# STRUCTURAL MAPPING OF MARTIN CRATER UPLIFT TO TEST ACOUSTIC FLUIDIZATION MODELS.

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**Introduction:** Understanding complex crater formation is an important and yet unrealized objective in planetary science. Foremost among the poorly understood issues is how originally deep-seated rocks are uplifted to form central structures [1]. Previous work suggest that ‘elastic rebound’ during the cratering process is inadequate unless some mechanism ‘fluidizes’ the rock mass [2]. According to the Melosh model of acoustic fluidization [3], an intense sound wave travels through the rock after it has been fractured by the impact process, causing the fractured pieces to vibrate. Once a period these vibrations cancel out with the overburden pressure and cause a temporary reduction in friction. This allows the fractured rock mass to behave like a fluid [3].

A common way that acoustic fluidization is implemented in numerical hydrodynamic models of impact formation [4] is the so-called Block Model [5]. This is a simple parameterization of the complex set of transient conditions associated with the acoustic fluidization process and its physical plausibility is based solely on Ivanov’s early study of the 40-km Puchezh-Katunky crater in Russia [6]. In this model the bedrock fractures to form megablocks 50-200 m across. These megablocks are brought up to the surface in an acoustically fluidized breccia matrix. For this to work the speed of sound in the block must be large compared to the period of the oscillation. Put another way, the speed of sound in the block must be larger than that of the breccia. Having a soft breccia whose thickness is no less than 10-20% of the thickness of the block would be sufficient to allow fluidization [2].

Acoustic fluidization in general, and the block model specifically, predict certain characteristics of the materials within central structures that are testable:

1. Fluidization should disaggregate the uplifted assemblage so that there is little-to-no structural coherence between adjacent blocks (i.e., strikes and dips should be uncorrelated between blocks);
2. Blocks should have simple shapes, free of complex protrusions;
3. Adjacent blocks should not show interlocking, jig-saw-like relationships;
4. The average width of the fine-grained matrix containing the megablocks should be no less than 10-20% the megablock width.

**Martin Crater:** Martin Crater (D=58 km) is a complex crater located at approximately 21.4° S 69.3° W in the Thaumasia Planum region of Mars. The region is composed of layered basaltic lava flows interbedded with softer pyroclastics [7]. Scarps and ridges oriented roughly N-S are common in the area surrounding the crater but don’t cut through it [7]. The exposed central uplift of Martin Crater is ~16 km in diameter and composed of large interlocking megablocks brought up from a depth of ~5.3 km according to scaling relationships in [1]. Most of these blocks have been rotated so that the bedding is near-vertical; revealing the cross sections of the blocks. This orientation provides a unique opportunity to study the deformation from aerial orbital images. Previous work on Martin Crater [8] has suggested that the overall NW-SE strike of the bedding is a remnant of oblique impact. Other complex craters with exposed layered bedrock have been identified and investigated on Mars [9].

**Methods:** Mars Reconnaissance Orbiter (MRO) data was used as a base map for this analysis. Context Camera (CTX) images and High Resolution Imaging Science Experiment (HiRISE) images were compiled in ArcGIS 10.1 for detailed mapping. The central uplift was divided into three units based on the level of bedrock exposure and the continuity in the megablocks (obscured, partially mantled, bedrock). Megablocks are distinguishable and the bedding within them is continuous throughout the block. In mapping the separate megablocks, distinctions were made based on the overall orientation of the block and major faults. The strike and dip of the bedding were estimated based on analysis of HiRISE stereo pairs and topography.

**Discussion:** In this study structural mapping of the Martin Crater uplift was done to compare the styles and magnitudes of deformation seen there with those predicted by the acoustic fluidization models. Assuming original horizontality of the lava, we conclude that all deformation seen in the megablocks is the result of the impact process itself.

As seen in Figure 1 and 2 the megablocks are intricately packed together with interlocking, jigsaw-like intersections. Only in a few places are they randomly oriented. In most of the uplift the bedding plains of the separate blocks correlate across local block boundaries to form large folds that extend across the majority of the uplift. These folds are accommodated by the

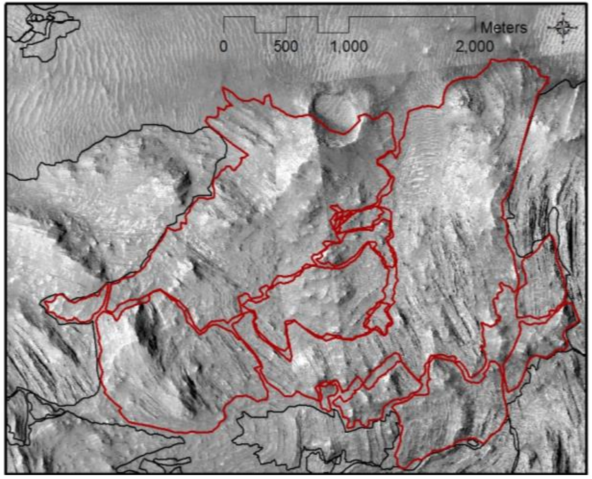

**Figure 1.** Map showing location and orientation of megablocks used in Table 1. These block were used because they are very well exposed and the transition from block to block is clear.

