A PLAUSIBLE METEOROID CONTROL OF THE BENIGN CLIMATE OF THE HADEAN EARTH. M.Lefort\textsuperscript{1} and M.Maurette\textsuperscript{2}. \textsuperscript{1}ICS, BP 84047, 67034 Strasbourg, France. \textsuperscript{2}CSNSM, Bat. 108, 91405 Orsay-Campus, France. E-mail: Maurette@csnsm.in2p3.fr.

Introduction: During the first \(~200\) Ma of the post-lunar Hadean Eon, meteoroids similar to Antarctic micrometeorites were probably initiating the formation of the Earth's atmosphere upon their sharp deceleration around the mesopause [1, 2]. We focus on their high S (\(~5\%\)), C (\(~2.5\%) and H\textsubscript{2}O (\(~10\%\)) contents as to decrypt their role in both the birth of old Australian zircons and the onset of a benign Hadean climate around 4.3 Ga ago.

Initial cooling by meteoroid sulfate aerosols: The existence of mild climatic conditions in the early Hadean Eon is encrypted in the U–Pb age, the lithium concentration and the oxygen isotopic composition of old Australian zircons with ages ~4.3 Ga [3]. Previous models fabricated these conditions while counterbalancing the extended period of reduced luminosity of the early Sun (that would have frozen the oceans) by the effects of strong greenhouse gases (CO\textsubscript{2}, CH\textsubscript{4}) emanating from the Earth's interior. They ignored the effects of both SO\textsubscript{2} and the Moon forming impact, which blew off the pre-lunar greenhouse gases at a time when the young upper mantle was almost fully degassed.

The accretion equation [2] predicts huge and similar input rates of meteoroid SO\textsubscript{2}, CO\textsubscript{2} and H\textsubscript{2}O of ~5000 Mt/yr, which are typical of mega–eruptions. They likely formed sulfate aerosols (H\textsubscript{2}SO\textsubscript{4}, nH\textsubscript{2}O) in the upper atmosphere that reflected sunlight back to space and cooled the Earth, thus enhancing the faint early Sun cooling. This effect is well established for the most explosive volcanic eruptions that inject material in the stratosphere, such as Toba (74,000 yr ago), which erupted a rather similar input rate of SO\textsubscript{2}, and triggered a 4–5 yr long volcanic winter [4].

But the meteoroid volcanic winter lasted for ~100 Ma. How did the Earth bypass freezing?

A meteoroid "acid" weathering for the birth of old zircons and the onset of a CO\textsubscript{2} controlled benign climate: With a meteoroid SO\textsubscript{2} / H\textsubscript{2}O mass ratio of ~1 (c.f., Table 1, Ref. 1), meteoroid water might have formed ice crystals, like in contemporary noctilucent clouds clustering around the mesopause. They nucleated sulfate aerosols that did rain on the Earth (either as liquid droplets or dirty hail stones) while being constantly regenerated by meteoroid outgassing during the first 100–200 Ma of the post-lunar period. The highly acidic water (pH ~0) of the nascent oceans inhibited the formation of carbonates. The intense greenhouse effect of meteoroid CO\textsubscript{2} still in the "air" led to the heavy weathering of the early continental crust, required for the birth of old zircons, as soon as 4.3 Ga ago [3]. This warming was probably regulated through the gradual scavenging of meteoroid sulfur in the upper mantle [2]. The pH of water increased up to the critical value (~6) when CO\textsubscript{2} started to precipitate as carbonates. Simultaneously, the delivery of meteoroid SO\textsubscript{2} and CO\textsubscript{2} was sharply decaying by a factor ~100x during the first 200 Ma of the post-lunar period. This launched the long-term CO\textsubscript{2} "greenhouse" control of the benign climate.