**POLYGONAL CRACKING AND "WOPMAY" WEATHERING PATTERNS ON EARTH AND MARS: IMPLICATIONS FOR HOST-ROCK PROPERTIES.** Marjorie A. Chan [1], Winston M. Seiler[1], Richard L. Ford[2], and W. Adolph Yonkee[2], [1]University of Utah- Department of Geology & Geophysics, Salt Lake City, UT 84112, [2]Department of Geosciences, Weber State University, Ogden, UT 84408.

**Introduction:** Terrestrial analogs of sedimentary and weathering features are valuable for understanding similar features at Meridiani Planum [1] imaged by the Mars Exploration Rover (MER) Opportunity. The Jurassic Navajo Sandstone exposed in southern Utah and northern Arizona shares three important characteristics with traits recognized in the Burns formation at Meridiani Planum: 1) iron oxide mineralogy preserved in concretions ("blueberries") [2, 3], 2) eolian stratified sedimentary rocks, and 3) distinctive polygonal cracking (Fig. 1). These important physical traits are linked to a relatively porous, homogeneous host rock that facilitates diagenesis and weathering.

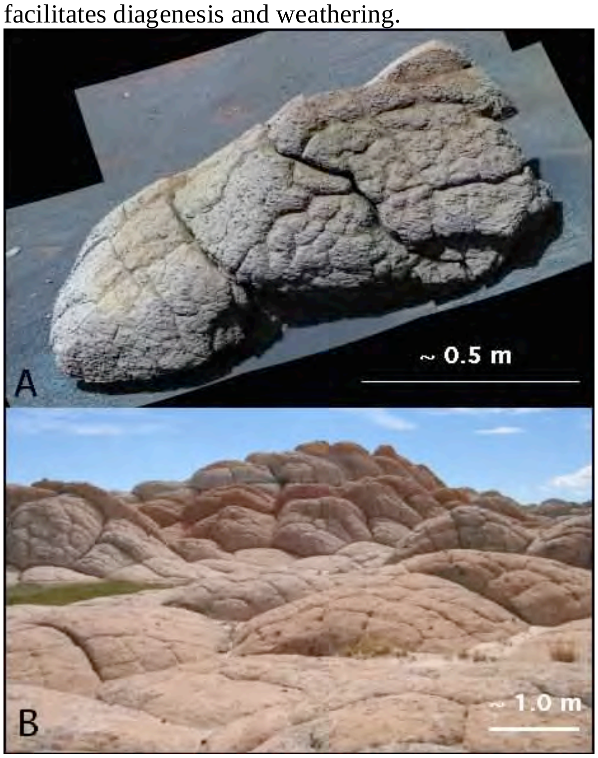


*Fig. 1. A. Polygonal cracks in the Wopmay rock imaged by the MER Opportunity, Endurance Crater area of Meridiani Planum, Mars (Pancam false color photo credit: NASA/JPL/Cornell). The coloring accentuates iron-rich spherical concretions as bluish dots embedded in the rock and loose accumulations on the ground around it. B. Similar terrestrial examples of pervasive polygonal cracks and "cauliflower"-like weathering in the Jurassic Navajo Sandstone, Vermillion Cliffs, northern Arizona.*

The Navajo Sandstone commonly displays shallow cracks (penetration depths typically < 1m, below which cracks die out) with low persistence that mimic exposed rock surfaces, and are interpreted to form by weathering. These regular cracks are distinguishable from persistent tectonic joints that sharply cross cut multiple beds and have systematic trends and near vertical dips, although some weathering cracks may coincide with the tectonic joints (sharing a polygon side along the joint). Observations over large areas reveal distinct crack patterns that range from rectangular to polygonal. The main controls of crack patterns are host rock characteristics (including extent of bedding anisotropy), and slope aspect (orientation of face exposed to weathering).

Rectangular-style crack patterns develop in areas with distinct bedding anisotropy, mostly controlled by variations in grain size, sorting, and clay content. The cracks are perpendicular to eolian cross bedding and to weathering faces across varying slope aspect. At one site, measured crack angles from dune toe and up the foresets are consistently orthogonal to eolian lamination (mean=$87^o$, sd=$\pm 5.3^o$). Cracks appear to curve in order to maintain orthogonality to both the exposure face and cross bedding that systematically changes dip (Fig. 2A). Cracks may abruptly terminate against the fine-grained layers or laminations that typically comprise upper and lower unit boundaries. Rectangular crack patterns are interpreted to form by differential expansion/contraction of rock during rapid heating/cooling, where tensile stresses develop perpendicular to exposure faces and are also partly controlled by anisotropy related to eolian bedding and laminations.

Polygonal crack patterns (Fig. 2B-C), also called pachydermal or tortoiseshell weathering [1], typically have 5- and 6-sided forms and develop where sandstone is relatively massive from either soft-sediment deformation or bioturbation. Individual polygons typically have interior angles of 90 – $140^o$. In areas where cracking is particularly well developed, nested polygon sets are developed. Large polygons have sides up to ~2 m in length, whereas smaller nested polygons have sides ~10+ cm in length. Crack depth is typically less than polygon diameter and varies between nested sets. Larger polygons locally have bulbous vertical, "cauliflower" relief. Polygonal crack patterns change abruptly to gradually where eolian laminations become better developed, even in areas with the same slope aspect (Fig. 2B).

