



Smithsonian  
*National Air and Space Museum*

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Washington, DC 20546

Dear Michael:

This letter summarizes the outcomes and findings of the fourth Mars 2020 Landing Site Workshop held in Glendale, CA, from October 16-18, 2018. The meeting was very well attended, with more than 150 to over 200 people present on each of the three days of the workshop. Participants included members of science community and the Mars 2020 project and instrument science teams on all three days of the workshop. The workshop was broadcast using Adobe Connect and attracted an additional ~80 participants daily, though remote attendees did not participate in assessment of the candidate landing sites.

The workshop included oral presentations and discussion related to the science potential of the four remaining candidate landing sites (Table 1): Columbia Hills, Jezero Crater, and NE Syrtis, including an additional landing ellipse within the NE Syrtis region dubbed “Midway.” Midway is located closer to Jezero crater than the original NE Syrtis ellipse and was proposed as a site by the Mars 2020 Science Team that might enable achieving the science objectives of the mission by accessing exploration targets relevant to both Jezero crater and NE Syrtis.

**Table 1.** Remaining Candidate Landing Sites for Mars 2020 Mission. Ellipse center point, elevation and ellipse size with the long axis oriented east-west.

| Location       | Lat (degN) | Long (degE) | Approx MOLA Elevation (km) | Approx Buffered Ellipse Axes (km) |
|----------------|------------|-------------|----------------------------|-----------------------------------|
| Columbia Hills | -14.5711   | 175.4374    | -1.9                       | 9 x 8                             |
| Jezero         | 18.4463    | 77.4565     | -2.6                       | 9 x 8                             |
| Midway         | 18.2747    | 77.0480     | -2.0                       | 9 x 8                             |
| NE Syrtis      | 17.8899    | 77.1599     | -2.0                       | 9 x 8                             |

Presentations emphasized new science content, increasing confidence in the interpretations of site science potential, and (or) potential extended mission targets for the sites. In addition,

the Mars 2020 Project provided mission scenarios for each site that included discussion of potential exploration targets, observations, and sampling strategies relative to mission goals and important Mars science described in the 2013-2022 Planetary Science Decadal Survey.

Workshop presentations were grouped into introductory sessions related to mission status and strategies that were followed by sessions focused on each of the candidate sites. The website [marsnext.jpl.nasa.gov](https://marsnext.jpl.nasa.gov) serves as an archive for the workshop program, scientific selection criteria used for assessment, and workshop presentations. The final sessions on the third day were geared towards compilation of summary quad charts for each site and community assessment relative to the scientific selection criteria (Table 2). Additional time was provided for discussion at the end of each session and all discussion sessions were lively and involved. We recognize and sincerely appreciate the considerable time and effort made by participants in preparing what were uniformly excellent presentations for the workshop.

The quad charts summarizing the science pros, issues, and remaining uncertainties are provided in Figures 1-4 and as a separate attachment to this letter. The assessment relative to the scientific selection criteria (Table 2) that followed was made using an online “ballot” submitted to Google Forms and subsequently tabulated in near real-time. Workshop participants were instructed to assess each site relative to each criterion using values of one (low) to five (high). We want to recognize Jacob Adler at ASU for his continued work in creating the assessment tool. Summary results were presented as color plots (red low, yellow intermediate, green high) portraying the average and standard deviation of each site relative to individual criteria (Figure 5) and in tabular form (Figure 6) for the average score for all six criteria for each site.

**Table 2.** Criteria Used to Assess Candidate Sites at 4th 2020 Landing Site Workshop

**Prime Mission Assessment**

Criterion 1 (In-Situ Science):

The landing site includes an astrobiologically-relevant ancient environment and has geologic diversity with the potential to yield fundamental scientific discoveries when it is a) characterized for the processes that formed and modified the geologic record; and b) subjected to astrobiologically-relevant investigations (e.g., assessment of habitability and biosignature preservation potential). (scoring: 1=low potential, 5=high potential)

Criterion 2 (Returnable Cache Science):

A rigorously documented and returnable cache of rock and regolith samples assembled at this site has the potential to yield fundamental scientific discoveries if returned to Earth in the future. (scoring: 1=low potential, 5=high potential)

Criterion 3:

There is confidence in the assumptions, evidence, and any interpretive models that support the assessments for Criteria 1 and 2 for this site (or proposed traverse). (scoring: 1=low confidence, 5=high confidence).

