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Raditladi : Numerical Modeling of a Hermean peak-ring basin

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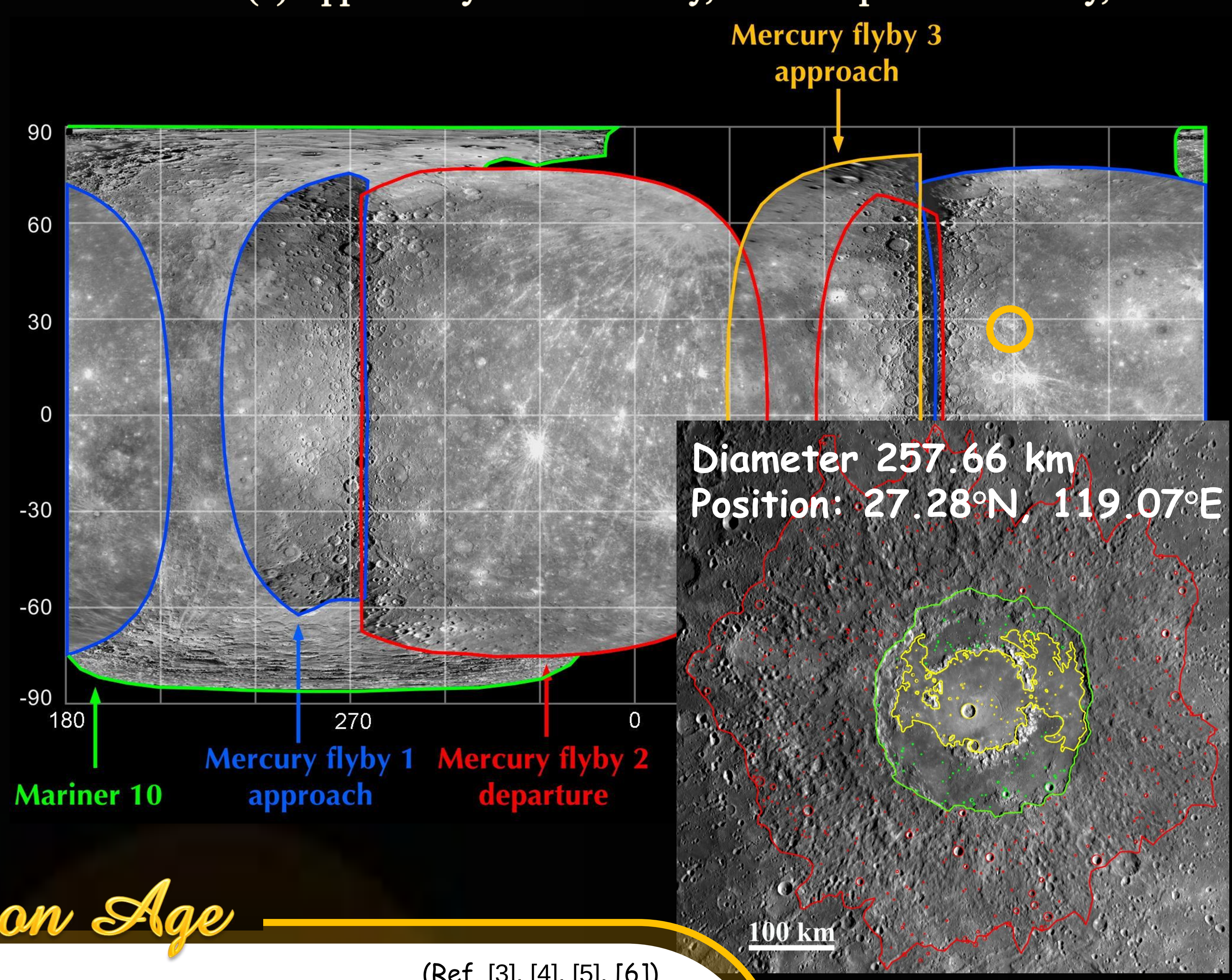
Abstract

Mercury has remained an "enigmatic body" among the terrestrial planets for more than three decades, caused by the paucity of data collected by the NASA Mariner 10 spacecraft in the Seventies. The recent flybys of the Discovery mission MESSENGER with Mercury updated our knowledge about this planet, in particular new areas of Mercury have been imaged, revealing structures never observed before.

