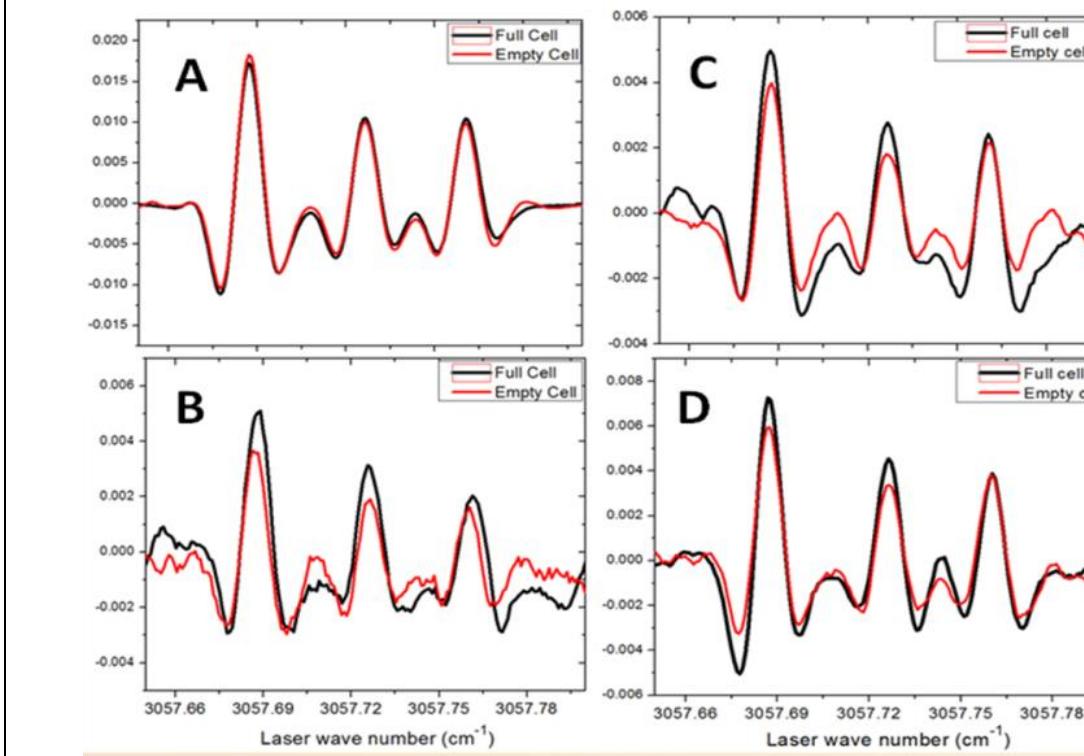
*Changes to data processing since the first Science paper (33) results:* All our data have now been reprocessed with the same new algorithm that reduces any susceptibility to variations in the laser plate temperature by automatically rejecting the few 2-minute points that resulted from a laser plate temperature changing by more than 0.1 deg/minute. The need for this quality control is because the spectral lines will blur somewhat during the 2-minute average by an amount dependent on the laser plate temperature; the faster the laser plate temperature changes during the 2-minute collection, the smaller the methane spectral lines will be in depth. Although it is true that our integrated area under the spectral line will take care of this, it is not perfect since we integrate not across the full lineshape, but across the area between the second harmonic lobe positions (still most of the line). Not all runs require point removal, and point removal can result in either or both the full or empty cell runs. The most significant change that this reprocessing produces is for the daytime run of Sol 306: removing the few low points that were associated with a fast-moving laser plate temperature results in raising the mean value of the full cell abundance to produce the now-high retrieved value for the daytime abundance (Table 1 and Figure 1).

Comparing the data for the six observations of sols 79–313 in this paper with those in Webster et al. (2013), the results for sols 81 and 292 are rather similar, while those for sols 79, 106, 306, and 313 are different. Using the current data, the published value of  $0.18 \pm 0.67$  ppbv and the upper limit of 1.3 ppbv in Webster et al. (33) should be revised to  $0.88 \pm 0.81$  ppbv and 2.2 ppbv, respectively. Although the revised mean for this 6-sol group is 0.88 ppbv, at 95% confidence level the upper limit is  $0.88 + 1.645 * SEM = 2.2$  ppbv, because in this case a one-sided Student distribution needs to be considered for upper limits.

#### Averaged Spectra:

We choose to partition our data points of Fig. 1 into 3 groups for independent analysis: (i) the “low methane” direct ingest results of sols 79, 81, 106, 292, 313 and 684; (ii) the “low methane” enrichment results for sols of 573 and 684; and (iii) the “high methane” four sequential runs of sols 466, 474, 504, and 526, since each of these groups shows no significant variations within. The daytime result of sol 306 is not included. The averaged spectra for these three groups are plotted in Fig. S6 below where a definitive increase in signal size (integrated area) is evident for each line in the methane signature.

Figure S6 follows on next page.



**Fig. S6.** Visual comparison between full and empty cell average spectra: A. “Low methane” from Sols 79, 81, 106, 292, 313 and 684; B. “High methane” from Sol 474 only; C. “High methane” from Sols 466, 474, 504, and 526; and D. “Low methane” from the enrichment experiment sols of 573 and 684 before dividing the difference by the enrichment factor of 23.

**Computation of mean values, standard error of the means and confidence intervals:**

For each sol, the average net signal  $\overline{Net}$  (in ppbv) is obtained from the Full and Empty cell analyses from the following equation:

$$\overline{Net} = \overline{Full} - \overline{Empty} \quad (S1)$$

where  $\overline{Full}$  and  $\overline{Empty}$  are the mean values of the Full and Empy cell analyses for a given sol.

The variance is thus:

$$\sigma_{\overline{Net}}^2 = \sigma_{\overline{Full}}^2 + \sigma_{\overline{Empty}}^2 \quad (S2)$$

which is estimated by means of replication:

$$\frac{s_{Net}^2}{n_F} = \frac{s_{Full}^2}{n_F} + \frac{s_{Empty}^2}{n_E} \quad (S3)$$

where  $n_F$  and  $n_E$  are the number of Full and Empty cell analyses acquired on a given sol. The value  $\frac{s_{Net}}{\sqrt{n_F}}$  calculated from Eq. S3 is given in Table 1 as the Standard Error of the Mean.

The 95% Confidence Interval is given by:

$$\Delta \overline{Net} = \pm \frac{s_{Net} t(P, df)}{\sqrt{n_F}} \quad (S4)$$

where the critical values of the t-distribution are taken for a significance level  $P$  of 95% and the degrees of freedom  $df = n_F - 1$ . Note that usually  $n_F \approx 25-30$ , and thus the critical value is close to 2, which is the value we considered in Table 1.

The mean net values provided for each series (“low methane”, “low methane with enrichment”, “high methane”) are calculated as the average of all individual 2-min full cell analyses of that series, from which the average empty cell of the corresponding sol is subtracted, i.e., net values are calculated for each sol with the appropriate background, and then are averaged over all the sols of that series. The mean value can thus be written as:

$$\begin{aligned} \overline{Net} &= \frac{1}{n_{F,tot}} \left[ \sum_{i=1}^{n_F(1)} \left( Full_1(i) - \overline{Empty(1)} \right) + \sum_{i=1}^{n_F(2)} \left( Full_2(i) - \overline{Empty(2)} \right) + \dots \right] \\ &= \frac{1}{n_{F,tot}} \left[ \sum_{k=1}^{n_{F,tot}} Full(k) - \sum_{j=1}^N n_F(j) \overline{Empty(j)} \right] \end{aligned} \quad (S5)$$

where indices 1, 2, ..., N correspond to the sol index within a series,  $n_F(j)$  is the number of full cell analyses performed on the  $j^{\text{th}}$  sol, and  $n_{F,tot}$  is the total number of full cell analyses over the given series.  $\overline{Net}$  refers here to the mean net values of that series, while  $\overline{Empty(j)}$  is the mean of the Empty cell analyses measured on sol  $j$ .

Although the Full and Empty cell values exhibit some non-random fluctuations over different sols, the set of net values is randomly distributed over each series. A possible real (non-random) variation of the net signal may be observed during the enrichment series (as reflected by the different mean values obtained on sol 573 and 684, although confidence intervals overlap), so that the estimated standard deviation of the net values may be overestimated for that series.

Since only mean daily values of the background were subtracted from individual Full cell analyses, the variance of the net signal as calculated from Eq. S5 only reflects the variance of the Full cell analyses. In reality, the variance of the net signal is the sum of the variances of the Full and Empty cell analyses. Since both are similar to a good approximation, the real variance of the net signal should be  $\approx 2 s_{Net}^2$  (where  $s_{Net}^2$  is the variance calculated from the dataset of net values described above). As a result, the SEM and Confidence Intervals for the mean values of each series are calculated as:

$$SEM_{\overline{Net}} = \frac{\sqrt{2} \times s_{Net}}{\sqrt{n_{F,tot}}} \quad (S6)$$

and

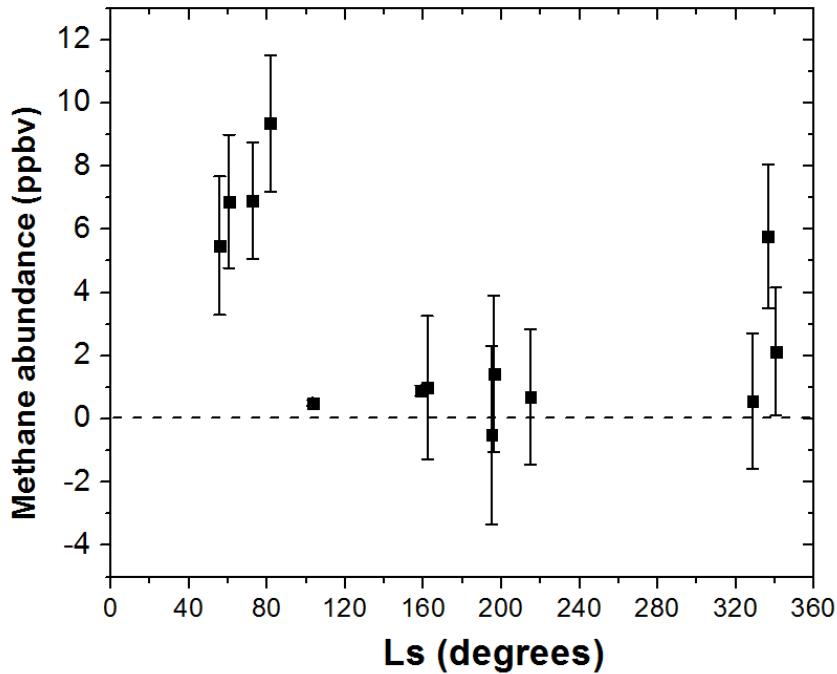
$$\Delta \overline{Net} = \pm \frac{\sqrt{2} s_{Net} t(P, df)}{\sqrt{n_{F,tot}}} \quad (S7)$$

with  $df = n_{F,tot} - 1$  degrees of freedom. With this approach, the uncertainty on the Empty cell values is also taken into account.

## Supplementary Text

### Correlations with other measured parameters:

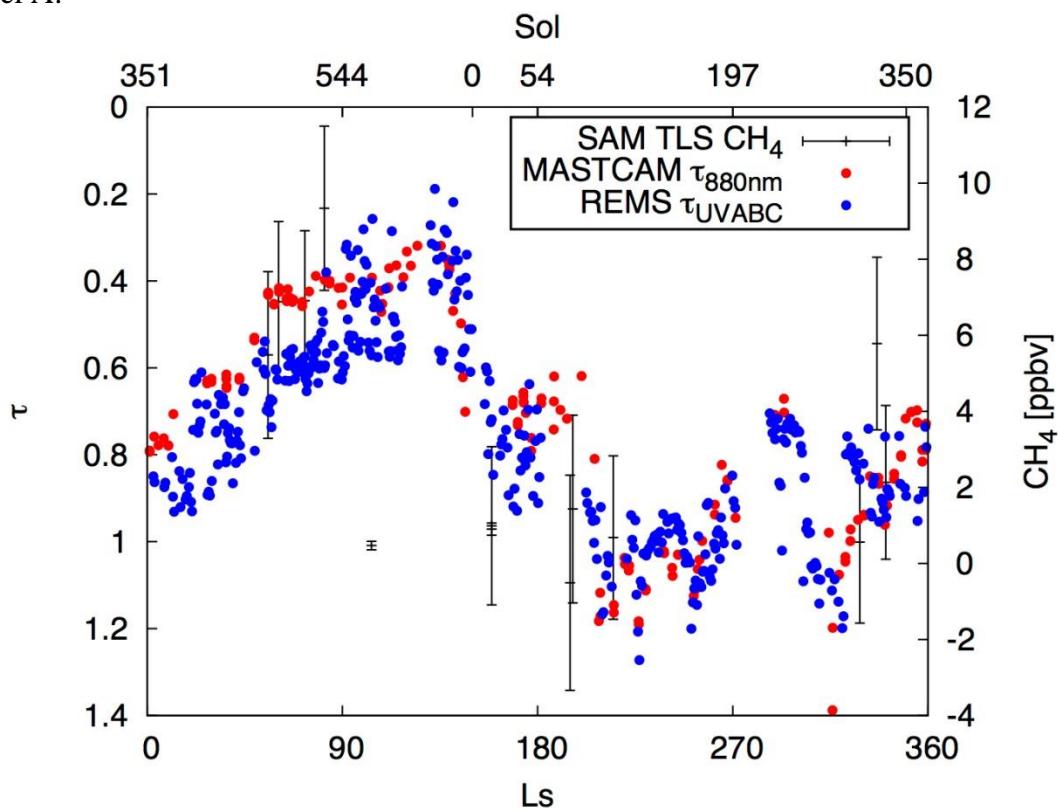
Correlations with other measurements have been described in the main text, and the data plots are presented below.



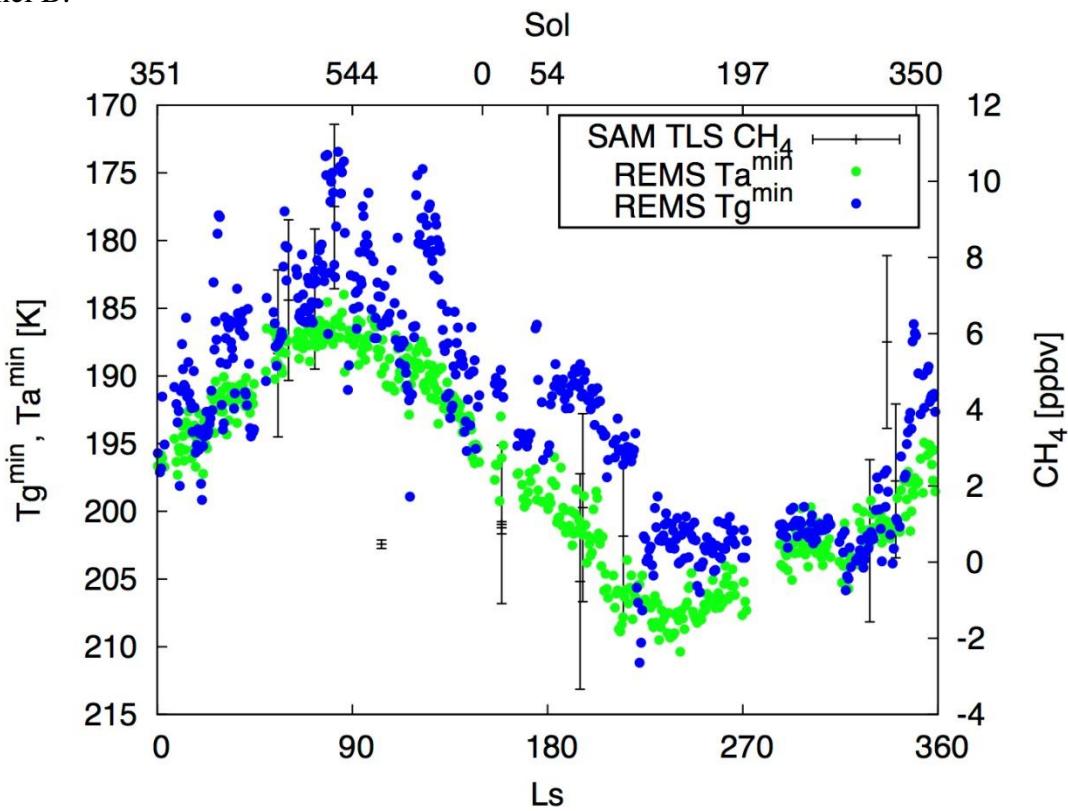
**Fig. S7.** Plot of TLS methane abundances vs. solar longitude (degrees).

Figure S8 follows on next page.

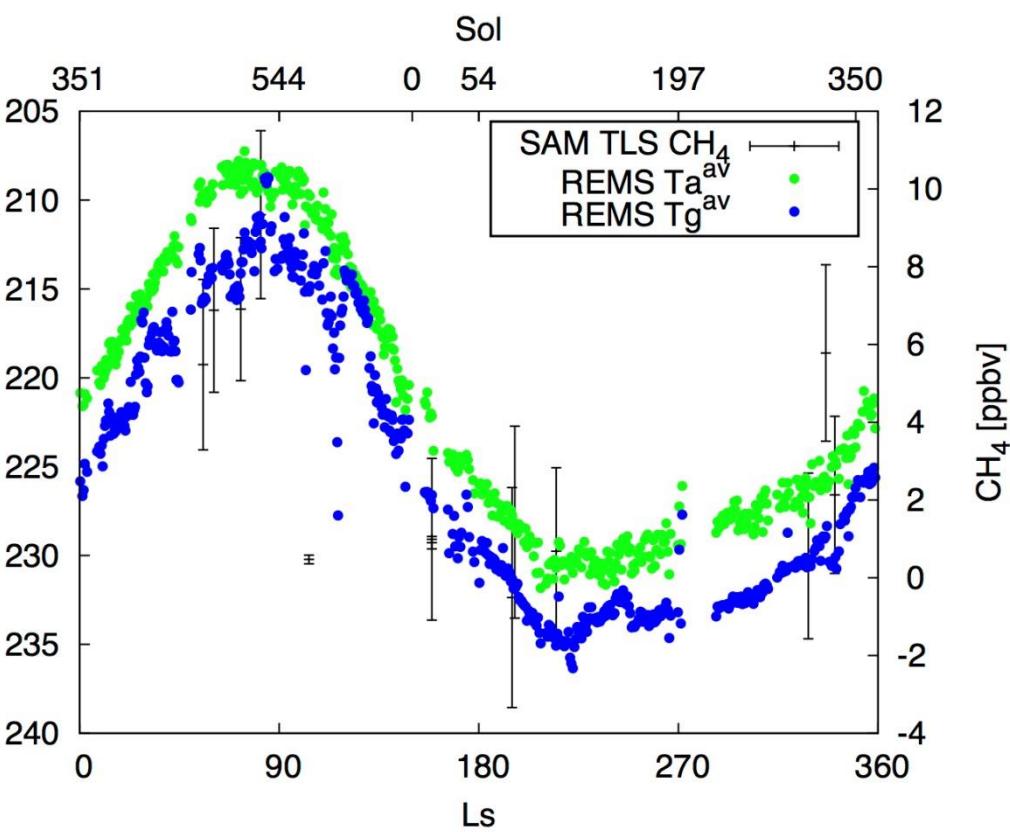
Panel A:



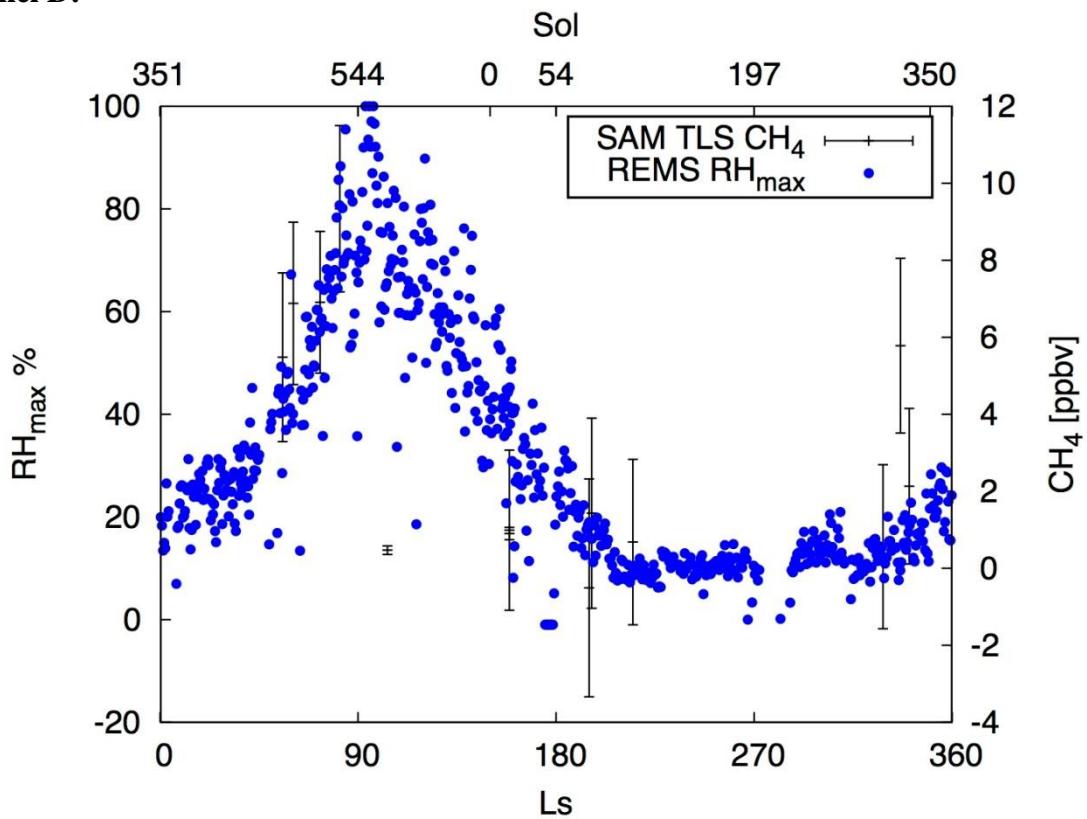
Panel B:



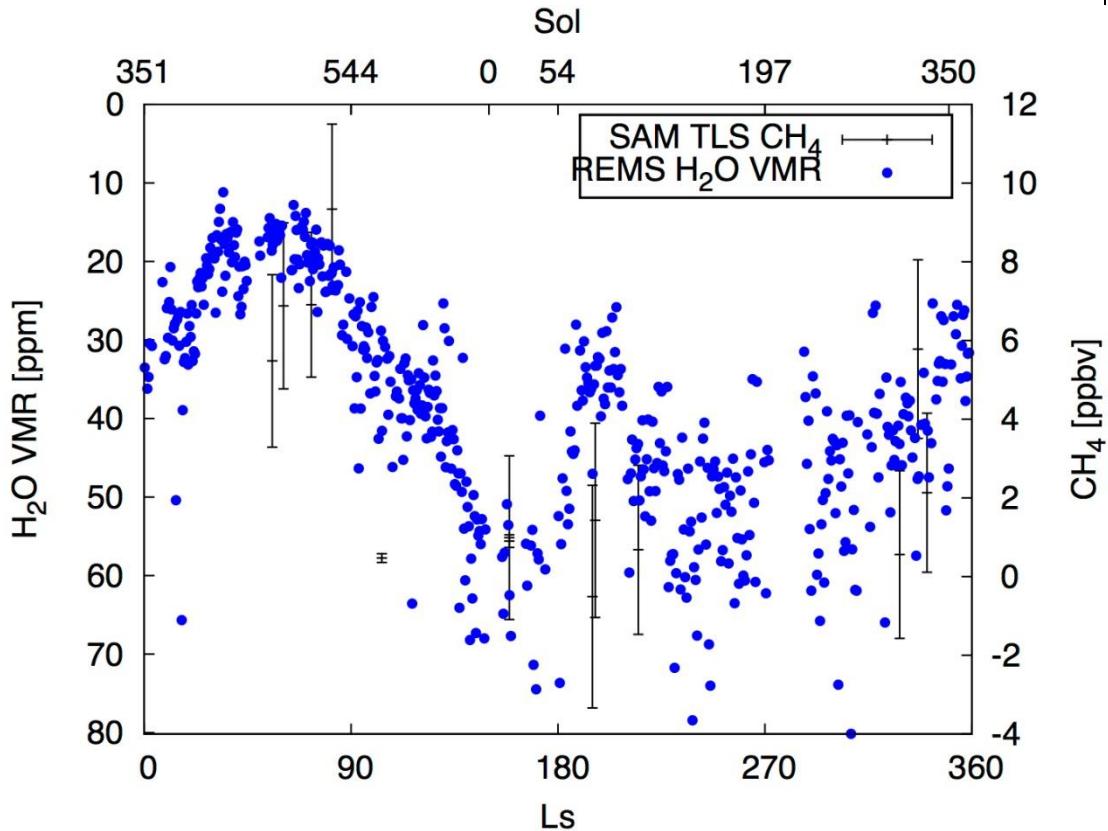
Panel C:



Panel D:

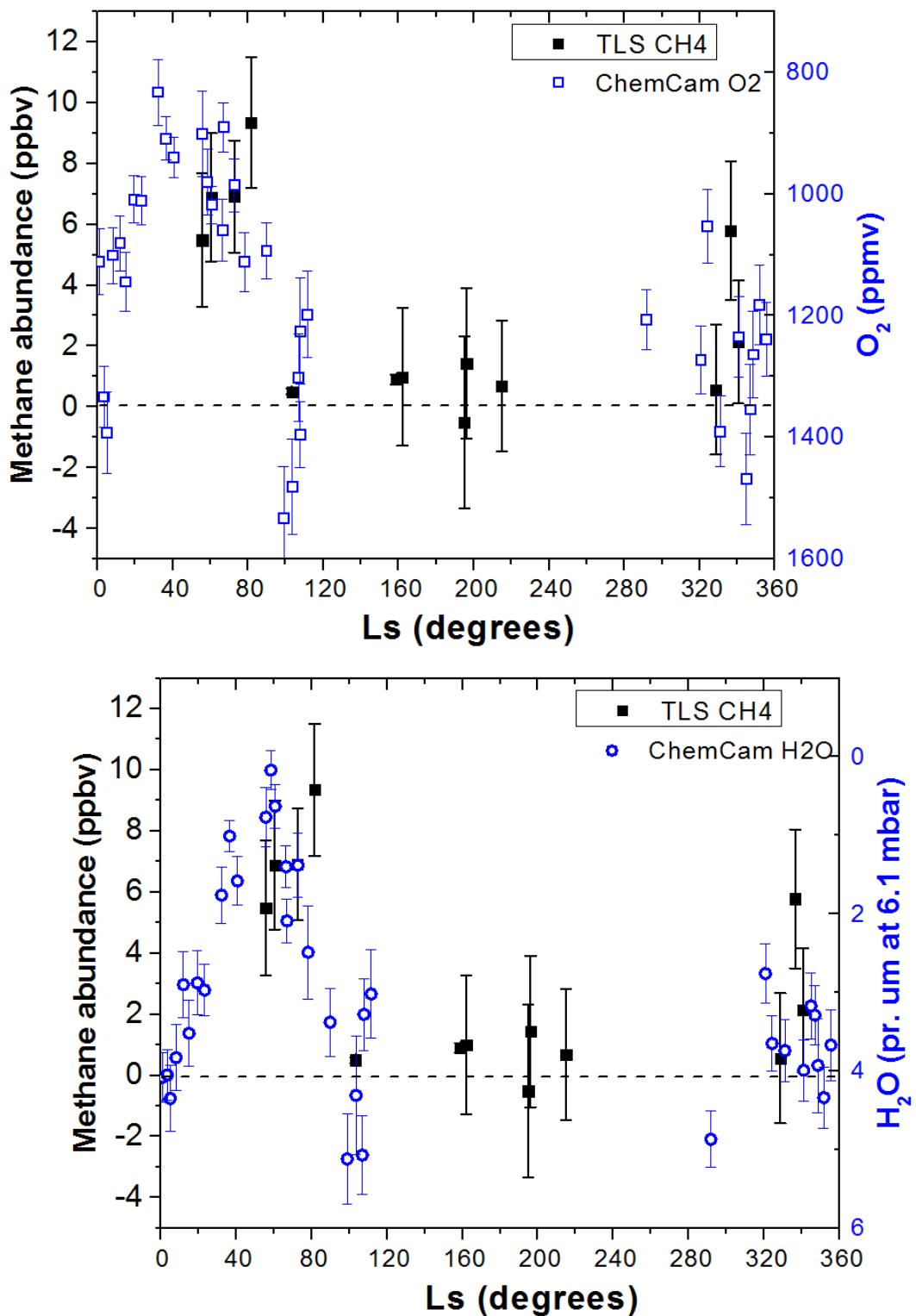


**Panel E:**



**Fig. S8. Panel A:** Comparison between TLS methane measurements and dust opacity measured by MSL's mast camera (MASTCAM) at 880 nm and by the REMS instrument across UV-abc wavelengths. **Panel B:** Comparison between TLS methane measurements and the minimum ground (Tg) and air (Ta) temperatures as measured by REMS. **Panel C:** Comparison between TLS methane measurements and the average ground (Tg) and air (Ta) temperatures as measured by REMS. **Panel D:** Comparison between TLS methane measurements and the maximum daily relative humidity RH as measured by REMS. **Panel E:** Comparison between TLS methane measurements and the in situ water vapor volume mixing ratio (vmr) as measured by REMS.  
For a description of REMS and MASTCAM, see (36) and (39).