**Extended Mission Scenario Assessment**

Criterion 1 (In-Situ Science):

The extended mission scenario has the potential to yield fundamental additional scientific discoveries using the rover payload. (scoring: 1=low potential, 5=high potential)

Criterion 2 (Returnable Cache Science):

Rock and regolith samples assembled in the extended mission have the potential to yield fundamental additional scientific discoveries if returned to Earth in the future. (scoring: 1=low potential, 5=high potential)

Criterion 3:

There is confidence in the assumptions, evidence, and any interpretive models that support the assessments for Criteria 1 and 2 for the extended mission. (scoring: 1=low confidence, 5=high confidence).

The quad charts (Figures 1-4) reveal that all four candidate sites represent diverse and potentially high value exploration targets for the Mars 2020 rover. The Columbia Hills site within Gusev crater includes putative hot spring deposits of opaline silica sinter with small (cm's scale) finger-like features that, on Earth, form in association with biological activity. Moreover, the nearby carbonate rocks may record past weathering in a thicker atmosphere. Landing on cratered volcanic plains would enable sampling that could eventually constrain the age of cratered surfaces across Mars. Targets for extended mission exploration include possible lake and delta deposits to the south of the landing site and within Gusev crater. Nevertheless, it is uncertain whether the finger-like features were formed by deposition or erosion, how old they are, or whether they may relate to past biological activity. Moreover, it is unclear whether the rocks forming the Columbia Hills can be confidently placed in a broader context.

The Jezero crater site includes a river delta that extends into the crater and occurs at the same elevation as an outlet on the far side of the crater, thereby indicating the presence of a lake once filling the crater in Noachian to Early Hesperian times on Mars. The delta and nearby outcrops expose clays and other materials whose properties make them favorable for preserving organics and (or) other biogenic signatures. In addition, there are carbonate-bearing rocks whose origin may relate to past weathering and overlying cratered and possibly volcanic rocks on the crater floor that could be used to help constrain Martian chronology. Candidate extended mission targets include access to the rocks in and around the Midway site (below). Remaining uncertainties relate to the duration of the lake and the age, the origin of the carbonate-bearing rocks, and whether the crater floor rocks are of the correct type and extent to be useful in constraining the broader chronology of the planet.

The Midway and NE Syrtis Sites include access to ancient rocks that include clays and carbonate-bearing rocks with evidence for past alteration by water. These rocks form a widespread and diverse sequence spanning from the Noachian to Hesperian in age and may be accessible at either of the two sites. Importantly, both sites expose large blocks of ancient and sometimes layered materials dubbed "megabreccia" that were likely excavated and emplaced during formation of the nearby Isidis (NE Syrtis) and (or) Jezero craters (Midway). As such, these rocks, and others in and around the sites may provide insight into the changing conditions on Mars, ranging from those recorded in ancient subsurface groundwater environments to younger sequences possibly shaped by surface drainage. Possible extended mission scenarios include a trek to the south from the NE

Syrtis site to interrogate younger sulfate and volcanic rocks to a journey from the Midway site to Jezero crater to access the materials exposed near the delta there (above). Both sites have remaining uncertainties: there are multiple hypotheses for the origin of rocks exposed at the sites and it is unclear how organics might be concentrated and preserved. Moreover, high-resolution spectral data at Midway is sparse and makes understanding key aspects of the exploration targets more difficult and it is not clear whether the megabreccia blocks at Midway are derived from Isidis basin or Jezero crater.

The summary assessment plots (Figures 5 and 6) reveal the Jezero crater site is assessed the highest or nearly the highest for all criteria relative to both the prime and extended mission. The Midway and NE Syrtis sites were also assessed highly for all criteria for the prime and extended mission, but slightly below the Jezero crater site. By contrast, the Columbia Hills site was consistently assessed lower than the other three sites for almost all criteria related to both the prime mission and extended mission objectives (except it was assessed slightly higher than the Midway site relative to the confidence in interpretations for the prime mission). Interestingly, the Midway and Jezero crater sites were assessed the highest (and received the most votes for high potential) with respect to extended mission criteria, perhaps reflecting the interest in possible extended mission opportunities between the two sites.

We continue to appreciate the opportunity for the science community to contribute to the Mars 2020 landing site selection process. It is clear that the workshops bring broad expertise into assessment of the candidate landing sites and result in energetic discussion of the relative merits of candidate landing sites.

