Deep impacts in deep time explains Earth's lost childhood

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Earth's first 500 million years of life—known as the Hadean Eon, named after the Greek god of the underworld—is almost entirely missing from the geological record.

By analogy to an optimistic 100-year human lifetime, such a gap would be like having your birth certificate (Earth's birthdate 4.53 billion years ago) but then having no physical evidence—no family pictures, no home videos, no mementoes from primary school—until you were *11 years old*.

Earth's first real memories were practically as a teenager…why?

The glaring lack of rocks from Earth's childhood has long shrouded the Hadean in mystery.

But according to a new study published in *Science* Earth's lost childhood may be an expected consequence of the trauma it incurred from large, repeated asteroid impacts early on.[1] Although Earth may have blacked out its tumultuous Hadean childhood, lead author Tim Johnson, a geologist at Curtin University, suggests we might not have to look too much further for some clues.

"Just look at the surface of the Moon," says Johnson, "there are impact craters everywhere."

Unlike Earth, the Moon's surface is dominantly Hadean. So our nearest neighbor provides a window into what the Earth is missing and maybe also why. And given Earth's greater gravity and larger target size, its early barrage of impacts would have been even more violent than the Moon's.

But just because impacts would have been inevitable in the Solar System early on, "the real question comes in actually putting a number on it," says co-author Craig O'Neill, geodynamicist at Macquarie University. "How important was impacting really?"

Johnson and O'Neill's team made use of the ancient cratered surfaces of the Moon, Mercury, and Mars to anchor their modeling in the historical reality of the early inner Solar System.

"After that," says O'Neill making his sophisticated modeling sound easy, "it's just a matter of fundamental Newtonian fluid mechanics and doing the accounting of Earth's energy budget."

Modesty aside, O'Neill's estimates for the heat generated by Hadean impacts on Earth dwarfed its internal heat sources. "The implied impact from the outside, from outer space, was a force to be reckoned with," says O'Neill, insisting that both puns were intended.

Other researchers had modeled impact heating effects before, but had focused on Earth's crust and found only a very small percentage would be molten.

But considering conservation of energy, that energy has to go somewhere, and may not just be restricted to the crust. So Johnson and O'Neill's team wondered if previous work hadn't thought (figuratively and literally) deep enough.

"If someone throws a stone at your head really, really hard," says Johnson, "all of that kinetic energy is gone instantaneously. The event is only a fraction of a second. But then over the next minutes and hours your head swells up."

The point is that most of that energy from the impact goes through the crust and into Earth's mantle below.

To explore this possibility, the team coupled O'Neill's impacting heating physics with Johnson's use of thermodynamic models capable of revealing how primitive rocks melt at much deeper depths.

But absence of evidence isn't evidence of absence—although super rare, there are more Hadean rocks on Earth than previously known, as reported recently in *Science*.[2]

Johnson predicts that more such glimpses of Hadean rocks will be discovered around the world in coming years. "Since impacting was global, it is precisely such fragments of Hadean crust that just barely avoided complete recycling that impacts predict."

"If they're right about the Hadean," says geophysicist Ross Mitchell of the Chinese Academy of Sciences, "then it turns out that its naming was prescient but also ironic. Because the lost Hadean crust was hidden down deep in the mantle—Earth's underworld—largely because of early impacting from the skies above."

Many large impacts in the young Solar System would have induced mantle melting and crustal recycling, effectively hiding most of Earth's Hadean rocks deep within.

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DECLARATION OF INTERESTS

The author declares no competing interests.