Mineralogy at Meridiani Planum from the Mini-TES Experiment on the Opportunity Rover

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The Miniature Thermal Emission Spectrometer (Mini-TES) on Opportunity investigated the mineral abundances and compositions of outcrops, rocks, and soils at Meridiani Planum. Coarse crystalline hematite and olivine-rich basaltic sands were observed as predicted from orbital TES spectroscopy. Outcrops of aqueous origin are composed of 15 to 35% by volume magnesium and calcium sulfates [a high-silica component modeled as a combination of glass, feldspar, and sheet silicates (~20 to 30%)], and hematite; only minor jarosite is identified in Mini-TES spectra. Mini-TES spectra show only a hematite signature in the millimeter-sized spherules. Basaltic materials have more plagioclase than pyroxene, contain olivine, and are similar in inferred mineral composition to basalt mapped from orbit. Bounce rock is dominated by clinopyroxene and is close in inferred mineral composition to the basaltic martian meteorites. Bright wind streak material matches global dust. Waterlain rocks covered by unaltered basaltic sands suggest a change from an aqueous environment to one dominated by physical weathering.

The Mini-TES has provided remote measurements of mineral abundances and compositions, thermophysical properties, atmospheric temperature profiles, and atmospheric dust and ice opacities at the Opportunity rover landing site in Meridiani Planum. Mini-TES is a Michelson interferometer that collects infrared spectra from 5 to 29 μm (339 to 1997 cm⁻¹) at a spectral sampling of 10.0 cm⁻¹ (~3). Mini-TES observations of varying raster size and dwell lengths were acquired during rover operations within Eagle crater and during the traverse across the plains between Eagle and Endurance craters (4, 5). Co-registered panoramic camera (Pancam) observations (6) provide context and additional multispectral visible and near-infrared observations. Reflected down-welling atmospheric radiance has been removed from all spectra presented here with the use of Mini-TES sky observations to directly measure the atmospheric radiance (7, 8).

Mg and Ca sulfate–rich outcrops. Among the most exciting discoveries at Meridiani is the occurrence of bedrock with high...
sulfur abundances and preserved sedimentary structures (4, 9). Mini-TES spectra were acquired in long-integration single-point stare at 14 locations along the outcrops at Eagle and other craters (Figs. 1 and 2). These spectra have varying amounts of a surface dust component (3, 10), which was removed by first deconvolving each spectrum with an endmember library of 47 laboratory minerals and four scene spectra (Fig. 3) (11–15) and then subtracting the derived dust component to produce a dust-free spectrum (Fig. 4). Once dust has been removed, the resulting spectra still have subtle differences in shape and derived mineral abundances, but all spectra show (i) a pronounced absorption beginning at \( \sim 1250 \text{ cm}^{-1} \), (ii) a relatively flat shape between 900 and 1200 cm\(^{-1}\), (iii) an absorption shoulder at \( \sim 780 \text{ cm}^{-1} \), and (iv) deep absorptions near 450 and 550 cm\(^{-1}\) (Fig. 4). The absorption edge at 1250 cm\(^{-1}\) is consistent with the sulfate mineral group. The broad mid-wavelength absorption is fit by a mixture of glass, silicates, and sulfates. The long wavelength absorptions coincide with coarsely crystalline hematite (Fig. 3).

Sulfates are present in all of the outcrops we observed, with volume abundances, normalized to remove airfall dust, of 15 to 35% (Table 1) (16). The spectral library used to deconvolve the samples contained representative hydrous and anhydrous sulfates, including gypsum [\( \text{CaSO}_4 \cdot 2\text{H}_2\text{O} \)], bassanite [\( 2\text{CaSO}_4 \cdot (\text{H}_2\text{O})_2 \)], epsomite [\( \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \)], kieserite (\( \text{MgSO}_4 \cdot \text{H}_2\text{O} \)), glauberite [\( \text{Na}_2\text{Ca} \cdot \text{SO}_4 \cdot 3 \cdot \text{H}_2\text{O} \)], and jarosite [\( \text{KFe}_3(\text{SO}_4) \cdot \text{H}_2\text{O} \cdot 2\text{OH}_2 \)] species. The best fit to the Mini-TES spectra was consistently provided by the Mg and Ca sulfates.