Sincerely,



John Grant



Matt Golombek

Co-Chairs, Mars 2020 Landing Site Steering Committee

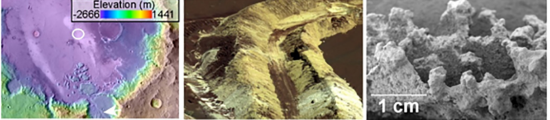
|   |  |
|---|--|
| <p><b>Columbia Hills (Gusev Crater) Site</b></p>  <p>14.4S, 175.6E</p> <p><b>Overarching Hypothesis: <i>Candidate Silica Hot Spring and detection of Olivine Carbonate-bearing Deposits</i></b></p> <ul style="list-style-type: none"> <li>• Columbia Hills preserves candidate opaline silica sinter and may have formed by precipitation at hot springs. Outcrops expressing digitate-nodular features may represent primary depositional forms associated with past biological activity. Local outcrops of olivine-carbonate may be representative of more widespread occurrences. Carbonate-bearing rocks may indicate weathering of mafic rocks in a denser CO<sub>2</sub> atmosphere.</li> </ul> | <p><b>Specific Pros of Site:</b></p> <p><b>Setting -</b></p> <ul style="list-style-type: none"> <li>• Columbia Hills is located in the ~166 km diameter Gusev crater, and lies at the downstream terminus of Ma'adim Vallis. Water draining from Ma'adim Vallis into Gusev in the Noachian may have deposited lacustrine/deltaic sediments, subsequently largely buried by Hesperian-aged basalts. Past exploration by the MER <i>Spirit</i> showed evidence for opaline silica that could result from hot springs.</li> </ul> <p><b>Diversity -</b></p> <ul style="list-style-type: none"> <li>• Olivine Carbonate-bearing ("Comanche" outcrop) may be representative of more widespread occurrences of similar materials</li> <li>• Hesperian plains volcanics provide an excellent tie point for Martian crater chronology</li> <li>• Diverse igneous rocks in Columbia Hills provide insight into evolution and differentiation of Mars.</li> <li>• Wide range of aqueously processed rocks and soils in Columbia Hills</li> <li>• Presence of sulfates and diversity of alteration mineralogies</li> <li>• Opaline silica including centimeter to decimeter-scaled nodular and digitate-nodular features may be primary depositional forms (sinter) associated with past biological activity.</li> <li>• Volcanic lava and ash plains modified by impact and aeolian processes and volcaniclastic sediments</li> <li>• Possible lacustrine and (or) deltaic materials south of landing ellipse add diversity of samples during the extended mission.</li> </ul> <p><b>Preservation -</b></p> <ul style="list-style-type: none"> <li>• Terrestrial hot spring silica deposits have analogous digitate features and are biologically mediated.</li> <li>• Any identifiable lacustrine facies likely have predictable properties that include deposition/formation of fine-grained clays and concentration and burial of organics and biosignatures.</li> </ul> <p><b>Exploration Targets -</b></p> <ul style="list-style-type: none"> <li>• Previous exploration provides specific targets for sample acquisition</li> <li>• Outcrops expressing opaline silica digitate features, olivine-carbonate-bearing rocks (Comanche). Extended mission targets include possible ash and lacustrine/deltaic deposits to south.</li> </ul> |
| <p><b>Site Issues:</b></p> <ul style="list-style-type: none"> <li>• Uncertain whether digitate-nodular features are primary depositional or erosional features</li> <li>• Unclear whether stratigraphic sequence for Columbia Hills rocks can be established</li> <li>• Lacks novelty</li> </ul>  | <p><b>Remaining Uncertainties:</b></p> <ul style="list-style-type: none"> <li>• Stratigraphic position (are they Noachian?) and origin of digitate features (biogenic v. erosion/leaching) and duration of setting (relatively short?)</li> <li>• Is diversity of Columbia Hills representative of local or global processes and conditions?</li> <li>• Whether outcrops of olivine carbonate-bearing materials are more widespread in Gusev and beyond (e.g. Jezero crater) and whether they represent habitable environments.</li> <li>• Uncertain whether preservation state/potential digitate structures is consistent with gradational setting.</li> </ul>   |

