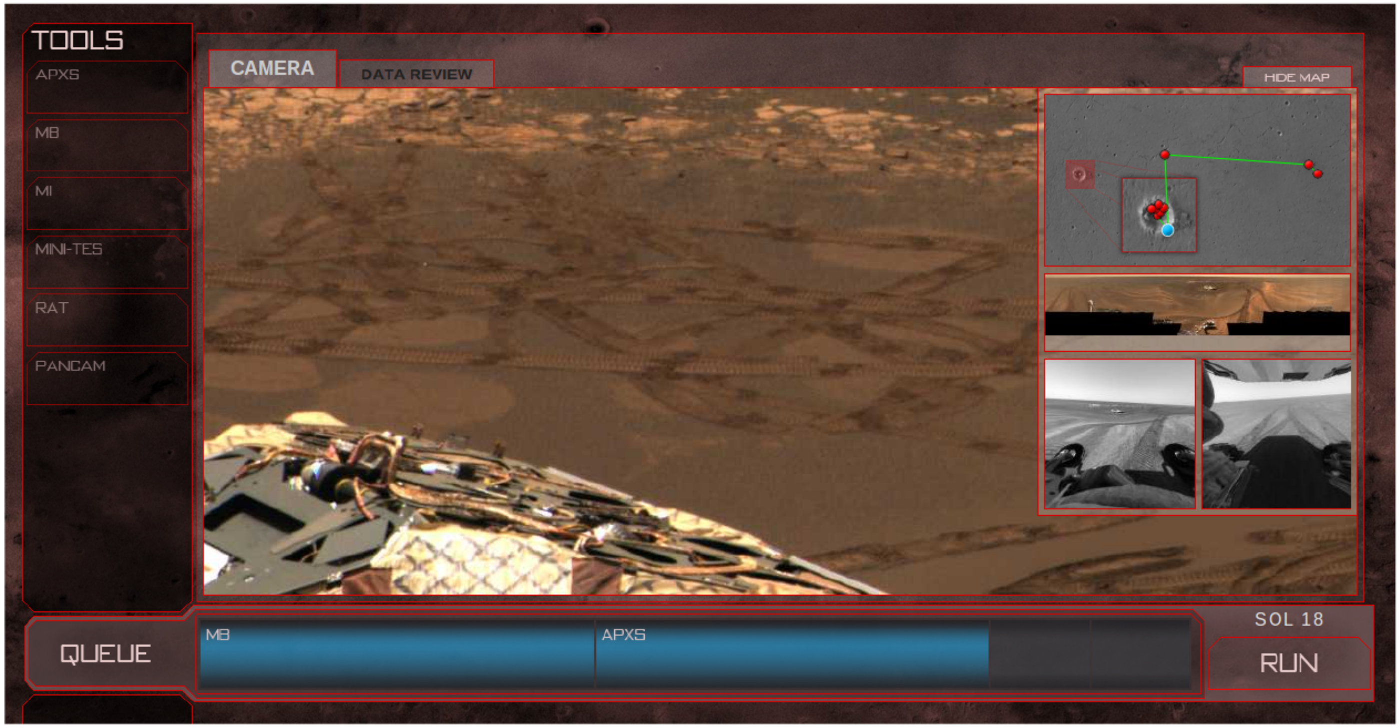
The Extraterrestrial Virtual Field Experience

Putting students in the role of a NASA mission science team.

Asking questions, directing observations, analyzing results.



The EVFE is entering an “open beta.” We’re seeking educators interested in serving as “beta testers” by using the activity in their own classrooms and providing feedback.

spif.astro.cornell.edu

To express interest, please contact:
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Extraterrestrial Virtual Field Experience: Rover *Opportunity* on Mars

- This is a computer-based laboratory module for high-school students.
- The module uses actual NASA data returned by one of the Mars rovers.
- The module puts students in the scientific "driver's seat" to see if they can make some of the important discoveries about Mars that the rover science team did using the same data.
  - While this might sound ambitious, the software simplifies mission operations and science concepts to make them accessible to the students.
  - In addition, students (and the teacher) get help from the "Mission Manager" embedded in the software that helps explain the latest data, and sometimes poses questions to guide student inquiries toward the ultimate scientific goals.