One new feature, a double-ring impact basin named Raditladi, soon appeared very interesting for the small number of craters detected either on its floor and its ejecta, suggesting a young age. The peculiarity to have a very young age estimate in the case of such a large impact crater is the starting point for a deepen analysis on this structure. In this work we will show the result of the hydrocode simulations of the basin to be used to investigate the layering, at the basis of the age determination, and the impactor size.



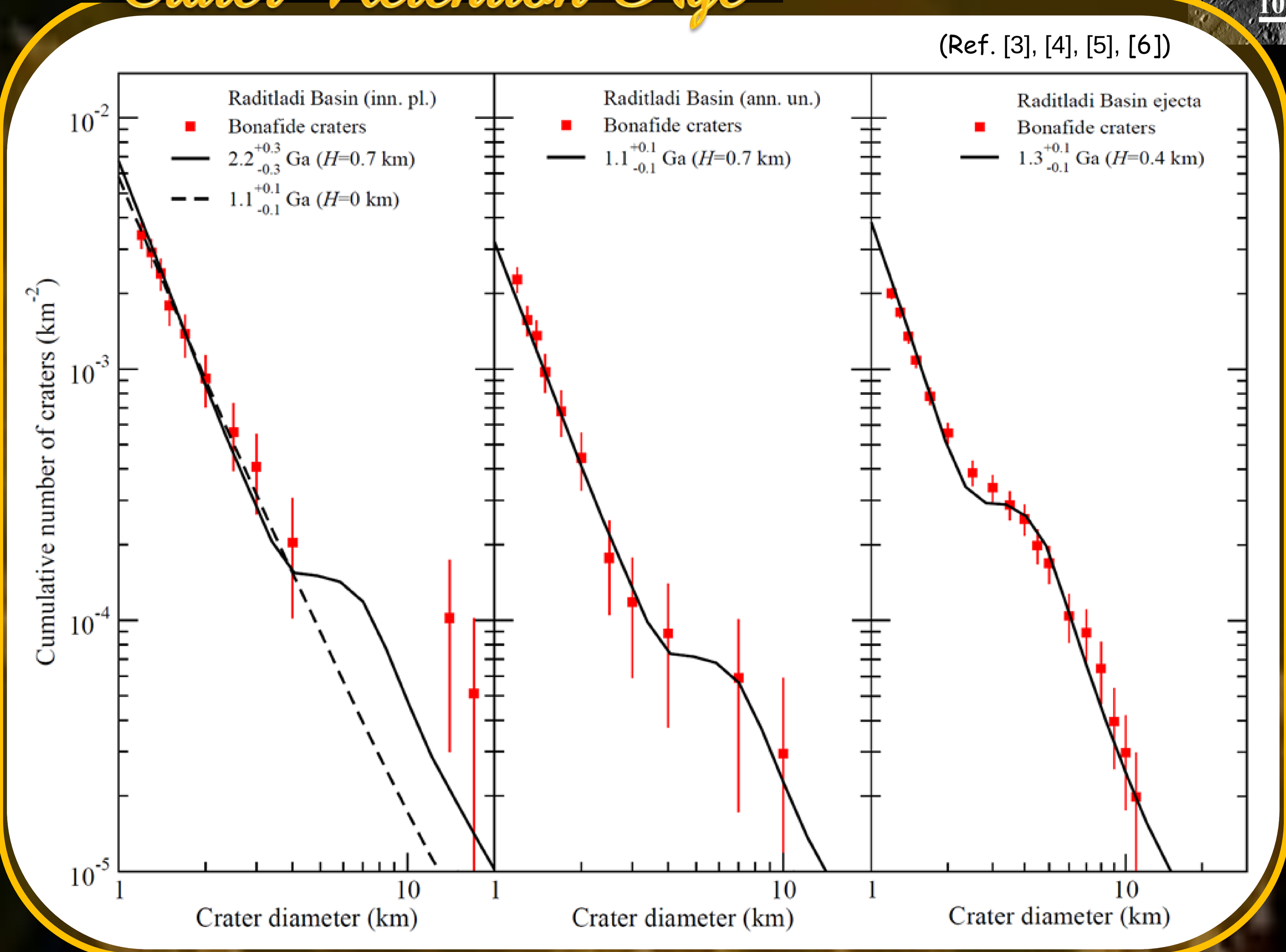
Introduction

Raditladi is a 257 km-diameter Hermean peak-ring basin, observed for the first time on September 2008 during the 1st fly-by of MESSENGER with the planet and located at 27.0° N, 119.0° E west of the Caloris basin. Its floor is partially filled with smooth, bright plains material that embays the rim and the central peak ring, inside which troughs are arranged in a partially concentric pattern.

