

**GEOLOGY AND ORIGIN OF TACONITE CRATER ON THE VERA RUBIN RIDGE.** F. J. Calef III<sup>1</sup>, D. Wellington<sup>2</sup>, H. Newsom<sup>3</sup>, T. Gabriel<sup>4</sup> <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA 91109, Fred.Calef@jpl.caltech.edu. <sup>2</sup>School of Earth and Space Exploration, Arizona State University, Bateman Physical Sciences, F-Wing, Room 686, Tempe, AZ 85287-1404, dfwellin@asu.edu. <sup>3</sup>U. New Mexico, Albuquerque, NM 8713, newsom@unm.edu, <sup>4</sup>Arizona State University, AZ, tgabriel@asu.edu

**Introduction:** Sub-kilometer diameter ('small') primary and secondary craters dominate the impact population on Mars and other planetary bodies [1]. 'Fresh' craters, those whose fine and blocky ejecta components remains extant on the surface as rays visible from orbit, occur more often in the aforementioned size range, with a few notable exceptions [2]. Most small fresh craters observations come from orbital measurements and morphologic studies using high-resolution imagery and digital elevation models [3,4,5]. Direct in situ observations of small fresh craters are recorded by the Mars Exploration Rover Opportunity, e.g. Concepción crater [6] and the InSight Lander, Corintito [7]. This research documents the first small fresh crater investigated by the Curiosity rover in Gale Crater, Mars during its investigation along the Vera Rubin Ridge (VRR) (Figure 1).

**Physical Description:** Taconite crater impacted into the side of a 'bench' that separates lower and upper parts of the Vera Rubin Ridge. This elliptical crater is 12 m by 9 m as measured in the MSL HiRISE orthophoto basemap [8]. The largest diameter is oriented along an axis angle 15° west of north. The lowest to highest part of the crater rim differs by ~2.5 m. Crater depth is difficult to assess as the crater form is emplaced within an irregular slope. Detrending orbital elevation data (1 m/pixel) yields ~0.3 m depth for a depth/Diameter (d/D) ratio of 0.028. Meter to decimeter scale blocks line the rim and more so to the west. From orbit, finer component (sand-sized) ejecta can be seen extending to the northwest and within one crater radii to the north, west, and south. The eastern edge of the rim appears ejecta free, perhaps due to the impact geometry. The irregular crater shape, lack of a well defined rim, and shallow d/D ratio lend to the interpretation that this is a secondary crater. Similar sized craters with more typical circular crater shapes with sharp rims are present on the VRR, some even with a potential dark, fine grained, ejecta blanket. While the crater is elliptical, it's difficult to discern whether its shape or orientation is merely due to pre-existing target topography or from a very shallow impact. We do know that the upper parts of the VRR resist Curiosity's percussive drill, even at the highest percuss levels, yet retains small D craters. A low velocity (100's m/sec), low angle impact is consistent with the Taconite crater morphology described above. For a fresh crater of this size, it's retention age is on order ~1-10 Mya or younger, if

we compare it's morphology to similar young secondary impacts from craters like Zunil [1].

**Multispectral Observations of Ejecta Field and Rim Blocks:** Several decimeter to meter scale ejecta blocks and nearby ejecta field were imaged by the MASTCAM 34 mm (M34 or L) and 100 mm (M100 or R) focal length instruments. One example can be seen in Figure 2. A decorrelation stretch using bands L3, L5, and L6 (751, 867, 1012 nm centered bandpass filters respectively) reveal two distinct rock populations: hematite-like ferric 'purple' rocks consistent with the iron rich Vera Rubin Ridge and a lower ferric component 'green-yellow' rocks excavated by the impact. Multispectral analysis is ongoing and expected to reveal more of the ejecta pattern in situ at centimeter scales.

Several sub-meter to meter-scale blocks were imaged at sufficient resolution to reveal textural features. Some blocks, e.g. target "Logan", are layered and cross-stratified as seen in the outcrop as we approached the VRR (Figure 3). Others display weak or no stratification similar to conglomeritic material seen earlier along the rover traverse, but not this high on the ridge.

**Crater Origin:** If Taconite crater is a secondary impact, two questions arise: where did the impactor originate and are any fragments of the impactor discernible from the target material. For the latter, Taconite ejecta is spectrally different from the surrounding exposed bedrock. That said, these blocks have had much less surface exposure and may reflect material we have not seen before, having been excavated a meter or so from the subsurface. There is no obvious morphologic structure to the ejecta blocks that precludes them being parts of the VRR. A low-velocity impact acts more like a "shovel", pushing material out of the target surface, than "exploding" to generate flow fields that remove material in a spherical expansion from the impact point. One might expect, however, that a low-velocity impact may preserve more impactor material, though it's unclear whether such material remains buried in the crater or is also "shoveled" out with the ejecta as well.

A search for similar fresh small craters across Aeolis Palus reveals several candidates (Figure 4). While many lack fine component ejecta, several as similar in their irregular planform and block ejecta (see crater 1 in the figure). If Taconite is part of a secondary field, it is not obviously so as no secondary crater dense rays from any nearby fresh multi-kilometer craters extend to

Gale or are 1000s kilometers away, making them unlikely (e.g. Corinto or Zunil). A more intriguing possibility are several fresh craters within Gale itself. A ~5km diameter, single-layer ejecta, complex crater called Slangpos is ~33 km to the west, just inside the Gale crater rim. There is no obvious secondary crater rays from it, but Taconite is at a distance where a few distal secondaries could occur. A back-of-the-envelope calculation using Mars' gravity, a 45° ejection angle and initial velocity at ~350 m/sec can eject a block ~33 km away with an impact velocity of ~250 m/sec. Such a low speed impact would be consistent forming an irregular blocky crater, like Taconite. Though sparsely cratered and a very small area (~52 km<sup>2</sup>), a crater count on the Slangpos ejecta yields an age of ~100 Ma.