Extraterrestrial Virtual Field Experience: Rover *Opportunity* on Mars

- The module includes
  - Software at http://spif.astro.cornell.edu/EVFE/default.htm
  - Teacher's Guide (27 pp.)
  - Teacher's Introduction Slides (source material for the teacher to extract and use)
- Skills emphasized in this module:
  - Making an observation, interpreting an observation, and the difference between the two
  - Note-taking as an aid for distilling information toward an overall learning objective
  - Prioritization during inquiry for efficiency and effectiveness
- Intended for
  - Two or more sessions of an Earth Science class as syllabus enrichment, OR
  - An after-school enrichment activity for a science-oriented student group.

Teacher Presentation Slides for

Mars Exploration Rover
Opportunity

An Extraterrestrial Virtual Field Experience

The following source material can be modified and adapted by the teacher for introducing students to the MER *Opportunity* EVFE module.

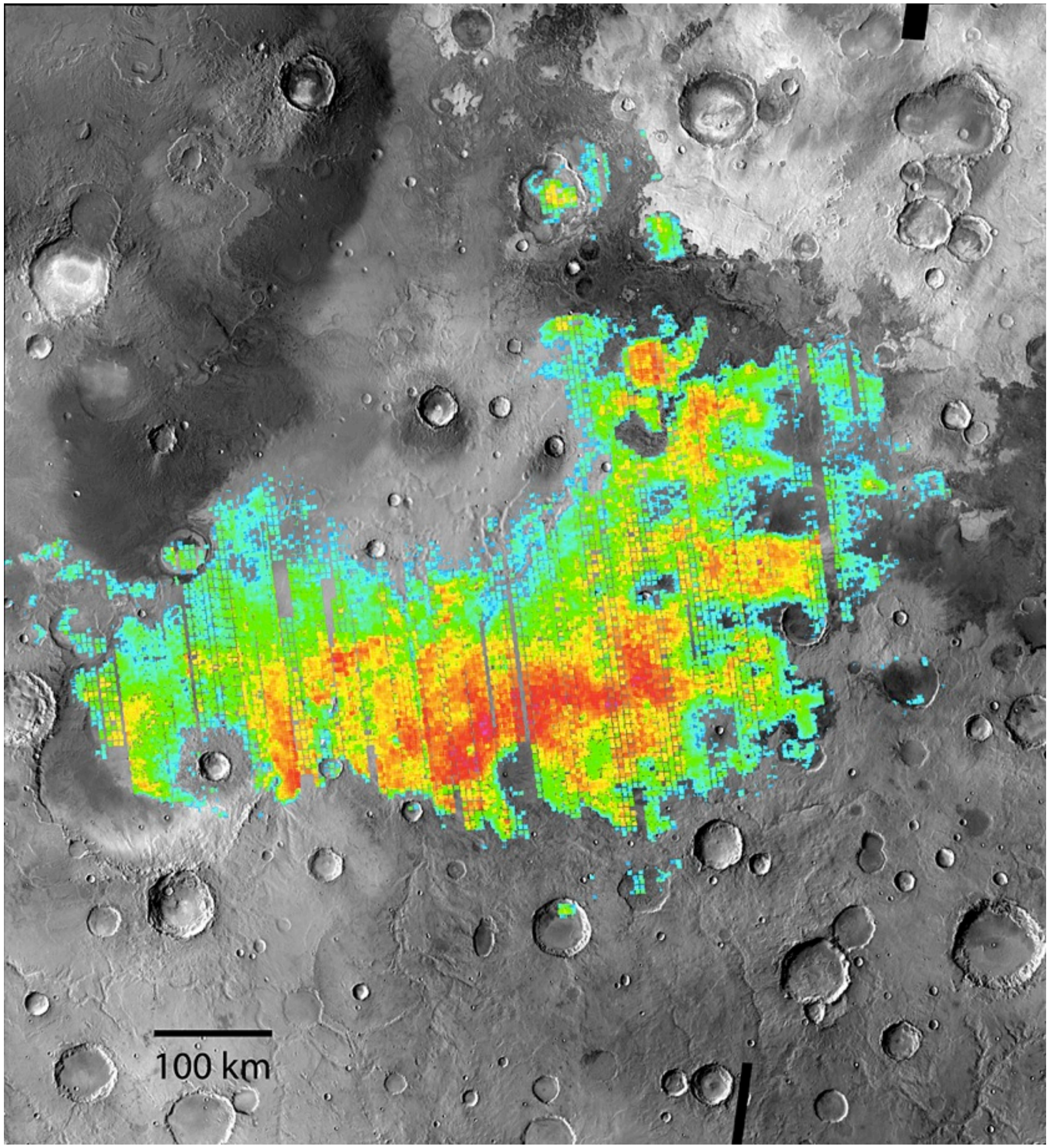
What's a "Virtual Field Experience" (VFE?)

