Equilibrium state in impact-generated porosity on a lunar surface (#2491.487)

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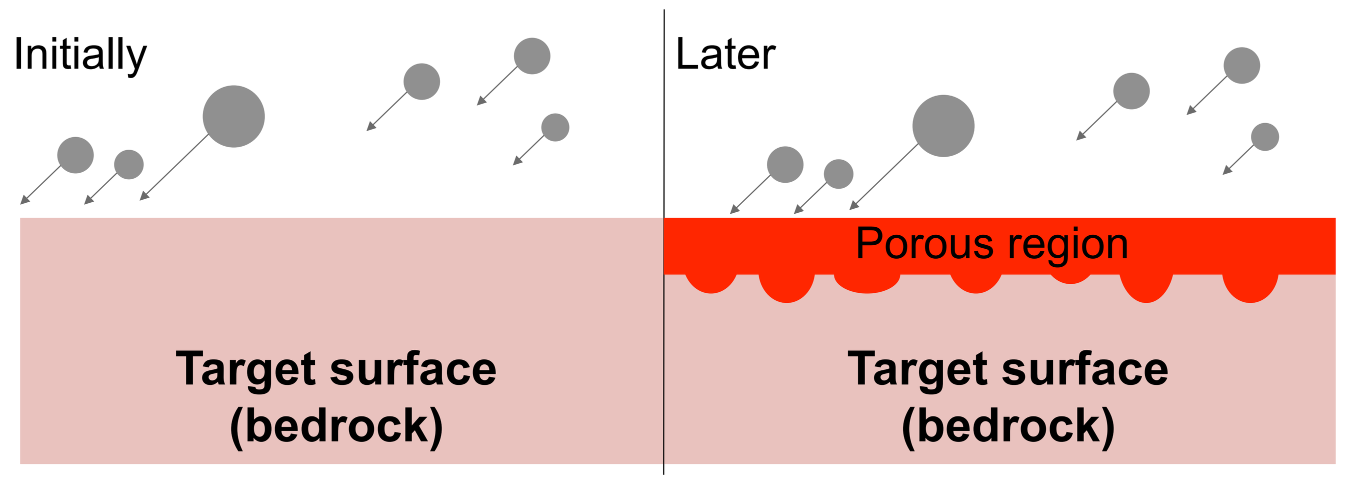
Abstract:

Scientists have argued the thickness of porosity over the last 50 years. Observations that an estimated thickness of lunar regolith ranges from 5 to 15 meters [1]. Shoemaker et al. [2] and Oberbeck et al. [3] proposed analytical and numerical models, respectively, to study the observed thickness of lunar regolith, while Gault et al. [4] pointed out that a well-mixed regolith zone only appeared over a few centimeters of the upper lunar surface and mainly resulted from impact-generated ejecta. Regardless of such arguments, the formation mechanism of impact-generated porosity is still unknown. One way to quantify the formation of impact-generated porosity is to track the evolution of porosity on a surface.

Here we show the evolution of impact-generated porosity on a lunar surface. We observed that the regions beneath the lunar surface still preserved impact-generated porosity even after new craters started to degrade old ones on the surface. This mechanism caused the porosity thickness to evolve further until larger craters become saturated. This result implies that an understanding of the porosity thickness may lead us to give constraints on the size frequency distribution of impactors that hit the lunar surface.

Important role of porosity in crater formation:

- Porosity can increase or decrease due to the initial target porosity [5].
- Porosity also affects the cratering process, resulting in changes in the size scaling relationships [6]
- Porosity can control the amount of impact-generated regolith, controlling the regolith thickness [7]



Cratered Terrain Evolution Model (CTEM):

CTEM is a Monte-Carlo simulation code that generates impact-generated craters to model the crater distribution on a test surface from the impactor size frequency distribution function [8, 9].

