BOTANICAL SIGNATURE OF TECTONIC FRACTURES IN THE TARGET ROCKS OF BARRINGER METEORITE CRATER, ARIZONA. David A. Kring[1,2], [1]Center for Lunar Science and Exploration, USRA Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (kring@lpi.usra.edu), [2]NASA Solar System Exploration Research Virtual Institute.

Introduction: The well-exposed Barringer Meteorite Crater (aka Meteor Crater) is not radially symmetric. It has a polygonal, rather than circular, outline in plan view. This has long been attributed to pre-impact tectonic fractures or joints [1,2] that affected the flow of excavated material and uplift of the crater walls [1-5]. Based on that finding, polygonally shaped craters on other planetary surfaces (e.g., on the Moon [6] and Mars [7]) have been used to study target structural and/or tectonic histories.

Meteor Crater remains the best terrestrial example of pre-impact tectonic structures affecting impact crater processes. As will be shown here, some of those features are illuminated with indicator plants that form long lines of vegetation (e.g., sagebrush, snakeweed, rabbitbrush, groundsel, cliffrose, grama) along the joints, providing an easy-to-observe method to study their orientations and spatial properties. This is, perhaps, best seen in an aerial view (Fig. 1), but is also easily recognizable at ground level (Fig. 2). The joints capture water in the arid environment, providing the necessary sustenance for plant growth. These lineaments occur beyond the edge of the ejecta blanket (Fig. 3). Where vegetation lines are present, bedrock is either exposed or covered with only a thin shaly scree or organic-poor soil.

Measurements: The bearings of 80 vegetation lines were measured. Thirty-eight bearings were measured adjacent to Meteor Crater Road on the north side of the crater, which is on the west limb of a monocline that Meteor Crater penetrates (e.g., Fig. 1 of [1] or Fig. 2.7 of [8]). Forty-two bearings were measured on the south side of the crater on the east limb of the monocline. The monocline, which affects dips by only a degree or less in the immediate vicinity of the crater [2], had little effect on the bearings. The measurements confirm the dominant joint set runs NW-SE [1,2]. A smaller number of minor cross-joints exist, which are generally oriented NE-SW. These weaker cross-sets have short lengths (≤5 m) and are bounded by the longer NW-SE-trending joints.

On the south side of the crater the spacing of the dominant joints ranges from 2.00 to 6.40 m and the spacing of minor cross-joints ranges from 1.55 to 3.42 m (or far greater where they were virtually non-existent). On the north side of the crater the spacing of dominant joints ranges from 1.35 to 7.20 m.

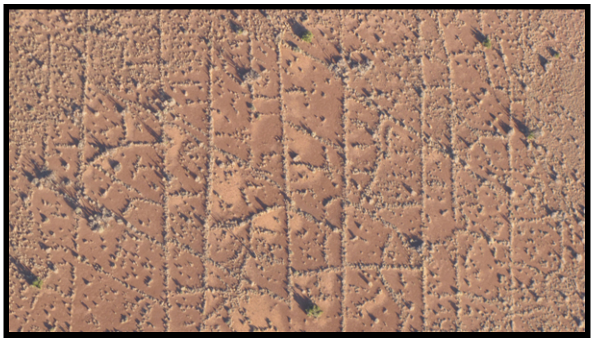

Fig. 1. Aerial view of vegetation lines in bedrock Moenkopi that surrounds Meteor Crater. Spacing between the lines is typically a few meters. The dominant NW-SE joint set is oriented vertically in this photograph.

Fig. 2. Roadside views of several vegetation lines on shaly Moenkopi that trend away from viewer (top) and lie oblique to the viewer (bottom).

The bearings are illustrated in a rose diagram (Fig. 4). The 61 measurements of the dominant joint set produce a mean bearing of 114 (294) ± 1.1º (corrected for a magnetic declination of 10.6º E at the time of the measurements). The bearings of the joints in the weaker set are between 25 and 30º. These values are consistent with [2], which included 24 rock surface measurements and 158 stereophotographic measurements on both Moenkopi and Kaibab surfaces. In the subset of

Moenkopi data, [2] reported an average bearing of 293º (=113º) with a range of 290 to 297º. A small fraction of the joints have other orientations.

Discussion and Conclusions: The bearing of the dominant joint set corresponds to high points on the crater rim that are bounded by radial corner faults. In the SE quadrant, the orientation of the joints correspond to the highest topographical point (elev. 5706 ft) on the rim on a block that is bounded by two major faults along which the block rose far higher than the adjacent crater walls. In the NW quadrant, the orientation of the joints corresponds to Barringer Point (elev. 5723 ft), beneath which an extra section of Kaibab was thrust into the crater wall (e.g., Fig. 14.13 of [8] and Fig. 11a-b of [5]). A cross-section of the crater along the bearing that connects those two points is illustrated in Fig. 3.2 of [8]. As nicely shown in Fig. 2a of [4] and Fig. 8b of [5], both the NW and SE blocks are structurally higher than the adjacent blocks in the crater wall.

