THE K-PG IMPACTOR WAS LIKELY A HIGH VELOCITY COMET.

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Introduction: The nature of the K-Pg impactor, and the global influence of its impact has been the subject of extensive research since it was first described by Alvarez et al. [1], who hypothesized the bolide to be a 6 to 14-km diameter asteroid. Subsequent studies in the 1980s suggested that K-Pg impactor could be a comet [2] or part of a comet shower [3,4]. Mathematical modelling of the K-Pg impact [5] could not definitively differentiate asteroid and cometary impactors. Discoveries of a meteorite fragment in K-Pg boundary age sediments in the Pacific Ocean [6], and Cr isotope anomalies [7] indicated that the bolide was carbonaceous chondritic in nature, but these data also do not discriminate asteroids from comets. Mukhopadhyay et al. [8] did not find increased ^{3}He abundance across the K-Pg boundary suggesting the impactor was an asteroid or a lone comet, rather than part of a comet shower, but could not differentiate further. Recent studies of impact cloud dynamics [9] and impact spherule formation [10] are similarly unable to distinguish slow, rocky asteroidal impactors from faster, icy cometary impactors.

Increasingly sophisticated hydrocode models [9,11] have shed insights into the energy required to create a crater the size of Chicxulub, independently demonstrating that an asteroid of ~13km diameter would be required to produce a 180 km crater. This is in stark contrast to the published estimates of background iridium fluence [12], which suggest a much smaller impactor (~7 km diameter). Suitable candidate impactors must, however, be coherent with both datasets simultaneously.

Methods: Recalculated, independent global iridium and osmium budgets show that the global fluences at the K-Pg boundary were 28 ng cm^{-2} and 30 ng cm^{-2}, respectively [13] – exactly in line with the expected ratio from an extraterrestrial body, and predicting a smaller impactor than previous estimates. The most recent 3-dimensional hydrocode simulations indicate that the kinetic energy of the impactor required to produce a transient cavity that is ~100 km wide is $3 \pm 1 \times 10^{23}$ J [9]. Using these two sets of estimators and measurements of the composition of asteroids and comets it is possible to constrain an impactor parameter space (velocity, density and diameter) within which all geochemically and geophysically plausible impactors must lie (Figure 1).

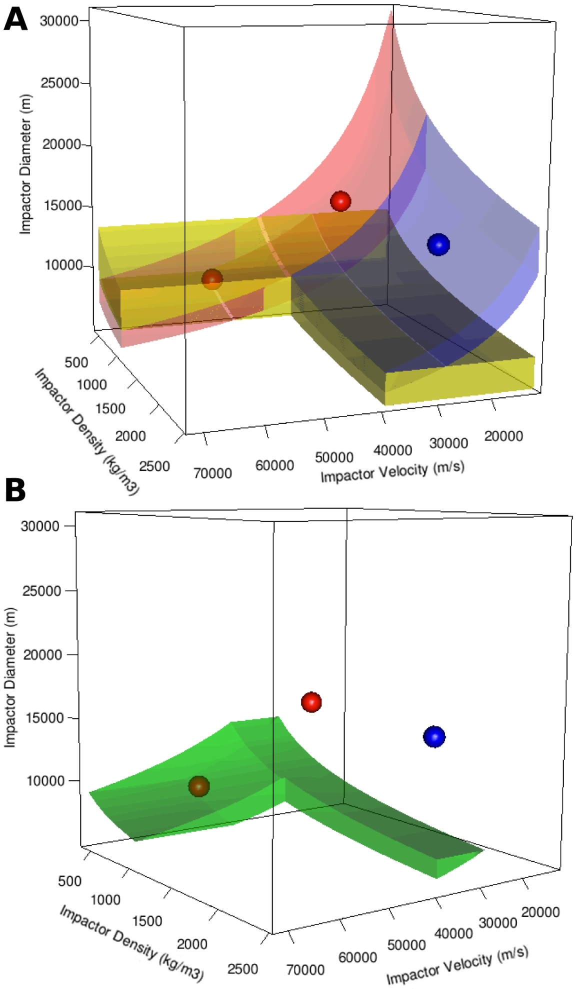

Figure 1 – Conservative estimate of the parameter space for impactor candidates congruent with geophysical and geochemical data from the Chicxulub impact. Spheres represent most common parameters for long period comets (left red), short period comets (right red), and asteroids (blue). A) Geochemically plausible parameter space in yellow, geophysically plausible parameter space for comets in red, geophysically plausible parameter space for asteroids in blue. B) Intersection of geophysically and geochemically plausible parameter spaces in green.