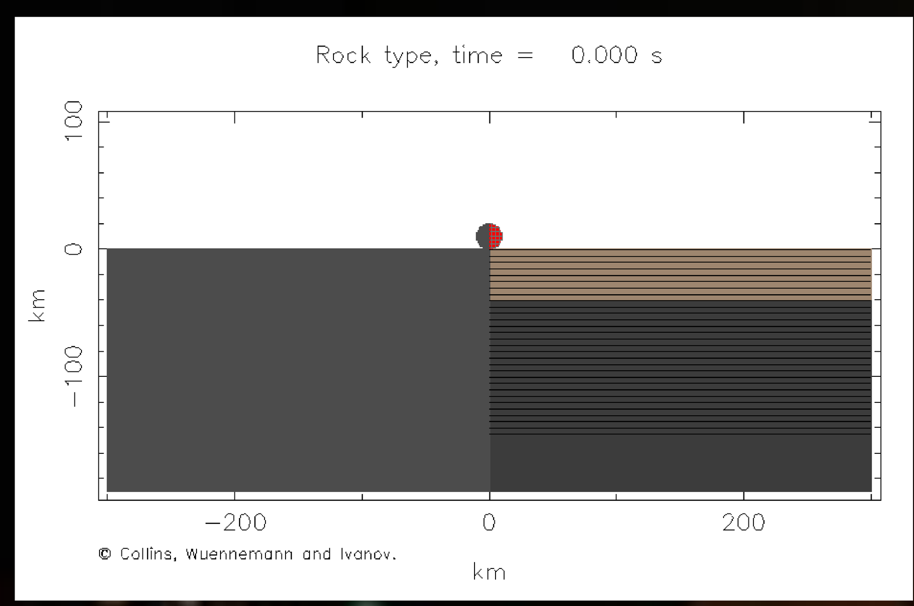
Raditladi soon appeared to be remarkably young because of the small number of impact craters seen within its rims ([1], [2]), in particular it was proposed to be as young as 1 *Ga* ([1]). The presumed young age of Raditladi together with its large sizes poses some interesting questions regarding the impactor population responsible for its formation, since very few asteroids are presently known to have sizes large enough to originate such a basin. In this context, our group performed both crater retention age analysis to better constrain the timing of the impact event and numerical modeling to deepen the impact process and give some constraints on the impactor dimensions.

Crater Retention Age

(Ref. [3], [4], [5], [6])