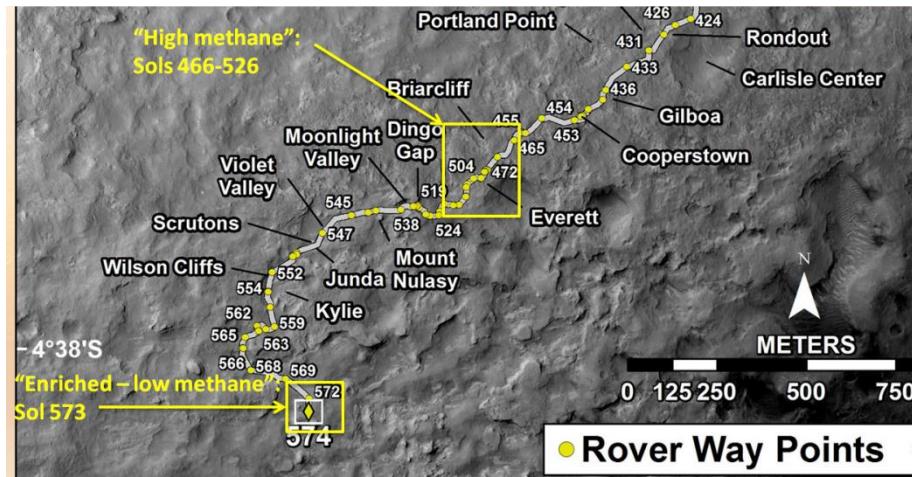
Figure S9 follows on next page.



**Fig. S9.** Comparison between TLS-SAM methane measurements and preliminary ChemCam oxygen (top panel) and water (lower panel) column abundances, the latter

plotted in precipitable microns at 6.1 mbar. The preliminary ChemCam data is from the presentation by McConnochie et al. (37) at the 8<sup>th</sup> Mars International Conference (2014).

Regarding the Curiosity rover location during the TLS methane measurements, the “high” methane results were all obtained in one region near Everett, as shown below in Fig. S10.



**Fig. S10.** Schematic showing the Curiosity rover’s location during the observations of “high” methane, near Everett. The subsequent low value observed for sol 573 was only ~800 m away.

#### Arguments against terrestrial contamination:

During evolved gas analysis (EGA) runs conducted by SAM, a portion of gas from a specific temperature cut containing helium carrier gas and gases evolved from the sample during pyrolysis is delivered to TLS primarily for isotopic analysis (H, C, O isotopes). During these runs, we also measure high levels (typically ~10 ppmv) of methane produced from the decomposition and reaction products of N-Methyl-N-tert-butyldimethylsilyl trifluoroacetamide (MTBSTFA) present in the sample system as a terrestrial contaminant (45). Measured values of  $d^{13}\text{C}$  in the evolved methane are in the range of -40 to -100 per mil. The occurrence of these EGA runs is plotted along the bottom of Figure 1 in the main body of the paper. In light of this known contamination, we here consider scenarios by which this source of terrestrial contamination could be responsible for our methane detection at both high and low values, and present arguments below to rule these scenarios out.

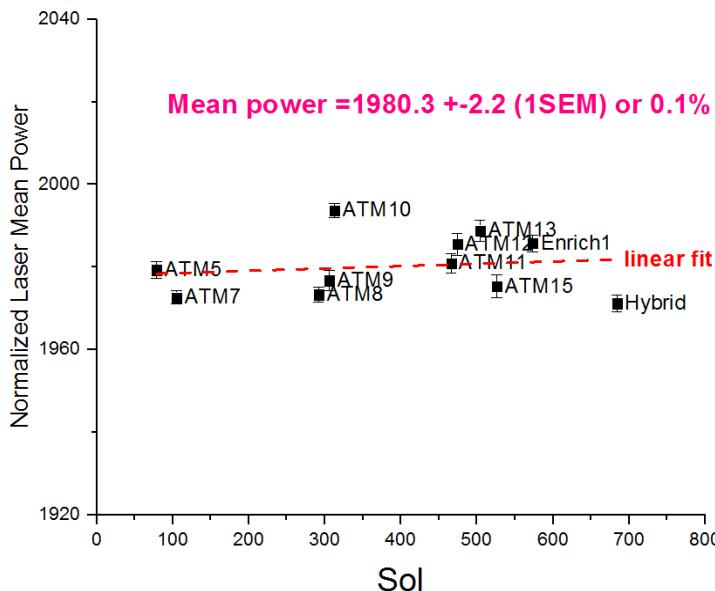
#### **Hypothesis: The observed methane is the result of incomplete pumping out (evacuation) of the Herriott cell:**

From observed signals comparing the Mars atmospheric carbon dioxide (~96% pure) to those of an evacuated cell, we measure that the cell is pumped to <0.007 mbar, so that 10 ppmv  $\text{CH}_4$  in 10 mbar He could leave a few ppbv methane after the end-of-EGA evacuation. However, before and after each atmospheric ingest reported here (performed days to weeks after EGA runs), the cell is again pumped out to <0.007 mbar, so that the contribution would be negligible. Moreover, the 4 “high methane” results

were recorded over a continuous period spanning 60 sols during which time no EGA runs of any kind were made, yet the 4 methane values remained consistently high. Note also that several earlier measurements made after RN, JK and CB sample analysis (see Fig. 1 caption) are low, not high.

**Hypothesis: There is a coating (MTBSTFA or reaction products) inside the Herriott cell that emits methane after reacting with ingested Mars atmosphere. This coating has built up over time, and may have been cleaned/removed by the combustion run leading to the lower methane values in the subsequent (enriched plus hybrid) runs. The empty cell would not show methane that would appear only once Mars atmospheric gas is ingested.**

We first note that both the Herriott cell interior and its primary mirror pair are both gold-coated, and can be considered the same surface for film coating or reaction. Because the interband cascade (IC) laser used for methane detection bounces 81 times between mirror surfaces, changes in the transmitted laser power provide a very sensitive detection of any film build up inside the cell. Figure S11 below shows that the methane laser power has not significantly diminished since landing, and if anything shows a minor trend toward higher power (cleaner mirrors). The measured 1SEM scatter in the data is only ~0.1% over the whole time period, and this change in laser power would require a change in mirror reflectivity of only ~10 parts per million! Should a putative polymeric type film cause such a change in reflectivity as a loss (absorption), we calculate that this tiny absorption could result from a film of  $5 \times 10^{-3}$  monolayers thick. Although very small, if every molecule of such a fractional layer was converted somehow to one molecule of methane, a few ppmv of methane could result in the 7 mbar Herriott cell when full. Therefore, any methane production from such a contamination must be limited not by the tiny film thickness, but by the available putative reactants ingested from the Martian atmosphere. We also know from full cell and before-and-after-empty-cell measurements that no trend is observed on any run over time (30 mins for each component, typically), so that any such chemistry must be very fast (less than a minute or so) and then immediately terminate.



**Fig. S11.** Normalized mean laser power of the Interband Cascade (IC) laser as a function of Martian sol, showing no significant change over time. If anything, a linear fit shows a slight trend toward increasing power (cleaner mirrors). Because the IC laser beam bounces 81 times between Herriott cell mirrors, this implies no change to mirror reflectivity within a few parts per thousand. Enrich 1=first enrichment run; Hybrid=direct ingest + second enrichment run.

Should this mechanism be occurring, we need to question exactly what Martian gases would be involved in this fast chemistry to produce methane? And what would the proposed surface coating be made of? We consider ozone at 10-200 ppbv, or hydrogen peroxide at <40 ppbv that potentially could react with a surface coating. Although methyl propene was first suggested as a potential “coating” material since it is a known byproduct of MTBSTFA degradation, this is ruled out since it is highly unlikely that methyl propene is adsorbed to surfaces, since it is much too volatile at 10 mbar (comparable to chloromethane). Better candidate MTBSTFA products that are more likely to condense on surfaces at 45 °C, 10 mbar, are the silylated water products, tert-butyldimethylsilanol and 1,3-bis(1,1-dimethylethyl)-1,1,3,3 tetramethyldisiloxane identified by SAM or something like the C4 ketones or aldehydes that have been seen in lab analog studies.

Regarding the possible “cleaning” effect of the combustion run, we rule this out since the EGA runs themselves produce oxygen at measured values (QMS) higher than the oxygen accompanying the combustion experiment temperature cut given to TLS.

Note that the TLS Herriott cell is maintained at 45 °C and only occasionally sees the EGA experiment. TLS receives a “temperature cut” (ingested gas from a predetermined oven temperature range) only ONCE per EGA run - not continuously - and this is a single 400 cc volume of mainly He at 10 mbar with EGA products fed to TLS.

In summary, we conclude that the possibility of terrestrial contamination producing the “high” methane signals is very unlikely, and with no evidence to back this scenario, we rule it out for the following main reasons:

There is no evidence of a coating/film that formed inside the TLS Herriott cell. Measured laser light level changes during the mission can accommodate no more than  $10^{-3}$  monolayer at most.

The earlier TLS methane data do not show any increase after 15 (!) EGA runs (RN, JK, CB1-3, BK’s), with the “high methane” occurring suddenly after an additional 3 EGA runs (CB5-7) and then disappearing after a single combustion run that is not significantly different to TLS than a standard EGA run of an oxygen-containing sample.

It is difficult to identify atmospheric reactants and chemistry that would react with any putative film or coating inside the Herriott cell to produce methane. During SAM EGA the QMS has not detected any atmospheric oxidants that could react with any coating in the TLS at 45 °C that would release methane.

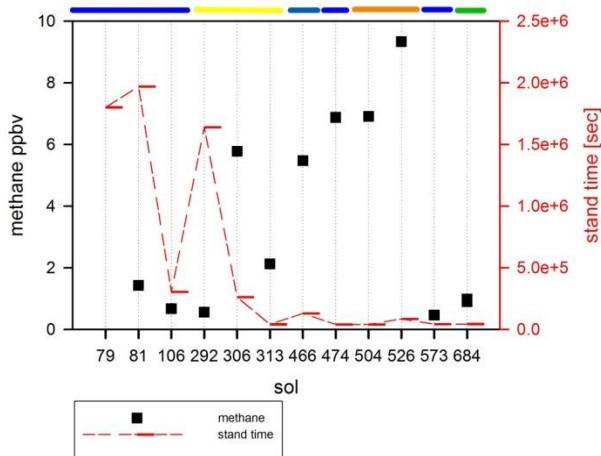
While there is no evidence to suggest an analytical problem despite an exhaustive search for one, such a short-lived elevated methane signal is surprising. Given its transience, an undetected analytical problem cannot be ruled out. Continued measurements of the atmospheric methane abundance, especially using the enrichment procedure, may further establish the reliability of this detection, and possibly of the recurrence frequency of elevated methane concentrations.

#### Study of Curiosity Wheel Degradation and Changing Terrain during Transit:

Because the observation of high methane occurred on four sols only, rover motion and geologic features of the terrain had to be excluded as possible methane release mechanisms in the unlikely scenario of methane being trapped in voids in crushed rocks, particularly since the Curiosity wheel degradation occurred during transit over harsh environments. The wheels themselves are made of aluminum, and there is no possibility that the wheel degradation can itself produce methane, but a two-ton rover traversing over differing rock terrain may crush rocks and somehow release methane in some places and not others. Therefore, the following correlations were tested against the high methane results: a) rover stand time, b) general terrain features, c) geochemistry of individual rocks.

##### **a) Rover stand time**

Rover stand time is the time elapsed between the last wheel motion and the ingest of atmosphere into the SAM instrument. To calculate this, the difference between the time of last wheel motion (extracted from the rover motion protocols) and the ingest start time (from the SAM protocols) was calculated (Fig. S12). All four observations of high methane (sols 466, 474, 504, 526) were made after relatively short rover stand times (Fig. S12). Within those four sols the longest stand time of ~36 hours occurred on sol 466, sol 526 had ~23 hours stand time and sols 474 and 504 ~11 hours. Similarly short but also long stand times (up to 555 hours) are related to low methane observations. Heating of the ground from the RTG as a cause for high methane measurements can be excluded as it would increase with time, which is not seen.



**Fig. S12.** Diagram relating rover stand time and terrain classification to the methane measurements. Methane measurements are plotted in ppbv, for error bars refer to Fig. 1 and Table 1 one in the main manuscript. Mean values of high methane (left axis and black squares) were taken from sols 466, 474, 504, and 526, all other sols are classified as ‘low methane’. Note that sols 306 and 526 are daytime runs. With this in mind, sol 306 is classified as a low-methane result. Unit of rover stand time is seconds, because the basis for the calculation is the spacecraft clock. Bar above the plot represents terrain classification from orbital mapping, whereby grey-blue, yellow and orange colors represent increasingly more rough terrain, while green and blue represent smooth terrain.

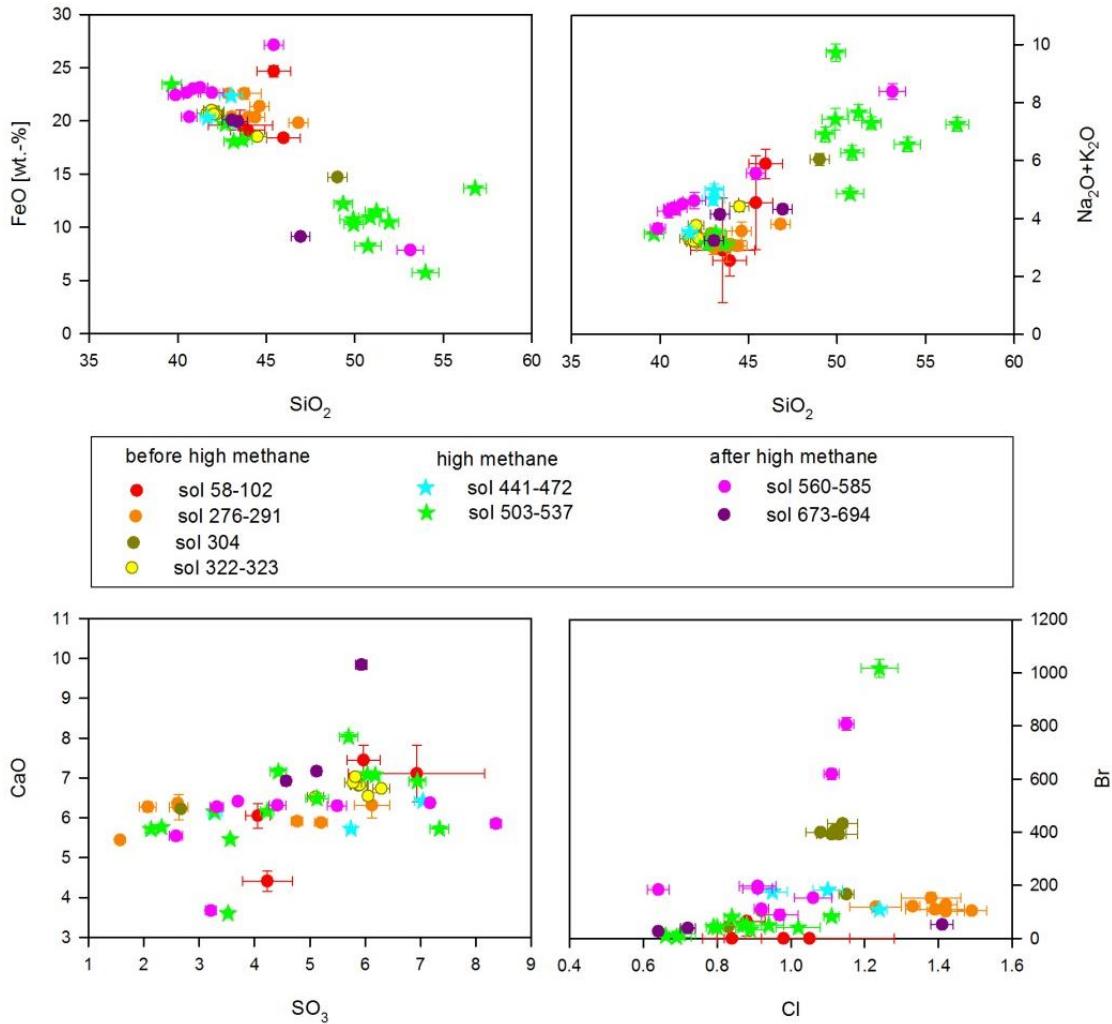
### b) General terrain features

Considering next the release of methane from crushing of rocks or disturbing soil while driving we take the following factors into account: rover stand time and the classification of the terrain from mapping (Fig. S12) and elevation . Elevation of the ingest location does not correlate with the methane measurements. The overall distance driven is a measure of the rover location and is best represented by the terrain mapping (bar above Fig. S12). Observation of high methane occurred over terrain classified as smooth (blue) and rough (orange), and low methane observations also occurred over both types of terrain, excluding a direct correlation between orbiter data based terrain classification and the methane observations.

### c) Geochemistry of individual rocks

To further test a correlation of rock properties with the observation of high methane, we next turn to the chemistry of rocks and soils as measured by APXS (41). Because the rover wheels crush and disturb rock fragments and soil along the traverse randomly, we therefore do not select individual measurements or attempt to single out rock classes but, rather, test chemical data grouped around the sols of the methane experiments. We tested the entire range of elements measured by APXS (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Zn, and Br) and show selected diagrams in Fig. S13. We investigated elements important for rock forming minerals (Fe, Mg for olivine and pyroxene, Na, K for feldspar plotted vs Si, all as oxides) and elements important for later fluid rock interaction (Ca, S for sulfates, Cl, Br for evaporation processes, Zn for hydrothermal processes; all as oxides). None of the plots shows any correlation between the

observation of high methane and the rocks in the immediate area of the rover position at ingest. Since the diversity of rocks crushed by the rover wheels is likely similar to the diversity measured by APXS (but exceptions may exist), and no correlation is observed between rock geochemistry and the methane observations, rover-generated heating, rock crushing or soil disturbance are an unlikely cause for the high methane observation. However, this assumes that the wheels and APXS sample possible methane-laden rocks equally. The rover wheels may be more likely to crush weakly bound rocks such as carbonaceous ones, but the APXS samples may be less likely to sample them if sparsely distributed.



**Fig. S13.** Plots of APXS (41) chemical data. Dots represent APXS measurements taken in the timeframe of low-methane observations, stars represent APXS measurements taken in the same timeframe as the high-methane observations were made. The upper two panels represent oxides important for the host rock classification, e.g., Fe in olivine and alkali oxides in feldspars. The lower two panels represent elements important in secondary alteration e.g., for the formation of Ca-sulfates or evaporitic minerals.

### TLS Raw Science and Housekeeping Data for Each Sol

In this section we present two-minute point-by-point raw data that includes relevant science and housekeeping data for both full and empty cells of each sol for which data was recorded. The table S2 below allows the reconstruction / traceability of the final data results and statistics given in the main body of the paper as Table 1.

For all the data given in Table S2 below, the TLS Herriott cell path length is 1680 cm. An average value of the 3 read temperatures (columns E, F, G) is used to process the data. For empty cell runs, the actual pressure in the Herriott cell is  $<10^{-4}$  mbar. All quoted mixing ratios in ppbv have been first corrected by a calibration factor resulting from pre-launch calibrations with standard mixtures as described earlier in the SOM.

The columns given in Table S2 below are:

A = Index number for each 2-minute data point

B = Elapsed time (seconds)

C = Fore optics Pressure (mbar) as read. The true fore optics pressure (given in Table 1) is column C values minus 3 mbar.

D = Laser plate temp (deg C)

E = Fore optics temp (deg C)

F = Ref cell temp (deg C)

G = Science detector temp (deg C)

H = Herriott cell pressure (mbar). For full cells this is the actual Herriott cell pressure. For empty cells, this column will read the mean value of the full cell pressure since we convert the fore optics methane abundance signal to what it would be in the Herriott cell prior to subtracting it later in the final column.

I = CH<sub>4</sub> mixing ratio (ppbv) from weighting the mixing ratio from 3 lines that takes into account that the g line is about twice as strong (SNR) as the e and f lines that have equal magnitude.

J = Weighted CH<sub>4</sub> mixing ratio (ppbv) calculated as the difference of the value in column I minus the mean value for the empty cell for each particular run. Note for the empty cell values, the mean value of column J will therefore be zero, and the data scatter gives us the empty cell SEM value to add (RSS) with the data scatter of the full cell.