- Geological fieldwork is the backbone of the Earth Science. It's front-line, boots-on-the-ground exploration.
- VFE = Virtual Field Experience, or doing geological fieldwork *virtually*, without actually being on-site.
- A sense of "you are there" immersion requires lots of on-scene imagery (and other data) acquired ahead of time somehow, then organized to develop an exploratory experience for the user.
- A VFE, like any fieldwork, is *inquiry*-based, guided by an overarching goal.
  - Not just "looking around"
  - Real fieldwork is expensive (whether for scientific or industry purposes)
    - Transportation costs of personnel to/from the field site
    - Maintenance of the field crew and equipment on site
    - Paying the highly-trained professional personnel for their time!
  - So fieldwork needs to be *carefully justified* against its financial costs.
  - Fieldwork is purposeful, and, if one even gets to do it, it must be done *efficiently*.
    - Don't forget the reason you're out there
    - Yet be responsive to recognize the value of unexpected discoveries, and react accordingly
    - Use the right tool for the right job, in the right order → *efficiency*.

Differences Between a VFE and an *Extraterrestrial* VFE

- Doing fieldwork (virtual or actual), and exploring an extraterrestrial landscape share a number of strategies, but also differ in important ways.
- In extraterrestrial VFEs (EVFEs), additional motivations come into play!
  - For NASA, $$ mission costs and technical demands constrain in situ exploration to only
    - very specific locations
    - very limited time
    - specific, carefully justified reasons.
    - These factors strongly guide the user experience for EVFE realism.
  - The costs of doing real NASA flight operations on a daily basis and the finite lifetimes of space hardware impose significant pressures.
  - So, as one begins to learn about an alien landscape in an EVFE, one must constantly ask "Based on what I've been finding here, what should be done *next* to learn the *most* about this landscape, as quickly as possible?"
  - High costs and finite mission lifetimes mean that exploring inefficiently on a NASA mission has far greater negative consequences than in a terrestrial fieldwork setting.
  - An EVFE emphasizes developing an efficient, dynamic path of inquiry.
  - Skills can be honed that not only yield insights into the history of landscapes, but, just as importantly, also help to refine the effectiveness of the user's skills of inquiry.

EVFE: MER at Meridiani Planum



In 2004, the Thermal Emission Spectrometer orbiting on Mars Global Surveyor detected the presence of hematite—a mineral commonly associated with aqueous processes on Earth—in a few places on the surface of Mars (Christensen et al., 2000; 2001).

One of these locations, in Meridiani Planum, was determined safe enough to land a Mars rover.

~7% hematite

~11% hematite

15% hematite

After Christensen et al. (2001) *JGR-Planets*, plate. 2.

EVFE: MER at Meridiani Planum

- Mars rover *Opportunity* was sent to Meridiani Planum to determine the
  - nature of hematite at the surface, in order to explain the signature detected from orbit
  - origin of the hematite and evolution of the landscape
  - implications for past aqueous, potentially habitable, environments on Mars