Jarosite, the Fe-bearing sulfate that was identified by the Mössbauer spectrometer (17), was detected in deconvolutions of several Mini-TES outcrop spectra but never in concentrations >5%. The outcrop has 17 weight % (wt %) FeO (9), with 28% of this Fe as jarosite (17). Together, these data indicate that \( \sim 10 \text{ wt }% \) of the jarosite is jarosite. The average density of the jarosite derived with the Mini-TES mineral abundances (\( \sim 3.3 \text{ g cm}^{-3} \)) (Table 1) is similar to the density of jarosite (3.1 to 3.3 g cm\(^{-3}\)).

**Table 1.** Numerical deconvolution results for Mini-TES outcrop spectra. The volume abundances listed have been rounded to the nearest 5% from the values from the deconvolution model.

<table>
<thead>
<tr>
<th>Mineral group</th>
<th>Guadalupe</th>
<th>Gills</th>
<th>Last Chance Lower</th>
<th>Last Chance Left</th>
<th>Hippo</th>
<th>Pilbara</th>
<th>Tamanend Park</th>
<th>Chantry Flats</th>
<th>Tres Creek</th>
<th>Rhino Horn</th>
<th>Bunny Slope</th>
<th>Dolphin</th>
<th>Hamersley</th>
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<tr>
<td>Sulfate</td>
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<td>25</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>30</td>
<td>35</td>
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</tr>
<tr>
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<td>20</td>
<td>35</td>
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<td>35</td>
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<td>45</td>
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<td>10</td>
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<td>0</td>
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indicating that the jarosite volume abundance is also ~10%. Given the low spectral contrast of this outcrop, this value is consistent with the marginal detection of jarosite by Mini-TES. The finding that Mg and Ca sulfates dominate is consistent with the Alpha Particle X-ray Spectrometer (APXS) results, which show that Mg and Ca are present, and that there is substantially more S and too little Fe for the sulfates to be jarosite alone (9, 18).

Hematite is detected at volume abundances >10% in all but three outcrop locations (Table 1). Basaltic minerals are detected in all spectra. Loose, dark-toned sands and spherules that are likely wind transported from the overlying plains are common in cracks and ledges on the outcrop (Fig. 5) (6). Given the presence of these materials and the 12- to 15-cm diameter of the Mini-TES field of view (19), most of the Mini-TES observations are likely contaminated by these wind-blown materials and overestimate the hematite and basalt components (pyroxene and olivine) actually present in the outcrop. However, samples with the lowest basalt component (5 to 10%) still have hematite abundances of >30%. This Mini-TES–derived hematite abundance is higher than the abundance determined from the Mössbauer and APXS Fe results for the outcrop (9, 17). However, it is likely that the larger Mini-TES fields of view (Fig. 5) included loose hematite-rich spherules observed in the Microscopic Imager (MI) (20) and Pancam images in the surrounding soils (6) in addition to the outcrop matrix and embedded spherules.

The areas of outcrop named Guadalupe, Gills, Last Chance Lower, Last Chance Left, and Hippo, and Pilbara have the deepest absorption bands and provide the best Mini-TES measurement of the outcrop composition (Fig. 4). The reduced spectral contrast in other samples is likely due to multiple complicating effects, including blackbody cavity and temperature difference effects resulting from millimeter-scale pits (21). Intermediate- to high-silica components, modeled as high-silica glasses and feldspar, are fit to these six samples at abundances of ~10 to 25% (Table 1) (13, 14, 16, 22–25). The derived abundance of the mafic igneous phases (olivine and pyroxene) varies from ~10 to 30%, with some of this component likely due to draping wind-blown sands (6). The derived abundance of oxides and hydroxides other than crystalline hematite, typically modeled as magnetite and goethite, except hematite, is 5 to 20%. Taking the aver-
age of these best six outcrop spectra and deconvolving gives dust-removed abundances of 25% sulfate, 20% hematite, 30% high-silica component, 20% igneous phases, and 5% oxides other than hematite.

Light-toned outcrop is exposed in the ~10-m-diameter Fram crater, which is located 450 m from Eagle crater (4, 6). Mini-TES spectra obtained from a sample of this outcrop at Pilbara (Fig. 4 and Table 1) are similar in spectral shape and derived mineral abundances to the outcrops at Eagle crater, suggesting that the process that formed these rocks was relatively uniform over a lateral distance of at least 450 m.