Figure 1. Columbia Hills summary quad chart

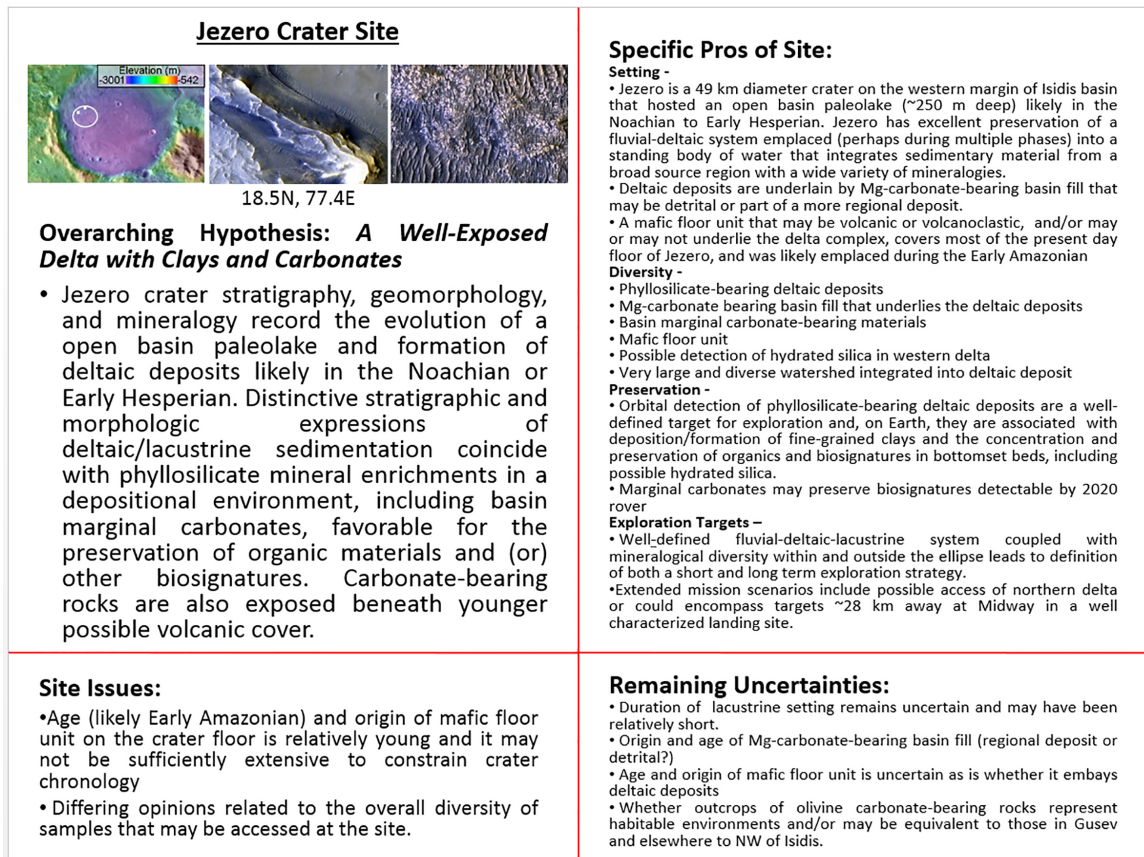


Figure 2. Jezero crater summary quad chart



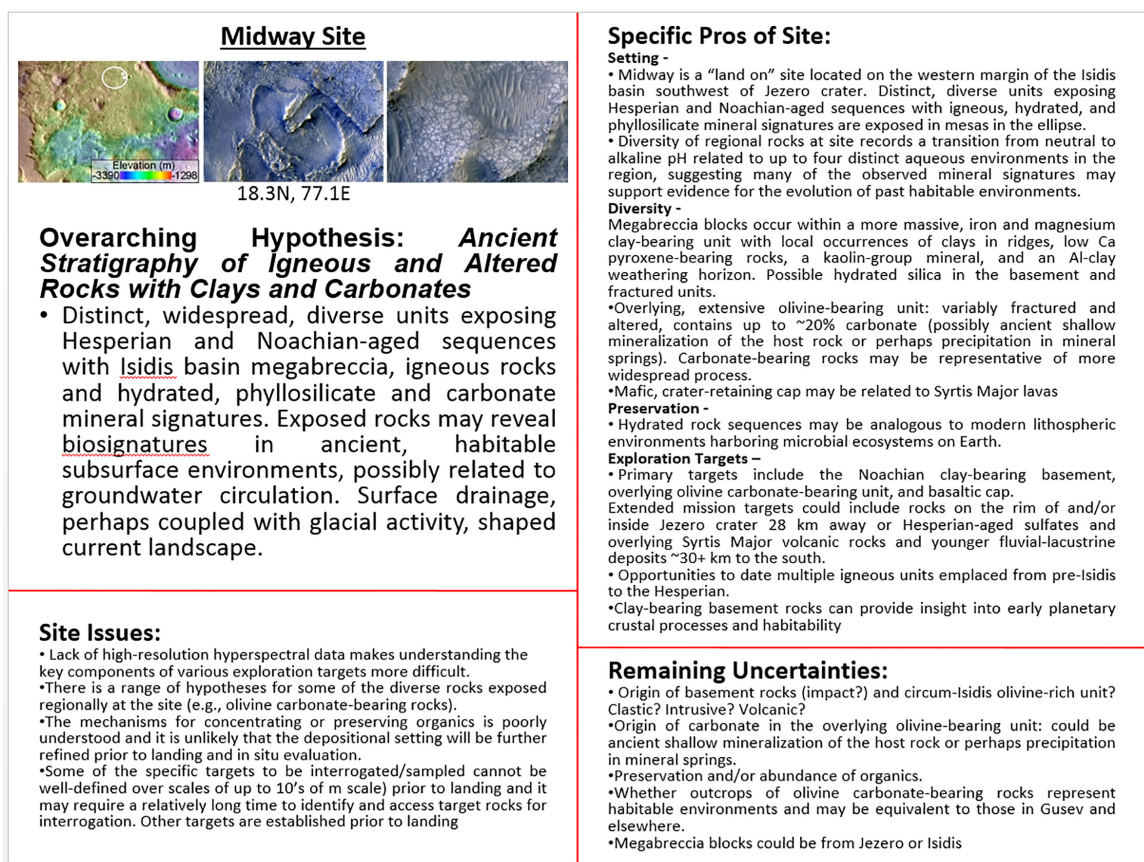