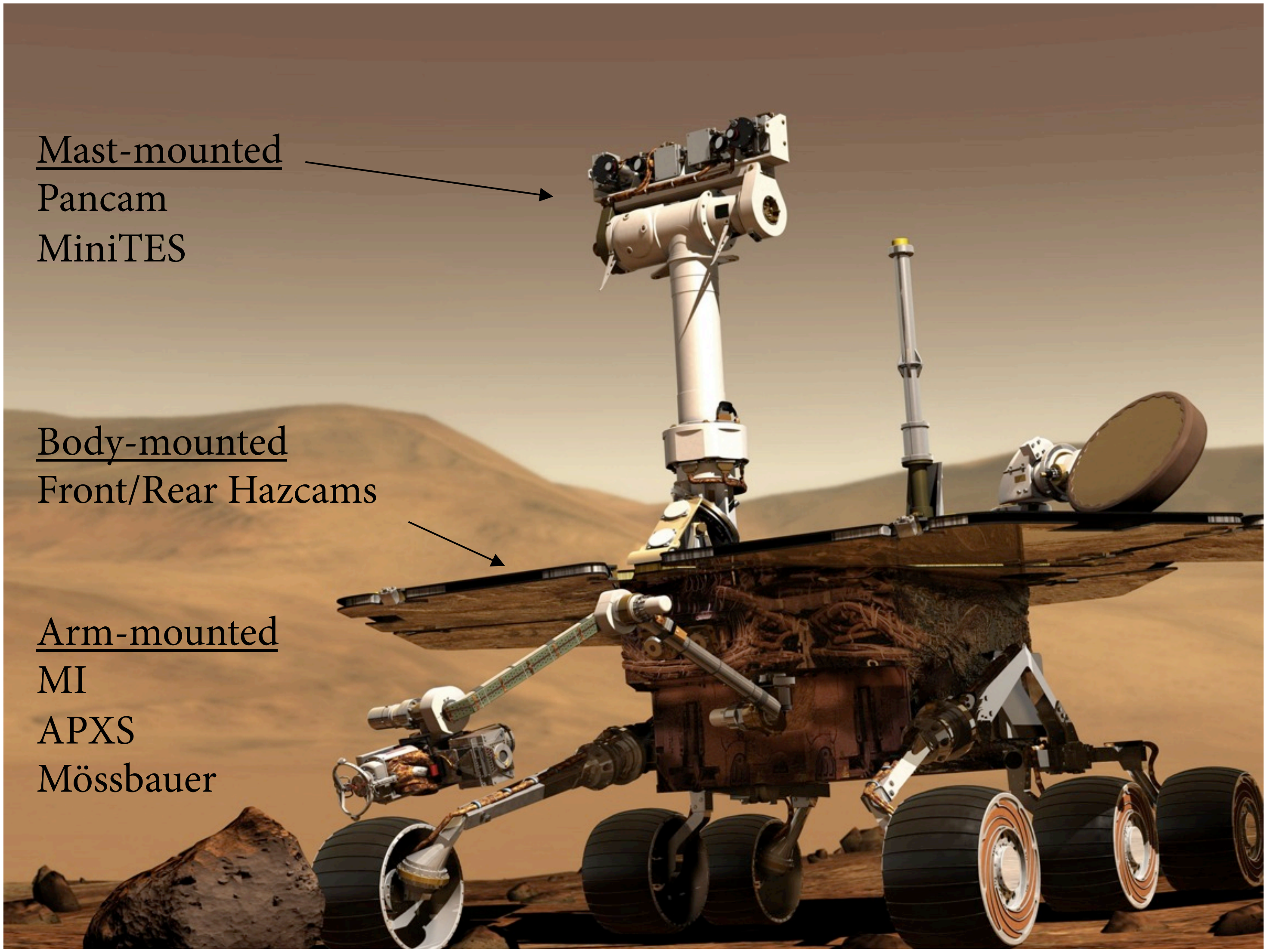
- Mission objectives for the EVFE are similar:
  - Find where the hematite is on the surface
  - How did the hematite get there?
  - Why does the landscape look the way it does?
  - What role did water play in the evolution of this landscape?

- You will be "collecting" and consulting real Mars Exploration Rover (MER) data to address these questions.

- You will "get the keys to the rover," and be turned loose on the plains of Meridiani Planum with a job to do.

EVFE: MER at Meridiani Planum

- You will be working with the spacecraft MER-B, named *Opportunity*, which was launched toward Mars in 2003, landing in 2004.



EVFE: MER at Meridiani Planum

MER instrument inventory (tools in your toolbox):

- Pancam = color camera, mounted about eye-level for a person standing on Mars
- MI = hand lens, for close-up views, nearly touching the target
- APXS *touches* targets to tell you which elements are present, and their relative quantities,
  - e.g., how much iron is present
- Mössbauer *touches* targets to tell you about minerals containing iron
  - This might seem like a narrow job description, but much Mars mineralogy involves iron
  - Mössbauer tells you how much of the iron in a sample is in the form of hematite.
  - Need both APXS *and* Mössbauer to determine the amount of hematite in a sample
  - Good strategy for efficient hematite hunters:
    - On a promising soil or rock target, do APXS measurement first.
    - Do the APXS results indicate the sample has lots of iron?
    - If not, skip the Mössbauer measurement, and move on to *save time*
- Navcam, Front Hazcam for targeting all of the above
- (Other: MiniTES hematite signature map used only at mission start; RAT for grinding—no science product; Rear Hazcam included for completeness)

EVFE: MER at Meridiani Planum

The data you will be working with are pretty realistic.