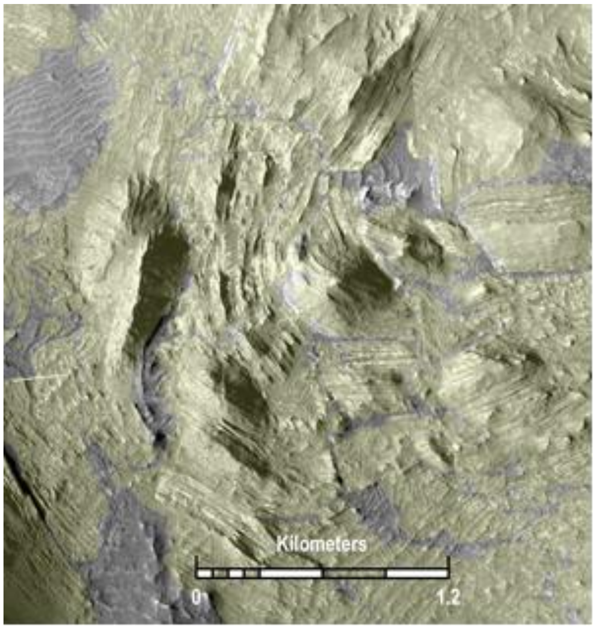

**Figure 2.** Map of western part of Martin's uplift showing a 5-km-thick tightly folded near-vertical layered sequence. Yellow indicates exposed megablocks.

fracturing of the bedrock, so that the individual blocks show little internal strain. The average amount of shortening within the individual blocks measured is only 4.3%, and most of the blocks showed no shortening at all. Where the folds are the tightest the blocks are smaller, indicating brittle folding.

Block separation was measured in a well exposed area of the uplift, as seen in Figure 1, and the results are shown in Table 1. The amount of separation needed for fluidization is only present around a few of the very small blocks. These blocks are within a large crack between two major blocks. The separation between the larger blocks is far less than what is needed for fluidization.

**Conclusion:** The continuity of the bedding across local block boundaries in large folds, the complex interconnected block boundaries, and the lack of sufficient breccia matrix are incompatible with the Block Model specifically, or a fluidization mechanism, in general. Our analysis of Martin Crater suggests that fluidization may play a minor role in localized zones within the uplift; however, it does not appear to be a viable explanation for central peak formation. We are not able to propose an alternate mechanism at this time; however, any model advanced to explain central uplift should address the constraints observed at Martin crater.

| Block # | Average Width (m) | Expected Breccia Thickness* (m) | Actual Average Thickness (m) |
|---|---|---|---|
| 335 | 704.5 | 140.9-70.4 | 22.6 |
| 339 | 1,400.8 | 280.2-140.1 | 29.5 |
| 312 | 997.7 | 199.5-99.8 | 50.0 |
| 331 | 166.7 | 33.3-16.7 | 13.3 |
| 269 | 266.5 | 53.3-26.6 | 21.7 |
| 336 | 321.8 | 64.4-32.2 | 21.9 |
| 338 | 195.8 | 39.2-19.6 | 18.7 |
| 333 | 45.2 | 9.0-4.5 | 15.3 |
| 332 | 44.3 | 8.9-4.4 | 15.3 |
| 334 | 33.6 | 6.7-3.4 | 11.9 |
| 337 | 24.5 | 4.9-2.5 | 16.2 |
| 330 | 1,577.6 | 315.5-157.8 | 34.0 |
| 326 | 135.9 | 27.2-13.6 | 25.4 |
| 328 | 389.9 | 78.0-39.0 | 35.8 |
| 327 | 685.0 | 137.0-68.5 | 21.2 |
| 355 | 406.4 | 81.3-40.6 | 46.4 |
| 344 | 413.8 | 82.8-41.4 | 36.3 |

**Table 1**. The average measured block separation is far lower than what is required by the Block Model of acoustic fluidization. The Block # corresponds to the blocks as shown in Figure 1. The Average width of the block was determined by taking the square root of the measured blocks area. The Expected Block Separation is 10-20% of the width of the block according to [2].

## References:

[1] Grieve R. A. F. et. al. (1981) *Proc. Lunar Planet. Sci.* 12A, 37-57. [2] Melosh H. J. and Ivanov B. A. (1999) *Annu. Rev. Earth Planet. Sci., 27,* 385-415. [3] Melosh H. J. (1979) *J. Geophys. Res. 84,* 7513-7520. [4] Collins. G. S. et. al. (2002) *Icarus, 157,* 24-33. [5] Ivanov B. A. et. al. (1997) *LPS XXVIII*, Abstract #1655. [6] Kocharyan G. G. et. al. (1995) *LPS XXVII*, 677-678. [7] Dohm. J. M et. al. (1999) *Planet. Space Sci.* 47, 411-431. [8] Poelchau M. H. (2009) *LPS XL*, Abstract #1796. [9] Caudill C. et. al. (2012) *Icarus* 221, 710-720.