**Discussion:** Terrestrial polygons patterns can originate from cooling (e.g., columnar basalts), dessication (e.g., mud cracks), and intense freeze-thaw or salt crusting (e.g., bounding surfaces or pans). However, such patterns (particularly in vertical cross section) differ significantly from the shallow weathering patterns described here which display shallow perpendicular cracks that follow the entirety of outcrop surfaces, even along subvertical faces.

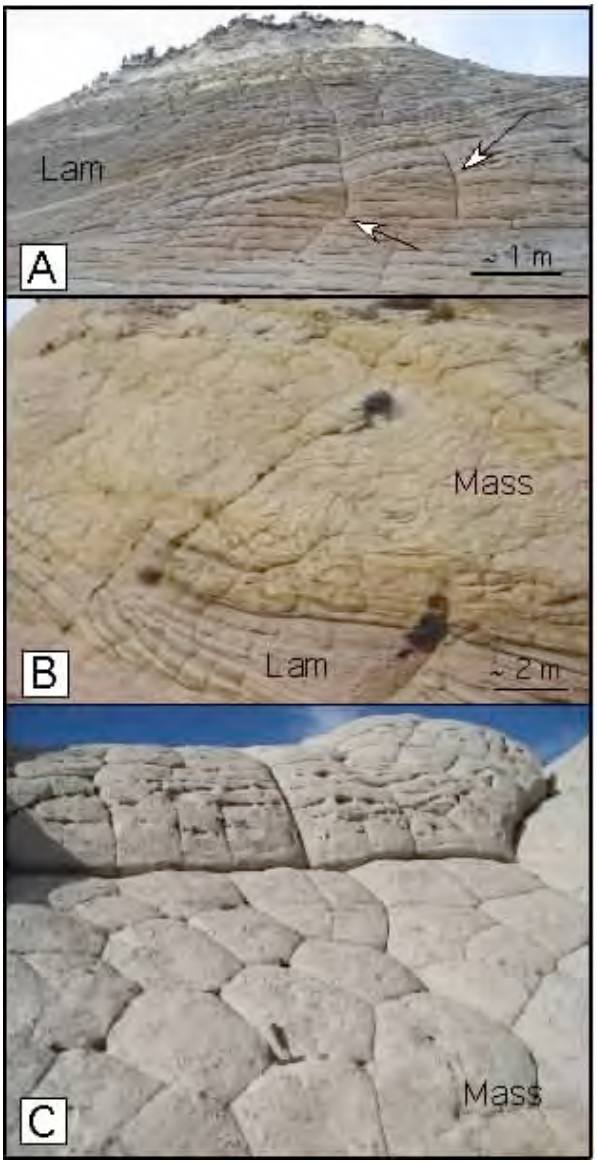


*Fig. 2. Navajo Sandstone crack patterns controlled by host-rock characteristics: Lam=eolian laminated and Mass=massive/structureless. A. Rectangular-style cracks perpendicular to eolian stratification. Arrows mark bounding surfaces where the lamination inclination changes, and cracks patterns shift orientation to remain perpendicular to bedding in Zion National Park-Utah. B. Change from rectangular cracks (where host rock is laminated) to polygonal cracks (where host rock is massive due to soft-sediment deformation) in Grand Staircase National Monument-Utah. C. Polygonal cracks in massive sandstone, Vermillion Cliffs-northern Arizona.*

These polygonal weathering features are not exclusive to eolian sandstones but have also been observed by the senior author as cm-scale surface cracks on young Hawaiian basalts and meter-scale cracks in Cretaceous shoreface sandstones in New Mexico. Hypotheses for the origin of shallow polygonal crack patterns include thermal expansion/contraction, surface crusting, episodic water films, and minor amounts of expanding/contracting silica gel [1, 4]. Development of surface crusts or case hardening is very limited in the Navajo Sandstone, such that processes involving mineral precipitation/dissolution are likely minor.

Terrestrial analogues are important because characteristics of concretions and/or weathering patterns observed remotely may imply certain host rock properties and weathering processes. Distinctive extraterrestrial polygonal crack patterns are locally present on Mars (e.g., MER images of Wopmay and Escher rocks). Wopmay rock and surrounding areas of Endurance Crater also contain abundant iron concretions with a tightly constrained spherical size distribution [5], consistent with an isotropic host rock that facilitates diffusion of dissolved materials in fluid. Polygonal weathering patterns of Wopmay rock are similar to those in massive parts of the Navajo Sandstone, which also contains widely developed iron oxide concretions. Further investigation of the Navajo Sandstone may thus lead to fruitful insights on weathering processes on both Earth and Mars.

**Conclusions:** The study of rectangular and polygonal shallow crack patterns on exposed outcrops surfaces of the Jurassic Navajo Sandstone are interpreted as weathering features that are predominantly controlled by tensile stresses dictated by original host rock properties (lamination or bedding anisotropies vs. massive isotropic character). Different polygonal sizes and nested patterns may be controlled by the age and stage of development and/or the thickness of the weathering "layer". Similar polygonal crack patterns on the Mars Wopmay rock in particular suggest a relatively homogeneous and porous host rock subjected to weathering conditions on the surface of Mars.

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