Table S2. TLS Raw Data for Full and Empty Cell runs for each sol.

| Sol79 Full: |       |       |       |       |       |       |       |          |          |
|-------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| A           | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1           | 16445 | 14.56 | 18.54 | 44.62 | 42.79 | 46.98 | 6.662 | 71.54362 | -8.54402 |
| 2           | 16605 | 14.52 | 18.54 | 44.65 | 42.48 | 46.4  | 6.452 | 74.55205 | -5.53559 |
| 3           | 16766 | 14.53 | 18.53 | 44.48 | 42.74 | 46.89 | 6.632 | 73.92872 | -6.15892 |
| 4           | 16927 | 14.55 | 18.53 | 45.16 | 42.54 | 46.58 | 6.442 | 83.21665 | 3.129013 |
| 5           | 17088 | 14.55 | 18.54 | 44.33 | 42.68 | 46.78 | 6.612 | 74.10462 | -5.98302 |
| 6           | 17249 | 14.53 | 18.55 | 45.23 | 42.66 | 46.82 | 6.442 | 78.1916  | -1.89604 |
| 7           | 17409 | 14.54 | 18.56 | 44.2  | 42.62 | 46.67 | 6.572 | 87.57683 | 7.489191 |
| 8           | 17570 | 14.53 | 18.57 | 45.06 | 42.74 | 46.95 | 6.502 | 82.71834 | 2.630704 |
| 9           | 17731 | 14.54 | 18.58 | 44.07 | 42.55 | 46.56 | 6.522 | 71.70673 | -8.38091 |
| 10          | 17891 | 14.56 | 18.58 | 44.9  | 42.77 | 47    | 6.582 | 75.84954 | -4.2381  |
| 11          | 18052 | 14.56 | 18.58 | 43.95 | 42.49 | 46.45 | 6.482 | 66.4225  | -13.6651 |
| 12          | 18213 | 14.55 | 18.58 | 44.75 | 42.76 | 47    | 6.622 | 72.4699  | -7.61774 |

|              |       |       |       |       |       |       |       |          |          |
|--------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| 13           | 18374 | 14.51 | 18.57 | 43.87 | 42.43 | 46.32 | 6.452 | 55.79384 | -24.2938 |
| 14           | 18534 | 14.54 | 18.52 | 44.61 | 42.73 | 46.94 | 6.622 | 80.7523  | 0.664663 |
| 15           | 18695 | 14.54 | 18.55 | 44.32 | 42.37 | 46.28 | 6.432 | 79.63755 | -0.45009 |
| 16           | 18856 | 14.55 | 18.53 | 44.47 | 42.69 | 46.87 | 6.622 | 73.84749 | -6.24015 |
| 17           | 19017 | 14.55 | 18.51 | 44.85 | 42.42 | 46.41 | 6.412 | 81.97289 | 1.885247 |
| 18           | 19178 | 14.53 | 18.48 | 44.34 | 42.65 | 46.79 | 6.592 | 69.13349 | -10.9541 |
| 19           | 19338 | 14.53 | 18.45 | 45.23 | 42.54 | 46.66 | 6.412 | 78.99308 | -1.09456 |
| 20           | 19499 | 14.53 | 18.41 | 44.23 | 42.59 | 46.73 | 6.562 | 88.48778 | 8.400142 |
| 21           | 19660 | 14.52 | 18.37 | 45.11 | 42.65 | 46.89 | 6.402 | 85.08292 | 4.995284 |
| 22           | 19820 | 14.53 | 18.33 | 44.08 | 42.52 | 46.57 | 6.512 | 99.85333 | 19.76569 |
| 23           | 19981 | 14.53 | 18.29 | 44.92 | 42.7  | 46.94 | 6.502 | 96.92697 | 16.83933 |
| 24           | 20142 | 14.53 | 18.25 | 43.95 | 42.45 | 46.45 | 6.462 | 95.41509 | 15.32745 |
| 25           | 20302 | 14.53 | 18.21 | 44.76 | 42.69 | 46.95 | 6.562 | 91.17831 | 11.09067 |
| Sol79 Empty: |       |       |       |       |       |       |       |          |          |
| A            | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1            | 13327 | 14.56 | 18.66 | 45.05 | 42.5  | 46.97 | 6.523 | 76.64755 | -3.44009 |
| 2            | 13487 | 14.52 | 18.73 | 44.07 | 42.45 | 46.73 | 6.523 | 60.95483 | -19.1328 |
| 3            | 13648 | 14.54 | 18.77 | 44.96 | 42.67 | 47.11 | 6.523 | 82.62281 | 2.535167 |
| 4            | 13809 | 14.56 | 18.79 | 44.02 | 42.49 | 46.64 | 6.523 | 73.51998 | -6.56766 |
| 5            | 13969 | 14.57 | 18.8  | 44.88 | 42.77 | 47.15 | 6.523 | 63.65598 | -16.4317 |
| 6            | 14131 | 14.56 | 18.81 | 43.96 | 42.5  | 46.55 | 6.523 | 96.19029 | 16.10265 |
| 7            | 14291 | 14.55 | 18.8  | 44.86 | 42.72 | 47.01 | 6.523 | 76.71578 | -3.37186 |
| 8            | 14452 | 14.55 | 18.8  | 43.93 | 42.46 | 46.47 | 6.523 | 94.80176 | 14.71412 |
| 9            | 14613 | 14.55 | 18.78 | 44.78 | 42.77 | 47.05 | 6.523 | 80.5615  | 0.473861 |
| 10           | 14774 | 14.56 | 18.76 | 43.91 | 42.45 | 46.39 | 6.523 | 69.33734 | -10.7503 |
| 11           | 21340 | 14.53 | 17.95 | 44.16 | 42.56 | 46.68 | 6.523 | 86.05545 | 5.967811 |
| 12           | 21646 | 14.52 | 17.86 | 44.08 | 42.49 | 46.6  | 6.523 | 81.6454  | 1.557759 |
| 13           | 21806 | 14.53 | 17.81 | 44.9  | 42.64 | 46.93 | 6.523 | 90.54097 | 10.45333 |
| 14           | 21967 | 14.52 | 17.76 | 43.92 | 42.4  | 46.46 | 6.523 | 79.73747 | -0.35017 |
| 15           | 22128 | 14.51 | 17.71 | 45.14 | 42.75 | 47.16 | 6.523 | 85.11004 | 5.022396 |
| 16           | 22289 | 14.52 | 17.67 | 44.12 | 42.54 | 46.69 | 6.523 | 80.5477  | 0.460058 |
| 17           | 22449 | 14.51 | 17.64 | 44.91 | 42.72 | 47.08 | 6.523 | 82.62589 | 2.538247 |
| 18           | 22610 | 14.51 | 17.6  | 43.93 | 42.42 | 46.5  | 6.523 | 66.95215 | -13.1355 |
| 19           | 22771 | 14.52 | 17.57 | 44.71 | 42.67 | 47.02 | 6.523 | 83.40107 | 3.313429 |
| 20           | 22932 | 14.52 | 17.54 | 43.78 | 42.3  | 46.33 | 6.523 | 83.22399 | 3.136354 |
| 21           | 23092 | 14.6  | 17.53 | 44.89 | 42.79 | 47.22 | 6.523 | 90.81838 | 10.73074 |
| 22           | 23253 | 14.51 | 17.49 | 43.91 | 42.42 | 46.52 | 6.523 | 76.26169 | -3.82595 |
| Sol81 Full:  |       |       |       |       |       |       |       |          |          |
| A            | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1            | 17544 | 14.76 | 21    | 45.25 | 43.11 | 46.88 | 6.602 | 67.01518 | -16.8779 |
| 2            | 17705 | 14.75 | 20.91 | 44.35 | 42.95 | 46.54 | 6.612 | 90.95843 | 7.065365 |
| 3            | 17865 | 14.75 | 20.83 | 45.28 | 43.07 | 46.88 | 6.522 | 93.36267 | 9.469611 |
| 4            | 18026 | 14.76 | 20.75 | 44.37 | 42.95 | 46.59 | 6.632 | 99.33399 | 15.44093 |

|              |       |       |       |       |       |       |       |          |          |
|--------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| 5            | 18187 | 14.75 | 20.69 | 45.35 | 43.02 | 46.8  | 6.542 | 100.7288 | 16.83578 |
| 6            | 18347 | 14.74 | 20.62 | 44.41 | 42.95 | 46.63 | 6.642 | 89.5342  | 5.641139 |
| 7            | 18508 | 14.73 | 20.56 | 45.4  | 42.95 | 46.72 | 6.482 | 95.66268 | 11.76962 |
| 8            | 18669 | 14.73 | 20.51 | 44.44 | 42.94 | 46.67 | 6.642 | 83.8953  | 0.002236 |
| 9            | 18829 | 14.72 | 20.45 | 45.41 | 42.87 | 46.62 | 6.482 | 74.77954 | -9.11352 |
| 10           | 18990 | 14.73 | 20.39 | 44.45 | 42.93 | 46.69 | 6.652 | 75.77327 | -8.11979 |
| 11           | 19151 | 14.71 | 20.34 | 45.34 | 42.77 | 46.48 | 6.452 | 79.23326 | -4.6598  |
| 12           | 19311 | 14.72 | 20.28 | 44.47 | 42.91 | 46.7  | 6.632 | 84.77684 | 0.883782 |
| 13           | 19472 | 14.7  | 20.22 | 45.42 | 42.98 | 46.87 | 6.532 | 78.09694 | -5.79612 |
| 14           | 19633 | 14.73 | 20.17 | 44.44 | 42.94 | 46.73 | 6.642 | 73.44997 | -10.4431 |
| 15           | 19793 | 14.69 | 20.12 | 45.4  | 42.88 | 46.72 | 6.472 | 90.88347 | 6.990406 |
| 16           | 19954 | 14.71 | 20.06 | 44.38 | 42.9  | 46.71 | 6.622 | 90.57041 | 6.67735  |
| 17           | 20115 | 14.73 | 20.02 | 45.35 | 42.78 | 46.55 | 6.442 | 95.28182 | 11.38876 |
| 18           | 20275 | 14.71 | 19.97 | 44.41 | 42.86 | 46.69 | 6.612 | 93.01972 | 9.126661 |
| 19           | 20582 | 14.69 | 19.89 | 44.44 | 42.89 | 46.74 | 6.622 | 102.7503 | 18.85724 |
| 20           | 20743 | 14.68 | 19.83 | 45.33 | 42.73 | 46.54 | 6.432 | 84.35604 | 0.462979 |
| 21           | 20903 | 14.69 | 19.77 | 44.42 | 42.85 | 46.71 | 6.602 | 87.79615 | 3.903088 |
| 22           | 21064 | 14.67 | 19.72 | 45.33 | 42.9  | 46.87 | 6.492 | 74.99412 | -8.89894 |
| 23           | 21225 | 14.68 | 19.66 | 44.35 | 42.83 | 46.68 | 6.592 | 84.00213 | 0.109071 |
| 24           | 21385 | 14.66 | 19.61 | 45.3  | 42.78 | 46.69 | 6.432 | 75.1058  | -8.78726 |
| 25           | 21546 | 14.69 | 19.56 | 44.31 | 42.77 | 46.63 | 6.572 | 67.78387 | -16.1092 |
| Sol81 Empty: |       |       |       |       |       |       |       |          |          |
| A            | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1            | 12193 | 14.85 | 22.96 | 44.7  | 42.75 | 46.32 | 6.558 | 89.72983 | 5.836767 |
| 2            | 12353 | 14.87 | 23.04 | 44.76 | 43.17 | 46.99 | 6.558 | 68.68776 | -15.2053 |
| 3            | 12514 | 14.87 | 23.07 | 44.05 | 42.87 | 46.33 | 6.558 | 82.68542 | -1.20764 |
| 4            | 12675 | 14.86 | 23.07 | 45.07 | 43.18 | 46.93 | 6.558 | 84.03241 | 0.139354 |
| 5            | 12835 | 14.87 | 23.05 | 44.3  | 43.02 | 46.51 | 6.558 | 89.33652 | 5.443463 |
| 6            | 12996 | 14.87 | 23.03 | 45.38 | 43.14 | 46.78 | 6.558 | 82.58879 | -1.30427 |
| 7            | 13157 | 14.86 | 22.99 | 44.53 | 43.14 | 46.68 | 6.558 | 71.29067 | -12.6024 |
| 8            | 13318 | 14.86 | 22.95 | 45.14 | 42.92 | 46.32 | 6.558 | 79.57029 | -4.32277 |
| 9            | 13479 | 14.87 | 22.9  | 44.74 | 43.24 | 46.83 | 6.558 | 69.3854  | -14.5077 |
| 10           | 13639 | 14.85 | 22.84 | 44.18 | 42.89 | 46.15 | 6.558 | 80.11882 | -3.77424 |
| 11           | 13800 | 14.87 | 22.78 | 44.94 | 43.3  | 46.92 | 6.558 | 79.32419 | -4.56887 |
| 12           | 13961 | 14.86 | 22.71 | 44.18 | 43    | 46.3  | 6.558 | 79.64448 | -4.24858 |
| 13           | 14121 | 14.88 | 22.64 | 45.15 | 43.3  | 46.93 | 6.558 | 94.45001 | 10.55695 |
| 14           | 14282 | 14.85 | 22.58 | 44.35 | 43.08 | 46.47 | 6.558 | 78.63773 | -5.25533 |
| 15           | 14443 | 14.85 | 22.51 | 45.39 | 43.21 | 46.8  | 6.558 | 93.46878 | 9.57572  |
| 16           | 14603 | 14.85 | 22.45 | 44.51 | 43.15 | 46.61 | 6.558 | 83.54709 | -0.34597 |
| 17           | 14764 | 14.83 | 22.38 | 45.51 | 43.24 | 46.84 | 6.558 | 93.15173 | 9.258674 |
| 18           | 14925 | 14.84 | 22.3  | 44.62 | 43.21 | 46.73 | 6.558 | 90.04398 | 6.150921 |
| 19           | 15085 | 14.83 | 22.22 | 45.13 | 42.95 | 46.32 | 6.558 | 91.82756 | 7.934504 |
| 20           | 15247 | 14.86 | 22.14 | 44.75 | 43.24 | 46.81 | 6.558 | 77.36701 | -6.52605 |

|               |       |       |       |       |       |       |       |          |          |
|---------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| 21            | 15407 | 14.81 | 22.06 | 44.99 | 42.95 | 46.33 | 6.558 | 77.18287 | -6.71019 |
| 22            | 15568 | 14.84 | 21.99 | 44.8  | 43.29 | 46.91 | 6.558 | 90.74457 | 6.851507 |
| 23            | 15874 | 14.8  | 21.83 | 45.07 | 43.29 | 46.96 | 6.558 | 82.10128 | -1.79178 |
| 24            | 22572 | 14.65 | 19.33 | 44.64 | 42.55 | 46.33 | 6.558 | 88.63764 | 4.744581 |
| 25            | 22733 | 14.67 | 19.28 | 44.58 | 42.86 | 46.89 | 6.558 | 85.44725 | 1.55419  |
| 26            | 22894 | 14.65 | 19.23 | 45.05 | 42.61 | 46.48 | 6.558 | 96.94305 | 13.04999 |
| 27            | 23054 | 14.67 | 19.19 | 44.79 | 43    | 47.14 | 6.558 | 82.01316 | -1.8799  |
| 28            | 23215 | 14.65 | 19.16 | 44.08 | 42.59 | 46.35 | 6.558 | 87.04733 | 3.154273 |
| Sol106 Full:  |       |       |       |       |       |       |       |          |          |
| A             | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1             | 17558 | 14.06 | 16.58 | 44.92 | 42.23 | 46.52 | 6.932 | 89.78309 | -2.50446 |
| 2             | 17719 | 14.07 | 16.56 | 44.16 | 42.34 | 46.77 | 7.072 | 79.02951 | -13.258  |
| 3             | 17879 | 14.07 | 16.51 | 44.97 | 42.55 | 47.09 | 7.052 | 99.72478 | 7.43723  |
| 4             | 18041 | 14.06 | 16.49 | 43.91 | 42.3  | 46.58 | 7.002 | 88.95635 | -3.3312  |
| 5             | 18201 | 14.05 | 16.48 | 44.72 | 42.51 | 47.02 | 7.052 | 87.42899 | -4.85856 |
| 6             | 18362 | 14.08 | 16.46 | 44.08 | 42.18 | 46.4  | 6.972 | 101.8558 | 9.568269 |
| 7             | 18523 | 14.07 | 16.45 | 44.43 | 42.49 | 46.99 | 7.122 | 86.93041 | -5.35714 |
| 8             | 18683 | 14.05 | 16.44 | 45.26 | 42.41 | 46.87 | 6.962 | 81.70218 | -10.5854 |
| 9             | 18844 | 14.07 | 16.43 | 44.15 | 42.42 | 46.82 | 7.072 | 98.59034 | 6.302794 |
| 10            | 19005 | 14.06 | 16.42 | 45.01 | 42.46 | 46.95 | 6.962 | 85.22281 | -7.06474 |
| 11            | 19165 | 14.06 | 16.42 | 43.94 | 42.29 | 46.6  | 7.002 | 90.30474 | -1.98281 |
| 12            | 19326 | 14.08 | 16.41 | 44.7  | 42.56 | 47.17 | 7.132 | 98.63445 | 6.346905 |
| 13            | 19487 | 14.08 | 16.42 | 43.72 | 42.15 | 46.39 | 6.932 | 111.1797 | 18.89219 |
| 14            | 19647 | 14.13 | 16.41 | 44.47 | 42.49 | 46.98 | 7.092 | 97.42717 | 5.139618 |
| 15            | 19809 | 14.06 | 16.4  | 45    | 42.26 | 46.63 | 6.962 | 95.27248 | 2.984929 |
| 16            | 19969 | 14.07 | 16.4  | 44.2  | 42.41 | 46.85 | 7.082 | 96.76998 | 4.48243  |
| 17            | 20130 | 14.05 | 16.41 | 45.08 | 42.34 | 46.77 | 6.912 | 94.29407 | 2.006516 |
| 18            | 20291 | 14.05 | 16.41 | 43.97 | 42.28 | 46.63 | 6.992 | 102.6842 | 10.39661 |
| 19            | 20451 | 14.07 | 16.41 | 45.23 | 42.42 | 46.96 | 6.942 | 88.54785 | -3.7397  |
| 20            | 20612 | 14.06 | 16.41 | 44.12 | 42.38 | 46.79 | 7.062 | 95.92603 | 3.638481 |
| 21            | 20773 | 14.06 | 16.41 | 44.87 | 42.57 | 47.16 | 7.092 | 86.97158 | -5.31597 |
| 22            | 20933 | 14.06 | 16.41 | 43.84 | 42.26 | 46.54 | 6.972 | 98.79886 | 6.511306 |
| 23            | 21094 | 14.06 | 16.41 | 44.61 | 42.49 | 47.02 | 7.082 | 84.27955 | -8.008   |
| 24            | 21255 | 14.06 | 16.41 | 44.4  | 42.16 | 46.43 | 6.942 | 101.9578 | 9.670247 |
| 25            | 21416 | 14.07 | 16.4  | 44.33 | 42.45 | 46.93 | 7.102 | 88.03032 | -4.25723 |
| 26            | 21577 | 14.06 | 16.4  | 44.82 | 42.17 | 46.48 | 6.882 | 87.00388 | -5.28367 |
| Sol106 Empty: |       |       |       |       |       |       |       |          |          |
| A             | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1             | 12512 | 14.07 | 16.52 | 43.62 | 42.01 | 46.52 | 7.015 | 73.72393 | -18.5636 |
| 2             | 12673 | 14.07 | 16.6  | 44.77 | 42.46 | 47.31 | 7.015 | 88.29278 | -3.99477 |
| 3             | 12833 | 14.07 | 16.65 | 43.77 | 42.17 | 46.64 | 7.015 | 90.05381 | -2.23374 |
| 4             | 12994 | 14.08 | 16.69 | 44.61 | 42.45 | 47.15 | 7.015 | 98.52705 | 6.2395   |
| 5             | 13155 | 14.07 | 16.71 | 43.64 | 42.11 | 46.44 | 7.015 | 91.3843  | -0.90325 |

| 6            | 13315 | 14.11 | 16.72 | 44.45 | 42.42 | 47.03 | 7.015 | 105.0055 | 12.71792 |
|--------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| 7            | 13476 | 14.09 | 16.73 | 44.03 | 42.05 | 46.3  | 7.015 | 88.88768 | -3.39987 |
| 8            | 13637 | 14.08 | 16.73 | 44.29 | 42.38 | 46.91 | 7.015 | 85.33829 | -6.94926 |
| 9            | 13798 | 14.07 | 16.73 | 44.56 | 42.07 | 46.35 | 7.015 | 90.9739  | -1.31365 |
| 10           | 13959 | 14.08 | 16.73 | 44.15 | 42.33 | 46.78 | 7.015 | 97.11357 | 4.826016 |
| 11           | 14119 | 14.06 | 16.72 | 45.11 | 42.19 | 46.56 | 7.015 | 96.23221 | 3.94466  |
| 12           | 14280 | 14.08 | 16.72 | 44.01 | 42.28 | 46.65 | 7.015 | 93.53963 | 1.252085 |
| 13           | 14441 | 14.07 | 16.71 | 44.84 | 42.5  | 47.07 | 7.015 | 81.96601 | -10.3215 |
| 14           | 14602 | 14.11 | 16.71 | 43.82 | 42.23 | 46.5  | 7.015 | 83.96638 | -8.32117 |
| 15           | 14762 | 14.09 | 16.71 | 44.63 | 42.49 | 47.05 | 7.015 | 105.3195 | 13.03194 |
| 16           | 14923 | 14.08 | 16.71 | 43.65 | 42.13 | 46.32 | 7.015 | 86.05727 | -6.23028 |
| 17           | 15084 | 14.09 | 16.71 | 44.46 | 42.44 | 46.93 | 7.015 | 100.2554 | 7.96783  |
| 18           | 15245 | 14.07 | 16.7  | 44.9  | 42.22 | 46.55 | 7.015 | 100.8997 | 8.612148 |
| 19           | 15405 | 14.1  | 16.7  | 44.24 | 42.44 | 46.86 | 7.015 | 92.69327 | 0.405721 |
| 20           | 15566 | 14.06 | 16.69 | 45.14 | 42.34 | 46.74 | 7.015 | 100.395  | 8.107438 |
| 21           | 15727 | 14.1  | 16.68 | 44.04 | 42.34 | 46.68 | 7.015 | 89.48796 | -2.79959 |
| 22           | 15887 | 14.07 | 16.67 | 44.94 | 42.41 | 46.87 | 7.015 | 93.35371 | 1.066156 |
| 23           | 16048 | 14.08 | 16.65 | 43.87 | 42.24 | 46.51 | 7.015 | 112.0794 | 19.79183 |
| 24           | 22476 | 14.06 | 16.42 | 44.79 | 42.16 | 46.46 | 7.015 | 81.66766 | -10.6199 |
| 25           | 22637 | 14.1  | 16.4  | 44.1  | 42.32 | 46.73 | 7.015 | 89.55833 | -2.72922 |
| 26           | 22797 | 14.1  | 16.39 | 44.9  | 42.48 | 47.01 | 7.015 | 87.02799 | -5.25956 |
| 27           | 22958 | 14.07 | 16.36 | 43.83 | 42.22 | 46.53 | 7.015 | 98.64219 | 6.35464  |
| 28           | 23119 | 14.08 | 16.34 | 44.56 | 42.51 | 47.07 | 7.015 | 82.82373 | -9.46382 |
| 29           | 23279 | 14.07 | 16.31 | 43.88 | 42.09 | 46.3  | 7.015 | 91.073   | -1.21455 |
| Sol292 Full: |       |       |       |       |       |       |       |          |          |
| A            | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1            | 17416 | 12.46 | 17.15 | 44.83 | 42.67 | 47.11 | 7.292 | 96.76794 | -13.1652 |
| 2            | 17577 | 12.44 | 17.15 | 44.18 | 42.35 | 46.48 | 7.122 | 101.7995 | -8.13364 |
| 3            | 17738 | 12.44 | 17.19 | 44.53 | 42.63 | 47.05 | 7.342 | 88.46887 | -21.4643 |
| 4            | 17898 | 12.46 | 17.18 | 44.58 | 42.29 | 46.42 | 7.112 | 111.4216 | 1.488405 |
| 5            | 18059 | 12.45 | 17.17 | 44.3  | 42.53 | 46.84 | 7.292 | 107.8867 | -2.04645 |
| 6            | 18220 | 12.44 | 17.14 | 45.11 | 42.59 | 46.99 | 7.182 | 107.393  | -2.54019 |
| 7            | 18380 | 12.45 | 17.1  | 44.04 | 42.44 | 46.65 | 7.212 | 99.99757 | -9.93558 |
| 8            | 18541 | 12.5  | 17.04 | 44.84 | 42.59 | 46.96 | 7.202 | 119.321  | 9.3878   |
| 9            | 18702 | 12.43 | 16.98 | 43.83 | 42.29 | 46.42 | 7.152 | 111.2752 | 1.342021 |
| 10           | 18862 | 12.44 | 16.92 | 44.53 | 42.58 | 46.97 | 7.312 | 117.5766 | 7.643471 |
| 11           | 19023 | 12.44 | 16.85 | 45    | 42.36 | 46.6  | 7.142 | 103.6145 | -6.31865 |
| 12           | 19184 | 12.43 | 16.8  | 44.23 | 42.5  | 46.81 | 7.262 | 118.9729 | 9.039723 |
| 13           | 19344 | 12.43 | 16.76 | 45    | 42.63 | 47.08 | 7.222 | 113.713  | 3.779828 |
| 14           | 19505 | 12.41 | 16.72 | 43.95 | 42.37 | 46.58 | 7.182 | 117.581  | 7.647871 |
| 15           | 19666 | 12.43 | 16.7  | 45.11 | 42.68 | 47.2  | 7.272 | 112.8337 | 2.900532 |
| 16           | 19826 | 12.44 | 16.68 | 43.98 | 42.44 | 46.7  | 7.232 | 118.1863 | 8.253178 |
| 17           | 19987 | 12.42 | 16.66 | 44.82 | 42.59 | 47.03 | 7.222 | 104.3821 | -5.55102 |