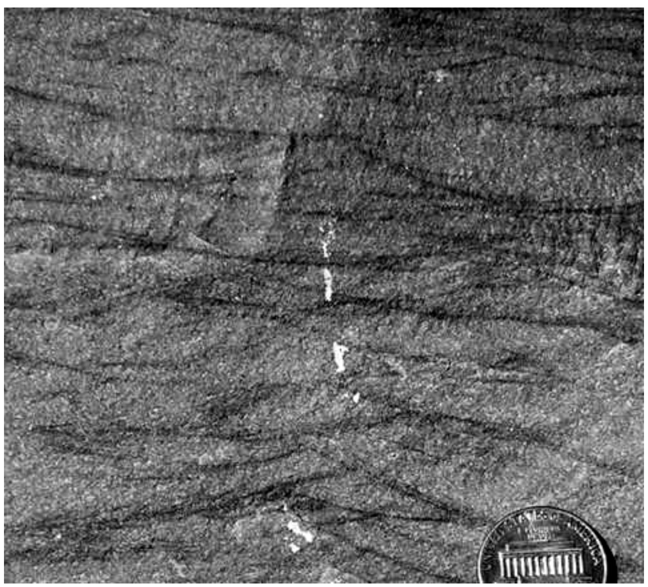
- Pancam, Navcam, Front/Rear Hazcam, MI images and mosaics were created from full-resolution, calibrated data.
- APXS and Mössbauer results are sourced from peer-reviewed journal articles (e.g., Morris et al., 2006).

Each observation has accompanying text:

- For the planning phase, an “advertisement” is accessible, telling what might be learned if the observation were carried out.
  - Remember, time is of the essence. Based on the information provided about the observation and its cost in resources, you must decide (fairly quickly) if the potential science gain is worth the resource cost—or if there are better choices.
- After execution, a “Mission Manager” report helps you assess the observation.
  - a basic discussion hinting at the utility and value of the completed observation
  - implications for future planning
  - questions for you to answer and address in your Mission Log

Some useful science information for exploring Meridiani Planum

- A little about the mineral hematite:
  - An iron-rich, generally *aqueous* mineral
  - Powder is always reddish
  - Relatively hard
- Several clues can point to water in the past:
  - Some minerals (e.g., hematite) are typically made with water
  - Salts are made when water evaporates (e.g., sulfates)
  - Some geological features can only be made with water (e.g., diagnostic sedimentary rock textures)



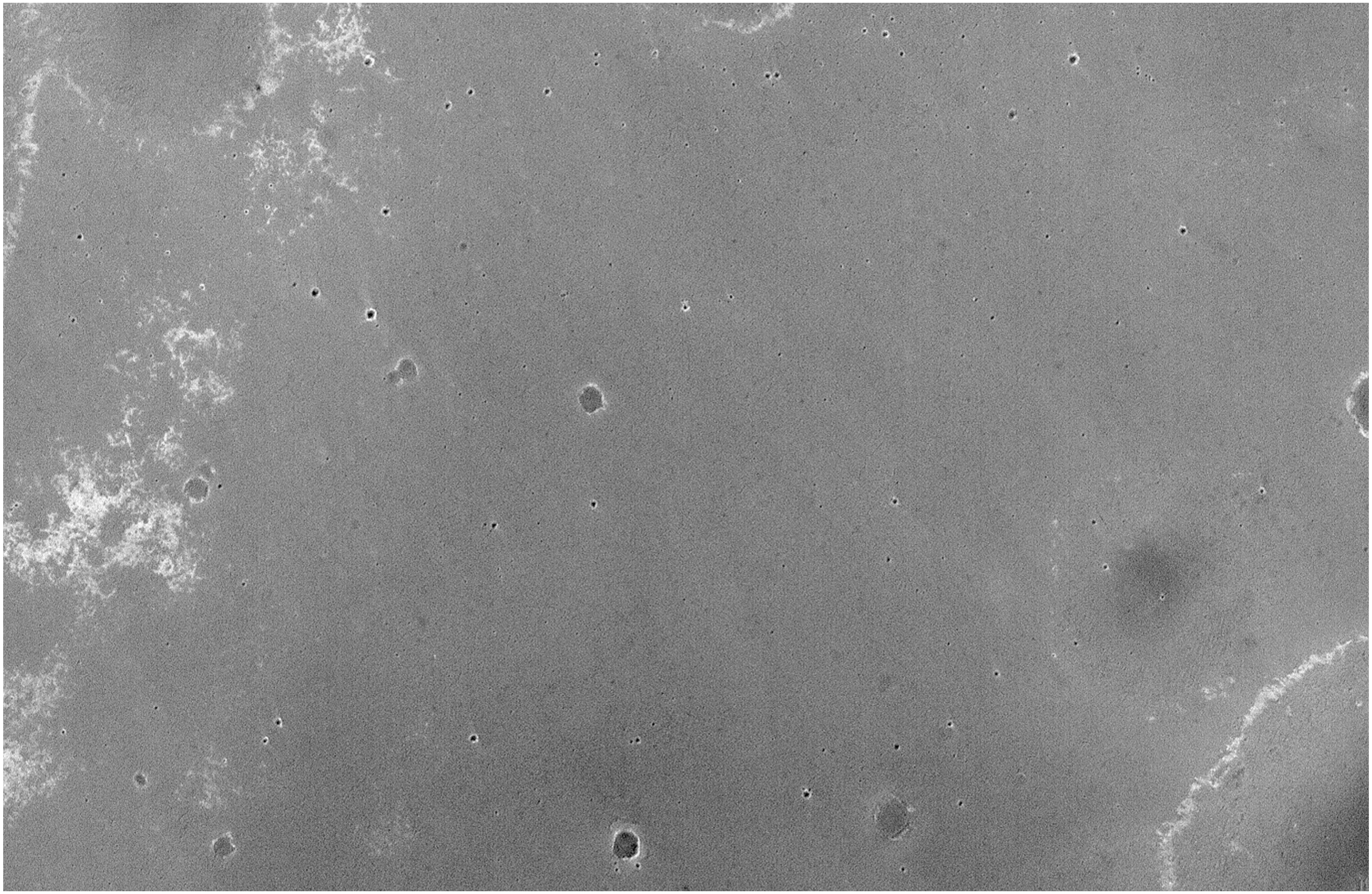
Small upward curving ripples indicate water-lain deposits.