Model SETUP



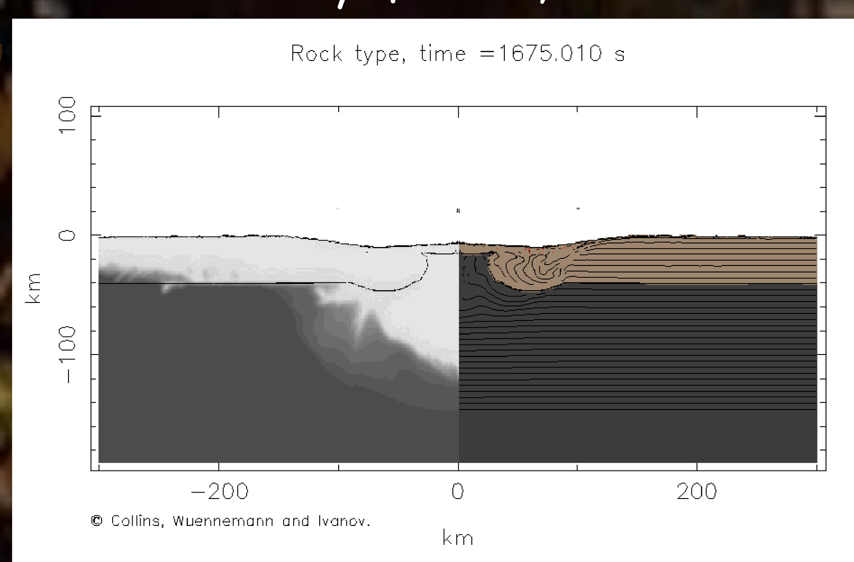
Grid 300 x 300 CPPR

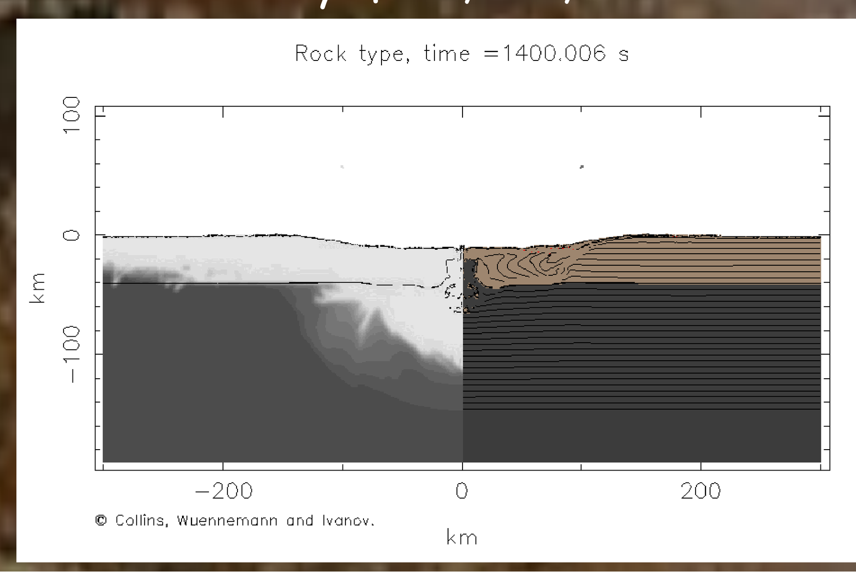
Projectile
Diameter: 20 km ≡ 10 CPPR
Impact velocity: 30 km s^{-1}
Material: Basalt ANEOS (10% porosity)

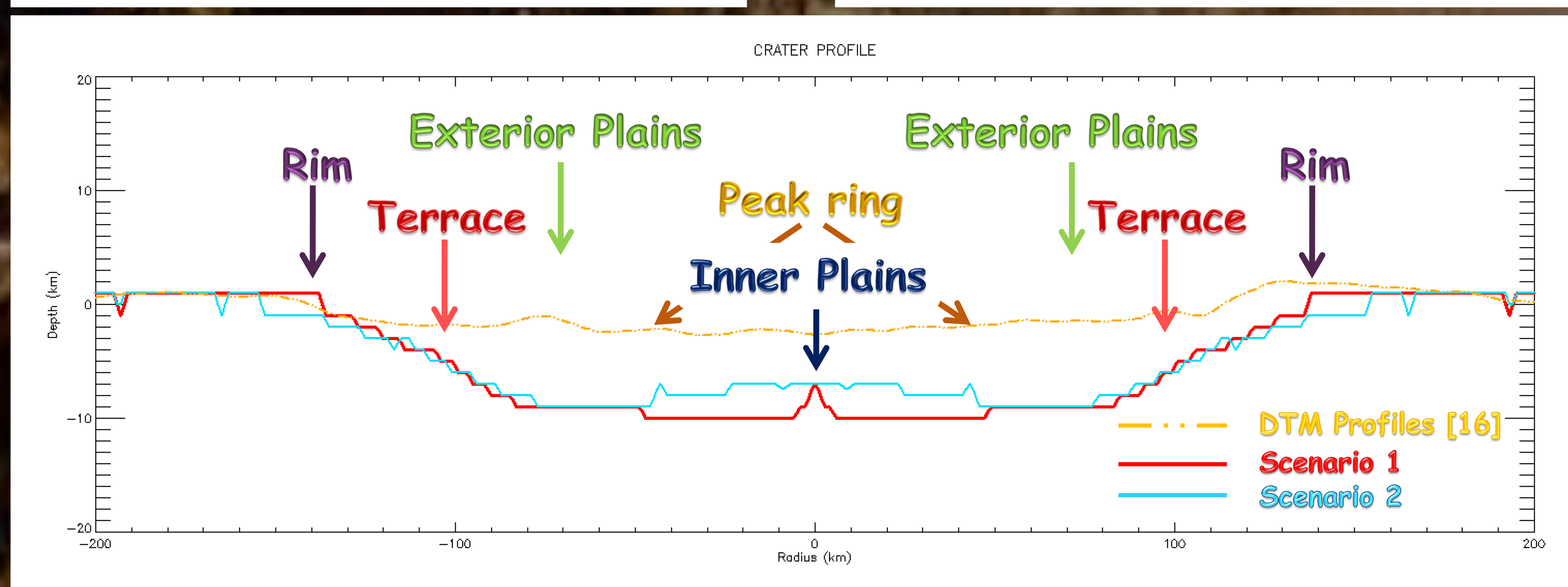
Target
40 km — *Material*: Basalt ANEOS (15% porosity)
150 km — *Material*: Dunite ANEOS (0% porosity)