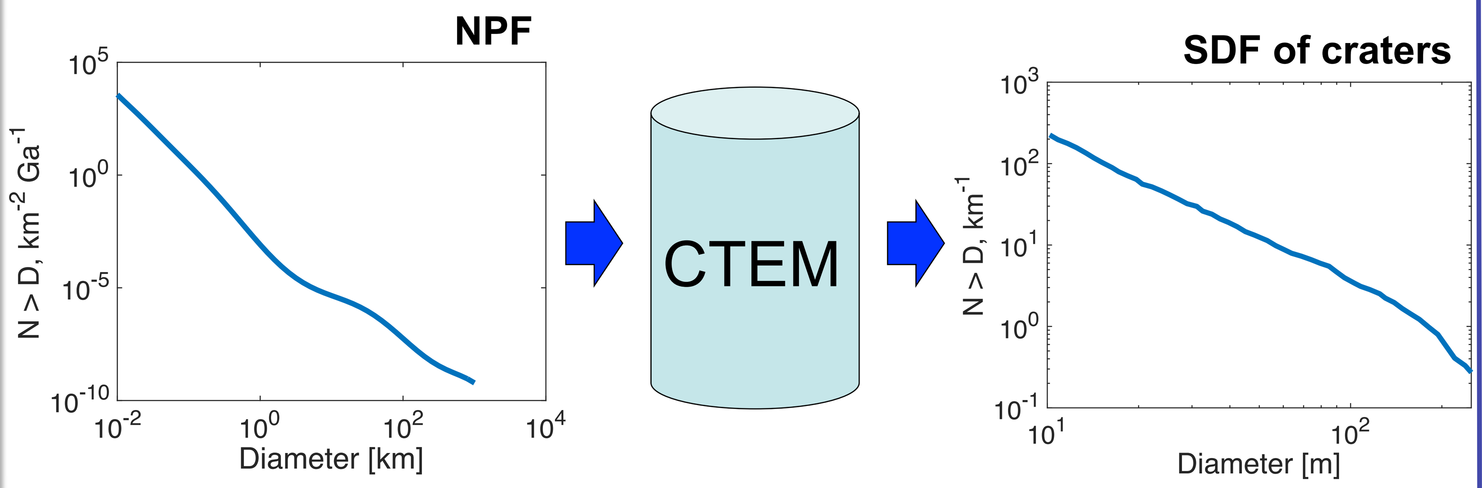


Figure 1. Schematic plot the CTEM architecture.

Porous regions are generated above the transient crater.

