Evidence for an Explosive Origin of Central Pit Craters on Mars

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Abstract #1041

1. Introduction

- Central pit craters (CPCs) occur in over 1,000 impact structures on Mars in the low- to mid-latitudes and exhibit a crater-in-crater configuration [1-3]
- CPCs also occur in impact craters on icy satellites [1], but rarely on other rocky planets, so an icy origin is inferred [4]
- Models proposed for CPC formation fall under 2 broad categories: explosive excavation [e.g. 2,4-6], or drainage and collapse [e.g. 7,8]
- The presence or absence of ejecta around CPCs can be used to distinguish between these two model categories:
  - In explosive scenarios, material is ejected and distributed around the pit
  - In collapse scenarios, material travels gravitationally down into a cavity
- If pit ejecta is present, grain sizes should be greatest near the pit rim and fine outwards across the parent crater floor
- We use temperature and thermal inertia images to test if pit ejecta is present

2. Methodology

- Thermal inertia on Mars is primarily a function of grain size and can be calculated from diurnal thermal variations [9-12]
- Thermal inertias in this study were calculated from Mars Odyssey Thermal Emission Imaging System (THEMIS) [13] thermal infrared (TIR) images and viewed in JMARS [14]
- We surveyed the population of CPCs in impact craters ≥10 km in diameter and within ±60° of the equator using the THEMIS TIR global mosaic and thermal inertia images [9-12]
- This study focuses on CPCs that are deeper than their parent crater floors ("floor pit craters"), as opposed to CPCs atop central peaks ("summit pit craters") where any coarse summit pit ejecta may be thermally indistinguishable on the rocky sides of central peaks
- Morphology of CPCs in this study was assessed quantitatively using profiles from Mars Orbiter Laser Altimeter (MOLA) data [15], and qualitatively with shaded relief images from THEMIS, MRO Context Camera [16] and High Resolution Imaging Science Experiment (HiRISE) [17]

3. Results

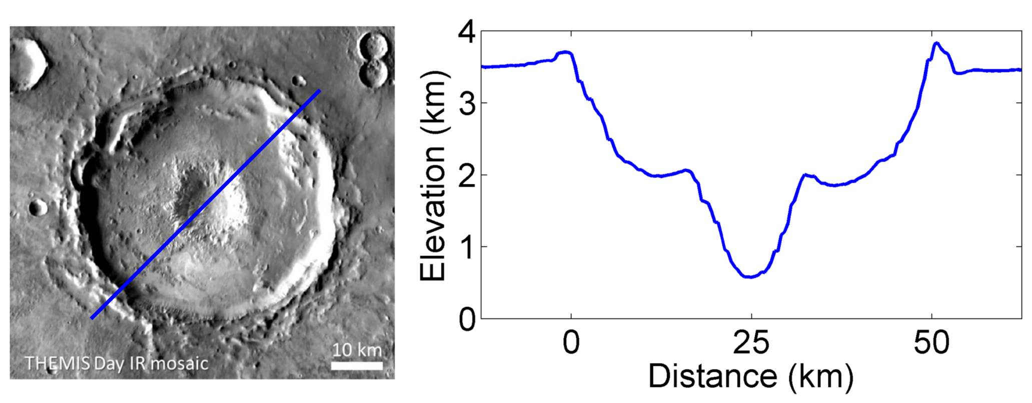


Fig. 1: MOLA elevation profiles across some large (~50 km) CPCs show rims slightly raised above the floors of the parent craters. The crater shown above is located at 17.6°S, 63.6°W.

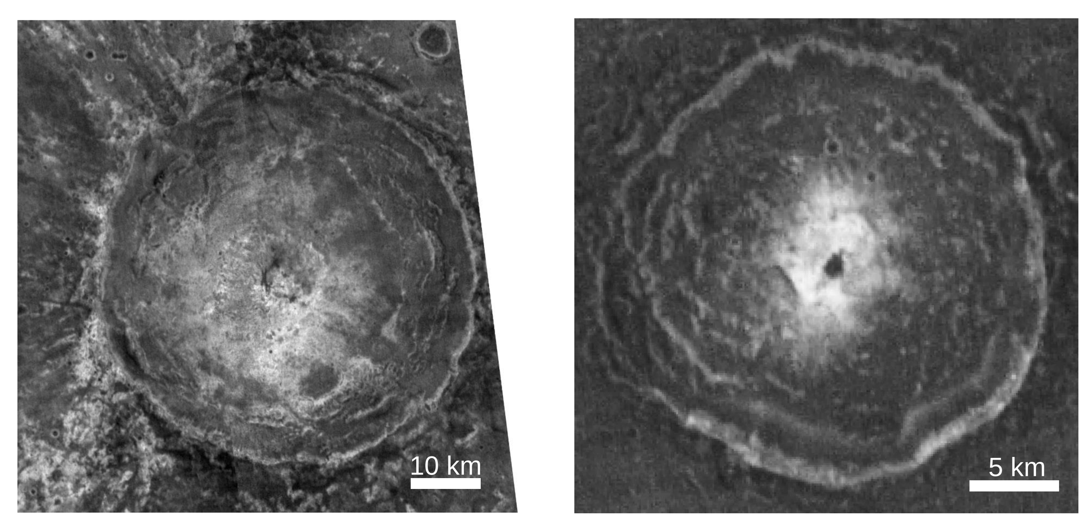


Fig. 2: THEMIS nighttime thermal inertia images showing higher values (coarser material) around CPCs compared to the surrounding parent crater floor. Craters shown above are located at 15.8°S, 63.7°W and 14.9°S, 93.3°E.