| 18            | 20148 | 12.41 | 16.64 | 43.89 | 42.27 | 46.53 | 7.152 | 112.086  | 2.152864 |
|---------------|-------|-------|-------|-------|-------|-------|-------|----------|----------|
| 19            | 20308 | 12.45 | 16.63 | 44.85 | 42.72 | 47.29 | 7.392 | 120.2703 | 10.33719 |
| 20            | 20469 | 12.43 | 16.62 | 43.85 | 42.34 | 46.52 | 7.152 | 131.5083 | 21.57513 |
| 21            | 20630 | 12.43 | 16.6  | 44.51 | 42.59 | 47.03 | 7.302 | 112.0479 | 2.114744 |
| 22            | 20790 | 12.43 | 16.59 | 44.03 | 42.17 | 46.27 | 7.092 | 105.9282 | -4.00495 |
| 23            | 20951 | 12.43 | 16.59 | 44.71 | 42.65 | 47.19 | 7.362 | 105.2734 | -4.65976 |
| 24            | 21111 | 12.43 | 16.59 | 43.92 | 42.25 | 46.4  | 7.152 | 115.7771 | 5.843952 |
| 25            | 21272 | 12.43 | 16.58 | 44.79 | 42.7  | 47.26 | 7.372 | 108.3582 | -1.57492 |
| Sol292 Empty: |       |       |       |       |       |       |       |          |          |
| A             | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1             | 12372 | 12.41 | 17.13 | 44.57 | 42.49 | 47.25 | 7.229 | 110.2908 | 0.357647 |
| 2             | 12533 | 12.41 | 17.2  | 43.86 | 42.13 | 46.47 | 7.229 | 107.7875 | -2.14566 |
| 3             | 12693 | 12.45 | 17.25 | 44.4  | 42.47 | 47.05 | 7.229 | 97.62357 | -12.3096 |
| 4             | 12854 | 12.44 | 17.28 | 44.36 | 42.13 | 46.39 | 7.229 | 110.2016 | 0.268405 |
| 5             | 13014 | 12.42 | 17.3  | 44.57 | 42.61 | 47.19 | 7.229 | 100.8571 | -9.07601 |
| 6             | 13176 | 12.44 | 17.32 | 44.25 | 42.23 | 46.44 | 7.229 | 113.2934 | 3.360294 |
| 7             | 13336 | 12.46 | 17.34 | 44.38 | 42.54 | 46.98 | 7.229 | 97.56478 | -12.3684 |
| 8             | 13497 | 12.47 | 17.3  | 44.73 | 42.25 | 46.47 | 7.229 | 114.7462 | 4.813009 |
| 9             | 13658 | 12.46 | 17.36 | 44.21 | 42.46 | 46.8  | 7.229 | 104.6422 | -5.29093 |
| 10            | 13818 | 12.46 | 17.42 | 45.04 | 42.6  | 47.06 | 7.229 | 105.3439 | -4.58926 |
| 11            | 13979 | 12.47 | 17.35 | 44    | 42.42 | 46.64 | 7.229 | 114.5773 | 4.644116 |
| 12            | 14140 | 12.47 | 17.32 | 45.17 | 42.7  | 47.21 | 7.229 | 109.9898 | 0.056694 |
| 13            | 14300 | 12.47 | 17.29 | 44.13 | 42.52 | 46.77 | 7.229 | 116.1044 | 6.171202 |
| 14            | 14461 | 12.45 | 17.25 | 44.94 | 42.66 | 47.09 | 7.229 | 105.533  | -4.40012 |
| 15            | 14622 | 12.5  | 17.2  | 43.93 | 42.39 | 46.55 | 7.229 | 118.465  | 8.531816 |
| 16            | 14782 | 12.46 | 17.14 | 45.08 | 42.73 | 47.24 | 7.229 | 110.2832 | 0.350048 |
| 17            | 14943 | 12.47 | 17.09 | 44.05 | 42.48 | 46.69 | 7.229 | 111.9352 | 2.002023 |
| 18            | 15103 | 12.46 | 17.04 | 44.83 | 42.66 | 47.07 | 7.229 | 112.2417 | 2.308552 |
| 19            | 15264 | 12.46 | 17    | 44.11 | 42.34 | 46.46 | 7.229 | 100.3607 | -9.57247 |
| 20            | 15425 | 12.47 | 16.97 | 44.55 | 42.64 | 47.04 | 7.229 | 110.604  | 0.670833 |
| 21            | 15586 | 12.46 | 16.96 | 44.52 | 42.28 | 46.4  | 7.229 | 123.3894 | 13.45628 |
| 22            | 15746 | 12.48 | 16.94 | 44.32 | 42.53 | 46.86 | 7.229 | 107.5007 | -2.43243 |
| 23            | 22175 | 12.45 | 16.64 | 45.01 | 42.73 | 47.33 | 7.229 | 108.0585 | -1.87467 |
| 24            | 22335 | 12.45 | 16.63 | 43.97 | 42.42 | 46.67 | 7.229 | 114.2711 | 4.337924 |
| 25            | 22496 | 12.44 | 16.64 | 44.7  | 42.61 | 47.08 | 7.229 | 111.0682 | 1.13502  |
| 26            | 22657 | 12.43 | 16.66 | 44.35 | 42.26 | 46.46 | 7.229 | 112.1906 | 2.257421 |
| 27            | 22817 | 12.44 | 16.68 | 44.39 | 42.54 | 46.94 | 7.229 | 119.9849 | 10.05178 |
| 28            | 22978 | 12.44 | 16.7  | 45.18 | 42.51 | 46.95 | 7.229 | 109.2195 | -0.7137  |
| Sol306 Full:  |       |       |       |       |       |       |       |          |          |
| A             | B     | C     | D     | E     | F     | G     | H     | I        | J        |
| 1             | 3045  | 2.83  | 14.32 | 44.01 | 42.11 | 48.23 | 6.522 | 3.815164 | 0.882994 |
| 2             | 3206  | 2.84  | 14.4  | 44.96 | 42.36 | 48.42 | 6.462 | 7.34974  | 4.41757  |
| 3             | 3367  | 2.87  | 14.44 | 43.47 | 42.06 | 47.59 | 6.412 | 20.85264 | 17.92047 |

|               |       |      |       |       |       |       |       |          |          |
|---------------|-------|------|-------|-------|-------|-------|-------|----------|----------|
| 4             | 3527  | 2.87 | 14.48 | 44.5  | 42.47 | 48.22 | 6.602 | 16.35376 | 13.42159 |
| 5             | 3688  | 2.89 | 14.52 | 44.67 | 42.15 | 47.5  | 6.342 | -3.06665 | -5.99882 |
| 6             | 3848  | 2.89 | 14.55 | 44.08 | 42.43 | 47.84 | 6.612 | -2.54729 | -5.47946 |
| 7             | 4009  | 2.89 | 14.58 | 45.21 | 42.55 | 48.01 | 6.482 | 7.940311 | 5.008141 |
| 8             | 4170  | 2.93 | 14.61 | 43.72 | 42.33 | 47.44 | 6.512 | 3.422185 | 0.490015 |
| 9             | 4330  | 2.93 | 14.64 | 44.69 | 42.68 | 48.05 | 6.682 | 11.13514 | 8.202975 |
| 10            | 4491  | 2.95 | 14.67 | 44.64 | 42.31 | 47.3  | 6.452 | 4.758878 | 1.826708 |
| 11            | 4652  | 2.96 | 14.7  | 44.28 | 42.62 | 47.78 | 6.692 | 9.257345 | 6.325175 |
| 12            | 4812  | 2.95 | 14.73 | 45.37 | 42.67 | 47.86 | 6.542 | 14.87495 | 11.94278 |
| 13            | 4973  | 2.98 | 14.75 | 43.91 | 42.5  | 47.42 | 6.592 | 15.71087 | 12.7787  |
| 14            | 5134  | 2.97 | 14.79 | 44.88 | 42.82 | 48.01 | 6.732 | 15.59188 | 12.65971 |
| 15            | 5294  | 2.99 | 14.82 | 44.62 | 42.43 | 47.26 | 6.552 | 12.66532 | 9.733147 |
| 16            | 5455  | 2.98 | 14.87 | 44.47 | 42.77 | 47.82 | 6.772 | 5.882562 | 2.950392 |
| 17            | 5615  | 3    | 14.99 | 45.49 | 42.75 | 47.8  | 6.592 | 5.412557 | 2.480387 |
| 18            | 5776  | 3.03 | 15.02 | 44.08 | 42.64 | 47.48 | 6.672 | 13.24316 | 10.31099 |
| 19            | 5937  | 3.02 | 15.09 | 44.56 | 42.75 | 47.7  | 6.692 | 8.598874 | 5.666704 |
| 20            | 6097  | 3.02 | 15.13 | 45.07 | 42.48 | 47.27 | 6.382 | 12.00407 | 9.071903 |
| 21            | 6258  | 3.03 | 15.16 | 44.26 | 42.69 | 47.55 | 6.722 | 1.61431  | -1.31786 |
| 22            | 6419  | 3.02 | 15.19 | 45.29 | 42.87 | 47.9  | 6.682 | -4.38101 | -7.31318 |
| 23            | 6579  | 3.04 | 15.2  | 43.91 | 42.51 | 47.26 | 6.622 | 12.60968 | 9.677507 |
| 24            | 6740  | 3.04 | 15.24 | 45.03 | 42.85 | 47.83 | 6.702 | 15.98493 | 13.05276 |
| Sol306 Empty: |       |      |       |       |       |       |       |          |          |
| A             | B     | C    | D     | E     | F     | G     | H     | I        | J        |
| 1             | 9101  | 3.04 | 15.91 | 44.96 | 42.69 | 47.28 | 6.584 | 10.29446 | 7.362286 |
| 2             | 9261  | 3.06 | 15.89 | 43.77 | 42.45 | 46.76 | 6.584 | 1.363006 | -1.56916 |
| 3             | 9422  | 3.06 | 15.86 | 44.46 | 42.67 | 47.21 | 6.584 | -2.92177 | -5.85394 |
| 4             | 9583  | 3.06 | 15.83 | 44.39 | 42.29 | 46.55 | 6.584 | 17.63237 | 14.7002  |
| 5             | 9743  | 3.06 | 15.8  | 44.44 | 42.73 | 47.33 | 6.584 | -4.9655  | -7.89767 |
| 6             | 9904  | 3.05 | 15.76 | 45.03 | 42.49 | 46.9  | 6.584 | 5.60066  | 2.66849  |
| 7             | 10065 | 3.06 | 15.72 | 43.94 | 42.52 | 46.93 | 6.584 | 8.789412 | 5.857242 |
| 8             | 10225 | 3.05 | 15.68 | 44.58 | 42.73 | 47.35 | 6.584 | 0.318399 | -2.61377 |
| 9             | 10386 | 3.04 | 15.65 | 45.18 | 42.56 | 47.07 | 6.584 | 8.240147 | 5.307977 |
| 10            | 10546 | 3.05 | 15.61 | 44.03 | 42.58 | 47.14 | 6.584 | -11.2075 | -14.1397 |
| 11            | 10707 | 3.08 | 15.59 | 45.19 | 42.77 | 47.5  | 6.584 | 9.844905 | 6.912735 |
| 12            | 10868 | 3.04 | 15.58 | 43.92 | 42.55 | 47.01 | 6.584 | 1.912447 | -1.01972 |
| 13            | 11028 | 3.04 | 15.57 | 45.03 | 42.86 | 47.64 | 6.584 | 8.372391 | 5.440221 |
| 14            | 11189 | 3.05 | 15.58 | 43.79 | 42.5  | 46.92 | 6.584 | 4.560537 | 1.628367 |
| 15            | 11350 | 3.04 | 15.6  | 44.42 | 42.69 | 47.33 | 6.584 | -6.72762 | -9.65979 |
| 16            | 11510 | 3.03 | 15.62 | 45.39 | 42.62 | 47.24 | 6.584 | 4.352027 | 1.419857 |
| 17            | 11671 | 3.04 | 15.64 | 44.21 | 42.7  | 47.31 | 6.584 | -5.61156 | -8.54373 |
| Sol313 Full:  |       |      |       |       |       |       |       |          |          |
| A             | B     | C    | D     | E     | F     | G     | H     | I        | J        |
| 1             | 17557 | 3.18 | 16.94 | 44.58 | 43.03 | 46.86 | 7.352 | 3.346288 | 2.001868 |

| 2             | 17718 | 3.18 | 16.98 | 45.38 | 42.97 | 46.79 | 7.212 | 8.582943 | 7.238523 |
|---------------|-------|------|-------|-------|-------|-------|-------|----------|----------|
| 3             | 17879 | 3.21 | 17.03 | 44.32 | 42.95 | 46.69 | 7.382 | 1.73746  | 0.39304  |
| 4             | 18039 | 3.19 | 17.09 | 45.12 | 43.01 | 46.83 | 7.212 | 5.93089  | 4.58647  |
| 5             | 18200 | 3.2  | 17.12 | 44.1  | 42.82 | 46.46 | 7.222 | 7.039234 | 5.694814 |
| 6             | 18361 | 3.19 | 17.14 | 44.81 | 43.08 | 46.96 | 7.352 | -6.24634 | -7.59076 |
| 7             | 18521 | 3.19 | 17.15 | 43.95 | 42.7  | 46.23 | 7.172 | -3.51292 | -4.85734 |
| 8             | 18682 | 3.19 | 17.16 | 44.62 | 43    | 46.76 | 7.322 | 1.170393 | -0.17403 |
| 9             | 18843 | 3.19 | 17.16 | 45.27 | 42.83 | 46.54 | 7.172 | -12.3959 | -13.7403 |
| 10            | 19004 | 3.2  | 17.16 | 44.36 | 42.96 | 46.7  | 7.302 | 4.001516 | 2.657096 |
| 11            | 19164 | 3.19 | 17.14 | 45.23 | 42.92 | 46.7  | 7.152 | -11.4434 | -12.7879 |
| 12            | 19325 | 3.21 | 17.11 | 44.17 | 42.85 | 46.52 | 7.242 | 0.800171 | -0.54425 |
| 13            | 19486 | 3.19 | 17.08 | 44.93 | 43.09 | 46.98 | 7.322 | -8.56252 | -9.90694 |
| 14            | 19647 | 3.2  | 17.04 | 43.95 | 42.75 | 46.32 | 7.172 | 17.14424 | 15.79982 |
| 15            | 19807 | 3.18 | 17    | 44.71 | 43.02 | 46.88 | 7.312 | 3.947851 | 2.603431 |
| 16            | 19968 | 3.19 | 16.96 | 44.93 | 42.76 | 46.41 | 7.172 | -1.1526  | -2.49702 |
| 17            | 20129 | 3.21 | 16.92 | 44.46 | 42.99 | 46.78 | 7.332 | 8.995767 | 7.651347 |
| 18            | 20289 | 3.19 | 16.89 | 45.25 | 43.1  | 46.99 | 7.242 | 13.58355 | 12.23913 |
| 19            | 20450 | 3.22 | 16.84 | 44.21 | 42.97 | 46.6  | 7.252 | 20.54244 | 19.19802 |
| 20            | 20611 | 3.18 | 16.83 | 45.01 | 43.07 | 46.95 | 7.262 | 8.387115 | 7.042695 |
| 21            | 20772 | 3.19 | 16.79 | 44.13 | 42.78 | 46.41 | 7.272 | 3.513235 | 2.168815 |
| 22            | 20932 | 3.19 | 16.76 | 44.73 | 43.09 | 47    | 7.452 | 1.953025 | 0.608605 |
| 23            | 21094 | 3.19 | 16.73 | 44.5  | 42.7  | 46.28 | 7.142 | 6.360597 | 5.016177 |
| 24            | 21254 | 3.19 | 16.69 | 44.51 | 42.99 | 46.8  | 7.312 | 10.01802 | 8.673602 |
| 25            | 21415 | 3.19 | 16.65 | 44.95 | 42.7  | 46.34 | 7.102 | 4.986781 | 3.642361 |
| 26            | 21576 | 3.19 | 16.61 | 44.33 | 42.87 | 46.61 | 7.252 | 1.734795 | 0.390375 |
| Sol313 Empty: |       |      |       |       |       |       |       |          |          |
| A             | B     | C    | D     | E     | F     | G     | H     | I        | J        |
| 1             | 12832 | 3.18 | 16.51 | 44.87 | 42.6  | 46.52 | 7.257 | -0.7421  | -2.08652 |
| 2             | 12993 | 3.19 | 16.6  | 44.32 | 42.82 | 46.84 | 7.257 | 3.720919 | 2.376499 |
| 3             | 13154 | 3.18 | 16.69 | 45.12 | 42.97 | 47.07 | 7.257 | 19.48798 | 18.14356 |
| 4             | 13314 | 3.2  | 16.8  | 44.11 | 42.78 | 46.64 | 7.257 | 3.442056 | 2.097636 |
| 5             | 13475 | 3.19 | 16.9  | 44.91 | 42.98 | 47.01 | 7.257 | -4.62418 | -5.9686  |
| 6             | 13636 | 3.21 | 16.98 | 44.13 | 42.69 | 46.42 | 7.257 | 21.11955 | 19.77513 |
| 7             | 13796 | 3.2  | 17.05 | 44.66 | 43.03 | 47    | 7.257 | -0.01354 | -1.35796 |
| 8             | 13957 | 3.19 | 17.09 | 44.57 | 42.67 | 46.34 | 7.257 | -3.32243 | -4.66685 |
| 9             | 14118 | 3.23 | 17.12 | 44.47 | 42.99 | 46.83 | 7.257 | 4.761399 | 3.416979 |
| 10            | 14279 | 3.21 | 17.14 | 45.05 | 42.72 | 46.42 | 7.257 | -0.48184 | -1.82626 |
| 11            | 14440 | 3.21 | 17.15 | 44.31 | 42.88 | 46.67 | 7.257 | -1.26126 | -2.60568 |
| 12            | 14600 | 3.2  | 17.17 | 45.13 | 43.06 | 47    | 7.257 | -7.39677 | -8.74119 |
| 13            | 14761 | 3.21 | 17.17 | 44.14 | 42.84 | 46.45 | 7.257 | 0.199528 | -1.14489 |
| 14            | 14922 | 3.2  | 17.16 | 44.93 | 43.07 | 46.97 | 7.257 | -0.08164 | -1.42606 |
| 15            | 15082 | 3.21 | 17.15 | 44.35 | 42.76 | 46.38 | 7.257 | 0.192271 | -1.15215 |
| 16            | 15243 | 3.21 | 17.14 | 44.69 | 43.1  | 46.98 | 7.257 | -1.07048 | -2.4149  |

| 17            | 15404 | 3.22   | 17.11    | 44.83    | 42.77    | 46.39    | 7.257  | -6.85488 | -8.1993  |
|---------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 18            | 15565 | 3.18   | 17.09    | 44.51    | 43.04    | 46.83    | 7.257  | -15.0198 | -16.3642 |
| 19            | 15726 | 3.2    | 17.06    | 45.24    | 42.84    | 46.54    | 7.257  | 1.0685   | -0.27592 |
| 20            | 15886 | 3.2    | 17.01    | 44.35    | 42.95    | 46.69    | 7.257  | 1.668028 | 0.323608 |
| 21            | 16047 | 3.19   | 17       | 45.14    | 43.14    | 47.06    | 7.257  | -1.05834 | -2.40276 |
| 22            | 17557 | 3.18   | 16.94    | 44.58    | 43.03    | 46.86    | 7.257  | 4.550112 | 3.205692 |
| 23            | 22469 | 3.2    | 16.5     | 44.03    | 42.76    | 46.43    | 7.257  | 6.146927 | 4.802507 |
| 24            | 22630 | 3.19   | 16.45    | 44.82    | 42.95    | 46.85    | 7.257  | 1.81682  | 0.4724   |
| 25            | 22791 | 3.19   | 16.41    | 44.17    | 42.62    | 46.25    | 7.257  | 5.711335 | 4.366915 |
| 26            | 22952 | 3.19   | 16.37    | 44.55    | 42.94    | 46.84    | 7.257  | 1.134143 | -0.21028 |
| 27            | 23112 | 3.17   | 16.34    | 45.35    | 42.84    | 46.7     | 7.257  | 5.258879 | 3.914459 |
| 28            | 23273 | 3.19   | 16.31    | 44.31    | 42.87    | 46.62    | 7.257  | -0.70735 | -2.05177 |
| Sol466 Full:  |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 15709 | 5.311  | 16.0123  | 43.92057 | 42.61845 | 46.42974 | 7.6587 | 28.30752 | 7.934239 |
| 2             | 16019 | 5.3141 | 16.09998 | 44.0702  | 42.50471 | 46.24944 | 7.6277 | 28.44428 | 8.070997 |
| 3             | 16179 | 5.3172 | 16.11435 | 44.82478 | 42.96845 | 47.11537 | 7.854  | 17.76879 | -2.60449 |
| 4             | 16343 | 5.3203 | 16.12872 | 43.99538 | 42.56896 | 46.33775 | 7.6401 | 33.35084 | 12.97756 |
| 5             | 16508 | 5.3172 | 16.13447 | 44.54899 | 42.85192 | 46.89182 | 7.7734 | 28.26643 | 7.893146 |
| 6             | 16672 | 5.3048 | 16.13447 | 45.35021 | 42.75901 | 46.75991 | 7.6277 | 35.82834 | 15.45506 |
| 7             | 16837 | 5.3141 | 16.12297 | 44.26077 | 42.77558 | 46.70653 | 7.7176 | 37.62974 | 17.25646 |
| 8             | 17001 | 5.2955 | 16.10142 | 45.05384 | 42.84362 | 46.89003 | 7.6556 | 23.93667 | 3.563393 |
| 9             | 17166 | 5.3079 | 16.07555 | 44.00218 | 42.62175 | 46.45275 | 7.6494 | 32.98423 | 12.61095 |
| 10            | 17330 | 5.3079 | 16.04105 | 45.18012 | 42.94178 | 47.10104 | 7.7455 | 22.56205 | 2.188769 |
| 11            | 17495 | 5.3265 | 15.99792 | 44.11782 | 42.70934 | 46.59104 | 7.6959 | 31.59868 | 11.2254  |
| 12            | 17805 | 5.3141 | 15.94616 | 44.27099 | 42.81539 | 46.75279 | 7.7331 | 45.04141 | 24.66813 |
| 13            | 17969 | 5.2924 | 15.91164 | 45.43375 | 42.98347 | 47.12613 | 7.6928 | 19.93991 | -0.43337 |
| 14            | 18129 | 5.311  | 15.8915  | 44.35787 | 42.87353 | 46.84722 | 7.7455 | 29.32337 | 8.95009  |
| 15            | 18293 | 5.2986 | 15.87567 | 45.28245 | 42.67792 | 46.59281 | 7.5564 | 29.57614 | 9.202861 |
| 16            | 18458 | 5.3079 | 15.87711 | 44.47727 | 42.88517 | 46.91502 | 7.7734 | 13.43971 | -6.93357 |
| 17            | 18622 | 5.2831 | 15.88287 | 45.35717 | 42.72423 | 46.67986 | 7.575  | 26.5934  | 6.220125 |
| 18            | 18787 | 5.2986 | 15.89725 | 44.53362 | 42.93178 | 46.9847  | 7.7889 | 11.44899 | -8.92429 |
| 19            | 18951 | 5.2986 | 15.91308 | 45.36761 | 42.75735 | 46.71898 | 7.5936 | 22.77721 | 2.403928 |
| 20            | 19116 | 5.3203 | 15.95191 | 44.54387 | 42.95011 | 47.00258 | 7.7982 | 26.12028 | 5.747001 |
| 21            | 19280 | 5.2955 | 16.07268 | 45.26856 | 42.7557  | 46.70653 | 7.5843 | 22.92588 | 2.552596 |
| 22            | 19584 | 5.3017 | 16.15745 | 45.28939 | 42.66635 | 46.59637 | 7.5378 | 18.46465 | -1.90863 |
| 23            | 19749 | 5.3048 | 16.22496 | 44.47897 | 42.88517 | 46.91324 | 7.7517 | 33.41192 | 13.03864 |
| 24            | 19913 | 5.2955 | 16.27378 | 45.38327 | 42.74576 | 46.69942 | 7.575  | 9.675543 | -10.6977 |
| 25            | 20078 | 5.3141 | 16.30967 | 44.53703 | 42.94344 | 46.99364 | 7.8013 | 16.98204 | -3.39124 |
| Sol466 Empty: |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 10603 | 5.2707 | 15.51416 | 44.03619 | 42.4126  | 46.72788 | 7.686  | 22.94446 | 2.57118  |
| 2             | 10767 | 5.2769 | 15.6093  | 44.88322 | 42.60195 | 47.01331 | 7.686  | 26.03333 | 5.660045 |

| 3            | 10927 | 5.2707 | 15.66837 | 43.85429 | 42.41096 | 46.54313 | 7.686  | 23.42095 | 3.047668 |
|--------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 4            | 11091 | 5.2769 | 15.70582 | 44.68585 | 42.64982 | 46.97219 | 7.686  | 15.64116 | -4.73212 |
| 5            | 11250 | 5.3172 | 15.71878 | 44.0617  | 42.35676 | 46.35543 | 7.686  | 11.09059 | -9.28269 |
| 6            | 11410 | 5.2924 | 15.72166 | 44.47556 | 42.71099 | 46.96682 | 7.686  | 13.48295 | -6.89033 |
| 7            | 11574 | 5.2986 | 15.71734 | 44.61396 | 42.38632 | 46.3519  | 7.686  | 29.55567 | 9.182386 |
| 8            | 11739 | 5.2831 | 15.70726 | 44.26588 | 42.65148 | 46.77594 | 7.686  | 24.02075 | 3.647475 |
| 9            | 11903 | 5.2862 | 15.69286 | 45.14029 | 42.536   | 46.59992 | 7.686  | 15.10421 | -5.26907 |
| 10           | 12068 | 5.3017 | 15.67846 | 44.05319 | 42.55413 | 46.5662  | 7.686  | 13.42484 | -6.94844 |
| 11           | 12232 | 5.28   | 15.66261 | 44.8368  | 42.80212 | 47.02762 | 7.686  | 23.63699 | 3.263714 |
| 12           | 12397 | 5.3048 | 15.64676 | 43.82031 | 42.47673 | 46.35366 | 7.686  | 18.59094 | -1.78234 |
| 13           | 12561 | 5.2986 | 15.6338  | 44.58831 | 42.76067 | 46.92038 | 7.686  | 32.88347 | 12.51019 |
| 14           | 12725 | 5.3017 | 15.61506 | 44.13313 | 42.36661 | 46.17711 | 7.686  | 20.20541 | -0.16787 |
| 15           | 12890 | 5.2893 | 15.59777 | 44.37151 | 42.68949 | 46.77238 | 7.686  | 18.86326 | -1.51002 |
| 16           | 13054 | 5.2831 | 15.58048 | 45.21998 | 42.70603 | 46.83296 | 7.686  | 17.0419  | -3.33138 |
| 17           | 13219 | 5.2955 | 15.57471 | 44.11102 | 42.63331 | 46.61057 | 7.686  | 20.94208 | 0.568802 |
| 18           | 13383 | 5.2893 | 15.56318 | 44.91074 | 42.76895 | 46.91145 | 7.686  | 24.25814 | 3.884864 |
| 19           | 13543 | 5.2986 | 15.55165 | 43.90358 | 42.51459 | 46.40142 | 7.686  | 25.37435 | 5.001068 |
| 20           | 13707 | 5.2924 | 15.53435 | 44.6208  | 42.82867 | 47.06342 | 7.686  | 25.03901 | 4.66573  |
| 21           | 13866 | 5.2893 | 15.52569 | 44.23013 | 42.4389  | 46.2565  | 7.686  | 14.53637 | -5.83691 |
| 22           | 14030 | 5.3017 | 15.51704 | 44.43972 | 42.75073 | 46.84009 | 7.686  | 33.22836 | 12.85508 |
| 23           | 21158 | 5.3017 | 16.36994 | 43.87468 | 42.61515 | 46.44036 | 7.686  | 3.038    | -17.3353 |
| 24           | 21322 | 5.2862 | 16.32976 | 45.00896 | 42.97012 | 47.17994 | 7.686  | 28.96963 | 8.59635  |
| 25           | 21486 | 5.2955 | 16.25368 | 43.99708 | 42.72423 | 46.47046 | 7.686  | 8.339099 | -12.0342 |
| 26           | 21651 | 5.2986 | 16.20342 | 44.70812 | 42.94011 | 46.9847  | 7.686  | 20.46948 | 0.096204 |
| 27           | 21815 | 5.2955 | 16.1632  | 44.23694 | 42.53435 | 46.24944 | 7.686  | 19.94311 | -0.43017 |
| Sol474 Full: |       |        |          |          |          |          |        |          |          |
| A            | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1            | 15524 | 5.2831 | 16.05543 | 45.20611 | 42.80709 | 46.79197 | 7.5471 | 19.90683 | -0.1882  |
| 2            | 15688 | 5.2831 | 16.02668 | 44.12633 | 42.70272 | 46.5591  | 7.6029 | 34.93569 | 14.84066 |
| 3            | 15852 | 5.2831 | 16.01086 | 45.35021 | 42.90514 | 47.0151  | 7.5998 | 19.53168 | -0.56335 |
| 4            | 16012 | 5.28   | 15.97204 | 44.28802 | 42.80709 | 46.74211 | 7.6618 | 42.00423 | 21.9092  |
| 5            | 16322 | 5.2831 | 15.99074 | 44.08721 | 42.69776 | 46.63188 | 7.5936 | 43.31711 | 23.22208 |
| 6            | 16486 | 5.2676 | 15.96773 | 45.30329 | 42.91845 | 47.02941 | 7.5998 | 30.05844 | 9.963411 |
| 7            | 16651 | 5.2955 | 15.94328 | 44.22332 | 42.77061 | 46.68697 | 7.6308 | 25.3376  | 5.242573 |
| 8            | 16815 | 5.2893 | 15.92171 | 44.94173 | 42.88351 | 46.94002 | 7.5998 | 12.11733 | -7.9777  |
| 9            | 16979 | 5.2831 | 15.89869 | 43.92737 | 42.5871  | 46.38019 | 7.5347 | 31.74783 | 11.6528  |
| 10           | 17144 | 5.28   | 15.87423 | 45.09531 | 42.95845 | 47.12254 | 7.6649 | 29.14913 | 9.054103 |
| 11           | 17308 | 5.2986 | 15.85409 | 44.0583  | 42.67792 | 46.53427 | 7.5812 | 33.21957 | 13.12454 |
| 12           | 17472 | 5.2924 | 15.83395 | 45.14375 | 43.02522 | 47.20866 | 7.6866 | 30.9649  | 10.86987 |
| 13           | 17632 | 5.2955 | 15.81812 | 44.13483 | 42.74079 | 46.6301  | 7.5936 | 25.74058 | 5.645545 |
| 14           | 17796 | 5.2955 | 15.80804 | 44.84024 | 42.92179 | 47.00795 | 7.6432 | 19.2979  | -0.79713 |
| 15           | 17955 | 5.2986 | 15.79509 | 43.87638 | 42.56896 | 46.34306 | 7.5037 | 25.61572 | 5.520693 |
| 16           | 18119 | 5.2893 | 15.78501 | 44.98309 | 42.97679 | 47.15482 | 7.6959 | 28.07835 | 7.983324 |