Spots are small round concretions left as minerals precipitated from ground water.

Salt deposits left at fringes of hot springs.

From orbit, a pre-landing view of Meridiani Planum: Where's the hematite?

Not a lot of clues from orbit; have to go down there and look…



3 km-wide excerpt from MOC R1104134. Source: MSSS, http://www.msss.com/mars_images/moc/2004/01/24/

EVFE: How to conduct the mission (i.e., how to use the software)

Establish and maintain a "sol-by-sol" detailed Mission Log of

- What you did
- Why you did it
- What you found out

The Mission Log should record "sol-by-sol" observations, hypotheses, results that seem most useful/significant toward achieving mission goals, and must include

- written answers to questions embedded in the software's "Mission Manager" results
- a final written summary of events describing where the hematite is found at the landing site, how it formed, and a simple outline of the geologic sequence of events that produced the landscape as we see it today.

Time limit

- There might not be time to do everything; must prioritize efficiently for obtaining the observations leading to results that matter most.

Recommended flow:

- The first two sites will be done as examples, before turning the rest of the mission operation over to you.
- A typical "sol" of your activities will involve
  - Looking at data you've just received (i.e., from the last plan you made)
  - Deciding what's most important about the new data, and how it relates to what you previously did/learned
  - Making an observation/action plan for the next "sol"
  - Execute the rover commands!
  - Good Mission Log practice is essential

  Compare latest data/results with data/results collected earlier

  → *making connections*

  → *hypothesizing, testing, observing, concluding*

Mission begins at:

http://spif.astro.cornell.edu/EVFE/default.htm

References

Christensen, P. R., J. L. Bandfield, R. N. Clark, K. S. Edgett, V. E. Hamilton, T. Hoefen, H. H. Kieffer, R. O. Kuzmin, M. D. Lane, M. C. Malin, R. V. Morris, J. C. Pearl, R. Pearson, T. L. Roush, S. W. Ruff, and M. D. Smith (2000) Detection of crystalline hematite mineralization on Mars by the Thermal Emission Spectrometer: Evidence for near-surface water, *J. Geophys. Res.*, *105*, E4, 9623-9642.

Christensen, P. R., R. V. Morris, M D. Lane, J. L. Bandfield, and M. C. Malin (2001) Global mapping of Martian hematite mineral deposits: Remnants of water-driven processes on early Mars (2001) *J. Geophys. Res.*, *106*, E10, 23873-23885.

Morris, R. V., et al. (2006) Mössbauer mineralogy of rock, soil, and dust at Meridiani Planum, Mars: Opportunity's journey across sulfate-rich outcrop, basaltic sand and dust, and hematite lag deposits, *J. Geophys. Res.*, *111*, E12S15, doi: 10.1029/2006JE002791.

Squyres, S. W. et al. (2004) The Opportunity Rover's Athena Science Investigation at Meridiani Planum, Mars, *Science*, *306*, 1698-1703.