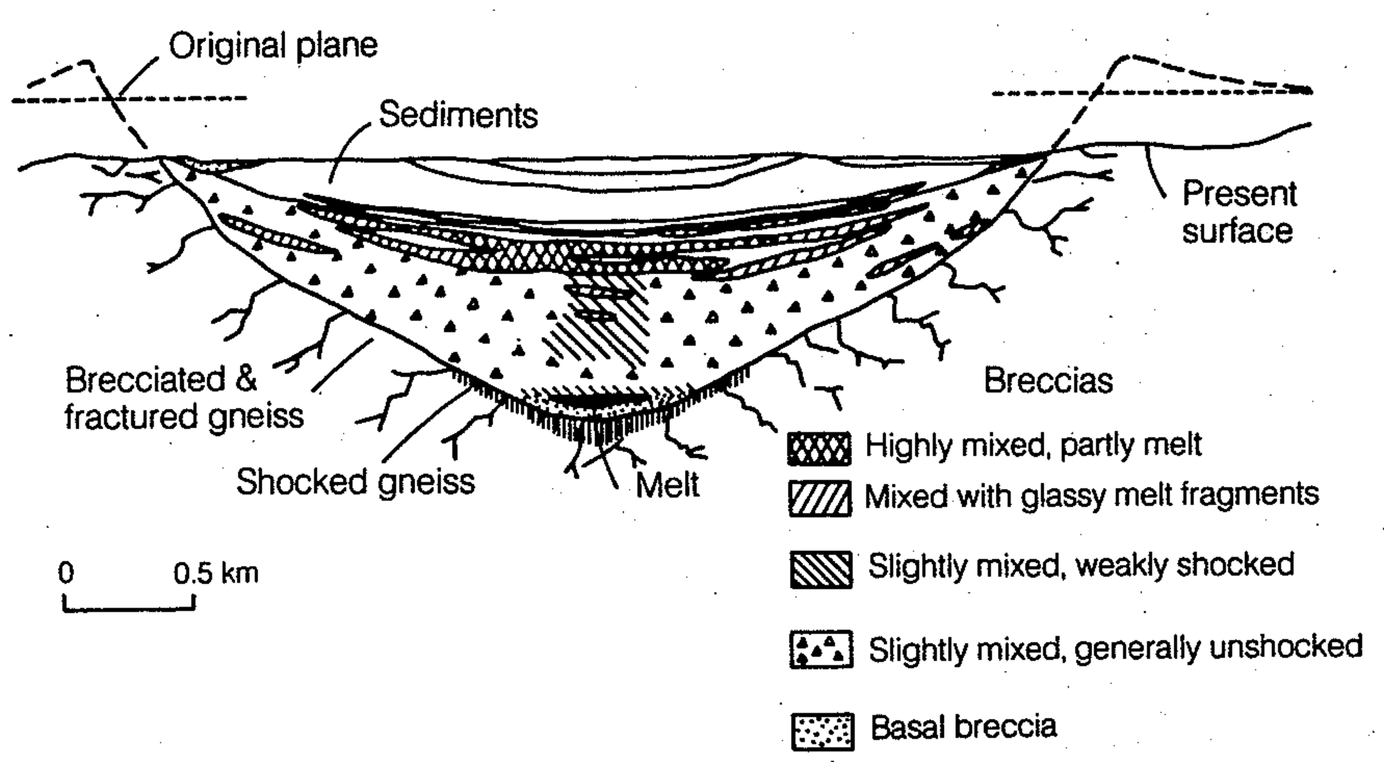


Figure 2. Geologic cross section of Brent Crater in Ontario, Canada [Fig. 8.1 in [10], originally in [11]]. We implemented the crater interior porosity model in CTEM based on this fact.

Implementation of a binary porosity model in CTEM:

The region above the transient crater is more fractured than the preimpact target (Figure 2). Fractured materials have cracks and voids, causing them to become porous. In CTEM, we considered materials filled in the transient crater after the excavation stage to be more porous than the preimpact (bedrock) target. The current model only considered impact-generated porosity in contrast to nonporous regions. To determine the shape of the transient crater, we computed the transient crater depth, ht , from the rim-to-rim diameter, Dt , as $ht = 0.3Dt$ [10]. The shape was then assumed to follow a simple parabolic profile. Because of this implementation, impact-generated porosity obtained in the new model differed from that in the original model in which porosity was generated only by ejecta accumulation. In Figure 3, we contrast the original and new porous model.