|               |       |        |          |          |          |          |        |          |          |
|---------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 17            | 18284 | 5.2955 | 15.78069 | 43.96988 | 42.63496 | 46.46161 | 7.5409 | 23.08255 | 2.987517 |
| 18            | 18448 | 5.2924 | 15.78213 | 44.65332 | 42.86356 | 46.92931 | 7.6525 | 24.43321 | 4.338177 |
| 19            | 18612 | 5.2862 | 15.78789 | 44.0753  | 42.44712 | 46.17887 | 7.482  | 17.52055 | -2.57448 |
| 20            | 18771 | 5.2707 | 15.78789 | 44.81276 | 42.93511 | 47.09208 | 7.7114 | 28.79869 | 8.703662 |
| 21            | 18936 | 5.2986 | 15.74182 | 44.03109 | 42.54259 | 46.32185 | 7.5316 | 31.72407 | 11.62904 |
| 22            | 19100 | 5.2986 | 15.8138  | 44.85055 | 42.9818  | 47.14585 | 7.73   | 17.11821 | -2.97682 |
| 23            | 19264 | 5.2893 | 15.85121 | 44.03789 | 42.5838  | 46.36427 | 7.5347 | 19.2237  | -0.87133 |
| 24            | 19429 | 5.2986 | 15.90301 | 44.88838 | 43.01686 | 47.18891 | 7.73   | 27.71287 | 7.617844 |
| 25            | 19593 | 5.3017 | 15.95191 | 44.04129 | 42.61515 | 46.40142 | 7.5409 | 32.28536 | 12.19033 |
| 26            | 19758 | 5.2924 | 15.95479 | 44.92624 | 43.0503  | 47.22123 | 7.7331 | 28.47158 | 8.376552 |
| Sol474 Empty: |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 10609 | 5.3017 | 15.35688 | 45.04693 | 42.597   | 47.09387 | 7.613  | 20.31876 | 0.223733 |
| 2             | 10773 | 5.3172 | 15.47666 | 43.95797 | 42.46357 | 46.6923  | 7.613  | 18.31722 | -1.77781 |
| 3             | 10938 | 5.3048 | 15.58624 | 45.16453 | 42.72423 | 47.15661 | 7.613  | 14.84457 | -5.25046 |
| 4             | 11097 | 5.3978 | 15.68278 | 44.10762 | 42.6036  | 46.78841 | 7.613  | 9.50554  | -10.5895 |
| 5             | 11261 | 5.2955 | 15.78357 | 45.28071 | 42.80046 | 47.15482 | 7.613  | 21.3261  | 1.231072 |
| 6             | 11420 | 5.3079 | 15.86848 | 44.21311 | 42.70603 | 46.85079 | 7.613  | 17.04259 | -3.05244 |
| 7             | 11585 | 5.2769 | 15.94328 | 44.95896 | 42.78387 | 46.99543 | 7.613  | 26.70237 | 6.607344 |
| 8             | 11744 | 5.2955 | 15.99074 | 43.94437 | 42.55907 | 46.5254  | 7.613  | 38.97767 | 18.88264 |
| 9             | 11908 | 5.2862 | 16.0468  | 44.97792 | 42.96678 | 47.26616 | 7.613  | 14.53356 | -5.56147 |
| 10            | 12218 | 5.2769 | 16.18044 | 45.30676 | 42.82701 | 46.9847  | 7.613  | 14.47054 | -5.62449 |
| 11            | 12378 | 5.2831 | 16.22783 | 44.23864 | 42.75404 | 46.7617  | 7.613  | 37.49272 | 17.39769 |
| 12            | 12542 | 5.2645 | 16.26517 | 45.41808 | 42.87353 | 47.01868 | 7.613  | 20.51183 | 0.416803 |
| 13            | 12707 | 5.2831 | 16.27378 | 44.30846 | 42.82369 | 46.82048 | 7.613  | 19.26225 | -0.83278 |
| 14            | 12871 | 5.2893 | 16.2824  | 45.05211 | 42.87353 | 46.94181 | 7.613  | 18.25512 | -1.83991 |
| 15            | 13035 | 5.3079 | 16.28096 | 44.00898 | 42.64817 | 46.48641 | 7.613  | 23.35    | 3.254969 |
| 16            | 13199 | 5.2893 | 16.27809 | 45.20264 | 42.94844 | 47.11    | 7.613  | 18.29715 | -1.79788 |
| 17            | 13364 | 5.2955 | 16.27235 | 44.14504 | 42.74245 | 46.6301  | 7.613  | 12.41914 | -7.67589 |
| 18            | 13528 | 5.2924 | 16.26804 | 45.26508 | 43.03358 | 47.19968 | 7.613  | 8.79226  | -11.3028 |
| 19            | 13693 | 5.2955 | 16.25942 | 44.2097  | 42.80875 | 46.7012  | 7.613  | 17.26117 | -2.83386 |
| 20            | 13852 | 5.2676 | 16.23645 | 45.45292 | 42.82037 | 46.83296 | 7.613  | 6.404321 | -13.6907 |
| 21            | 14016 | 5.2831 | 16.21491 | 44.38344 | 42.86688 | 46.83117 | 7.613  | 20.44452 | 0.349489 |
| 22            | 20837 | 5.3141 | 16.53773 | 44.52678 | 42.95011 | 46.96325 | 7.613  | 26.0597  | 5.964671 |
| 23            | 21001 | 5.3699 | 16.57212 | 44.52849 | 42.55578 | 46.24414 | 7.613  | 24.69647 | 4.601438 |
| 24            | 21166 | 5.3079 | 16.57212 | 44.67557 | 42.96845 | 47.02404 | 7.613  | 32.26013 | 12.1651  |
| 25            | 21330 | 5.2955 | 16.56926 | 44.62251 | 42.6069  | 46.35897 | 7.613  | 20.98654 | 0.891509 |
| 26            | 21495 | 5.3141 | 16.55493 | 44.75955 | 43.04027 | 47.11896 | 7.613  | 19.93859 | -0.15644 |
| Sol504 Full:  |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 14074 | 5.4133 | 16.27091 | 44.50117 | 42.88018 | 46.84365 | 7.6897 | 25.58666 | 2.902566 |
| 2             | 14239 | 5.4102 | 16.20055 | 44.92107 | 42.5937  | 46.36958 | 7.4913 | 11.46481 | -11.2193 |
| 3             | 14403 | 5.3172 | 16.14309 | 44.61054 | 42.93344 | 46.97934 | 7.7455 | 29.26331 | 6.579217 |

|               |       |        |          |          |          |          |        |          |          |
|---------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 4             | 14568 | 5.3854 | 16.09998 | 44.97964 | 42.66139 | 46.46515 | 7.5037 | 25.15922 | 2.475131 |
| 5             | 14732 | 5.3854 | 16.07268 | 44.33402 | 42.82037 | 46.72788 | 7.6432 | 30.76541 | 8.081324 |
| 6             | 14897 | 5.3792 | 16.0813  | 45.4355  | 42.75901 | 46.69764 | 7.5037 | 31.47654 | 8.79245  |
| 7             | 15056 | 5.3668 | 16.10573 | 44.47385 | 42.90181 | 46.88825 | 7.6928 | 26.68292 | 3.998829 |
| 8             | 15220 | 5.3823 | 16.1474  | 45.43201 | 42.7905  | 46.72432 | 7.5161 | 16.97346 | -5.71063 |
| 9             | 15380 | 5.3761 | 16.17613 | 44.54558 | 42.96512 | 46.96682 | 7.7052 | 30.40926 | 7.725167 |
| 10            | 15544 | 5.3761 | 16.18618 | 45.37631 | 42.79382 | 46.6923  | 7.513  | 28.18483 | 5.50074  |
| 11            | 15709 | 5.3916 | 16.18618 | 44.57805 | 43.0035  | 47.00437 | 7.7176 | 37.89604 | 15.21195 |
| 12            | 15873 | 5.3792 | 16.18331 | 45.35717 | 42.81871 | 46.71898 | 7.5161 | 30.62005 | 7.935963 |
| 13            | 16032 | 5.3823 | 16.17469 | 44.34254 | 42.86854 | 46.76704 | 7.6246 | 41.00506 | 18.32097 |
| 14            | 16192 | 5.2366 | 16.16176 | 45.21824 | 42.82867 | 46.81335 | 7.5068 | 40.50287 | 17.81878 |
| 15            | 16356 | 5.3761 | 16.14452 | 44.13824 | 42.73913 | 46.56087 | 7.5781 | 34.50312 | 11.81903 |
| 16            | 16521 | 5.3761 | 16.12441 | 45.30329 | 42.95678 | 47.04194 | 7.5874 | 31.17277 | 8.48868  |
| 17            | 16680 | 5.3916 | 16.11004 | 44.25907 | 42.81871 | 46.70297 | 7.6184 | 21.3753  | -1.30879 |
| 18            | 16844 | 5.373  | 16.08417 | 45.03485 | 42.92345 | 46.94538 | 7.5657 | 29.5489  | 6.864814 |
| 19            | 17004 | 5.3792 | 16.05687 | 44.02769 | 42.67957 | 46.46869 | 7.5347 | 29.85367 | 7.169578 |
| 20            | 17168 | 5.3761 | 16.02668 | 45.19224 | 42.99682 | 47.12075 | 7.6308 | 30.01755 | 7.333462 |
| 21            | 17333 | 5.3792 | 15.98498 | 44.13654 | 42.75238 | 46.59814 | 7.575  | 42.36706 | 19.68297 |
| 22            | 17643 | 5.3792 | 15.97204 | 43.99198 | 42.6102  | 46.43682 | 7.5192 | 34.84183 | 12.15774 |
| 23            | 17807 | 5.3761 | 15.9102  | 45.10223 | 43.0035  | 47.14226 | 7.6959 | 24.32199 | 1.637901 |
| 24            | 17971 | 5.3761 | 15.88718 | 44.0719  | 42.71761 | 46.53959 | 7.5502 | 25.28739 | 2.603301 |
| 25            | 18136 | 5.3885 | 15.86848 | 44.81447 | 42.92845 | 46.98649 | 7.637  | 30.61271 | 7.928617 |
| Sol504 Empty: |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 10613 | 5.3482 | 15.63668 | 43.65055 | 42.3026  | 46.41558 | 7.594  | 31.63759 | 8.953496 |
| 2             | 10777 | 5.3544 | 15.71014 | 44.41925 | 42.60525 | 46.93288 | 7.594  | 21.31742 | -1.36667 |
| 3             | 10942 | 5.3482 | 15.7303  | 44.94173 | 42.42082 | 46.55732 | 7.594  | 21.14177 | -1.54232 |
| 4             | 11101 | 5.3265 | 15.7663  | 44.21311 | 42.6201  | 46.81335 | 7.594  | 6.24349  | -16.4406 |
| 5             | 11265 | 5.3482 | 15.77925 | 45.34152 | 42.5904  | 46.76704 | 7.594  | 26.91865 | 4.234558 |
| 6             | 11425 | 5.3544 | 15.77925 | 44.34765 | 42.75073 | 46.93109 | 7.594  | 23.70877 | 1.024675 |
| 7             | 11589 | 5.3451 | 15.78789 | 45.20958 | 42.64157 | 46.74211 | 7.594  | 28.16617 | 5.482076 |
| 8             | 11748 | 5.3761 | 15.80084 | 44.15355 | 42.65974 | 46.6923  | 7.594  | 26.14193 | 3.457836 |
| 9             | 11913 | 5.3606 | 15.85265 | 45.01068 | 42.7292  | 46.85614 | 7.594  | 21.2061  | -1.47799 |
| 10            | 12072 | 5.3761 | 15.92027 | 43.98178 | 42.56896 | 46.50058 | 7.594  | 7.214975 | -15.4691 |
| 11            | 12231 | 5.3575 | 15.99649 | 44.75098 | 42.85358 | 47.02404 | 7.594  | 26.96003 | 4.275938 |
| 12            | 12395 | 5.3978 | 16.08561 | 43.86618 | 42.48825 | 46.28475 | 7.594  | 27.56261 | 4.878516 |
| 13            | 19039 | 5.3854 | 15.85265 | 45.3085  | 42.93844 | 47.05268 | 7.594  | 27.20582 | 4.521725 |
| 14            | 19204 | 5.3637 | 15.81812 | 44.22502 | 42.78221 | 46.69942 | 7.594  | 20.70492 | -1.97917 |
| 15            | 19368 | 5.3823 | 15.77637 | 44.96758 | 42.90014 | 47.02226 | 7.594  | 28.64022 | 5.956133 |
| 16            | 19533 | 5.404  | 15.74182 | 43.95797 | 42.61845 | 46.4262  | 7.594  | 22.29739 | -0.3867  |
| 17            | 19698 | 5.3854 | 15.71446 | 45.10569 | 42.97679 | 47.14406 | 7.594  | 30.07966 | 7.395573 |
| 18            | 19862 | 5.3823 | 15.68566 | 44.0702  | 42.69941 | 46.5662  | 7.594  | 17.68464 | -4.99945 |
| 19            | 20026 | 5.3637 | 15.65397 | 45.30502 | 42.86522 | 46.98291 | 7.594  | 28.00447 | 5.320382 |

| 20            | 20185 | 5.3978 | 15.61939 | 44.24034 | 42.76398 | 46.71898 | 7.594  | 13.60451 | -9.07958 |
|---------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 21            | 20350 | 5.3761 | 15.6093  | 45.40067 | 42.87187 | 47.04552 | 7.594  | 17.45912 | -5.22497 |
| 22            | 20509 | 5.3916 | 15.57183 | 44.32209 | 42.82203 | 46.81691 | 7.594  | 19.56566 | -3.11843 |
| 23            | 20673 | 5.3792 | 15.54011 | 45.15933 | 42.60525 | 46.49172 | 7.594  | 19.8017  | -2.88239 |
| 24            | 20838 | 5.3947 | 15.53146 | 44.47727 | 42.85691 | 46.92395 | 7.594  | 30.37542 | 7.691333 |
| 25            | 21002 | 5.4691 | 15.50551 | 45.23212 | 42.68949 | 46.62833 | 7.594  | 23.90435 | 1.220265 |
| 26            | 21161 | 5.3017 | 15.47954 | 44.23694 | 42.69776 | 46.69586 | 7.594  | 21.56018 | -1.12391 |
| 27            | 21321 | 5.3761 | 15.44925 | 45.42156 | 42.70438 | 46.75635 | 7.594  | 21.93089 | -0.7532  |
| 28            | 21480 | 5.3823 | 15.42039 | 44.4022  | 42.82037 | 46.87754 | 7.594  | 24.11609 | 1.432003 |
| Sol526 Full:  |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 2388  | 4.877  | 13.60426 | 43.79652 | 40.31692 | 47.95639 | 6.552  | 26.70648 | 4.022131 |
| 2             | 2552  | 4.8987 | 13.71572 | 44.0821  | 40.71419 | 47.83603 | 6.5737 | 31.73884 | 9.054487 |
| 3             | 2717  | 4.9142 | 13.80363 | 43.01352 | 41.11718 | 47.85607 | 6.6915 | 40.73792 | 18.05357 |
| 4             | 2881  | 4.9421 | 13.8622  | 44.01918 | 41.65141 | 48.37854 | 6.8124 | 37.63639 | 14.95204 |
| 5             | 3045  | 4.97   | 13.90757 | 44.85227 | 41.69388 | 48.08626 | 6.676  | 24.19203 | 1.507681 |
| 6             | 3209  | 5.0134 | 13.94268 | 43.47609 | 41.7674  | 47.82511 | 6.831  | 29.92991 | 7.245559 |
| 7             | 3373  | 5.0351 | 13.9734  | 44.28121 | 42.20096 | 48.36195 | 7.0325 | 40.66542 | 17.98107 |
| 8             | 3538  | 5.0723 | 14.00411 | 44.70298 | 41.9309  | 47.67427 | 6.7132 | 20.38637 | -2.29798 |
| 9             | 3702  | 5.1095 | 14.03188 | 43.81181 | 42.13217 | 47.83057 | 6.9178 | 22.39282 | -0.29153 |
| 10            | 4012  | 5.1281 | 14.08888 | 43.5404  | 42.06342 | 47.44088 | 6.8372 | 31.97966 | 9.295311 |
| 11            | 4176  | 5.1591 | 14.10641 | 44.52849 | 42.44219 | 48.06245 | 7.0046 | 33.76789 | 11.08354 |
| 12            | 4340  | 5.1591 | 14.11517 | 44.75441 | 42.14527 | 47.41021 | 6.8093 | 31.81215 | 9.1278   |
| 13            | 4668  | 5.1963 | 14.14147 | 45.10396 | 42.55083 | 48.0167  | 6.9333 | 38.73551 | 16.05116 |
| 14            | 4832  | 5.2335 | 14.15023 | 43.75577 | 42.2239  | 47.28414 | 6.9209 | 45.68799 | 23.00364 |
| 15            | 4997  | 5.249  | 14.15899 | 44.56779 | 42.6003  | 47.96187 | 7.0883 | 35.85912 | 13.17477 |
| 16            | 5161  | 5.1343 | 14.15899 | 45.1005  | 42.36661 | 47.47879 | 6.8744 | 33.15296 | 10.46861 |
| 17            | 5325  | 5.2862 | 14.16045 | 44.11102 | 42.48331 | 47.62351 | 7.0356 | 23.28492 | 0.600566 |
| 18            | 5489  | 5.2676 | 14.16775 | 45.08321 | 42.69445 | 48.00573 | 7.0201 | 35.30898 | 12.62463 |
| 19            | 5653  | 5.3048 | 14.18235 | 44.09401 | 42.30752 | 47.23022 | 6.9612 | 29.99786 | 7.313505 |
| 20            | 5817  | 5.3079 | 14.21008 | 44.54387 | 42.67296 | 47.87611 | 7.11   | 26.57218 | 3.887829 |
| 21            | 5981  | 5.3172 | 14.25386 | 45.37805 | 42.51294 | 47.60902 | 6.9333 | 26.11466 | 3.430306 |
| 22            | 6141  | 5.3389 | 14.3122  | 44.13654 | 42.54918 | 47.57642 | 7.0604 | 22.00618 | -0.67817 |
| 23            | 6304  | 5.3327 | 14.38218 | 45.07457 | 42.7789  | 48.00939 | 7.048  | 32.16148 | 9.477135 |
| 24            | 6469  | 5.3389 | 14.47103 | 43.69466 | 42.34855 | 47.14585 | 6.9271 | 28.5928  | 5.908451 |
| 25            | 6633  | 5.3513 | 14.58018 | 44.71669 | 42.67296 | 47.80145 | 7.0914 | 34.97912 | 12.29477 |
| 26            | 6797  | 5.3668 | 14.69503 | 44.86086 | 42.3584  | 47.22662 | 6.9085 | 36.53411 | 13.84976 |
| 27            | 6961  | 5.3761 | 14.78218 | 44.23694 | 42.6234  | 47.63257 | 7.1038 | 43.85713 | 21.17278 |
| Sol526 Empty: |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 9330  | 5.2893 | 14.91855 | 43.56072 | 42.13708 | 46.51831 | 6.906  | 29.15853 | 6.474172 |
| 2             | 9495  | 5.2924 | 14.87069 | 44.13143 | 42.44219 | 47.01868 | 6.906  | 27.31063 | 4.626278 |
| 3             | 9659  | 5.2831 | 14.86489 | 44.88322 | 42.46028 | 47.17455 | 6.906  | 19.36325 | -3.32111 |

| 4             | 9823  | 5.3017 | 14.80105 | 43.60138 | 42.2026  | 46.66031 | 6.906  | 23.33904 | 0.654683 |
|---------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 5             | 9982  | 5.2955 | 14.85764 | 44.73554 | 42.59535 | 47.43185 | 6.906  | 32.40373 | 9.719376 |
| 6             | 10146 | 5.3017 | 14.86489 | 43.74897 | 42.19768 | 46.64431 | 6.906  | 19.45841 | -3.22594 |
| 7             | 10305 | 5.3079 | 14.88955 | 44.60199 | 42.64487 | 47.48963 | 6.906  | 17.43427 | -5.25009 |
| 8             | 10469 | 5.2893 | 14.89535 | 44.35617 | 42.23537 | 46.72966 | 6.906  | 24.31777 | 1.633415 |
| 9             | 10633 | 5.3017 | 14.89245 | 44.42266 | 42.63661 | 47.45351 | 6.906  | 20.75485 | -1.92951 |
| 10            | 10792 | 5.2831 | 14.8823  | 44.94862 | 42.3584  | 46.97576 | 6.906  | 15.1262  | -7.55815 |
| 11            | 10956 | 5.2986 | 14.85909 | 44.25396 | 42.6003  | 47.36875 | 6.906  | 12.18626 | -10.4981 |
| 12            | 11121 | 5.2924 | 14.84458 | 45.32761 | 42.54424 | 47.33633 | 6.906  | 30.48526 | 7.800908 |
| 13            | 11285 | 5.3048 | 14.82282 | 44.04469 | 42.51624 | 47.21405 | 6.906  | 16.3586  | -6.32575 |
| 14            | 11449 | 5.2769 | 14.81266 | 45.13683 | 42.68618 | 47.59453 | 6.906  | 27.10577 | 4.421416 |
| 15            | 11613 | 5.2924 | 14.79234 | 43.8339  | 42.43561 | 47.03836 | 6.906  | 25.9052  | 3.220844 |
| 16            | 11778 | 5.2738 | 14.82427 | 44.90558 | 42.71761 | 47.65976 | 6.906  | 34.69257 | 12.00822 |
| 17            | 11942 | 5.2893 | 14.85329 | 43.72012 | 42.2944  | 46.83652 | 6.906  | 10.23369 | -12.4507 |
| Sol684 Full:  |       |        |          |          |          |          |        |          |          |
| A             | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1             | 23775 | 5.714  | 16.70962 | 45.25988 | 43.32241 | 47.39759 | 6.4218 | 39.20077 | -6.48523 |
| 2             | 23939 | 5.7264 | 16.68958 | 44.21821 | 42.97846 | 46.69586 | 6.2699 | 42.02916 | -3.65684 |
| 3             | 24099 | 5.7171 | 16.68385 | 45.32935 | 43.34771 | 47.42283 | 6.4156 | 55.28287 | 9.59687  |
| 4             | 24263 | 5.745  | 16.67955 | 44.2761  | 43.05365 | 46.75813 | 6.2668 | 42.40228 | -3.28372 |
| 5             | 24427 | 5.714  | 16.69387 | 45.33457 | 43.36289 | 47.43546 | 6.4094 | 51.74903 | 6.063025 |
| 6             | 24592 | 5.7202 | 16.70246 | 44.28121 | 43.03191 | 46.76704 | 6.2761 | 41.82418 | -3.86182 |
| 7             | 24756 | 5.7109 | 16.72107 | 45.51744 | 43.21802 | 47.21585 | 6.2637 | 38.81238 | -6.87362 |
| 8             | 24920 | 5.7202 | 16.74111 | 44.40902 | 43.06201 | 46.86327 | 6.3195 | 49.60469 | 3.918688 |
| 9             | 25085 | 5.714  | 16.75829 | 45.56107 | 43.2584  | 47.28414 | 6.304  | 54.44673 | 8.760727 |
| 10            | 25249 | 5.7388 | 16.77832 | 44.44996 | 43.09885 | 46.91502 | 6.3443 | 44.94186 | -0.74414 |
| 11            | 25413 | 5.7326 | 16.79835 | 45.15067 | 43.18609 | 47.12433 | 6.2916 | 52.18519 | 6.499188 |
| 12            | 25573 | 5.7233 | 16.82124 | 44.14164 | 42.89682 | 46.58039 | 6.2327 | 52.14915 | 6.463153 |
| 13            | 25737 | 5.7264 | 16.84412 | 45.16279 | 43.31904 | 47.37776 | 6.428  | 34.41851 | -11.2675 |
| 14            | 25896 | 5.7295 | 16.87272 | 44.16546 | 42.95344 | 46.64076 | 6.2389 | 40.10463 | -5.58137 |
| 15            | 26061 | 5.7295 | 16.90274 | 45.21131 | 43.34265 | 47.38857 | 6.4218 | 44.91344 | -0.77256 |
| 16            | 26225 | 5.7233 | 16.93562 | 44.17907 | 42.97179 | 46.6532  | 6.2358 | 41.14246 | -4.54354 |
| 17            | 26389 | 5.7295 | 16.96991 | 45.25294 | 43.36796 | 47.41562 | 6.4249 | 32.38898 | -13.297  |
| 18            | 26554 | 5.6241 | 17.0042  | 44.22162 | 43.0035  | 46.6923  | 6.2575 | 52.41802 | 6.732017 |
| 19            | 26718 | 5.7388 | 17.04419 | 45.27897 | 43.39328 | 47.43727 | 6.4249 | 41.80993 | -3.87607 |
| 20            | 26882 | 5.7326 | 17.08702 | 44.25056 | 43.03692 | 46.7172  | 6.2544 | 48.26239 | 2.576391 |
| 21            | 27042 | 5.7202 | 17.12983 | 44.94001 | 43.24494 | 47.16199 | 6.3505 | 65.8632  | 20.1772  |
| 22            | 27206 | 5.6954 | 17.17549 | 45.02622 | 42.95511 | 46.63188 | 6.2079 | 57.7761  | 12.0901  |
| 23            | 27370 | 5.7326 | 17.23539 | 44.56266 | 43.12567 | 46.93288 | 6.335  | 51.24721 | 5.561207 |
| 24            | 27534 | 5.7326 | 17.28814 | 45.6747  | 43.2786  | 47.25358 | 6.2885 | 52.9319  | 7.2459   |
| 25            | 27694 | 5.745  | 17.34087 | 44.5866  | 43.20962 | 47.02047 | 6.3722 | 48.07733 | 2.391331 |
| 26            | 27858 | 5.7264 | 17.40356 | 45.71671 | 43.27523 | 47.20327 | 6.2668 | 37.647   | -8.039   |
| Sol684 Empty: |       |        |          |          |          |          |        |          |          |

