**ASYMMETRICAL DISTRIBUTION OF IMPACT EJECTED LITHOLOGIES AT BARRINGER METEORITE CRATER (a k a METEOR CRATER).** D. A. Kring[1,2], J. Balcerski[3], D. M. Blair[4], M. Chojnacki[5], P. H. Donohue[6], S. A. Drummond[5], J. M. Garber[7], M. Hopkins[8], M. S. Huber[9], S. J. Jaret[10], A. Losiak[9], A. Maier[8], J. Mitchell[11], L. Ong[12], L. R. Ostrach[13], K. M. O'Sullivan[6], R. W. K. Potter[14], S. Robbins[8], B. Shankar[15], E. K. Shea[16], K. N. Singer[17], M. Sori[16], S. Sturm[18], M. Willmes[18], M. Zanetti[17], and A. Wittmann[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 Lunar Science Institute, [3]Case Western Reserve Univ., [4]Purdue Univ., [5]Univ. Tennessee, [6]Univ. Notre Dame, [7]Univ. California - Davis, [8]Univ. Colorado-Boulder, [9]Univ. Vienna, [10]Harvard Univ., [11]Univ. Houston-Clear Lake, [12]Univ. Arizona, [13]Arizona State Univ., [14]Imperial College London, [15]Univ. Western Ontario, [16]Massachusetts Institute of Technology, [17]Washington Univ., [18]Westfälische Wilhelms-Univ. Münster.

**Introduction:** The idealized model of impact ejecta, developed largely from observations at Barringer Meteorite Crater (a k a Meteor Crater), produces an overturned sequence of the target stratigraphy that is symmetrically emplaced around a crater. Ironically, that idealized model is inconsistent with observations at Meteor Crater, where surface exposures of ejecta to the south of the crater are dominated by Coconino sandstone, the deepest ejected lithology, whereas Kaibab dolomite, from an intermediate stratigraphic level, dominates elsewhere around the crater. That asymmetrical distribution of ejected lithologies is a hint that the excavation and ejection process may have also been asymmetrical. To explore those processes, we examined the uplifted and overturned rim sequence on the south side of the crater and compare that sequence to the remainder of the crater rim.

**Study Site:** Meteor Crater is a ~1.2 km diameter simple crater that was excavated from a horizontal sequence of sedimentary formations in the upper Grand Canyon sequence. The target stratigraphy consists of ~222 m of Permian Coconino and Toroweap sandstone, ~80 m of Permian Kaibab dolomite and lesser sandstone, and ~8.5 m of Triassic Moenkopi siltstones (*e.g.*, [1,2]). We measured the overturned sequence of those units as exposed in a relatively fresh outcrop carved in the rim of the crater by mining activities (*i.e.*, at the top of a 1,376 ft-deep churn drill hole). This exposure underlies the Coconino-dominated ejecta surface on the south side of the crater.

**Measured Section:** We anchored the measured section in the normally-stratified and uplifted contact between the Kaibab and Moenkopi Formations. As noted previously (Chapter 15 of [2]), this contact is composed of a thin lithified breccia unit that is dominated by Kaibab fragments, but also contains Moenkopi fragments. The uppermost section of the target sequence follows, with both the Wupatki (1.2 m shale and 3.6 m of massive, cross-bedded siltstone) and Moqui (5 m of shaly siltstone) Members of the Moenkopi Formation.

The stratigraphy is then overturned along an axial plane within the Moqui. The fold hinge is not exposed at this location (although it is elsewhere [2]), having been eroded. The basal portion of the overturned Moenkopi is incomplete and represented, instead, by a 0.3 to 0.7 m-thick unconsolidated breccia that contains blocks of both Moqui and Wupatki lithologies (Fig. 1). The blocks are longer than the unit is thick, so there is an inherent foliation to the unit.

That breccia is, in turn, overlaid by an ~1.4 m-thick unconsolidated breccia composed of both Moenkopi and Kaibab fragments. Blocks are randomly oriented and poorly sorted. Clasts range from 1 mm to 0.5 m in diameter. There is no sense of grading within the unit. A point-count of material exposed in outcrop indicates at least 4% of the material is derived from the red Moenkopi. The unit also contains gray or possibly bleached shaly fragments that, if derived from the Moenkopi rather than Kaibab, indicate up to 38% of the breccia comes from the Moenkopi.

Intermittent blocks of lithified breccia, similar to the breccia at the P-T boundary in the normal stratigraphic sequence, appear at the top of the mixed breccia horizon. There is, however, no other Kaibab. The sequence is next covered by >4.8 m of overturned Coconino and Toroweap, which form the uppermost portion of the rim section on the south side of the crater.

**Displacement of Ejected Kaibab:** Thus, the rim sequence is missing nearly 80 m of Kaibab that was overturned and ejected from the crater. To shear out (or displace the Kaibab to a more distant portion of the ejecta blanket) requires a pair of faults at the lower boundary of the overturned Coconino and Toroweap sandstone. The underlying mixed breccia wedge might then be interpreted as a fault breccia.