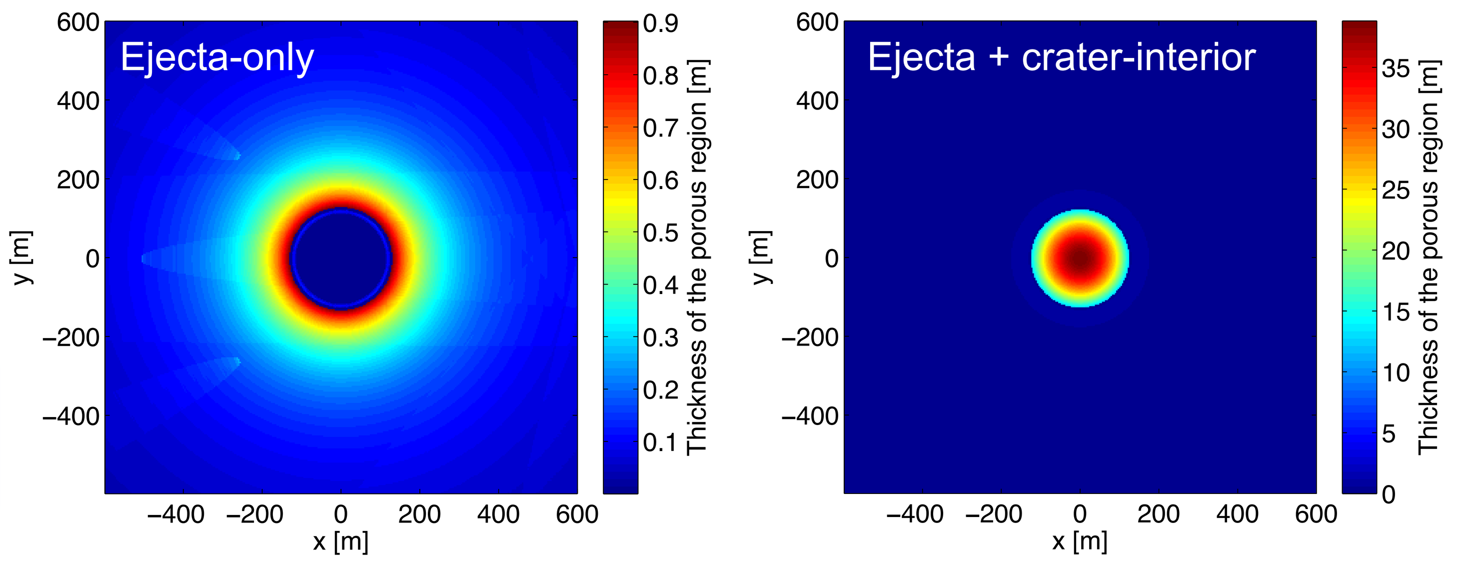


Figure 3. The thickness of porosity by the original model (the left) and that by and the new model (the right).

Results:

Simulation settings (we used parameters for a lunar surface):

- The impact velocity and size distribution profiles used were the same as used by Minton et al. [9].
- We defined a 720-m by 720-m square area as a test region and the size of each pixel as 3.6 meters. The maximum crater size was 720 m while the minimum crater size was 3.6 m.
- Initially, the surface in the test area consisted of bedrock.
- We considered a 3.5-Ga timescale to study the evolution of porosity.
- The simulation generated ~205,000 impact craters. Figure 4 describes the evolution of the porosity thickness in the test area.