Mini-TES observations have demonstrated that crystalline silica minerals, such as quartz and chert, and carbonate phases are not present in these outcrops at abundances >~5%. The low olivine and pyroxene abundances in these rocks indicate that either they did not form from basaltic material or alteration of pyroxene and olivine in a basaltic parent rock has been nearly complete. The exact mineral phase of the high-silica component has not yet been determined, but the presence of these phases is consistent with the bulk APXS chemistry for the outcrop (9, 16). The low abundance of other oxides and hydroxides in all but two samples (Table 1) is consistent with the results from the Mössbauer (17) and indicates that hematite is the dominant oxide and hydroxide in this outcrop.

Hematite spherules. The presence of coarsely crystalline hematite exposed on the surface has been predicted from orbital TES data (26, 27) and was confirmed in the Mission Success panorama acquired beginning on sol 3 (28). The Mini-TES spectral signature of hematite is associated with spherules 0.6 to 6 mm in diameter (20). Mini-TES vertical scans of the plains were acquired from the near field to the horizon. These observations show a systematic increase in the depth of the diagnostic 450 and 550 cm^{-1} hematite absorption bands with decreasing elevation angle (Fig. 6), and a corresponding decrease in the depth of the basalt and dust component in the 700- to 1200-cm^{-1} region. The spectral shape of the hematite bands does not vary with elevation angle (e, measured downward from the horizontal), indicating that viewing geometry does not affect the spectral character of the spherules up to elevation angles of ~5° (29). With an average diameter (d) of 3 mm for the hematite spherules and only ~0.1 to 0.2 mm for the intervening sand (30), the spacing (s) of spherules only needs to be s ≤ d/tan(90° − e), or ~25 mm, on the flat plains for the spherules to dominate the observed emission. This spacing is consistent with typical spherule spacing observed for plains soils (30, 31).

Differencing the spectra from the highest and lowest elevation angles effectively isolates the spherule component of the soil. This derived spectrum matches a laboratory hematite sample (Fig. 7A) (32), which indicates that the spherules are dominated by hematite. No other components, including silica, carbonates, sulfates, silicates, or other oxides, are detected in the derived Mini-TES spherule spectra at a total abundance for non-hematite components of 5 to 10%. Whereas Mini-TES only directly samples the outermost 50 to 100 μm of the spherules (33), many of the spherules are eroded or broken (30), suggesting that the interiors of these particles are also dominated by hematite.

We tried to determine the spherule composition with the use of the entire instrument suite by comparing the hematite-rich Berry Bowl and nearby hematite-poor outcrop surfaces. However, the Mini-TES difference spectrum (Fig. 7B) shows the presence of hematite and basaltic sand, and Pancam images show the presence of dark-toned sand and spherules in the Berry Bowl (Plate 11) (6). This experiment demonstrates that the spectral differencing technique identifies all of the components that differ between the two observations, and provides support for the hematite-dominated spherule composition derived from the plains emission angle experiment.

The lateral distribution of hematite within Eagle crater was mapped by deconvolving high-resolution Mini-TES rasters acquired during the crater traverse to obtain mineral abundances (Plate 3). Hematite spherules occur nonuniformly around Eagle crater, with the highest abundance occurring on the western inner wall and decreasing on the northern wall (Plate 3). The crater floor has a low-hematite spectral signature over much of its surface. The trend of decreasing hematite abundance from the surrounding plains, along troughs and cracks in the outcrop, and onto the crater floor (Plate 3), suggests that these troughs are pathways of hematite transport from the plains into the crater. Thus, the primary source of hematite within the crater appears to be from the overlying plains, rather than from erosion of spherules present in the outcrop exposed in the crater wall.

The vertical distribution of hematite within the soils was investigated by comparing Mini-TES spectra of soils within and adjacent to
OPPORTUNITY AT MERIDIANI PLANUM

Fig. 8. (A) The mineral composition and abundance of basaltic sands on the floor of Eagle crater as derived from the deconvolution of dust-removed Mini-TES spectra. These sands are derived from a plagioclase, pyroxene, and olivine basalt with hematite and sulfate contaminants from the Eagle crater outcrop. Oxide includes all oxides except hematite. Spectrum is the average of 225 spectra acquired on sol 34. (B) The mineral composition and abundance of basalt and hematite spherule sands on the plains between Fram and Endurance craters derived from the deconvolution of dust-removed Mini-TES spectra. These sands appear to be derived from a plagioclase, pyroxene, and olivine basalt with more hematite and fewer sulfate contaminants than in the sands inside Eagle crater. Oxide component includes all oxides except hematite. Spectrum is the average of 90 spectra acquired on sol 90.