**Conclusion and Future Work:** Taconite crater appears to be a fresh small secondary impact, possibly from the nearby Slangpos single layer ejecta crater. The ejecta blocks and fine component are spectrally distinct from the VRR surface outcrop and may represent original impactor material. Low velocity secondaries may offer a unique opportunity to sample geologic materials from 10 to 100 (even 1000+) km away. Further investigation is warranted to compare the spectral properties of the ejecta with nearby outcrops as well as exploring the chance of impactor survivability.

**References:** [1] McEwen et al. (2005) *Icarus* [2] Tornabene et al. (2006) *JGR Planets* [3] Calef et al., 2009, [4] Watters et al. (2017) *JGR Planets* [5] Sweeney et al. (2018) *JGR Planets* [6] Golombek et al., (2014) *JGR Planets* [7] Warner et al. LPSC2019. [8] Parker and Calef 2014, USGS Annex <https://on.doi.gov/2AiujuS>.

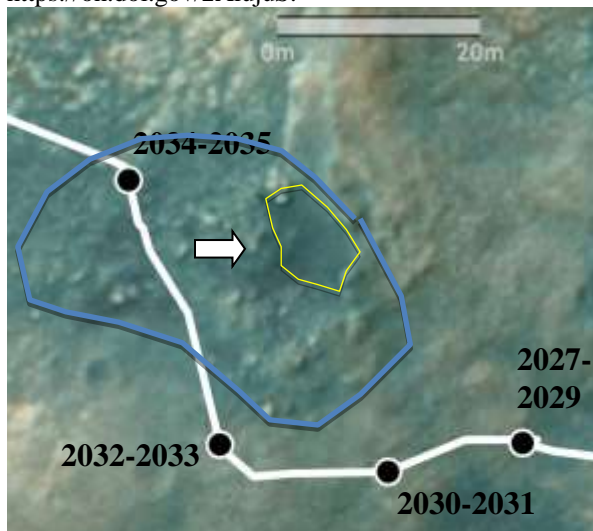


Figure 1: Taconite crater on the northern edge of the Vera Rubin Ridge (yellow line). Blue line denotes blocky ejecta field. White line is Curiosity's traverse. Black dots are 'way points' where the rover stopped

and made observations. White arrow is target "Logan". The arrival date in mission sols are labeled at each location. Crater center coordinates are 137.37981140° positive east longitude and -4.72431890 latitude.

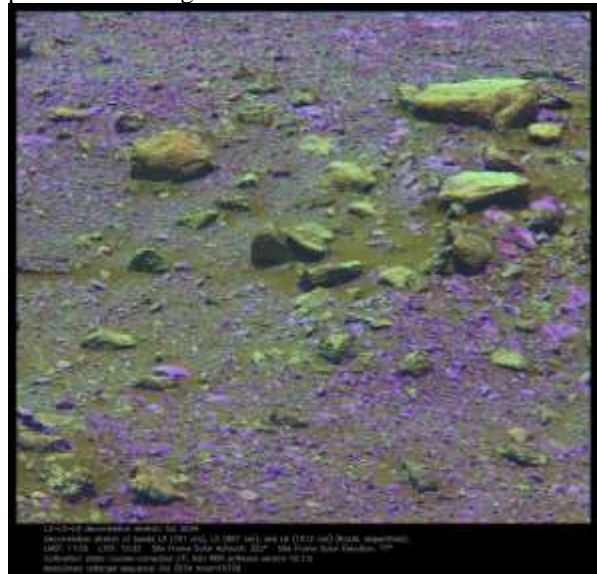


Figure 2: MASTCAM decorrelation stretch of Taconite crater ejecta blocks and fine component (sand-sized particles), southwest of the crater rim. The greenish-yellow ejecta blocks and some sand have a less ferric component (low NIR slope) compared to the purple rocks (high NIR slope).



Figure 3: Ejecta blocks from Taconite crater.

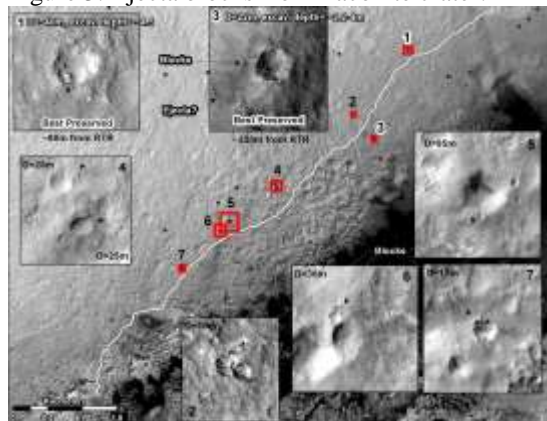


Figure 4: Several craters along the Curiosity rover traverse with ejecta blocks. Note crater 1 has a similar irregular crater planform oriented north-south with meter-scale ejecta blocks near the rim.