The orientation of the weaker joint set corresponds (albeit less precisely) with the two highest topographic points in the NE and SW quadrants. In the NE quadrant, the joint bearing corresponds roughly to Moon Mountain, adjacent to the museum, and beneath which lay an extra section of Kaibab that was thrust into the crater wall. In the SW quadrant, the joint bearing corresponds with the major fault in that quadrant, but is directly adjacent to the highest point (elev. ~5740 ft) along the entire crater rim. Another thrust wedge of Kaibab exists beneath that topographically high point.

Thus, the joints appear to have had two effects on crater formation. They made it easier for material to be excavated parallel to the joints (e.g., [3,5,6]), enlarging the radial dimensions of the crater in those directions. As illustrated previously (Fig. 12 of [5]), the joint sets also made it easier for the crater walls to be uplifted parallel to the joints, allowed thrust wedges to be added in the crater walls, both of which contributed to topographically high blocks along the crater rim. Relatively higher erosion rates along the faults that bounded those uplifted blocks [4] further accentuated the non-radial symmetry of the crater rim.

The west and east boulder fields of ejecta, originally noted by Barringer [9], bisect the major and minor joint orientations. Although this distribution could reflect the trajectory of the impactor, it is also possible that excavation flow, oblique to both sets of joints, created blocks with dimensions of the joint spacing and deposited them relatively close to the crater rim because excavation flow was not as effective in that direction.

Fig. 3. The tectonically fractured terrain is visible beyond the ejecta blanket, the edge of which can be seen here on the SW side of the crater at dawn, when the sun angle is very low. Arrows point to the edge of the ejecta blanket, which corresponds to the ejecta mapped by [1], although [10] argued the ejecta blanket extended farther and lies beneath Quaternary cover. The joint sets and the vegetation that they support, however, indicate some areas previously mapped as alluvium can, instead, be mapped as Moenkopi.

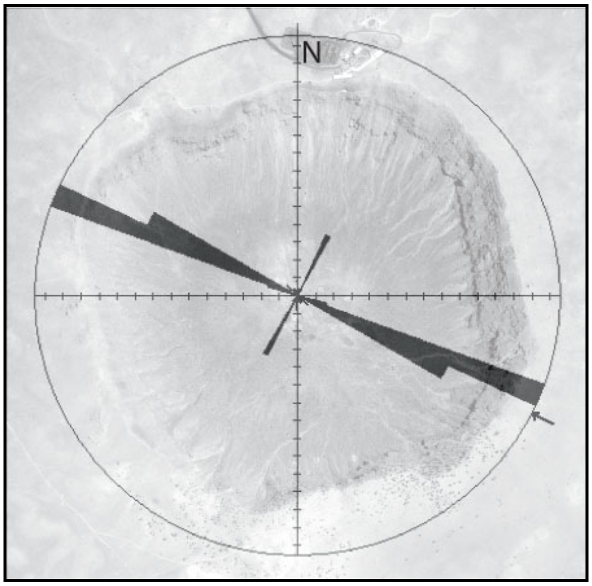

Fig. 4. Rose diagram with the bearings of vegetation lines, which are the same as the bearings of joints in outcrops of Moenkopi. Eighty measurements with a dominant joint set at 114 (294) ± 1.1º and a weaker joint set at 25-30º.

References: [1] Shoemaker E. M. (1960) *Internat. Geol. Congr. XXI Session,* Copenhagen, 418–434. [2] Roddy D. J. (1978) *Proc. LPSC* 9^{th}, 3891–3930. [3] Gault D. E. et al. (1968) in *Shock Metamorphism of Natural Materials*, 87-99. [4] Kumar P. S. and Kring D. A. (2008) *JGR, 113*, 17 p. [5] Poelchau M. H. et al. (2009) *JGR, 114*, 14 p. [6] Eppler D. T. et al. (1983) *GSA Bulletin, 94*, 274–291. [7] Öhman T. et al. (2008) *Meteoritics & Planet. Sci., 43*, 1605–1628. [8] Kring D. A. (2007) *Guidebook to the Geology of Barringer Meteorite Crater, Arizona*. LPI Contrib. No. 1355, 150 p. [9] Barringer D. M. (1905) *Proc. Acad. Natural Sci. Philadelphia, 57*, 861–886. [10] Roddy D. J. et al. (1975) *Proc. LSC* 6^{th}, 2621–2644.