Fig. 9. Comparison of the spectral properties of the major components observed at the Meridiani landing site. The outcrop spectrum is the average of spectra of Guadalupe, Gills, Last Chance Lower, Last Chance Left, Hippo, and Pilbara; the olivine basalt sand spectrum is from Fig. 8A; the Bounce rock spectrum is from Fig. 10A; the hematite spherule spectrum is from Fig. 7A.

Olive basalt soils. Soils with low hematite abundance all have similar mineralologies and are composed of basaltic minerals plagioclase, high-Ca clinopyroxene, olivine (~Fo60 (35)), oxides, orthopyroxene, and glass (Fig. 8). The sands on the floor of Eagle crater have derived mineral abundances, normalized to remove the dust, hematite, and sulfate components, of more intermediate plagioclase (~30%) than pyroxene (~20%), with ~20% olivine (~Fo60), ~10% glass, and ~15% oxides other than hematite, which are typically modeled as magnetite and lesser goethite (Fig. 8A). The sands on the plains between Eagle and Endurance craters typically have higher hematite abundance (Fig. 8B), but when these spectra are normalized to remove the dust, hematite, and sulfate components, they are also dominated by intermediate plagioclase (~35%), with 15% clinopyroxene, 10% ~Fo60 olivine, 15% glass, and 20% other oxides (Fig. 8B). Overall, these sands have a higher abundance of plagioclase relative to pyroxene and are close to the mineral compositions and abundances derived from orbital TES data for typical martian basaltic units found in the ancient cratered terrains of Mars (23, 24, 36).

These olivine basalt sands are not derived from any rock observed to date at Meridiani. It is possible that the sands at this site were transported from outside the layered terrain of Meridiani. However, the distance that a 500-μm basalt grain can be transported by aeolian saltation before it is reduced to a size that can be carried off in suspension is only ~300 km (37, 38). Alternatively, these sands may have been derived from the mechanical breakdown of an overlying layer or from underlying material brought to the surface by impact cratering. The variability in olivine abundance may be due to transport sorting processes or may reflect real variations in the composition of source rocks that produced these sands.

Bounce rock. Bounce rock, the largest and darkest rock present on the exterior rim of Eagle crater, was selected for detailed investigation (4). The Mini-TES–derived mineral composition of Bounce rock, after the removal of airfall dust and the small amount of fine dust contaminant produced by the Rock Abrasion Tool (RAT) during abrasion of this rock, shows that Bounce rock is unique
among rocks investigated at either the Meridional or Gusev sites (Fig. 9) (3, 39).

Bounce rock has much higher pyroxene abundance than the basaltic sands and rocks observed here and at Gusev crater (3, 39), with clinopyroxene accounting for ~55% of the rock and orthopyroxene ~5%, followed by ~20% plagioclase, ~5% olivine, and ~10% oxides (Fig. 10A). This composition is much closer to that of the martian basaltic sher- gottite meteorites (40) than the basaltic components observed at either Mars Exploration Rover (MER) site.

The elemental abundance of Bounce rock is similar to that of EETA#79001 lithology B (9); however, the infrared spectra of EETA#79001B (Fig. 10B) (41, 42) and Bounce rock differ in the 9- to 12-μm region. Deconvolution of the laboratory spectrum of EETA#79001B (Fig. 10B) gives mineral abundances that closely match its measured modal mineralogy of 30 to 50% pigeonite, 10 to 25% high-Ca clinopyroxene, ~30% maskelynite (shocked plagioclase), and 5% opaque minerals (43). The best fit to the Bounce rock spectrum (Fig. 10B) gives high-Ca clinopyroxene instead of the low-Ca clinopyroxene pigeonite, although the four emissivity minima between 850 and 1100 cm⁻¹ suggest that pigeonite is present in Bounce rock but poorly modeled with our current collection of pigeonite samples.