If the Kaibab was sheared from the rim sequence on the south side of the crater, then it was displaced to greater distances. Interestingly, [3] reported that drilling into the ejecta blanket "shows the overturned flap is thickest on the southern side of the crater where low hummocky hills composed of blocks of Kaibab lie as far as 1500 m from the center of the crater." Unfortunately, the detailed logs of that drilling campaign have been lost, but the summary report [3] and observations of outcrops, suggest an unusually large amount of Kaibab occurs lower on the ejecta slopes than elsewhere around the crater and that the topographic profile of the original ejecta deposit was less steep to the south.

**Coconino-Toroweap Ejecta:** Excavated sandstone initially covered the entire ejecta blanket, but most of it has been eroded from the north, west, and east sides of the crater, exposing Kaibab. On the south rim of the crater, however, the base of the overturned Coconino and Toroweap sandstone was lower than anywhere else around the crater, because Kaibab was sheared from the rim sequence. In addition, the dips of the uplifted (and underlying) target units are subdued in the south crater wall. In the measured section, dips are only 15 to 20 degrees, whereas they are typically twice those values elsewhere around the crater (*e.g.*, [2]). Thus, fault-modification of the normal ejecta process created lower topography and shallower slopes on the south side of the crater, which reduced erosion rates and allowed the Coconino ejecta to survive there.

**Implications:** The cause of the shearing that displaced Kaibab from the south crater rim is still uncertain, but it may be a consequence of the asteroid's trajectory and the trajectory's effect on the mechanics of crater excavation. That particular implication is the subject of a parallel study, but a trajectory with a N to S or S to N vector is implied by our observations.

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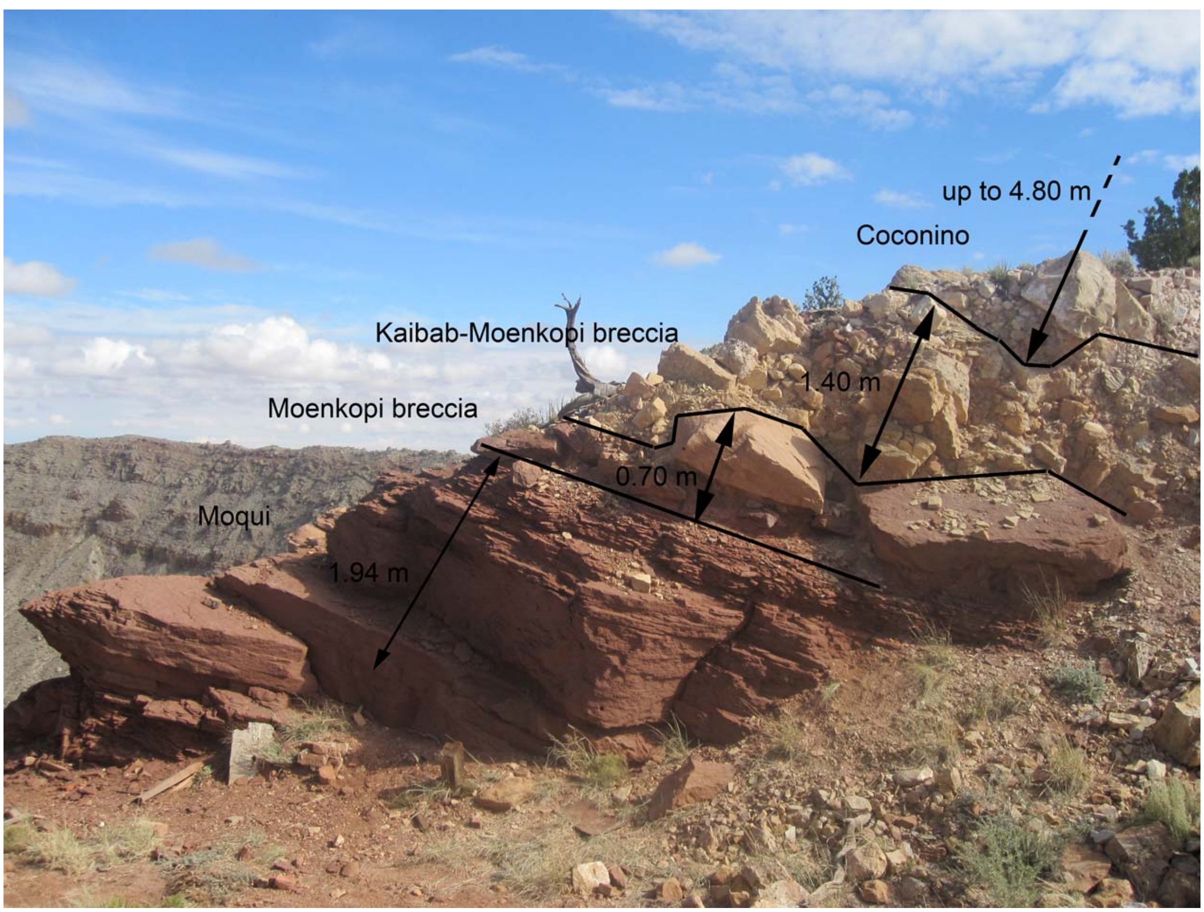


**Fig. 1.** Upper portion of the measured section on the south rim of Barringer Meteorite Crater at the location of a 1,376 ft-deep borehole. Approximately 80 m of Kaibab dolomite are missing from the section.