	Scenario 1	Scenario 2
40 km layer	damping time τ = 300 s viscosity η = 500,000 Pa s	
150 km layer	damping time τ = 300 s viscosity η = 500,000 Pa s	damping time τ = 130 s viscosity η = 5,000,000 Pa s

... from day to day To the last syllabe of the recorded time





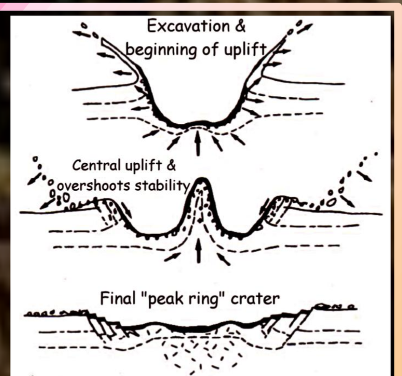


iSALE shock code

The principle of formation of an impact crater lies in the transfer of the kinetic energy of a high-velocity projectile into the kinetic and internal energy of the target material.

The internal energy heats both the impactor and target, resulting in melting or vaporization of material in close proximity to the impact site, whereas the residual kinetic energy is spent ejecting material and opening the cavity that will form the crater.

This transient cavity then undergoes a gravity-driven modification to a more stable structure.



Why Numerical Modeling ???

- it provides the only feasible method of studying the physics of impact cratering at all scales, becoming an invaluable tool that connects and complements geologic data, remote sensing observations and small scale laboratory experiments;
- it allows to reach conditions not achievable in laboratory scale and to study the effects of each variable acting during the process; *and ...*
- it represents the only means to deep our knowledge in "extra-terrestrial" craters

How does it work ???

The dynamics of a continuous media is described by a set of differential equations established through the principles of conservation of momentum, mass and energy from a macrosopic point of view.

In addition, two further equations are needed.

An Equation of State to describe the thermodynamic state of a given material over a wide range of pressures, internal energies and densities.

A Strength Model to describe the response of a material to stresses that induce deviatoric deformations or changes of shape. It combines the concepts of:

- Elasticity (strain proportional to stress)
- Plasticity (elastic until yield stress)
- Fluid flow (strain rate a function of stress)

and ... ACOUSTIC FLUIDIZATION (AF)

to explain the temporary liquid-like behaviour of rocks in the vicinity of the crater ([7]).

The behaviour of acoustically fluidized matter is mainly determined by the viscosity η and the decay time τ, that are both strongly linked with the fragmentation state of the rocks beneath the structure (e.g., [8]).

WHO ??? iSALE ...

Simplified Arbitrary Lagrangian Eulerian CODE

iSALE is a multi-material, multi-rheology code modified after the SALE hydrocode ([9]) since the early 1990s. Improvements to the code have spread into many topics, to include up to three target material, various equations of state, a variety of constitutive models along with the introduction of a porous-compaction model ([10], [11], [12], [8], [13]). It is well-tested against other hydrocodes ([14]).

Discussion

Raditladi basin is a young impact basin, about 1.1-1.3 Ga, whose interior was interested by either a great amount of impact melt either lava flows emplaced soon afterward the impact ([6]), both may have led to a complete hardening of the brecciated material generated by the impact.

In order to better asseess these findings derived from crater retention age analysis trhough MPF procedure, we simulated a 20 km diameter projectile striking perpendicularly the Hermean surface at 30 km/s, which is the component of the mean value of the impact velocity distribution on Mercury (42 km/s, cfr. [15]) at 45° angle. We performed several model runs varying the AF parameters to find the best fit with the DTM profiles ([16]).

In this preliminary analysis, we present the two modeled craters for the two different sets of AF-paramters giving the best match with DTM. Whereas the depth/diameter ratios for both the scenarios are nearly the same, the resulting morphology is different. Scenario 2 (high viscosity lasting a shorter time in the dunite layer) leads to a better development of the peak ring inside the basin and a higher fracturing beneath the floor of the crater.

In both the scenarios, whereas craters and peak rings diameters are quantitatively in agreement with observations, craters depth is almost twice the one obtained from DTM profiles, possibly explained by a post relaxation of the basin.

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