The TES-derived basalt compositions differ from those of the martian meteorites (24, 44, 45), and both lithologies have now been positively identified in situ on Mars. The ability of Mini-TES spectra to distinguish them and the similarity of Meridiani spectra to the TES orbital spectra strengthens previous interpretations that use TES data to determine the composition of basalt globally (23, 24, 36, 44).

The distinct mineral composition and chemistry of Bounce rock, together with its isolated occurrence (4), suggest that this rock may not be locally derived. A possible source region is a relatively unmodified 25-km crater located 75 km southwest of Eagle crater, the continuous ejecta of which lie atop the hematite-bearing plains (4, 27). In this case, Bounce rock may have been derived from materials that are compositionally distinct from the basaltic sands that cover the plains around Eagle crater (4).

Hamersley rock in Fram crater. A rock called Hamersley observed on the inner wall of the ~10-m-diameter crater Fram has a derived mineral abundance and composition that may be another endmember among the samples observed to date. Hamersley has the highest abundance of high-silica components (modeled as glass, feldspar, and sheet silicate) observed, although Bunny Slope and Dolphin at Eagle crater have similar spectral shapes.

Dust accumulation: Eagle crater bright streak. Upon exiting Eagle crater, Opportunity examined the composition and texture of the bright material seen from orbit to form a wind streak oriented downwind from Eagle crater (4, 30). Mini-TES spectra of the surface within this streak match the spectra of typical bright low-inertia dust seen globally from orbit (46) and in situ at Gusev crater (3) (Fig. 11). The spectral match between this wind streak and regional dust deposits provides support for the model of bright wind streaks forming by deposition of airborne dust in the stagnant air created downwind of topographic obstacles during periods of high atmospheric stability (47).

Dust accumulation occurs on all of the outcrop rocks to some degree (Fig. 2). On some rocks, such as Canidae observed on the
rim of Endurance crater, dust accumulates to sufficient thickness (~50 μm) (48, 49) to mask the spectrum of the underlying rock (Fig. 11). Dust may accumulate more readily on rock surfaces than on the soil, because occasional salutation of sand-sized grains may entrain and remove the dust, resulting in surfaces that are dark and have a small dust component in Mini-TES spectra.

**Global context.** Analysis of orbital data has suggested that the extensive (500 × 250 km), ancient (50–52), layered, hematite-bearing units in Meridiani Planum formed by (i) chemical precipitation of a hematite precursor (32) from Fe-rich aqueous fluids under ambient conditions (26, 27, 53); (ii) precipitation from Fe-rich hydrothermal fluids (26, 27, 51, 54); (iii) thermal oxidation of volcanic ash during eruption (26, 27, 51, 55); or (iv) precipitation of Fe-oxides that were metamorphosed by burial to platy hematite (56).

These units were deposited in a standing body of liquid water on the basis of the morphology, composition, and vertical distribution of the hematite-bearing units seen from orbit (53). The discovery of sulfate-rich outcrops and hematite in concretions provided conclusive evidence for deposition in an ancient aqueous system (18). However, the presence of extensive olivine, pyroxene, and feldspar in basaltic sands at this site and throughout Meridiani (53) suggests that physical weathering has dominated over chemical weathering during the time that these sands have been exposed on the surface. On a broader scale, the occurrence of basalts and olivine basalts throughout much of the equatorial and mid-latitude regions (3, 25, 57) suggests that chemical weathering may have been a relatively minor process, at least in low to mid-latitudes (58), throughout much of martian history. Thus, the presence of a body of water may represent a relatively brief, localized phenomenon early in Mars history.

**References and Notes**


2. Two-point radiometric calibration was intended to use two V-groove blackbody targets. However, as with the Spirit rover, the temperature sensors attached to the rover deck failed at extremely low temperatures (−90°C) on the first night after landing. The calibration was modified to use prelaunch measurements of the instrument response function taken over temperature, with the instrument response determined from observations of the target mounted in the Pancam Mast Assembly. On the basis of comparison with orbiting Mars Global Surveyor (MGS) TES data and modeling of the atmospheric observations, the response function has not changed from prelaunch values and the calibration approach is providing the required accuracy. The 2σ radiometric precision for two-spectra summation is 1.8 × 10⁻⁶ W cm⁻² sr⁻¹ cm⁻¹ for 450 and 1300 cm⁻¹, increasing to 7 × 10⁻⁵ W cm⁻² sr⁻¹ cm⁻¹ at shorter (300 cm⁻¹) and longer (1800 cm⁻¹) wave numbers. The absolute radiance error is <5 × 10⁻³ W cm⁻² sr⁻¹ cm⁻¹, decreasing to ~1 × 10⁻⁵ W cm⁻² sr⁻¹ cm⁻¹.