| A                   | B     | C      | D        | E        | F        | G        | H      | I        | J        |
|---------------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 1                   | 17586 | 5.7853 | 16.35129 | 44.37833 | 42.96011 | 46.70831 | 6.32   | 48.15077 | 2.46417  |
| 2                   | 17750 | 5.7543 | 16.30967 | 45.20611 | 43.03692 | 46.91681 | 6.32   | 37.11463 | -8.57196 |
| 3                   | 17909 | 5.7636 | 16.27091 | 44.208   | 42.86189 | 46.56087 | 6.32   | 41.6344  | -4.05219 |
| 4                   | 18068 | 5.7667 | 16.23645 | 45.03657 | 43.03191 | 46.93466 | 6.32   | 39.80011 | -5.88648 |
| 5                   | 18232 | 5.7605 | 16.19911 | 44.16546 | 42.74741 | 46.37665 | 6.32   | 54.52926 | 8.84266  |
| 6                   | 18397 | 5.7543 | 16.16895 | 44.73554 | 43.07038 | 46.99364 | 6.32   | 28.68083 | -17.0058 |
| 7                   | 18561 | 5.7605 | 16.1359  | 44.76298 | 42.7143  | 46.37488 | 6.32   | 53.41969 | 7.7331   |
| 8                   | 18726 | 5.7512 | 16.11004 | 44.46702 | 42.95344 | 46.80979 | 6.32   | 48.27744 | 2.59085  |
| 9                   | 18890 | 5.7357 | 16.08705 | 45.23385 | 43.04528 | 47.00973 | 6.32   | 41.75156 | -3.93503 |
| 10                  | 19049 | 5.7481 | 16.06693 | 44.19949 | 42.8486  | 46.61767 | 6.32   | 48.41022 | 2.72363  |
| 11                  | 19208 | 5.7357 | 16.0468  | 45.43898 | 43.11393 | 47.17635 | 6.32   | 50.43643 | 4.74984  |
| 12                  | 19373 | 5.7388 | 16.04249 | 44.34083 | 42.95344 | 46.79375 | 6.32   | 49.04306 | 3.35647  |
| 13                  | 19537 | 5.7264 | 16.04105 | 45.47384 | 43.17098 | 47.24998 | 6.32   | 45.27729 | -0.4093  |
| 14                  | 19701 | 5.7357 | 16.03674 | 44.37321 | 42.99849 | 46.85079 | 6.32   | 42.32977 | -3.35682 |
| 15                  | 19866 | 5.7233 | 16.06261 | 45.49127 | 43.18945 | 47.27155 | 6.32   | 38.95779 | -6.7288  |
| 16                  | 20030 | 5.7419 | 16.08705 | 44.38685 | 43.01686 | 46.87576 | 6.32   | 41.25668 | -4.42991 |
| 17                  | 20195 | 5.714  | 16.12728 | 45.53314 | 43.19449 | 47.28234 | 6.32   | 44.30899 | -1.3776  |
| 18                  | 20359 | 5.7264 | 16.19624 | 44.41925 | 43.03525 | 46.91681 | 6.32   | 53.4644  | 7.7778   |
| 19                  | 20523 | 5.714  | 16.27522 | 45.54187 | 43.20962 | 47.29134 | 6.32   | 28.91944 | -16.7672 |
| 20                  | 20682 | 5.7233 | 16.36277 | 44.45849 | 43.07038 | 46.95789 | 6.32   | 51.51425 | 5.82766  |
| 21                  | 20846 | 5.714  | 16.45744 | 45.62747 | 43.19617 | 47.25717 | 6.32   | 46.08513 | 0.39853  |
| 22                  | 21006 | 5.7388 | 16.53916 | 44.52508 | 43.11393 | 47.01152 | 6.32   | 47.27856 | 1.59197  |
| 23                  | 21170 | 5.7233 | 16.60794 | 45.72021 | 43.18777 | 47.21225 | 6.32   | 50.61143 | 4.92484  |
| 24                  | 21335 | 5.7295 | 16.65664 | 44.54558 | 43.14076 | 47.03836 | 6.32   | 47.09248 | 1.40589  |
| 25                  | 21499 | 5.714  | 16.69244 | 45.69745 | 43.20962 | 47.16558 | 6.32   | 56.84534 | 11.15875 |
| 26                  | 21658 | 5.7357 | 16.71248 | 44.57976 | 43.16762 | 47.06163 | 6.32   | 52.66145 | 6.97486  |
| Sol573 Enrich Full: |       |        |          |          |          |          |        |          |          |
| A                   | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1                   | 12555 | 5.4257 | 15.09671 | 44.15015 | 42.48002 | 47.20866 | 4.9152 | 54.82562 | 4.543876 |
| 2                   | 12719 | 5.4195 | 15.18784 | 44.94173 | 42.28948 | 46.84187 | 4.7168 | 56.81344 | 6.5317   |
| 3                   | 12884 | 5.4257 | 15.24132 | 44.23864 | 42.65148 | 47.2374  | 4.9245 | 73.37316 | 23.09142 |
| 4                   | 13048 | 5.4381 | 15.29045 | 44.99344 | 42.36825 | 46.86149 | 4.7137 | 96.32437 | 46.04263 |
| 5                   | 13212 | 5.4226 | 15.30778 | 44.30505 | 42.64652 | 47.25178 | 4.9462 | 56.05641 | 5.774669 |
| 6                   | 13376 | 5.4536 | 15.32367 | 44.12633 | 42.18949 | 46.42089 | 4.6796 | 34.79068 | -15.4911 |
| 7                   | 13541 | 5.4474 | 15.33234 | 44.48409 | 42.67461 | 47.28954 | 4.9586 | 57.26559 | 6.983847 |
| 8                   | 13705 | 5.435  | 15.34389 | 44.24375 | 42.28456 | 46.5254  | 4.7168 | 55.66849 | 5.386753 |
| 9                   | 13870 | 5.4598 | 15.35544 | 44.54045 | 42.74079 | 47.33813 | 4.9865 | 68.70816 | 18.42642 |
| 10                  | 14034 | 5.4567 | 15.36121 | 44.26418 | 42.33213 | 46.55732 | 4.7385 | 49.2632  | -1.01854 |
| 11                  | 14198 | 5.4722 | 15.36699 | 44.58489 | 42.78885 | 47.36334 | 4.9927 | 71.16022 | 20.87848 |
| 12                  | 14357 | 5.4505 | 15.36699 | 44.12803 | 42.37318 | 46.5662  | 4.7602 | 55.18941 | 4.907672 |
| 13                  | 14521 | 5.4722 | 15.36988 | 44.65845 | 42.82701 | 47.40119 | 5.0082 | 55.18932 | 4.907584 |
| 14                  | 14681 | 5.4536 | 15.37998 | 43.66921 | 42.39946 | 46.56265 | 4.7602 | 65.94145 | 15.65971 |

| 15                   | 14845 | 5.4567 | 15.38864 | 44.87634 | 42.79548 | 47.37235 | 4.9369 | 60.55532 | 10.27358 |
|----------------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 16                   | 15009 | 5.4567 | 15.38864 | 43.81351 | 42.46357 | 46.68341 | 4.7912 | 67.23216 | 16.95042 |
| 17                   | 15174 | 5.4536 | 15.40019 | 44.88494 | 42.83697 | 47.41021 | 4.9617 | 85.66665 | 35.38491 |
| 18                   | 15338 | 5.4753 | 15.42328 | 43.8288  | 42.48825 | 46.69586 | 4.8191 | 41.8814  | -8.40034 |
| 19                   | 15502 | 5.4536 | 15.44925 | 45.12298 | 42.73251 | 47.24998 | 4.8284 | 59.19456 | 8.912819 |
| 20                   | 15666 | 5.4722 | 15.48243 | 44.00728 | 42.55907 | 46.849   | 4.8687 | 51.23359 | 0.951845 |
| 21                   | 15831 | 5.5652 | 15.50406 | 45.14894 | 42.82369 | 47.34533 | 4.8656 | 58.27733 | 7.995595 |
| 22                   | 15995 | 5.4753 | 15.52137 | 44.04299 | 42.6036  | 46.89182 | 4.8873 | 68.86959 | 18.58785 |
| 23                   | 16154 | 5.4381 | 15.52858 | 45.23732 | 42.51294 | 46.83117 | 4.6951 | 77.74856 | 27.46682 |
| 24                   | 16318 | 5.4629 | 15.53435 | 44.24034 | 42.66139 | 47.0312  | 4.9245 | 52.0066  | 1.724857 |
| 25                   | 16483 | 5.4722 | 15.54011 | 45.33457 | 42.58545 | 46.94896 | 4.7664 | 56.25607 | 5.97433  |
| 26                   | 16647 | 5.4598 | 15.55885 | 44.29483 | 42.71761 | 47.09745 | 4.9524 | 38.26968 | -12.0121 |
| 27                   | 16811 | 5.4691 | 15.58336 | 44.54899 | 42.34034 | 46.46161 | 4.6889 | 54.66129 | 4.379554 |
| 28                   | 16976 | 5.4815 | 15.63236 | 44.47727 | 42.74907 | 47.18891 | 4.9679 | 56.59688 | 6.315138 |
| 29                   | 17140 | 5.4784 | 15.70726 | 43.76426 | 42.27964 | 46.40673 | 4.7292 | 88.8915  | 38.60976 |
| 30                   | 17305 | 5.4784 | 15.79365 | 44.6653  | 42.77392 | 47.28234 | 4.9679 | 60.29715 | 10.01541 |
| 31                   | 17469 | 5.4784 | 15.88862 | 43.64546 | 42.37646 | 46.46692 | 4.7509 | 57.40298 | 7.121236 |
| 32                   | 17634 | 5.4691 | 15.98355 | 44.8987  | 42.78387 | 47.26616 | 4.9307 | 54.48134 | 4.199604 |
| Sol573 Enrich Empty: |       |        |          |          |          |          |        |          |          |
| A                    | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1                    | 19022 | 5.4877 | 16.45171 | 44.79559 | 42.87686 | 47.30753 | 4.848  | 28.49673 | -21.785  |
| 2                    | 19181 | 5.4908 | 16.40438 | 43.78464 | 42.51953 | 46.57862 | 4.848  | 48.9216  | -1.36015 |
| 3                    | 19345 | 5.4877 | 16.33694 | 44.87806 | 42.91512 | 47.35974 | 4.848  | 40.7296  | -9.55215 |
| 4                    | 19510 | 5.4908 | 16.25512 | 43.80502 | 42.54259 | 46.62122 | 4.848  | 37.12602 | -13.1557 |
| 5                    | 19674 | 5.4753 | 16.17182 | 44.90214 | 42.92678 | 47.39398 | 4.848  | 52.94976 | 2.668017 |
| 6                    | 19838 | 5.4815 | 16.08705 | 43.80842 | 42.54589 | 46.60879 | 4.848  | 34.2071  | -16.0746 |
| 7                    | 19998 | 5.4939 | 16.0123  | 44.96068 | 42.92012 | 47.4048  | 4.848  | 72.92387 | 22.64212 |
| 8                    | 20162 | 5.3606 | 15.94616 | 43.86449 | 42.54589 | 46.70297 | 4.848  | 39.53002 | -10.7517 |
| 9                    | 20466 | 5.4505 | 15.88718 | 44.01408 | 42.64157 | 46.85792 | 4.848  | 52.67756 | 2.39582  |
| 10                   | 20625 | 5.4567 | 15.85265 | 44.64134 | 42.83365 | 47.26616 | 4.848  | 49.66292 | -0.61883 |
| 11                   | 20789 | 5.466  | 15.82099 | 44.61396 | 42.48002 | 46.65675 | 4.848  | 58.80831 | 8.526564 |
| 12                   | 20954 | 5.4567 | 15.79509 | 44.55583 | 42.86189 | 47.33453 | 4.848  | 66.42976 | 16.14801 |
| 13                   | 21118 | 5.5373 | 15.77349 | 44.49434 | 42.46028 | 46.58926 | 4.848  | 58.13909 | 7.857341 |
| 14                   | 21283 | 5.466  | 15.72454 | 44.52849 | 42.83033 | 47.30753 | 4.848  | 52.72514 | 2.443392 |
| 15                   | 21447 | 5.4257 | 15.68422 | 45.28071 | 42.65148 | 47.01868 | 4.848  | 52.56453 | 2.282789 |
| 16                   | 21611 | 5.4443 | 15.64964 | 44.39879 | 42.82369 | 47.27155 | 4.848  | 51.28901 | 1.007263 |
| 17                   | 21776 | 5.4381 | 15.61506 | 45.13337 | 42.58215 | 46.89539 | 4.848  | 57.60865 | 7.326903 |
| Sol684 Enrich Full:  |       |        |          |          |          |          |        |          |          |
| A                    | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1                    | 12136 | 5.6923 | 15.87711 | 44.41414 | 42.80709 | 47.07954 | 4.1805 | 93.17943 | 25.16943 |
| 2                    | 12301 | 5.6861 | 16.0008  | 45.46861 | 42.7441  | 46.92395 | 3.9914 | 79.12805 | 11.11805 |
| 3                    | 12460 | 5.7264 | 16.09567 | 44.56437 | 42.97012 | 47.17276 | 4.2208 | 110.9244 | 42.91444 |
| 4                    | 12770 | 5.7109 | 16.24507 | 45.0642  | 43.02856 | 47.25178 | 4.1681 | 56.79218 | -11.2178 |

| 5                    | 12935 | 5.7295 | 16.27378 | 44.0685  | 42.75238 | 46.61945 | 4.0782 | 79.3022  | 11.2922  |
|----------------------|-------|--------|----------|----------|----------|----------|--------|----------|----------|
| 6                    | 13099 | 5.7295 | 16.29531 | 45.34152 | 43.06369 | 47.22123 | 4.0999 | 82.76889 | 14.75889 |
| 7                    | 13263 | 5.7698 | 16.30967 | 44.37321 | 42.90514 | 46.7991  | 4.1619 | 110.9472 | 42.93719 |
| 8                    | 13427 | 5.7233 | 16.34268 | 45.61873 | 42.90181 | 46.97934 | 3.9976 | 76.78682 | 8.776818 |
| 9                    | 13592 | 5.7481 | 16.33694 | 44.53532 | 43.04027 | 46.99006 | 4.1991 | 113.1123 | 45.10232 |
| 10                   | 13751 | 5.7357 | 16.35416 | 45.10569 | 42.76564 | 46.53072 | 3.9635 | 102.4012 | 34.39118 |
| 11                   | 13915 | 5.7481 | 16.37281 | 44.76298 | 43.14412 | 47.12254 | 4.165  | 74.95907 | 6.949067 |
| 12                   | 14080 | 5.7481 | 16.39146 | 44.34083 | 42.71099 | 46.33422 | 4.0069 | 72.15404 | 4.144039 |
| 13                   | 14244 | 5.7636 | 16.40151 | 44.96413 | 43.20457 | 47.23561 | 4.2611 | 77.65707 | 9.64707  |
| 14                   | 14409 | 5.7636 | 16.42159 | 44.01748 | 42.83199 | 46.44921 | 4.0348 | 108.4102 | 40.40023 |
| 15                   | 14573 | 5.7543 | 16.42446 | 45.18705 | 43.23821 | 47.29313 | 4.2239 | 108.7435 | 40.73352 |
| 16                   | 14737 | 5.7698 | 16.43163 | 44.2063  | 42.92345 | 46.63188 | 4.0937 | 77.65813 | 9.648126 |
| 17                   | 14901 | 5.7729 | 16.44023 | 45.44247 | 43.23148 | 47.26256 | 4.1495 | 77.97625 | 9.96625  |
| 18                   | 15066 | 5.7791 | 16.4388  | 44.41584 | 43.04528 | 46.82939 | 4.1681 | 72.4543  | 4.444296 |
| 19                   | 15230 | 5.7636 | 16.4388  | 45.65895 | 43.11896 | 47.05089 | 4.0348 | 80.60734 | 12.59734 |
| 20                   | 15395 | 5.7729 | 16.44023 | 44.58318 | 43.12735 | 46.9704  | 4.1991 | 91.5853  | 23.5753  |
| 21                   | 15559 | 5.7791 | 16.43737 | 44.47385 | 42.66965 | 46.20003 | 3.9139 | 102.8001 | 34.79007 |
| 22                   | 15723 | 5.7915 | 16.42733 | 44.8815  | 43.1609  | 47.11179 | 4.2456 | 87.84815 | 19.83815 |
| 23                   | 15883 | 5.7729 | 16.41872 | 43.98008 | 42.77061 | 46.35897 | 4.0162 | 84.13345 | 16.12345 |
| 24                   | 16047 | 5.776  | 16.41155 | 45.13683 | 43.22139 | 47.23022 | 4.2239 | 112.2893 | 44.27932 |
| 25                   | 16207 | 5.7853 | 16.40294 | 44.19779 | 42.91346 | 46.58572 | 4.0968 | 73.1899  | 5.179897 |
| 26                   | 16371 | 5.7729 | 16.39577 | 45.58378 | 42.97012 | 46.82761 | 3.9821 | 99.57195 | 31.56195 |
| Sol684 Enrich Empty: |       |        |          |          |          |          |        |          |          |
| A                    | B     | C      | D        | E        | F        | G        | H      | I        | J        |
| 1                    | 17586 | 5.7853 | 16.35129 | 0.931593 | 44.37833 | 42.96011 | 4.111  | 71.97914 | 3.967781 |
| 2                    | 17750 | 5.7543 | 16.30967 | 0.912448 | 45.20611 | 43.03692 | 4.111  | 55.48204 | -12.5293 |
| 3                    | 17909 | 5.7636 | 16.27091 | 0.894619 | 44.208   | 42.86189 | 4.111  | 62.605   | -5.40636 |
| 4                    | 18068 | 5.7667 | 16.23645 | 0.878767 | 45.03657 | 43.03191 | 4.111  | 59.43607 | -8.57529 |
| 5                    | 18232 | 5.7605 | 16.19911 | 0.861591 | 44.16546 | 42.74741 | 4.111  | 81.5075  | 13.49614 |
| 6                    | 18397 | 5.7543 | 16.16895 | 0.847716 | 44.73554 | 43.07038 | 4.111  | 42.88791 | -25.1234 |
| 7                    | 18561 | 5.7605 | 16.1359  | 0.832516 | 44.76298 | 42.7143  | 4.111  | 79.8076  | 11.79624 |
| 8                    | 18726 | 5.7512 | 16.11004 | 0.820618 | 44.46702 | 42.95344 | 4.111  | 72.20165 | 4.190285 |
| 9                    | 18890 | 5.7357 | 16.08705 | 0.810042 | 45.23385 | 43.04528 | 4.111  | 62.39773 | -5.61363 |
| 10                   | 19049 | 5.7481 | 16.06693 | 0.800786 | 44.19949 | 42.8486  | 4.111  | 72.40265 | 4.391285 |
| 11                   | 19208 | 5.7357 | 16.0468  | 0.791529 | 45.43898 | 43.11393 | 4.111  | 75.48778 | 7.476422 |
| 12                   | 19373 | 5.7388 | 16.04249 | 0.789546 | 44.34083 | 42.95344 | 4.111  | 73.30206 | 5.290696 |
| 13                   | 19537 | 5.7264 | 16.04105 | 0.788884 | 45.47384 | 43.17098 | 4.111  | 67.72685 | -0.28451 |
| 14                   | 19701 | 5.7357 | 16.03674 | 0.786901 | 44.37321 | 42.99849 | 4.111  | 63.18049 | -4.83087 |
| 15                   | 19866 | 5.7233 | 16.06261 | 0.798802 | 45.49127 | 43.18945 | 4.111  | 58.25675 | -9.75461 |
| 16                   | 20030 | 5.7419 | 16.08705 | 0.810042 | 44.38685 | 43.01686 | 4.111  | 61.65215 | -6.35921 |
| 17                   | 20195 | 5.714  | 16.12728 | 0.82855  | 45.53314 | 43.19449 | 4.111  | 66.33318 | -1.67818 |
| 18                   | 20359 | 5.7264 | 16.19624 | 0.860269 | 44.41925 | 43.03525 | 4.111  | 79.87382 | 11.86246 |
| 19                   | 20523 | 5.714  | 16.27522 | 0.8966   | 45.54187 | 43.20962 | 4.111  | 43.22082 | -24.7905 |

|    |       |        |          |          |          |          |       |          |          |
|----|-------|--------|----------|----------|----------|----------|-------|----------|----------|
| 20 | 20682 | 5.7233 | 16.36277 | 0.936873 | 44.45849 | 43.07038 | 4.111 | 76.8138  | 8.802443 |
| 21 | 20846 | 5.714  | 16.45744 | 0.980424 | 45.62747 | 43.19617 | 4.111 | 61.11781 | -6.89356 |
| 22 | 21006 | 5.7388 | 16.53916 | 1.018014 | 44.52508 | 43.11393 | 4.111 | 70.89978 | 2.888423 |
| 23 | 21170 | 5.7233 | 16.60794 | 1.049653 | 45.72021 | 43.18777 | 4.111 | 75.65976 | 7.648398 |
| 24 | 21335 | 5.7295 | 16.65664 | 1.072055 | 44.54558 | 43.14076 | 4.111 | 70.46315 | 2.451786 |
| 25 | 21499 | 5.714  | 16.69244 | 1.088522 | 45.69745 | 43.20962 | 4.111 | 84.91746 | 16.9061  |
| 26 | 21658 | 5.7357 | 16.71248 | 1.097742 | 44.57976 | 43.16762 | 4.111 | 78.68243 | 10.67107 |

## References and Notes

1. S. K. Atreya, P. R. Mahaffy, A. S. Wong, Methane and related trace species on Mars: Origin, loss, implications for life, and habitability. *Planet. Space Sci.* **55**, 358–369 (2007). [doi:10.1016/j.pss.2006.02.005](https://doi.org/10.1016/j.pss.2006.02.005)
2. V. A. Krasnopolsky, J. P. Maillard, T. C. Owen, Detection of methane in the martian atmosphere: Evidence for life? *Icarus* **172**, 537–547 (2004). [doi:10.1016/j.icarus.2004.07.004](https://doi.org/10.1016/j.icarus.2004.07.004)
3. C. Oze, M. Sharma, Have olivine, will gas: Serpentization and the abiogenetic production of methane on Mars. *Geophys. Res. Lett.* **32**, L10203 (2005). [doi:10.1029/2005GL022691](https://doi.org/10.1029/2005GL022691)
4. F. Keppler, I. Vigano, A. McLeod, U. Ott, M. Frücht, T. Röckmann, Ultraviolet-radiation-induced methane emissions from meteorites and the martian atmosphere. *Nature* **486**, 93–96 (2012). [Medline](#)
5. A. Schuerger, J. E. Moores, C. A. Clausen, N. G. Barlow, D. T. Britt, Methane from UV-irradiated carbonaceous chondrites under simulated martian conditions. *J. Geophys. Res.* **117**, E08007 (2012). [doi:10.1029/2011JE004023](https://doi.org/10.1029/2011JE004023)
6. O. Poch, S. Kaci, F. Stalport, C. Szopa, P. Coll, Laboratory insights into the chemical and kinetic evolution of several organic molecules under simulated Mars surface UV radiation conditions. *Icarus* **242**, 50–63 (2014). [doi:10.1016/j.icarus.2014.07.014](https://doi.org/10.1016/j.icarus.2014.07.014)
7. V. A. Krasnopolsky, Some problems related to the origin of methane on Mars. *Icarus* **180**, 359–367 (2006). [doi:10.1016/j.icarus.2005.10.015](https://doi.org/10.1016/j.icarus.2005.10.015)
8. E. Chassefière, Metastable methane clathrate particles as a source of methane to the martian atmosphere. *Icarus* **204**, 137–144 (2009). [doi:10.1016/j.icarus.2009.06.016](https://doi.org/10.1016/j.icarus.2009.06.016)
9. P.-Y. Meslin, R. Gough, L. Lefevre, F. Forget, Little variability of methane on Mars induced by adsorption in the regolith. *Planet. Space Sci.* **59**, 247–258 (2011). [doi:10.1016/j.pss.2010.09.022](https://doi.org/10.1016/j.pss.2010.09.022)
10. R. V. Gough, M. A. Tolbert, C. P. McKay, O. B. Toon, Methane adsorption on a martian soil analog: An abiogenic explanation for methane variability in the martian atmosphere. *Icarus* **207**, 165–174 (2010). [doi:10.1016/j.icarus.2009.11.030](https://doi.org/10.1016/j.icarus.2009.11.030)
11. S. McMahon, J. Parnell, N. J. F. Blamey, Sampling methane in basalt on Earth and Mars. *Int. J. Astrobiol.* **12**, 113–122 (2013). [doi:10.1017/S1473550412000481](https://doi.org/10.1017/S1473550412000481)
12. G. Etiope, D. Z. Oehler, C. C. Allen, Methane emissions from Earth's degassing: Implications for Mars. *Planet. Space Sci.* **59**, 182–195 (2011). [doi:10.1016/j.pss.2010.06.003](https://doi.org/10.1016/j.pss.2010.06.003)
13. M. J. Mumma, G. L. Villanueva, R. E. Novak, T. Hewagama, B. P. Bonev, M. A. Disanti, A. M. Mandell, M. D. Smith, Strong release of methane on Mars in northern summer 2003. *Science* **323**, 1041–1045 (2009). [Medline](#) [doi:10.1126/science.1165243](https://doi.org/10.1126/science.1165243)
14. V. Formisano, S. Atreya, T. Encrenaz, N. Ignatiev, M. Giuranna, Detection of methane in the atmosphere of Mars. *Science* **306**, 1758–1761 (2004). [Medline](#) [doi:10.1126/science.1101732](https://doi.org/10.1126/science.1101732)