Discussion: The parameter space illustrated in Figure 1 represents a conservative estimate of the potential impactor parameters. Such estimates demonstrate that, in order to retain enough energy to create a

Impactor	Relative abundance within mass range	Proportion within velocity range	Proportion of viable candidates
Asteroid	0.0046	0.0949	0.00014
Short Period Comet	1	0.0445	0.04802
Long Period Comet	0.9041	0.9763	0.95184

Table 1 - Proportions of impactor candidates within the viable impactor parameter space

~180 km diameter crater and yet only deposit 28 ng cm^{-2} of iridium globally, the impactor must have been travelling at >28 km s^{-1} on impact. Similarly, the maximum allowable diameter for the impactor is ~15 km, which corresponds to the least dense cometary candidates. The maximum possible impact velocity is taken as the maximum observed velocity for potential impactor candidates in the solar system (72 km s^{-1}).

Given the current populations of asteroids and comets in the solar system [14,15,16], it is possible to estimate the proportions of each impactor candidate that lie within this parameter space (Table 1, Figure 2).

Mathematical modelling of the formation of spherules in an impact vapor plume, coupled with the average diameter of ~250 μm of spherules recovered from K-Pg boundary [17], has been used to argue for a slower-moving, asteroidal candidate model, larger than that which we suggest here [10,18]. This model is not necessarily incongruent with a faster-moving, smaller cometary candidate, as one particular spherule size can be produced by both high and low velocity impactors [10]. In fact, a global average spherule diameter of 250 μm with an ~10 km impactor would predict either a velocity of ~22 km s^{-1} or a velocity or ~32 km s^{-1}, the latter of which is congruent with the geochemical and geophysical evidence for a cometary candidate. Moreover, the global average spherule diameter of ~250 μm may be an overestimate as additional material can condense onto preexisting spherules on re-entry into the vapor plume [10]. If this is the case, the implied smaller average diameter would make even faster impact velocities congruent with the spherule record.

Conclusions: By reassessing and reconciling geophysical and geochemical evidence for the nature of the K-Pg impactor, we can demonstrate that 99.99% of potential impactor candidates that are coherent with both the geophysical and geochemical data are comets (and 95% are long period comets). This is at odds with the commonly held view that the impactor was a much larger, more slowly travelling asteroid, opening major new directions for the investigation of the K-Pg impact and its effects.

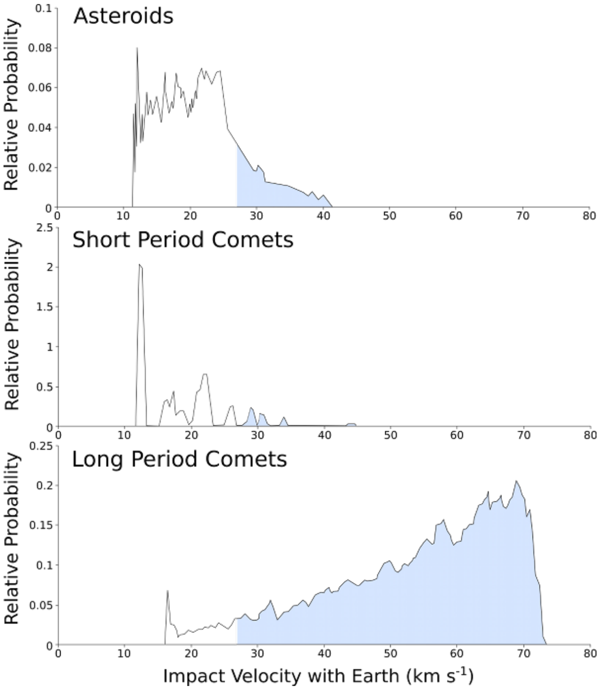

Figure 2 - Velocity distribution of potential impactor candidates. Shaded area shows those candidates falling within the viable velocity range for the K-Pg impactor.

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