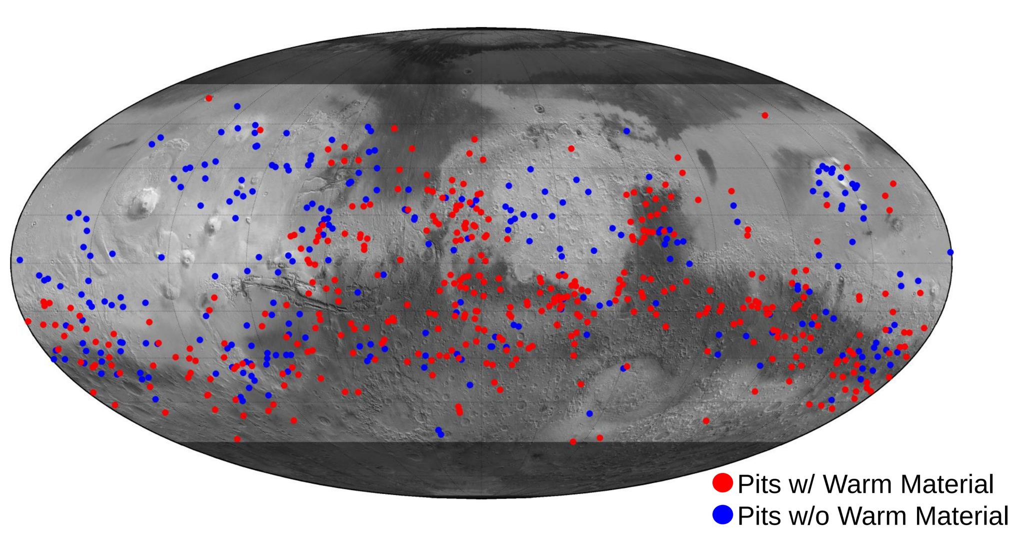


Fig. 3: 60% of CPCs globally are surrounded by relatively warm, higher thermal inertia material (n=388). Pit exteriors with uniform low thermal inertias (n=266) tend to occur in very dusty regions identified by the Thermal Emission Spectrometer [18] and appear mantled in visible images.