15. A. Geminale, V. Formisano, G. Sindoni, Mapping methane in martian atmosphere with PFS-MEX data. *Planet. Space Sci.* **59**, 137–148 (2011). [doi:10.1016/j.pss.2010.07.011](https://doi.org/10.1016/j.pss.2010.07.011)
16. S. Fonti, G. A. Marzo, Mapping the methane on Mars. *Astron. Astrophys.* **512**, A51 (2010). [doi:10.1051/0004-6361/200913178](https://doi.org/10.1051/0004-6361/200913178)
17. V. A. Krasnopolsky, A sensitive search for methane and ethane on Mars, *EPSC abstracts* **6**, 49 (2011).
18. V. A. Krasnopolsky, Search for methane and upper limits to ethane and SO<sub>2</sub> on Mars. *Icarus* **217**, 144–152 (2012). [doi:10.1016/j.icarus.2011.10.019](https://doi.org/10.1016/j.icarus.2011.10.019)
19. G. L. Villanueva, M. J. Mumma, R. E. Novak, Y. L. Radeva, H. U. Käufl, A. Smette, A. Tokunaga, A. Khayat, T. Encrenaz, P. Hartogh, A sensitive search for organics (CH<sub>4</sub>, CH<sub>3</sub>OH, H<sub>2</sub>CO, C<sub>2</sub>H<sub>6</sub>, C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>4</sub>), hydroperoxyl (HO<sub>2</sub>), nitrogen compounds (N<sub>2</sub>O, NH<sub>3</sub>, HCN) and chlorine species (HCl, CH<sub>3</sub>Cl) on Mars using ground-based high-resolution infrared spectroscopy. *Icarus* **223**, 11–27 (2013). [doi:10.1016/j.icarus.2012.11.013](https://doi.org/10.1016/j.icarus.2012.11.013)
20. F. Lefèvre, F. Forget, Observed variations of methane on Mars unexplained by known atmospheric chemistry and physics. *Nature* **460**, 720–723 (2009). [Medline](#) [doi:10.1038/nature08228](https://doi.org/10.1038/nature08228)
21. S. K. Atreya, O. Witasse, V. F. Chevrier, F. Forget, P. R. Mahaffy, P. Buford Price, C. R. Webster, R. W. Zurek, Methane on Mars: Current observations, interpretations, and future plans. *Planet. Space Sci.* **59**, 133–136 (2011). [doi:10.1016/j.pss.2010.10.008](https://doi.org/10.1016/j.pss.2010.10.008)
22. K. J. Zahnle, R. S. Freedman, D. C. Catling, Is there methane on Mars? *Icarus* **212**, 493–503 (2011). [doi:10.1016/j.icarus.2010.11.027](https://doi.org/10.1016/j.icarus.2010.11.027)
23. P. R. Christensen, Mars as seen from the 2001 Mars Odyssey Thermal Emission Imaging System experiment, *EOS Trans. AGU Fall Meet. Suppl.* **84** (46), Abstract P21A-02, 2003.
24. F. Gaillard, J. Michalski, G. Berger, S. M. McLennan, B. Scaillet, Geochemical reservoirs and timing of sulfur cycling on Mars. *Space Sci. Rev.* **174**, 251–300 (2013). [doi:10.1007/s11214-012-9947-4](https://doi.org/10.1007/s11214-012-9947-4)
25. M. A. Mischna, M. Allen, M. I. Richardson, C. E. Newman, A. D. Toigo, Atmospheric modeling of Mars methane surface releases. *Planet. Space Sci.* **59**, 227–237 (2011). [doi:10.1016/j.pss.2010.07.005](https://doi.org/10.1016/j.pss.2010.07.005)
26. S. K. Atreya, A. S. Wong, N. O. Renno, W. M. Farrell, G. T. Delory, D. D. Sentman, S. A. Cummer, J. R. Marshall, S. C. Rafkin, D. C. Catling, Oxidant enhancement in martian dust devils and storms: Implications for life and habitability. *Astrobiology* **6**, 439–450 (2006). [Medline](#) [doi:10.1089/ast.2006.6.439](https://doi.org/10.1089/ast.2006.6.439)
27. G. T. Delory, W. M. Farrell, S. K. Atreya, N. O. Renno, A. S. Wong, S. A. Cummer, D. D. Sentman, J. R. Marshall, S. C. Rafkin, D. C. Catling, Oxidant enhancement in martian dust devils and storms: Storm electric fields and electron dissociative attachment. *Astrobiology* **6**, 451–462 (2006). [Medline](#) [doi:10.1089/ast.2006.6.451](https://doi.org/10.1089/ast.2006.6.451)
28. W. M. Farrell, G. T. Delory, S. K. Atreya, Martian dust storms as a possible sink of atmospheric methane. *J. Geophys. Res.* **33**, L21203 (2006).

29. P. R. Mahaffy, C. R. Webster, M. Cabane, P. G. Conrad, P. Coll, S. K. Atreya, R. Arvey, M. Barciniak, M. Benna, L. Bleacher, W. B. Brinckerhoff, J. L. Eigenbrode, D. Carignan, M. Cascia, R. A. Chalmers, J. P. Dworkin, T. Errigo, P. Everson, H. Franz, R. Farley, S. Feng, G. Frazier, C. Freissinet, D. P. Glavin, D. N. Harpold, D. Hawk, V. Holmes, C. S. Johnson, A. Jones, P. Jordan, J. Kellogg, J. Lewis, E. Lyness, C. A. Malespin, D. K. Martin, J. Maurer, A. C. McAdam, D. McLennan, T. J. Nolan, M. Noriega, A. A. Pavlov, B. Prats, E. Raaen, O. Sheinman, D. Sheppard, J. Smith, J. C. Stern, F. Tan, M. Trainer, D. W. Ming, R. V. Morris, J. Jones, C. Gundersen, A. Steele, J. Wray, O. Botta, L. A. Leshin, T. Owen, S. Battel, B. M. Jakosky, H. Manning, S. Squyres, R. Navarro-González, C. P. McKay, F. Raulin, R. Sternberg, A. Buch, P. Sorensen, R. Kline-Schoder, D. Coscia, C. Szopa, S. Teinturier, C. Baffles, J. Feldman, G. Flesch, S. Forouhar, R. Garcia, D. Keymeulen, S. Woodward, B. P. Block, K. Arnett, R. Miller, C. Edmonson, S. Gorevan, E. Mumm, The Sample Analysis at Mars investigation and instrument suite. *Space Sci. Rev.* **170**, 401–478 (2012). [doi:10.1007/s11214-012-9879-z](https://doi.org/10.1007/s11214-012-9879-z)
30. C. R. Webster, P. R. Mahaffy, Determining the local abundance of martian methane and its'  $^{13}\text{C}/^{12}\text{C}$  and D/H isotopic ratios for comparison with related gas and soil analysis on the 2011 Mars Science Laboratory (MSL) mission. *Planet. Space Sci.* **59**, 271–283 (2011). [doi:10.1016/j.pss.2010.08.021](https://doi.org/10.1016/j.pss.2010.08.021)
31. C. R. Webster, P. R. Mahaffy, G. J. Flesch, P. B. Niles, J. H. Jones, L. A. Leshin, S. K. Atreya, J. C. Stern, L. E. Christensen, T. Owen, H. Franz, R. O. Pepin, A. Steele; the MSL Science Team, Isotope ratios of H, C, and O in CO<sub>2</sub> and H<sub>2</sub>O of the martian atmosphere. *Science* **341**, 260–263 (2013). [Medline doi:10.1126/science.1237961](https://doi.org/10.1126/science.1237961)
32. See supplementary materials on *Science* Online.
33. C. R. Webster, P. R. Mahaffy, S. K. Atreya, G. J. Flesch, K. A. Farley; MSL Science Team, Low upper limit to methane abundance on Mars. *Science* **342**, 355–357 (2013). [Medline doi:10.1126/science.1242902](https://doi.org/10.1126/science.1242902)
34. C. Freissinet *et al.*, Organic Molecules in the Sheepbed Mudstone of Gale Crater, Mars, *8th International Conf. on Mars*, Abstract No. 1349 (2014).
35. J. R. C. Garry, I. L. ten Kate, Z. Martins, P. Nørnberg, P. Ehrenfreund, Analysis and survival of amino acids in martian regolith analogs. *Meteorit. Planet. Sci.* **41**, 391–405 (2006). [doi:10.1111/j.1945-5100.2006.tb00470.x](https://doi.org/10.1111/j.1945-5100.2006.tb00470.x)
36. J. Gómez-Elvira, C. Armiens, I. Carrasco, M. Genzer, F. Gómez, R. Haberle, V. E. Hamilton, A.-M. Harri, H. Kahanpää, O. Kemppinen, A. Lepinette, J. Martín Soler, J. Martín-Torres, J. Martínez-Frías, M. Mischna, L. Mora, S. Navarro, C. Newman, M. A. de Pablo, V. Peinado, J. Polkko, S. C. R. Rafkin, M. Ramos, N. O. Rennó, M. Richardson, J. A. Rodríguez-Manfredi, J. J. Romeral Planelló, E. Sebastián, M. de la Torre Juárez, J. Torres, R. Urquí, A. R. Vasavada, J. Verdasca, M.-P. Zorzano, Curiosity's rover environmental monitoring station: Overview of the first 100 sols. *J. Geophys. Res.* **119**, 1680–1688 (2014). [doi:10.1002/2013JE004576](https://doi.org/10.1002/2013JE004576)
37. T. H. McConnochie *et al.*, ChemCam Passive Spectroscopy of Atmospheric O<sub>2</sub> and H<sub>2</sub>O, *8th International Conf. on Mars*, Abstract #1328 (2014).
38. D. M. Hassler, C. Zeitlin, R. F. Wimmer-Schweingruber, S. Böttcher, C. Martin, J. Andrews, E. Böhm, D. E. Brinza, M. A. Bullock, S. Burmeister, B. Ehresmann, M. Epperly, D.

Grinspoon, J. Köhler, O. Kortmann, K. Neal, J. Peterson, A. Posner, S. Rafkin, L. Seimetz, K. D. Smith, Y. Tyler, G. Weigle, G. Reitz, F. A. Cucinotta, The Radiation Assessment Detector (RAD) investigation. *Space Sci. Rev.* **170**, 503–558 (2012).  
[doi:10.1007/s11214-012-9913-1](https://doi.org/10.1007/s11214-012-9913-1)

39. M. T. Lemmon, The Mars Science Laboratory Optical Depth Record, *8th International Conf. on Mars*, Abstract #1338 (2014).
40. A. Geminal *et al.*, Methane in martian atmosphere: Average spatial, diurnal and seasonal behavior. *Planet. Space Sci.* **56**, 1194–1203 (2008). [doi:10.1016/j.pss.2008.03.004](https://doi.org/10.1016/j.pss.2008.03.004)
41. M. E. Schmidt *et al.*, Geochemical Classification of Rocks in Gale Crater with APXS to sol 360: Sediment provenance, mixing, and diagenetic processes, 45th Lunar and Planet. Sci. Conf. Abstr. #1504 (2014).
42. H. K. Newsom *et al.*, “Gale Crater and Impact Processes from Curiosity,” 45th Lunar and Planetary Science Conference (LPSC), Abstract #2103 (2014).
43. L. S. Rothman, I. E. Gordon, A. Barbe, D. C. Benner, P. F. Bernath, M. Birk, V. Boudon, L. R. Brown, A. Campargue, J.-P. Champion, K. Chance, L. H. Coudert, V. Dana, V. M. Devi, S. Fally, J.-M. Flaud, R. R. Gamache, A. Goldman, D. Jacquemart, I. Kleiner, N. Lacome, W. J. Lafferty, J.-Y. Mandin, S. T. Massie, S. N. Mikhailenko, C. E. Miller, N. Moazzen-Ahmadi, O. V. Naumenko, A. V. Nikitin, J. Orphal, V. I. Perevalov, A. Perrin, A. Predoi-Cross, C. P. Rinsland, M. Rotger, M. Šimečková, M. A. H. Smith, K. Sung, S. A. Tashkun, J. Tennyson, R. A. Toth, A. C. Vandaele, J. Vander Auwera, The HITRAN 2008 molecular spectroscopic database. *J. Quant. Spectrosc. Radiat. Transfer* **110**, 533–572 (2009). [doi:10.1016/j.jqsrt.2009.02.013](https://doi.org/10.1016/j.jqsrt.2009.02.013)
44. C. R. Webster, R. T. Menzies, E. D. Hinkley, “Infrared laser absorption: theory and applications,” in *Laser Remote Chemical Analysis*, R. M. Measures, Ed. (Wiley, New York, 1988), chap. 3.
45. A. Buch *et al.*, Detection of Organics at Mars: How Wet Chemistry Onboard SAM Helps,” 44th Lunar and Planetary Science Conference (LPSC) abstract #1512 (2013).

**Mars Science Laboratory (MSL) Science Team List**

October 2014

| <b>First name Last name</b>   | <b>Institution Affiliation</b>                                                                                 |
|-------------------------------|----------------------------------------------------------------------------------------------------------------|
| William Abbey                 | Jet Propulsion Laboratory, California Institute of Technology                                                  |
| Cherie Achilles               | Indiana University Bloomington                                                                                 |
| Christophe Agard              | Centre National d'Etudes Spatiales (CNES)                                                                      |
| José Alexandre Alves Verdasca | Centro de Astrobiología (CSIC/INTA)                                                                            |
| Dana Anderson                 | California Institute of Technology                                                                             |
| Robert C. Anderson            | Jet Propulsion Laboratory, California Institute of Technology                                                  |
| Ryan B. Anderson              | United States Geological Survey Flagstaff                                                                      |
| Jan Kristoffer Appel          | University of Kiel                                                                                             |
| Paul Douglas Archer           | Jacobs, NASA Johnson Space Center                                                                              |
| Ricardo Arevalo               | NASA Goddard Space Flight Center                                                                               |
| Carlos Armiens-Aparicio       | Centro de Astrobiología (CSIC/INTA)                                                                            |
| Raymond Arvidson              | Washington University in St. Louis                                                                             |
| Evgeny Atlaskin               | Finnish Meteorological Institute and University of Helsinki                                                    |
| Sushil Atreya                 | University of Michigan Ann Arbor                                                                               |
| Andrew Aubrey                 | Jet Propulsion Laboratory, California Institute of Technology                                                  |
| Sherif Azeez                  | Delaware State University                                                                                      |
| Burt Baker                    | Malin Space Science Systems                                                                                    |
| Michael Baker                 | California Institute of Technology                                                                             |
| Tonci Balic-Zunic             | University of Copenhagen                                                                                       |
| David Baratoux                | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier                       |
| Julien Baroukh                | Centre National d'Etudes Spatiales (CNES)                                                                      |
| Bruce Barracough              | Planetary Science Institute                                                                                    |
| Michael Battalio              | Texas A&M                                                                                                      |
| Michael Beach                 | Malin Space Science Systems                                                                                    |
| Keri Bean                     | Texas A&M                                                                                                      |
| Pierre Beck                   | Institut des Sciences de la Terre                                                                              |
| Richard Becker                | University of Minnesota                                                                                        |
| Luther Beegle                 | Jet Propulsion Laboratory, California Institute of Technology                                                  |
| Alberto Behar                 | Jet Propulsion Laboratory, California Institute of Technology                                                  |
| Inès Belgacem                 | IRAP (Institut de Recherche en Astrophysique et Planetologie) and<br>CNES (Centre National d'Etudes Spatiales) |
| James F. Bell III             | Arizona State University                                                                                       |
| Steven Bender                 | Planetary Science Institute                                                                                    |
| Mehdi Benna                   | University of Maryland Baltimore County                                                                        |
| Jennifer Bentz                | University of Saskatchewan                                                                                     |
| Gilles Berger                 | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier                       |

|                      |                                                                   |
|----------------------|-------------------------------------------------------------------|
| Jeffrey Berger       | Western University                                                |
| Thomas Berger        | Deutsches Zentrum für Luft- und Raumfahrt                         |
| Genesis Berlanga     | Mount Holyoke College                                             |
| Daniel Berman        | Planetary Science Institute                                       |
| David Bish           | Indiana University Bloomington                                    |
| Jordana Blacksberg   | Jet Propulsion Laboratory, California Institute of Technology     |
| David F. Blake       | NASA Ames Research Center                                         |
| Juan José Blanco     | Universidad de Alcalá                                             |
| Ávalos               |                                                                   |
| Diana Blaney         | Jet Propulsion Laboratory, California Institute of Technology     |
| Jennifer Blank       | Blue Marble Space Inst. of Science and NASA Ames Research Center  |
| Hannah Blau          | University of Massachusetts                                       |
| Lora Bleacher        | NASA Goddard Space Flight Center                                  |
| Eckart Boehm         | University of Kiel                                                |
| Jean-Yves Bonnet     | Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) |
| Oliver Botta         | Swiss Space Office                                                |
| Stephan Böttcher     | University of Kiel                                                |
| Thomas Boucher       | University of Massachusetts                                       |
| Hannah Bower         | University of Maryland College Park                               |
| Nick Boyd            | University of Guelph                                              |
| William Boynton      | University of Arizona                                             |
| Shaneen Braswell     | University of Michigan                                            |
| Elly Breves          | Mount Holyoke College                                             |
| John C. Bridges      | University of Leicester                                           |
| Nathan Bridges       | Johns Hopkins University Applied Physics Laboratory               |
| William Brinckerhoff | NASA Goddard Space Flight Center                                  |
| David Brinza         | Jet Propulsion Laboratory, California Institute of Technology     |
| Thomas Bristow       | NASA Ames Research Center                                         |
| Claude Brunet        | Canadian Space Agency                                             |
| Anna Brunner         | University of Maryland College Park                               |
| Will Brunner         | inXitu                                                            |
| Arnaud Buch          | Laboratoire Génie des Procédés et Matériaux                       |
| Mark Bullock         | Southwest Research Institute                                      |
| Sönke Burmeister     | University of Kiel                                                |
| John Burton          | York University                                                   |
| Jennifer Buz         | California Institute of Technology                                |
| Michel Cabane        | Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) |
| Fred Calef           | Jet Propulsion Laboratory, California Institute of Technology     |
| James Cameron        | Lightstorm Entertainment Inc.                                     |

|                         |                                                                                          |
|-------------------------|------------------------------------------------------------------------------------------|
| John L. Campbell        | University of Guelph                                                                     |
| Bruce Cantor            | Malin Space Science Systems                                                              |
| Michael Caplinger       | Malin Space Science Systems                                                              |
| Carey Clifton Jr.       | University of Massachusetts                                                              |
| Javier Caride Rodríguez | Centro de Astrobiología (CSIC/INTA)                                                      |
| Marco Carmosino         | University of Massachusetts                                                              |
| Isaías Carrasco         | Centro de Astrobiología (CSIC/INTA)                                                      |
| Blázquez                |                                                                                          |
| Patrick Cavanagh        | Indiana University Bloomington                                                           |
| Antoine Charpentier     | Atos                                                                                     |
| Steve Chipera           | Chesapeake Energy                                                                        |
| David Choi              | University of Michigan                                                                   |
| Lance Christensen       | Jet Propulsion Laboratory, California Institute of Technology                            |
| Benton Clark            | Space Science Institute                                                                  |
| Sam Clegg               | Los Alamos National Laboratory                                                           |
| Timothy Cleghorn        | retired                                                                                  |
| Ed Cloutis              | University of Winnipeg                                                                   |
| George Cody             | Carnegie Institution of Washington                                                       |
| Patrice Coll            | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)                        |
| Ecaterina I. Coman      | Washington University in St. Louis                                                       |
| Pamela Conrad           | NASA Goddard Space Flight Center                                                         |
| David Coscia            | Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS)                        |
| Agnès Cousin            | Los Alamos National Laboratory                                                           |
| David Cremers           | Applied Research Associates, Inc.                                                        |
| Joy A. Crisp            | Jet Propulsion Laboratory, California Institute of Technology                            |
| Kevin Cropper           | Planetary Science Institute                                                              |
| Alain Cros              | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Francis Cucinotta       | University of Nevada Las Vegas                                                           |
| Claude d'Uston          | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Scott Davis             | Malin Space Science Systems                                                              |
| Mackenzie Day           | University of Texas at Austin                                                            |
| Yves Daydou             | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Lauren DeFlores         | Jet Propulsion Laboratory, California Institute of Technology                            |
| Erwin Dehouck           | State University of New York Stony Brook                                                 |
| Dorothea Delapp         | Los Alamos National Laboratory                                                           |
| Julia DeMarines         | Denver Museum of Nature & Science                                                        |
| Tristan Dequaire        | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)                        |
| David Des Marais        | NASA Ames Research Center                                                                |

|                        |                                                                          |
|------------------------|--------------------------------------------------------------------------|
| Roch Desrousseaux      | University of Michigan Ann Arbor                                         |
| William Dietrich       | University of California Berkeley                                        |
| Robert Dingler         | Los Alamos National Laboratory                                           |
| Shawn Domagal-Goldman  | NASA Goddard Space Flight Center                                         |
| Christophe Donny       | Centre National d'Etudes Spatiales (CNES)                                |
| Robert Downs           | University of Arizona                                                    |
| Darrell Drake          | Retired                                                                  |
| Gilles Dromart         | Laboratoire de Géologie de Lyon : Terre, Planète, Environnement          |
| Audrey Dupont          | CS Systemes d'Inforation                                                 |
| Brian Duston           | Malin Space Science Systems                                              |
| Jason P. Dworkin       | NASA Goddard Space Flight Center                                         |
| M. Darby Dyar          | Mount Holyoke College                                                    |
| Lauren Edgar           | Arizona State University                                                 |
| Kenneth Edgett         | Malin Space Science Systems                                              |
| Christopher S. Edwards | California Institute of Technology                                       |
| Laurence Edwards       | NASA Ames Research Center                                                |
| Peter Edwards          | University of Leicester                                                  |
| Bethany Ehlmann        | Jet Propulsion Laboratory/Caltech and California Institute of Technology |
| Bent Ehresmann         | Southwest Research Institute                                             |
| Jennifer Eigenbrode    | NASA Goddard Space Flight Center                                         |
| Beverley Elliott       | University of New Brunswick                                              |
| Harvey Elliott         | University of Michigan Ann Arbor                                         |
| Ryan Ewing             | Texas A&M                                                                |
| Cécile Fabre           | GéoRessources                                                            |
| Alberto Fairén         | Centro de Astrobiología (CSIC/INTA)                                      |
| Alberto Fairén         | Cornell University                                                       |
| Kenneth Farley         | California Institute of Technology                                       |
| Jack Farmer            | Arizona State University                                                 |
| Caleb Fassett          | Mount Holyoke College                                                    |
| Laurent Favot          | Capgemini France                                                         |
| Donald Fay             | Malin Space Science Systems                                              |
| Fedor Fedosov          | Space Research Institute                                                 |
| Jason Feldman          | Jet Propulsion Laboratory, California Institute of Technology            |
| Kim Fendrich           | University of Arizona                                                    |
| Erik Fischer           | University of Michigan Ann Arbor                                         |
| Martin Fisk            | Oregon State University                                                  |
| Mike Fitzgibbon        | University of Arizona                                                    |
| Gregory Flesch         | Jet Propulsion Laboratory, California Institute of Technology            |
| Melissa Floyd          | NASA Goddard Space Flight Center                                         |
| Lorenzo Flückiger      | Carnegie Mellon University                                               |

|                         |                                                                                          |
|-------------------------|------------------------------------------------------------------------------------------|
| Olivier Forni           | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Valerie Fox             | Washington University in St. Louis                                                       |
| Abigail Fraeman         | Caltech                                                                                  |
| Raymond Francis         | Western University                                                                       |
| Pascaline François      | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)                        |
| Heather Franz           | University of Maryland Baltimore County                                                  |
| Caroline Freissinet     | NASA Goddard Space Flight Center                                                         |
| Katherine Louise French | Massachusetts Institute of Technology                                                    |
| Jens Frydenvang         | University of Copenhagen                                                                 |
| James Garvin            | NASA Goddard Space Flight Center                                                         |
| Olivier Gasnault        | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Claude Geffroy          | Institut de Chimie des Milieux et Matériaux de Poitiers                                  |
| Ralf Gellert            | University of Guelph                                                                     |
| Maria Genzer            | Finnish Meteorological Institute                                                         |
| Stephanie Getty         | NASA Goddard Space Flight Center                                                         |
| Daniel Glavin           | NASA Goddard Space Flight Center                                                         |
| Austin Godber           | Arizona State University                                                                 |
| Fred Goesmann           | Max Planck Institute for Solar System Research                                           |
| Walter Goetz            | Max Planck Institute for Solar System Research                                           |
| Dmitry Golovin          | Space Research Institute                                                                 |
| Felipe Gómez Gómez      | Centro de Astrobiología (CSIC/INTA)                                                      |
| Javier Gómez-Elvira     | Centro de Astrobiología (CSIC/INTA)                                                      |
| Brigitte Gondet         | Institut d'Astrophysique Spatiale                                                        |
| Suzanne Gordon          | University of New Mexico                                                                 |
| Stephen Gorevan         | Honeybee Robotics                                                                        |
| Heather Graham          | NASA Goddard Space Flight Center                                                         |
| John Grant              | Smithsonian Institution                                                                  |
| David Grinspoon         | Planetary Science Institute                                                              |
| John Grotzinger         | California Institute of Technology                                                       |
| Philippe Guillemot      | Centre National d'Etudes Spatiales (CNES)                                                |
| Jingnan Guo             | University of Kiel                                                                       |
| Sanjeev Gupta           | Imperial College                                                                         |
| Scott Guzewich          | NASA Goddard Space Flight Center                                                         |
| Robert Haberle          | NASA Ames Research Center                                                                |
| Douglas Halleaux        | University of Michigan Ann Arbor                                                         |
| Bernard Hallet          | University of Washington Seattle                                                         |
| Victoria Hamilton       | Southwest Research Institute                                                             |
| Kevin Hand              | Jet Propulsion Laboratory, California Institute of Technology                            |
| Craig Hardgrove         | Arizona State University                                                                 |
| Keian Hardy             | Los Alamos National Laboratory                                                           |