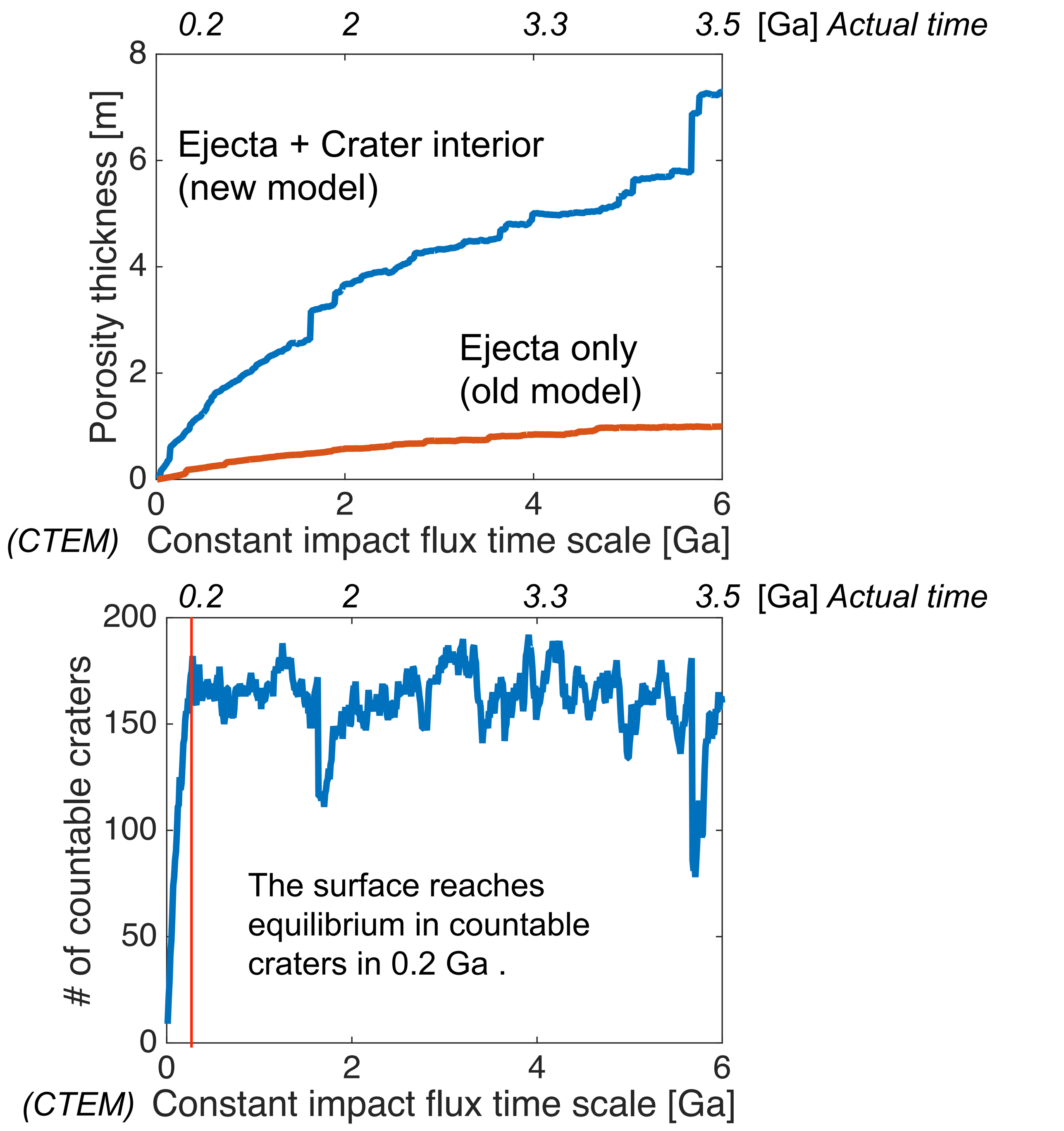


Figure 4. The thickness evolution of porosity (top) and the number of countable craters (bottom).

The porosity thickness keeps evolving over an actual timescale of 3.5 Ga, although the crater count of the surface reaches in equilibrium.

The locations of porous regions do not correlate with the variation in the surface elevation.