5. Names have been assigned to aeroglyphic features by the MER team for planning and operations purposes. The names are not formally recognized by the International Astronomical Union.


8. The downwelling radiation is removed by solving for r in the equation: radiant = Bsurf/Γsurf(r) + R atm/Γ atm(r) + R surf(r), where Bsurf is the measured total radiance from the surface, Γsurf is the Planck function, R atm is the atmospheric radiance and R surf is the surface emissivity, R atm/Γ atm is the downwelling atmospheric radiance, and R surf(r) is the surface infrared reflectivity that is equal to (1 − ε surf)/Γ surf.

9. The surface temperature derived from the measured Mini-TES spectrum (1, 3), R atm/Γ atm is the hemispherically integrated downwelling from the atmosphere and is approximated with Mini-TES observations taken at an emission angle of 60° from the zenith. The spectral radiance of the atmospheric path between Mini-TES and the target is assumed to be negligible, and the atmospheric transmissivity in this path is assumed to be 1.0. Removing the downwelling radiance deepens the absorption bands (7), but given the relatively high surface temperatures (typically ~265 K) and the relatively low atmospheric opacity, the effect of the atmosphere on the spectra presented here is relatively small. The observed derived mineral abundances typically vary by less than 5% for any mineral for deconvolutions done with and without an atmospheric correction. Calculations based on the Disruin model and are reported at the precision determined for similar analyses of laboratory and MGS TES rock and mineral mixtures. The abundances listed in the figures and tables are the numerical best fit values from the linear least squares deconvolution model and are reported at the precision determined from the deconvolution model.


12. The Mini-TES nominal field of view is 20 M at infinity. For near-field observations, the field of view is the aperture diameter (6.35 cm) plus the 20 rad divergence from the location of the telescope to the point being observed. Targets in the arm volume shown in Fig. 10 were imaged at 100 × 100 cm⁻¹, giving a total path length of ~3 m from the Mini-TES telescope. The resulting Mini-TES field of view is ~12 cm at the end of the rover arm.


14. The Mini-TES nominal field of view is 20 M at infinity. For near-field observations, the field of view is the aperture diameter (6.35 cm) plus the 20 rad divergence from the location of the telescope to the point being observed. Targets in the arm volume shown in Fig. 10 were imaged at 100 × 100 cm⁻¹, giving a total path length of ~3 m from the Mini-TES telescope. The resulting Mini-TES field of view is ~12 cm at the end of the rover arm.


17. The Mini-TES-derived volume abundances are estimated to have accuracies of ±5 to 10% on the basis of similar analyses of laboratory and MGS TES rock and mineral mixtures. The abundances listed in the figures and tables are the numerical best fit values derived from the linear least squares deconvolution model and are reported at the precision determined from the deconvolution model.


21. The Mini-TES-derived volume abundances are estimated to have accuracies of ±5 to 10% on the basis of similar analyses of laboratory and MGS TES rock and mineral mixtures. The abundances listed in the figures and tables are the numerical best fit values derived from the linear least squares deconvolution model and are reported at the precision determined from the deconvolution model.


24. The Mini-TES nominal field of view is 20 M at infinity. For near-field observations, the field of view is the aperture diameter (6.35 cm) plus the 20 rad divergence from the location of the telescope to the point being observed. Targets in the arm volume shown in Fig. 10 were imaged at 100 × 100 cm⁻¹, giving a total path length of ~3 m from the Mini-TES telescope. The resulting Mini-TES field of view is ~12 cm at the end of the rover arm.


32. We thank all of the individuals at Raytheon Santa Barbara Remote Sensing, led by S. Silverman, and at the Jet Propulsion Lab, whose effort and dedication have led to the successful acquisition of Mini-TES data from the surface at Meridiani Planum. We thank J. Bishop for providing us with the spectrum of EET A79901B. A. Watson provided assistance with data processing analysis. Funding was provided by the MER Project Science Office.

**Plates Referenced in Article**

www.sciencemag.org/cgi/content/full/306/5702/1733/DC1

Plates 3 and 11

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