Figure 3. Midway summary quad chart

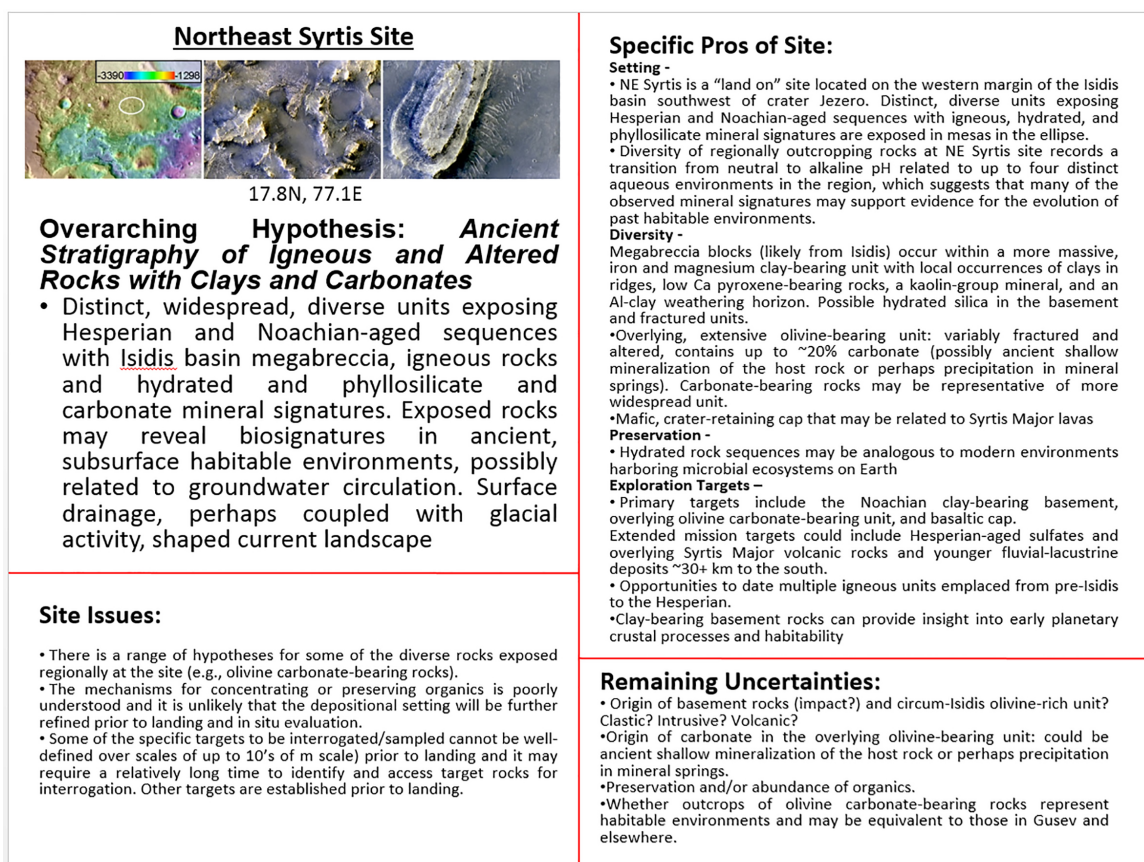


Figure 4. NE Syrtis summary quad chart



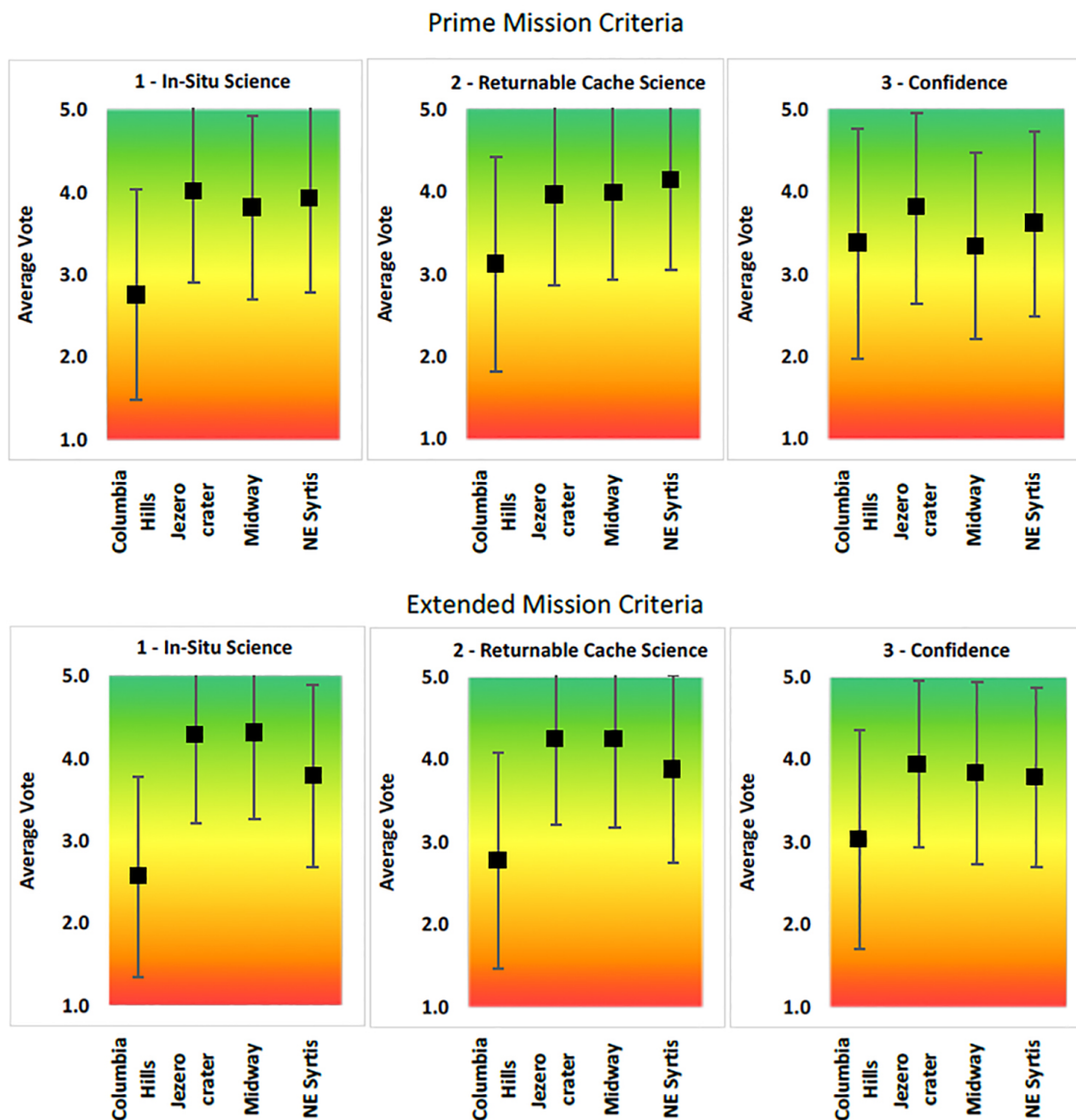


Figure 5. Summary assessment of the final four candidate sites (average and standard deviation) relative to each of the five criteria. Red/1 is the low, Yellow/3 is intermediate, and Green/5 is high.