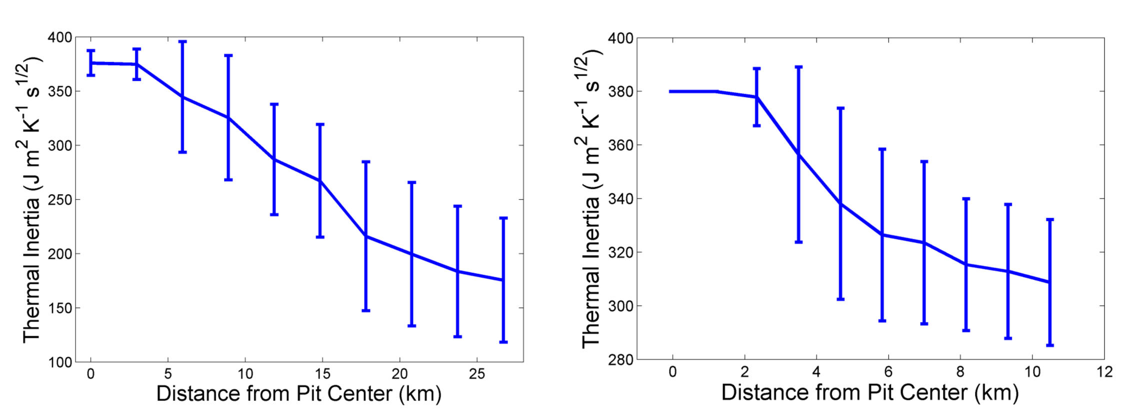
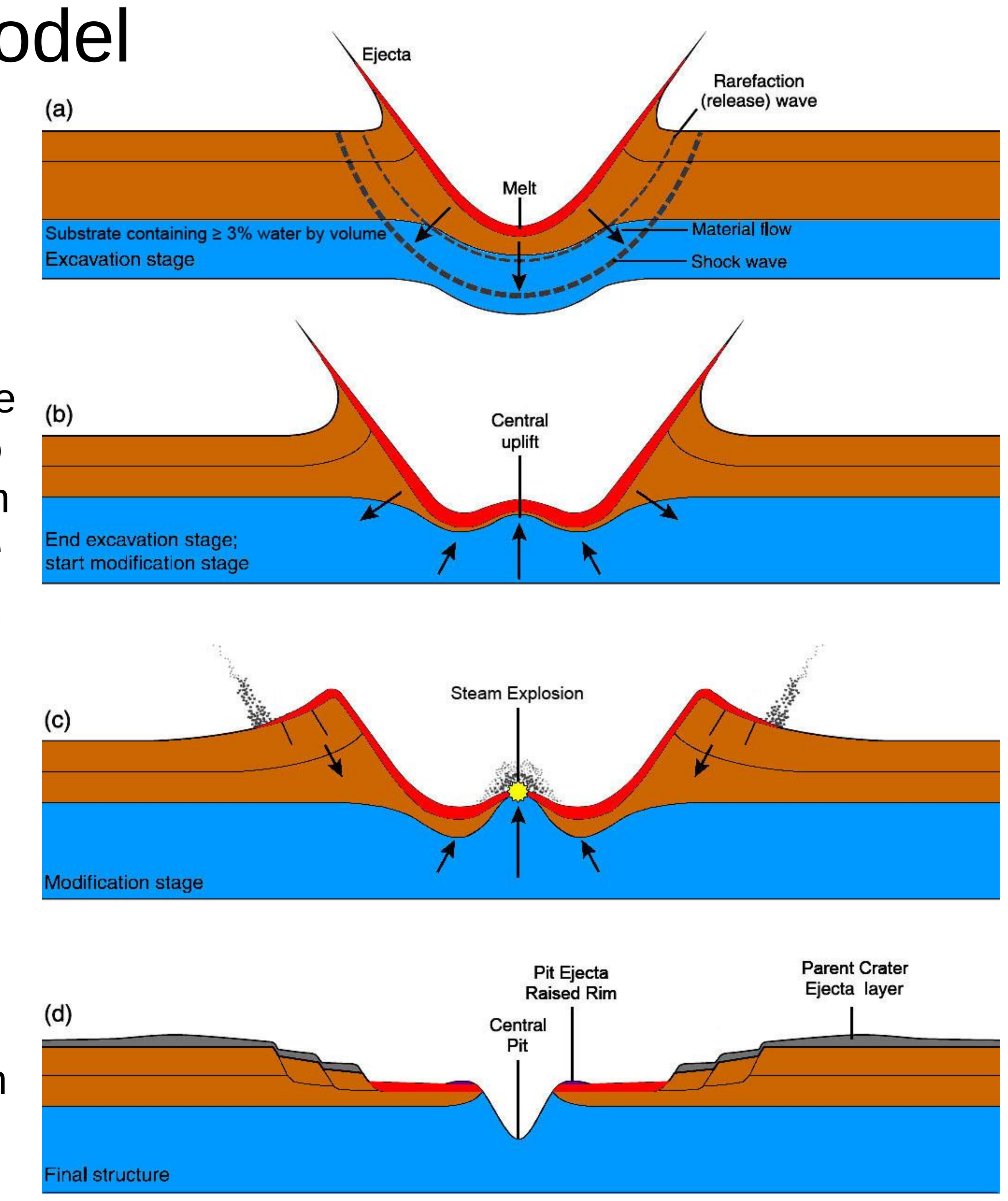


Fig. 4: Circumferentially averaged thermal inertia profiles of the CPCs above in Fig. 2 show decreasing thermal inertia values radially away from the pit rim.

4. Delayed Explosion Model



- A weakness of most models for an explosive origin is the inability to retain enough water/steam to explode when a pit can be preserved late in the impact process [19-21]
- We suggest a model (Fig. 5, right) where a water-bearing central uplift comes into contact with impact melt to form a steam explosion late, in the modification phase
- Comparably-sized craters (up to 8 km in diameter) [22] have formed on Earth during monogenetic maar volcano eruptions where magma comes into contact with groundwater or ice and generates a phreatomagmatic steam explosion despite small volumes of erupted magma [23]
- Central pits on Mars would not require endogenic Martian sources of volcanism since more than enough impact melt is created by the parent impact [24]
- We calculated the available thermal energy for example central pit craters using relations between crater diameter, energy, and estimates of the mass of impact melt. If the upper ~kilometer of the surface has >3% permafrost ice by volume (a reasonable assumption; see [24]), then the impact melt from the parent impacts has more than enough thermal energy to drive steam explosions capable of producing kilometer-sized central pits on Mars

5. Conclusions

- Raised rims are observed around most large central pits, similar to raised rims of impacts and other explosive craters, and therefore strongly suggest an origin by explosive excavation
- Coatings of dust (perhaps only a few cm thick or less) likely mask diurnal thermal inertia variations of many central pit craters in Tharsis, Arabia, Elysium, and other locations
- The inferred outward decrease of coarse material (based on thermal inertia) around non-dusty central pits is consistent with pit ejecta and an explosive origin of some central pit craters
- We propose a possible alternate model of pit formation where a ice-bearing central uplift reacts with impact melt to generate a steam explosion and form central pits on Mars

6. References

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