Red outlines: counted craters

Surface features

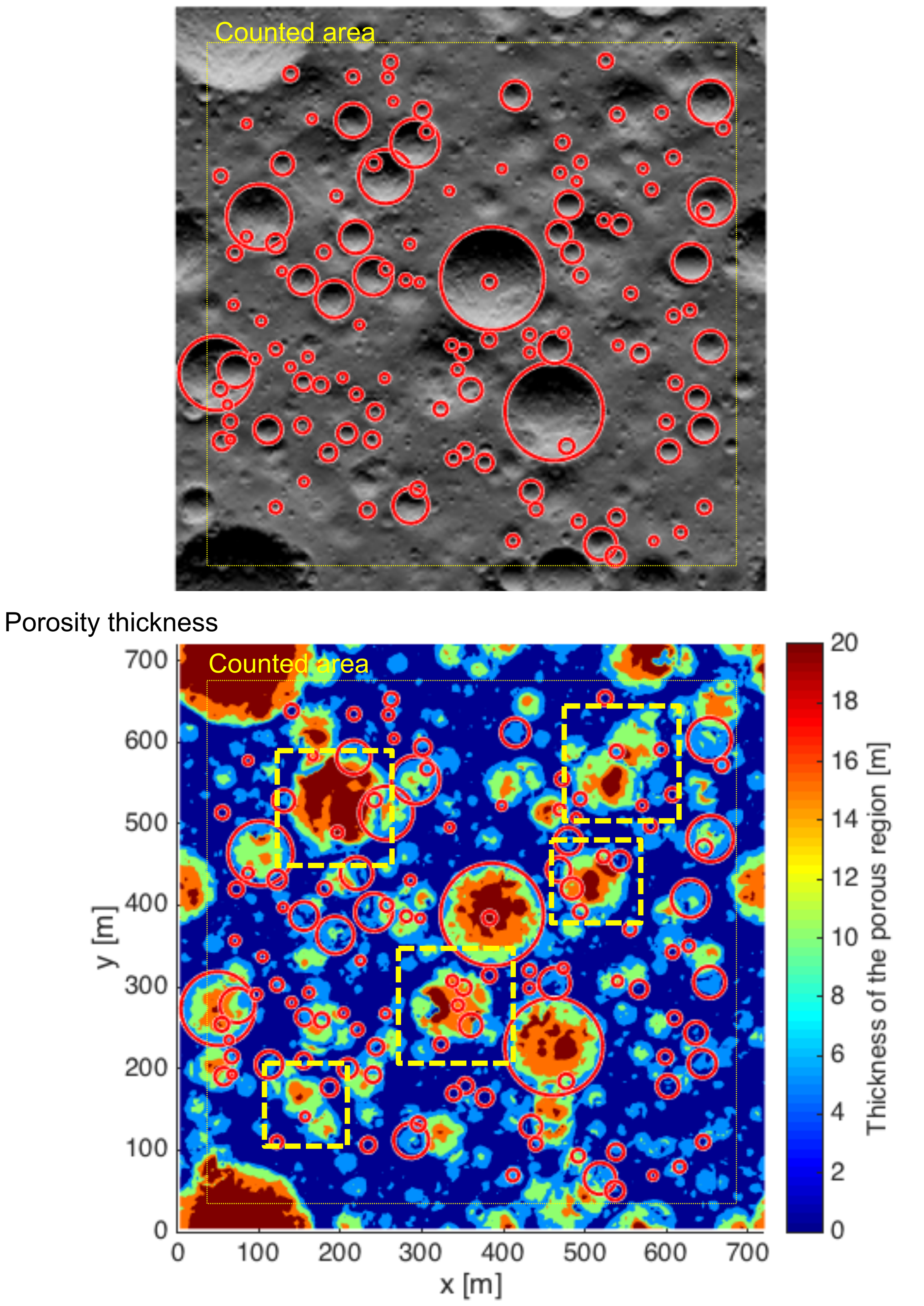


Figure 5. Surface elevation generated by craters after 3.5 Ga (top) and the porosity thickness beneath the surface (bottom).

While some craters are not visible, the porosity thickness perfectly preserves their traces (dashed yellow boxes).

Conclusion:

1. We developed a binary-porosity model in CTEM.
- We implemented a binary porosity model in CTEM.
- The new porous model in CTEM generated porous regions by considering the interior of craters and ejected materials.

2. The surface reaches in equilibrium of impact-generated craters at an early stage while the thickness of porosity still evolves over the time.
- The porosity thickness of a local area (720 m by 720 m) reaches 7 meters after 3.5 Ga. Since we limited the size of craters up to 720 m, we expect that the thickness becomes thicker in a larger size scale. This is consistent with earlier observations [1, 7].

3. The present study implies that the thickness of porosity may preserve the total number of impactors.
- The thickness of porosity evolves until possibly large craters are saturated.
- Porous regions generated by larger craters remain longer although such traces are completely erased from the surface.
- The variation in the surface condition does not always correlate with the thickness of porosity.

Reference: [1] V.R. Oberbeck et al. (1967) JGR 72(18): 4697. [2] Shoemaker et al. (1969) JGR 74(25): 6081. [3] Oberbeck et al. (1973) Icarus 19: 87. [4] Gault et al. Proc. of the fifth Lunar-Conference 2365. [5] C. Milbury, et al. (2015) GRL. [6] K. Wünnemann, et al. (2006) Icarus 180(2):514. [7] J. M. Soderblom, et al. (2015) GRL 42(17):6939. [8] J. E. Richardson (2009) Icarus204(2):697. [9] D. A. Minton, et al. (2015) Icarus 247:172. [10] H. J. Melosh (1989) Impact cratering: A geologic process 1. [11] R. A. Grieve, et al. (1977) in Impact and explosion cratering: Planetary and terrestrial implications vol. 1 791–814.