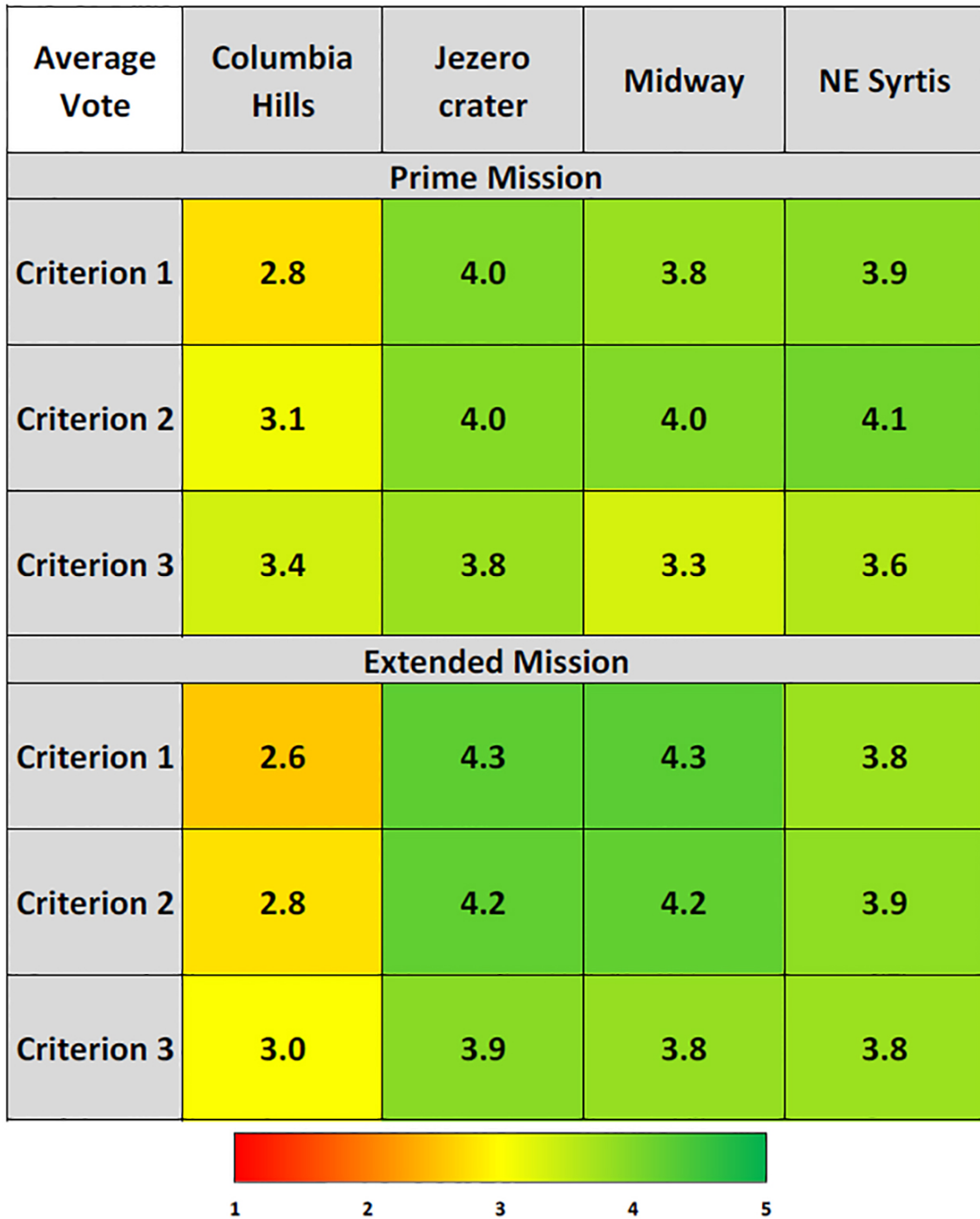


Figure 6. Summary of the average score for all six criteria for each of the final four candidate sites. Red/1 is low, Yellow/3 is intermediate, and Green/5 is high.