|                      |                                                                    |
|----------------------|--------------------------------------------------------------------|
| David Harker         | Malin Space Science Systems                                        |
| Daniel Harpold       | NASA Goddard Space Flight Center                                   |
| Ari-Matti Harri      | Finnish Meteorological Institute                                   |
| Karl Harshman        | University of Arizona                                              |
| Donald Hassler       | Southwest Research Institute                                       |
| Harri Haukka         | Finnish Meteorological Institute                                   |
| Alexander Hayes      | Cornell University                                                 |
| Kenneth Herkenhoff   | United States Geological Survey Flagstaff                          |
| Paul Herrera         | Malin Space Science Systems                                        |
| Sebastian Hettrich   | Centro de Astrobiología (CSIC/INTA)                                |
| Ezat Heydari         | Jackson State University                                           |
| Victoria Hipkin      | Canadian Space Agency                                              |
| Tori Hoehler         | NASA Ames Research Center                                          |
| Jeff Hollingsworth   | NASA Ames Research Center                                          |
| Judy Hudgins         | Salish Kootenai College                                            |
| Wesley Huntress      | Retired                                                            |
| Joel Hurowitz        | State University of New York Stony Brook                           |
| Stubbe Hviid         | Max Planck Institute for Solar System Research                     |
| Karl Iagnemma        | Massachusetts Institute of Technology                              |
| Stephen Indyk        | Honeybee Robotics                                                  |
| Guy Israël           | Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS)  |
| Ryan Steele Jackson  | University of New Mexico                                           |
| Samantha Jacob       | University of Hawai'i at Manoa                                     |
| Bruce Jakosky        | University of Colorado Boulder                                     |
| Laurent Jean-Rigaud  | Atos                                                               |
| Elsa Jensen          | Malin Space Science Systems                                        |
| Jacqueline Kløvgaard | University of Copenhagen                                           |
| Jensen               |                                                                    |
| Jeffrey R. Johnson   | Johns Hopkins University Applied Physics Laboratory                |
| Micah Johnson        | Microtel                                                           |
| Stephen Johnstone    | Los Alamos National Laboratory                                     |
| Andrea Jones         | Lunar and Planetary Institute and NASA Goddard Space Flight Center |
| John H. Jones        | NASA Johnson Space Center                                          |
| Jonathan Joseph      | Cornell University                                                 |
| Mélissa Joulin       | Laboratoire de Planétologie et Géodynamique de Nantes              |
| Insoo Jun            | Jet Propulsion Laboratory, California Institute of Technology      |
| Linda C. Kah         | University of Tennessee Knoxville                                  |
| Henrik Kahanpää      | Finnish Meteorological Institute                                   |
| Melinda Kahre        | NASA Ames Research Center                                          |
| Hannah Kaplan        | Brown University                                                   |

|                      |                                                                                          |
|----------------------|------------------------------------------------------------------------------------------|
| Natalya Karpushkina  | Space Research Institute                                                                 |
| Srishti Kashyap      | University of Maryland Baltimore County                                                  |
| Janne Kauhanen       | Finnish Meteorological Institute                                                         |
| Leslie Keely         | NASA Ames Research Center                                                                |
| Simon Kelley         | The Open University                                                                      |
| Fabian Kempe         | Max Planck Institute for Solar System Research                                           |
| Oska Kemppinen       | Finnish Meteorological Institute and Aalto University                                    |
| Megan R. Kennedy     | Malin Space Science Systems                                                              |
| Didier Keymeulen     | Jet Propulsion Laboratory, California Institute of Technology                            |
| Alexander Kharytonov | University of Kiel                                                                       |
| Myung-Hee Kim        | Universities Space Research Association                                                  |
| Kjartan Kinch        | University of Copenhagen                                                                 |
| Penelope King        | Australian National University                                                           |
| Randolph Kirk        | United States Geological Survey Flagstaff                                                |
| Laurel Kirkland      | Lunar and Planetary Institute                                                            |
| Jacob Kloos          | York University                                                                          |
| Gary Kocurek         | University of Texas at Austin                                                            |
| Asmus Koefoed        | University of Copenhagen                                                                 |
| Jan Köhler           | University of Kiel                                                                       |
| Onno Kortmann        | University of California Berkeley                                                        |
| Benjamin Kotrc       | Massachusetts Institute of Technology                                                    |
| Alexander Kozyrev    | Space Research Institute                                                                 |
| Johannes Krauß       | University of Kiel                                                                       |
| Gillian Krezski      | Malin Space Science Systems                                                              |
| Rachel Kronyak       | University of Tennessee Knoxville                                                        |
| Daniel Krysak        | Malin Space Science Systems                                                              |
| Ruslan Kuzmin        | Space Research Institute and Vernadsky Institute                                         |
| Jean-Luc Lacour      | Commissariat à l'Énergie Atomique et aux Énergies Alternatives                           |
| Vivian Lafaille      | Centre National d'Etudes Spatiales (CNES)                                                |
| Yves Langevin        | Institut d'Astrophysique Spatiale                                                        |
| Nina Lanza           | Los Alamos National Laboratory                                                           |
| Mathieu Lapôtre      | California Institute of Technology                                                       |
| Marie-France Larif   | Centre National d'Etudes Spatiales (CNES)                                                |
| Jérémie Lasue        | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Laetitia Le Deit     | Laboratoire de Planétologie et Géodynamique de Nantes                                    |
| Stéphane Le Mouélis  | Laboratoire de Planétologie et Géodynamique de Nantes                                    |
| Ella Mae Lee         | United States Geological Survey Flagstaff                                                |
| Qiu-Mei Lee          | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Rebekka Lee          | Brock University                                                                         |
| David Lees           | Carnegie Mellon University                                                               |

|                          |                                                               |
|--------------------------|---------------------------------------------------------------|
| Matthew Lefavor          | Microtel                                                      |
| Mark Lemmon              | Texas A&M                                                     |
| Alain Lepinette Malvitte | Centro de Astrobiología (CSIC/INTA)                           |
| Kate Lepore              | Mount Holyoke College                                         |
| Laurie Leshin            | Worcester Polytechnic Institute                               |
| Richard Léveillé         | McGill University                                             |
| Éric Lewin               | Institut des Sciences de la Terre                             |
| Kevin Lewis              | Johns Hopkins University                                      |
| Shuai Li                 | Brown University                                              |
| Kimberly Lichtenberg     | Jet Propulsion Laboratory, California Institute of Technology |
| Leslie Lipkaman          | Malin Space Science Systems                                   |
| Denis Lisov              | Space Research Institute                                      |
| Cynthia Little           | Los Alamos National Laboratory                                |
| Maxim Litvak             | Space Research Institute                                      |
| Lu Liu                   | University of Washington Seattle                              |
| Henning Lohf             | University of Kiel                                            |
| Eric Lorigny             | Centre National d'Etudes Spatiales (CNES)                     |
| Günter Lugmair           | University of California San Diego                            |
| Angela Lundberg          | Delaware State University                                     |
| Eric Lyness              | Microtel                                                      |
| Morten Bo Madsen         | University of Copenhagen                                      |
| Angela Magee             | Malin Space Science Systems                                   |
| Paul Mahaffy             | NASA Goddard Space Flight Center                              |
| Justin Maki              | Jet Propulsion Laboratory, California Institute of Technology |
| Teemu Mäkinen            | Finnish Meteorological Institute                              |
| Alexey Malakhov          | Space Research Institute                                      |
| Charles Malespin         | Universities Space Research Association                       |
| Michael Malin            | Malin Space Science Systems                                   |
| Nicolas Mangold          | Laboratoire de Planétologie et Géodynamique de Nantes         |
| Gerard Manhes            | Institut de Physique du Globe de Paris                        |
| Heidi Manning            | Concordia College                                             |
| Geneviève Marchand       | Canadian Space Agency                                         |
| Mercedes Marín           | Centro de Astrobiología (CSIC/INTA)                           |
| Jiménez                  |                                                               |
| César Martín García      | University of Kiel                                            |
| David K. Martin          | NASA Goddard Space Flight Center                              |
| Mildred Martin           | Catholic University of America                                |
| Peter Martin             | California Institute of Technology                            |
| Germán Martínez          | University of Michigan Ann Arbor                              |
| Martínez                 |                                                               |
| Jesús Martínez-Frías     | Instituto de Geociencias (CSIC-UCM)                           |
| Jaime Martín-Sauceda     | Centro de Astrobiología (CSIC/INTA)                           |

|                         |                                                                                          |
|-------------------------|------------------------------------------------------------------------------------------|
| Martín                  |                                                                                          |
| Javier Martín-Soler     | Centro de Astrobiología (CSIC/INTA)                                                      |
| F. Javier Martín-Torres | Instituto Andaluz de Ciencias de la Tierra (CSIC-UGR)                                    |
| Emily Mason             | Texas A&M                                                                                |
| Tristan Matthews        | York University                                                                          |
| Daniel Matthiä          | Deutsches Zentrum für Luft- und Raumfahrt                                                |
| Patrick Mauchien        | Commissariat à l'Énergie Atomique et aux Énergies Alternatives                           |
| Sylvestre Maurice       | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Amy McAdam              | NASA Goddard Space Flight Center                                                         |
| Marie McBride           | Malin Space Science Systems                                                              |
| Elaina McCartney        | Malin Space Science Systems                                                              |
| Timothy McConnochie     | University of Maryland                                                                   |
| Emily McCullough        | Western University                                                                       |
| Ian McEwan              | Ashima Research                                                                          |
| Christopher McKay       | NASA Ames Research Center                                                                |
| Hannah McLain           | Catholic University of America                                                           |
| Scott McLennan          | State University of New York Stony Brook                                                 |
| Sean McNair             | Malin Space Science Systems                                                              |
| Noureddine Melikechi    | Delaware State University                                                                |
| Teresa Mendaza de Cal   | Centro de Astrobiología (CSIC/INTA)                                                      |
| Sini Merikallio         | Finnish Meteorological Institute                                                         |
| Sean Merritt            | Malin Space Science Systems                                                              |
| Pierre-Yves Meslin      | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Michael Meyer           | NASA Headquarters                                                                        |
| Alissa Mezzacappa       | Delaware State University                                                                |
| Sarah Milkovich         | Jet Propulsion Laboratory, California Institute of Technology                            |
| Maëva Millan            | Laboratoire Atmosphères, Milieux, Observations Spatiales<br>(LATMOS)                     |
| Hayden Miller           | California Institute of Technology                                                       |
| Kristen Miller          | Massachusetts Institute of Technology                                                    |
| Ralph Milliken          | Brown University                                                                         |
| Douglas Ming            | NASA Johnson Space Center                                                                |
| Michelle Minitti        | Planetary Science Institute                                                              |
| Michael Mischna         | Jet Propulsion Laboratory, California Institute of Technology                            |
| Julie Mitchell          | Arizona State University                                                                 |
| Igor Mitrofanov         | Space Research Institute                                                                 |
| Jeffrey Moersch         | University of Tennessee Knoxville                                                        |
| Maxim Mokrousov         | Space Research Institute                                                                 |
| Antonio Molina Jurado   | Centro de Astrobiología (CSIC/INTA)                                                      |
| Casey Moore             | York University                                                                          |

|                                 |                                                                   |
|---------------------------------|-------------------------------------------------------------------|
| John E. Moores                  | York University                                                   |
| Luis Mora-Sotomayor             | Centro de Astrobiología (CSIC/INTA)                               |
| Gines Moreno                    | Centro de Astrobiología (CSIC/INTA)                               |
| John Michael Morookian          | Jet Propulsion Laboratory, California Institute of Technology     |
| Richard V. Morris               | NASA Johnson Space Center                                         |
| Shaunna Morrison                | University of Arizona                                             |
| Valérie Mousset                 | Centre National d'Etudes Spatiales (CNES)                         |
| Alankrita Mrigakshi             | Deutsches Zentrum für Luft- und Raumfahrt                         |
| Reinhold Mueller-Mellin         | University of Kiel                                                |
| Jan-Peter Muller                | University College London                                         |
| Guillermo Muñoz Caro            | Centro de Astrobiología (CSIC/INTA)                               |
| Marion Nachon                   | Laboratoire de Planétologie et Géodynamique de Nantes             |
| Abbey Nastan                    | California Institute of Technology                                |
| Sara Navarro López              | Centro de Astrobiología (CSIC/INTA)                               |
| Rafael Navarro-González         | University Nacional Autónoma de México                            |
| Kenneth Nealson                 | University of Southern California                                 |
| Ara Nefian                      | Carnegie Mellon University                                        |
| Tony Nelson                     | Los Alamos National Laboratory                                    |
| Megan Newcombe                  | California Institute of Technology                                |
| Claire Newman                   | Ashima Research                                                   |
| Horton Newsom                   | University of New Mexico                                          |
| Sergey Nikiforov                | Space Research Institute                                          |
| Matthew Nikitczuk               | Brock University                                                  |
| Paul Niles                      | NASA Johnson Space Center                                         |
| Brian Nixon                     | Malin Space Science Systems                                       |
| Audrey Noblet                   | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA) |
| Eldar Noe Dobrea                | Planetary Science Institute                                       |
| Thomas Nolan                    | Nolan Engineering                                                 |
| Dorothy Oehler                  | Jacobs Technology                                                 |
| Ann Ollila                      | University of New Mexico                                          |
| Timothy Olson                   | Salish Kootenai College                                           |
| Tobias Orthen                   | University of Kiel                                                |
| Tobias Owen                     | University of Hawai'i at Manoa                                    |
| Marie Ozanne                    | Mount Holyoke College                                             |
| Miguel Ángel de Pablo Hernández | Universidad de Alcalá                                             |
| Hannah Pagel                    | Los Alamos National Laboratory                                    |
| Alexis Paillet                  | Centre National d'Etudes Spatiales (CNES)                         |
| Etienne Pallier                 | Institut de Recherche en Astrophysique et Planétologie,           |

|                           |                                                                   |
|---------------------------|-------------------------------------------------------------------|
| Marisa Palucis            | CNRS/University Paul Sabatier                                     |
| Timothy Parker            | University of California Berkeley                                 |
| Yann Parot                | Jet Propulsion Laboratory, California Institute of Technology     |
|                           | Institut de Recherche en Astrophysique et Planétologie,           |
| Alex Parra                | CNRS/University Paul Sabatier                                     |
| Kiran Patel               | Los Alamos National Laboratory                                    |
| Mark Paton                | Global Science & Technology, Inc.                                 |
| Gale Paulsen              | Finnish Meteorological Institute                                  |
| Alexander Pavlov          | Honeybee Robotics                                                 |
| Betina Pavri              | NASA Goddard Space Flight Center                                  |
| Verónica Peinado-González | Jet Propulsion Laboratory, California Institute of Technology     |
| Robert Pepin              | Centro de Astrobiología (CSIC/INTA)                               |
| Laurent Peret             |                                                                   |
| René Pérez                | University of Minnesota                                           |
| Glynis Perrett            | Atos                                                              |
| Joseph Peterson           | Centre National d'Etudes Spatiales (CNES)                         |
| Cedric Pilorget           | University of Guelph                                              |
| Patrick Pinet             | Southwest Research Institute                                      |
|                           | California Institute of Technology                                |
| Veronica Pinnick          | Institut de Recherche en Astrophysique et Planétologie,           |
| Jorge Pla-García          | CNRS/University Paul Sabatier                                     |
| Ianik Plante              | University of Maryland Baltimore County                           |
| Franck Poitrasson         | Centro de Astrobiología (CSIC/INTA)                               |
| Jouni Polkko              | Universities Space Research Association                           |
| Radu Popa                 | Géosciences Environnement Toulouse                                |
| Liliya Posiolova          | Finnish Meteorological Institute                                  |
| Arik Posner               | University of Southern California                                 |
| Irina Pradler             | Malin Space Science Systems                                       |
| Benito Prats              | NASA Headquarters                                                 |
| Vasily Prokhorov          | University of Guelph                                              |
| Eric Raaen                | eINFORMe Inc.                                                     |
| Leon Radziemski           | Space Research Institute                                          |
| Scot Rafkin               | NASA Goddard Space Flight Center                                  |
| Miguel Ramos              | Piezo Energy Technologies, Tucson                                 |
| Elizabeth Rampe           | Southwest Research Institute                                      |
| William Rapin             | Universidad de Alcalá                                             |
|                           | Aerodyne, NASA Johnson Space Center                               |
| François Raulin           | Institut de Recherche en Astrophysique et Planétologie,           |
| Michael Ravine            | CNRS/University Paul Sabatier                                     |
| Günther Reitz             | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA) |
|                           | Malin Space Science Systems                                       |
|                           | Deutsches Zentrum für Luft- und Raumfahrt                         |

|                                 |                                                                                          |
|---------------------------------|------------------------------------------------------------------------------------------|
| Jun Ren                         | Delaware State University                                                                |
| Nilton Rennó                    | University of Michigan Ann Arbor                                                         |
| Melissa Rice                    | Western Washington University                                                            |
| Mark Richardson                 | Ashima Research                                                                          |
| Birgit Ritter                   | Deutsches Zentrum für Luft- und Raumfahrt                                                |
| Frances Rivera-Hernández        | University of California Davis                                                           |
| François Robert                 | IMPMC, Muséum d'Histoire Naturelle                                                       |
| Kevin Robertson                 | Brown University                                                                         |
| José Antonio Rodriguez Manfredi | Centro de Astrobiología (CSIC/INTA)                                                      |
| Julio José Romeral-Planelló     | Centro de Astrobiología (CSIC/INTA)                                                      |
| Scott Rowland                   | University of Hawai'i at Manoa                                                           |
| David Rubin                     | University of California Santa Cruz                                                      |
| Muriel Saccoccio                | Centre National d'Etudes Spatiales (CNES)                                                |
| David Said                      | Centre National d'Etudes Spatiales (CNES)                                                |
| Andrew Salamon                  | Malin Space Science Systems                                                              |
| Anton Sanin                     | Space Research Institute                                                                 |
| Sara Alejandra Sans Fuentes     | Centro de Astrobiología (CSIC/INTA)                                                      |
| Lee Saper                       | Malin Space Science Systems                                                              |
| Philippe Sarrazin               | SETI Institute                                                                           |
| Violaine Sautter                | IMPMC, Muséum d'Histoire Naturelle                                                       |
| Hannu Savijärvi                 | University of Helsinki                                                                   |
| Juergen Schieber                | Indiana University Bloomington                                                           |
| Mariek Schmidt                  | Brock University                                                                         |
| Walter Schmidt                  | Finnish Meteorological Institute                                                         |
| Daniel Scholes                  | Washington University in St. Louis                                                       |
| Marcel Schoppers                | Jet Propulsion Laboratory, California Institute of Technology                            |
| Susanne Schröder                | Institut de Recherche en Astrophysique et Planétologie,<br>CNRS/University Paul Sabatier |
| Susanne P. Schwenzer            | The Open University                                                                      |
| Cauê Sciascia Borlina           | University of Michigan Ann Arbor                                                         |
| Anthony Scodary                 | Jet Propulsion Laboratory, California Institute of Technology                            |
| Eduardo Sebastián Martínez      | Centro de Astrobiología (CSIC/INTA)                                                      |
| Aaron Sengstacken               | Jet Propulsion Laboratory, California Institute of Technology                            |
| Jennifer Griffes Shechet        | California Institute of Technology                                                       |
| Ruslan Shterts                  | Canadian Space Agency                                                                    |
| Kirsten Siebach                 | California Institute of Technology                                                       |
| Tero Siili                      | Finnish Meteorological Institute                                                         |
| John J. Simmonds                | Jet Propulsion Laboratory, California Institute of Technology                            |

|                      |                                                                       |
|----------------------|-----------------------------------------------------------------------|
| Jean-Baptiste Sirven | Commissariat à l'Énergie Atomique et aux Énergies Alternatives        |
| Susan Slavney        | Washington University in St. Louis                                    |
| Ronald Sletten       | University of Washington Seattle                                      |
| Michael D. Smith     | NASA Goddard Space Flight Center                                      |
| Pablo Sobron Sanchez | Space Research Institute                                              |
| Nicole Spanovich     | Jet Propulsion Laboratory, California Institute of Technology         |
| John Spray           | University of New Brunswick                                           |
| Justin Spring        | Honeybee Robotics                                                     |
| Steven Squyres       | Cornell University                                                    |
| Katie Stack          | Jet Propulsion Laboratory, California Institute of Technology         |
| Fabien Stalport      | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)     |
| Richard Starr        | The Catholic University of America & NASA Goddard Space Flight Center |
| Andrew Steele        | Carnegie Institution of Washington                                    |
| Thomas Stein         | Washington University in St. Louis                                    |
| Jennifer Stern       | NASA Goddard Space Flight Center                                      |
| Noel Stewart         | Salish Kootenai College                                               |
| Wayne Stewart        | University of Washington                                              |
| Susan Louise Svane   | University of Copenhagen                                              |
| Stipp                |                                                                       |
| Kevin Stoiber        | Malin Space Science Systems                                           |
| Edward Stolper       | California Institute of Technology                                    |
| Robert Sucharski     | United States Geological Survey Flagstaff                             |
| Robert Sullivan      | Cornell University                                                    |
| Roger Summons        | Massachusetts Institute of Technology                                 |
| Dawn Y. Sumner       | University of California Davis                                        |
| Vivian Sun           | Brown University                                                      |
| Kimberley Supulver   | Malin Space Science Systems                                           |
| Brad Sutter          | Jacobs, NASA Johnson Space Center                                     |
| Cyril Szopa          | Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS)     |
| Florence Tan         | NASA Goddard Space Flight Center                                      |
| Christopher Tate     | University of Tennessee Knoxville                                     |
| Samuel Teinturier    | Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)     |
| Inge Loes ten Kate   | Utrecht University                                                    |
| Alicia Thomas        | Brock University                                                      |
| Peter Thomas         | Cornell University                                                    |
| Lucy Thompson        | University of New Brunswick                                           |
| Franck Thuillier     | Laboratoire de Planétologie et Géodynamique de Nantes                 |
| Emmanual Thulliez    | Centre National d'Etudes Spatiales (CNES)                             |
| Robert Tokar         | Planetary Science Institute                                           |
| Michael Toplis       | Institut de Recherche en Astrophysique et Planétologie,               |

|                                        |                                                               |
|----------------------------------------|---------------------------------------------------------------|
|                                        | CNRS/University Paul Sabatier                                 |
| Manuel de la Torre Juárez              | Jet Propulsion Laboratory, California Institute of Technology |
| Josefina Torres Redondo                | Centro de Astrobiología (CSIC/INTA)                           |
| Melissa Trainer                        | NASA Goddard Space Flight Center                              |
| Allan Treiman                          | Lunar and Planetary Institute                                 |
| Vladislav Tretyakov                    | Space Research Institute                                      |
| Aurora Ullán-Nieto                     | Centro de Astrobiología (CSIC/INTA)                           |
| Roser Urqui-O'Callaghan                | Centro de Astrobiología (CSIC/INTA)                           |
| Patricia Valentín-Serrano              | Centro de Astrobiología (CSIC/INTA)                           |
| Jason Van Beek                         | Malin Space Science Systems                                   |
| Tessa Van Beek                         | Malin Space Science Systems                                   |
| Scott VanBommel                        | University of Guelph                                          |
| David Vaniman                          | Planetary Science Institute                                   |
| Alexey Varenikov                       | Space Research Institute                                      |
| Ashwin R. Vasavada                     | Jet Propulsion Laboratory, California Institute of Technology |
| Paulo Vasconcelos                      | University of Queensland                                      |
| Álvaro de Vicente-Retortillo Rubalcaba | Universidad Complutense Madrid and University of Michigan     |
| Edward Vicenzi                         | Smithsonian Institution                                       |
| Andrey Vostrukhin                      | Space Research Institute                                      |
| Mary Voytek                            | NASA Headquarters                                             |
| Meenakshi Wadhwa                       | Arizona State University                                      |
| Jennifer Ward                          | Washington University in St. Louis                            |
| Jessica Watkins                        | University of California Los Angeles                          |
| Christopher R. Webster                 | Jet Propulsion Laboratory, California Institute of Technology |
| Gerald Weigle                          | Big Head Endian LLC                                           |
| Danika Wellington                      | Arizona State University                                      |
| Frances Westall                        | Centre National de la Recherche Scientifique (CNRS)           |
| Roger Wiens                            | Los Alamos National Laboratory                                |
| Mary Beth Wilhelm                      | Georgia Institute of Technology and NASA Ames Research Center |
| Amy Williams                           | University of California Davis                                |
| Joshua Williams                        | University of New Mexico                                      |
| Rebecca Williams                       | Planetary Science Institute                                   |
| Richard B. Williams                    | Los Alamos National Laboratory                                |
| Kenneth Williford                      | Jet Propulsion Laboratory, California Institute of Technology |
| Michael A. Wilson                      | University of California San Francisco                        |
| Sharon A. Wilson                       | Smithsonian Institution                                       |
| Robert Wimmer-Schweingruber            | University of Kiel                                            |

|                        |                                                               |
|------------------------|---------------------------------------------------------------|
| Michael Wolff          | Space Science Institute                                       |
| Michael Wong           | University of Michigan Ann Arbor                              |
| James Wray             | Georgia Institute of Technology                               |
| Charles Yana           | Centre National d'Etudes Spatiales (CNES)                     |
| Albert Yen             | Jet Propulsion Laboratory, California Institute of Technology |
| Aileen Yingst          | Planetary Science Institute                                   |
| Cary Zeitlin           | Southwest Research Institute                                  |
| Robert Zimdar          | Malin Space Science Systems                                   |
| María-Paz Zorzano Mier | Centro de Astrobiología (CSIC/INTA)                           |