COSMOCHEMISTRY

The origins of water

New measurements of Earth's building blocks point to a simpler water source

By **Anne H. Peslier**

Our blue planet having water seems such a simple and obvious fact that the question of why Earth has water at all feels like a trivial one. However, the origin of this key ingredient for life has remained a long-standing topic of debate. According to models of Solar System formation, Earth, as an inner Solar System planet, should have little to no water. On page 1110 of this issue, Piani *et al.* (*1*) analyze enstatite chondrite meteorites, a material similar to Earth's main building blocks, and address the origins of Earth's water.

Early models of planetary formation predicted that the nebular gas near our young Sun was too hot to form ice. Water as vapor therefore could not have been easily incorporated into the materials that formed the inner rocky planets Mercury, Venus, Earth, and Mars (*2*). Only the outer Solar System planets, such as Jupiter, contain an abundance of water and other volatiles, because they formed beyond the "snow line," the imaginary boundary between water vapor and water ice in the solar nebula (*2*, *3*). These planets were born far enough from the Sun to be able to easily incorporate frozen water.

Earth not only has water in its oceans and atmosphere but also contains the equivalent of several oceans' worth of water locked inside the rocks of its deep interior (*4*). To solve this puzzle, special types of meteorites that formed at the very beginning of the Solar System can be analyzed. These space rocks, called chondrites, have not been incorporated and chemically modified into a large planet. Chondrites represent condensates of the solar nebular gas and are the best representatives of the type of material that aggregated to eventually form planets. Earth's isotopic composition indicates that the main building blocks of rocky planets are enstatite chondrite–like materials [e.g., (*5*)].

However, enstatite chondrites were believed to be too dry to account for Earth's water. Instead, a water-rich type of chondrite called carbonaceous chondrite was suggested to have brought most of the planet's water. Carbonaceous chondrites, however, are not ideal because they have a very different isotopic composition than Earth and formed outside of the snow line (*6*). To reconcile these apparent inconsistencies, carbonaceous chondrite–like material was proposed to have been added to Earth from beyond the snow line when the planet was already mostly formed [e.g., (*4*)]. For these chondrites to pelt the early Earth, either the formation of Jupiter or its inner Solar System wandering has been suggested to have disturbed the orbits of asteroids, ejecting them from the outer part of the asteroid belt (*6*).

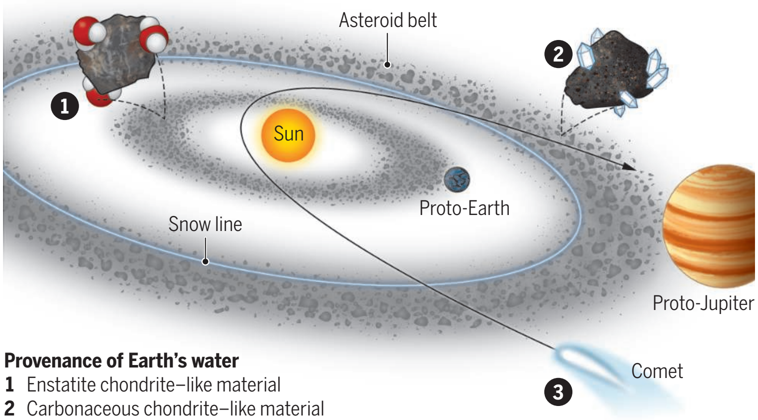
Piani *et al.* offer a simpler explanation. The authors convincingly argue that water could come from enstatite chondrites (see the figure). The authors measured the water concentration and deuterium to hydrogen (D/H) ratios of these meteorites. Enstatite chondrites apparently do have enough water to provide Earth with the mass equivalent of several surface oceans' worth of water. In addition, the D/H ratio and nitrogen isotope composition match those of Earth's interior.

It would now seem that Earth could have acquired its water during accretion after all. Alternative models suggest the possibility of retaining water in the inner planets' building blocks. Surface adsorption of water on nebular condensates (*7*), retention of nebular gas around planet embryos (*8*), or inward migration of the snow line (*2*) have all been proposed. That enstatite chondrites formed in the inner Solar System (*5*, *6*) relaxes the challenging requirement of bringing water to Earth from farther away from the Sun.

Piani *et al.*'s observations do not provide any constraints on timing for the incorporation of water into Earth. Early incorporation during accretion could be irrelevant if most water degassed during early events in the planet's history. Formation of magma oceans and intense asteroid bombardment would both cause water to be lost to space (*9*, *10*). Alternatively, enstatite chondrite–like material could have been incorporated into Earth after accretion (*11*). After Earth's accretion, it appears that water was added to its oceans and atmosphere (not its interior), with contributions from comets and carbonaceous chondrite–like material (*3*, *12*). Nevertheless, the authors' work brings a crucial and elegant element to this puzzle. Earth's water may simply have come from the nebular material from which the planet accreted. ■

Sources of Earth's water

New measurements of enstatite chondrites indicate that water could have been primarily acquired from Earth's building blocks. Additional water was delivered to Earth's early oceans and atmosphere by water-rich material from comets and the outer asteroid belt.



Provenance of Earth's water
1 Enstatite chondrite–like material
2 Carbonaceous chondrite–like material
3 Comets contributing to the atmosphere's composition

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