Pebbles, comets and damp asteroids

That's what the young earth was made of. **Robin George Andrews** reports

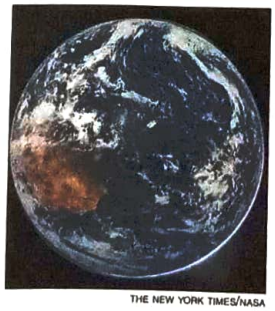
Making planets is an extreme enterprise. Although it starts with dust and gas gently sticking together, it culminates with gigantic space rocks walloping into one another at unfathomable speeds until, eventually, you're left with newborn worlds.

Most scientists think that Earth and Mars took shape this way from rocky pieces swirling around the young Sun around 4.5 billion years ago. But despite being the same age and having broadly the same basic ingredients, Earth (a biodiverse paradise) and Mars (a cold, irradiated desert) are very different worlds today. That may be, in part, because Earth and Mars had surprisingly different origin stories.

Scientists effectively designed a new game that can forge virtual planets. They took an array of chemical clues found in the rocks of both worlds and ran them through a battery of statistical models and computer simulations, repeatedly trying to end up with an Earth and a Mars that resembled the real things.

Their results, published in the journal *Nature Astronomy*, suggest that Mars was mostly pieced together from big, asteroid-like objects. Conversely, Earth's existence largely relied on a swarm of self-assembling pebbles.

The new model adds an exciting piece to a planetary puzzle: how did Earth get its enduring supply of life-giving water aeons ago? Experts think a mixture of comets and damp asteroids was largely responsible, but others have suggested that a cavalcade of icy pebbles arriving from the outer solar system may have added to the torrent. If Earth is mostly pebble-made, that supports this idea.



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Anders Johansen, a planetary scientist at the University of Copenhagen in Denmark and one of the study authors, said that his team was taken aback by how two neighbouring planets could form in two unique ways.

Scientists already had some clues that Earth and Mars were assembled differently — the clearest being that Mars is just one-tenth the mass of Earth. Scientists typically attribute the Mars mass mystery to the emergence of Jupiter. This behemoth has such immense gravity that it could have grabbed many of the rocky building blocks in embryonic Mars' orbital path and thrown them elsewhere.

The elements that make up the crust and mantle of both planets offer another clue.

Ancient meteorites record the composition of the solar system's starting material. Compared with those meteorites, Earth and Mars are depleted in things such as sodium, potassium, lithium and zinc. If Earth and Mars had divergent origins, they would have lost these moderately volatile elements in different ways.

Colliding space rocks generate very high temperatures that tend to cook off these volatiles into space, although as the objects involved get bigger, some volatiles buried deep below the surface may be preserved. Objects made mostly from gently coalescing pebbles will retain more of their volatiles.

Based on its volatile mix, Mars must have gathered 73 per cent of its mass from larger, asteroid-like bodies colliding, according to Johansen's team. The rest came from sweeping up small pebbles.

By contrast, the researchers said, 75 per cent of Earth's mass probably comes from pebbles that clumped together to form two protoplanets, which then smashed into each other. This titanic pileup was supplemented by a bombardment of smaller space rocks.

The new model relies on several simplifications, so trying to determine exactly what proportion of pebbles went into making Earth and Mars "is out of the question", said Paolo Sossi, a planetary scientist at ETH Zurich in Switzerland, who was not involved with the new study.

But Sossi added that Earth's volatile depletion pattern strongly hints that multiple types of building blocks were involved in its construction. And this new study implies that "pebbles could be allowed in the formation of the Earth", he said.

"This paper is intriguing," said Conel Alexander, a cosmochemist at Carnegie Science in Washington, D.C., US, who was not involved with the study. "It's certainly not the final answer," he said but the proposed hybrid model is worth considering.

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