Origin of water on Earth

The **origin of water on Earth**, or the reason that there is clearly more liquid water on Earth than on the other rocky planets of the Solar System, is not completely understood. There exist numerous more or less mutually compatible hypotheses as to how water may have accumulated on Earth's surface over the past 4.5 billion years in sufficient quantity to formoceans.

Water covers about 71% of Earth's surface[1]

Contents

Possible sources

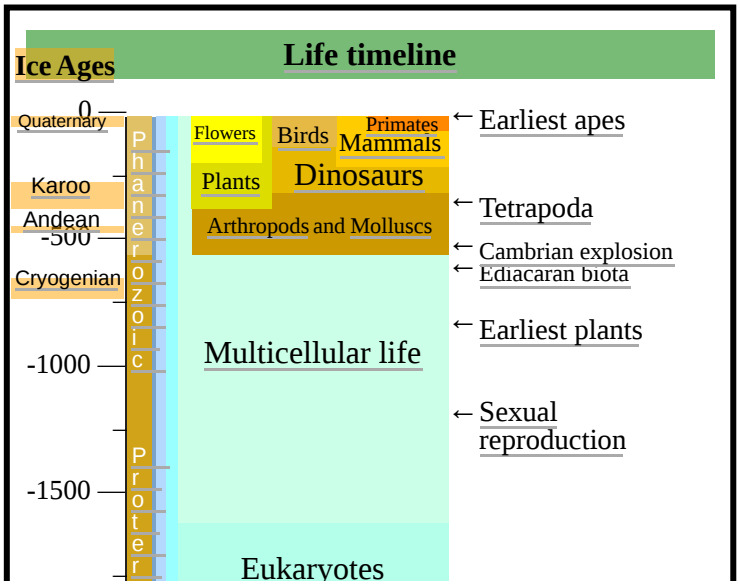
Internal sources

Gradual "dehydration melting"—leakage of water stored in hydrate minerals of Earth's rocks—could have formed a portion of its water.[2][3][4] Water may also have come from volcanism: water vapor in the atmosphere that originated in volcanic eruptions may have condensed to form rain, slowly filling Earth's oceanic basins.[5]

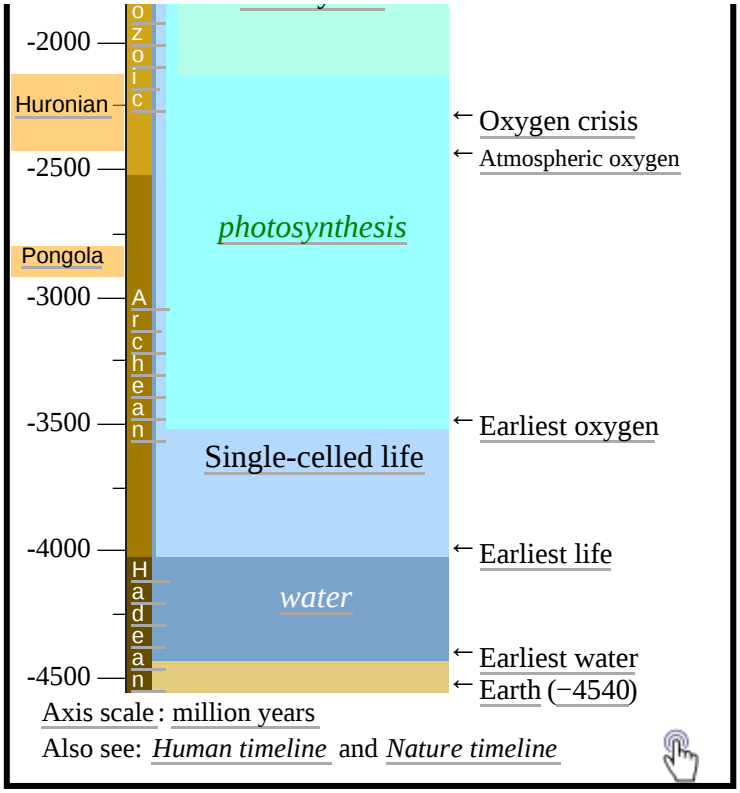
Water in the development of Earth

A sizeable quantity of water would have been in the material that formed Earth.[6][7] Water molecules would have escaped Earth's gravity more easily when it was less massive during its formation. Hydrogen and helium are expected to leak from the atmosphere continually, but the lack of denser noble gases in the modern atmosphere suggests that something disastrous happened to the early atmosphere.

Part of the young planet is theorized to have been disrupted by the impact which created the Moon, which should have caused melting of one or two large areas. Present composition does not match complete melting and it is hard to melt and mix huge rock masses completely.[8]



However, a fair fraction of material should have been vaporized by this impact, creating a rock-vapor atmosphere around the young planet. The rock vapor would have condensed within two thousand years, leaving behind hot volatiles which probably resulted in a heavy carbon dioxide atmosphere with hydrogen and water vapor. Liquid water oceans existed despite the surface temperature of 230 °C (446 °F) because of the atmospheric pressure of the heavy CO_2 atmosphere. As cooling continued, subduction and dissolving in ocean water removed most CO_2 from the atmosphere but levels oscillated wildly as new surface and mantle cycles appeared.[9]



Study of zircons has found that liquid water must have existed as long ago as 4.404 ± 0.008 Ga, very soon after the formation of Earth.[10][11][12][13] This requires the presence of an atmosphere. The cool early Earth theory covers a range from about 4.4 Ga to 4.0 Ga.

In fact, recent studies of zircons (in the fall of 2008) found in Australian Hadean rock hold minerals that point to the existence of plate tectonics as early as 4 billion years ago. If this holds true, the previous beliefs about the Hadean period are far from correct. That is, rather than a hot, molten surface and atmosphere full of carbon dioxide, Earth's surface would be very much like it is today. The action of plate tectonics traps vast amounts of carbon dioxide, thereby reducing greenhouse effects, and leading to a much cooler surface temperature, and the formation of solid rock, and possibly even life![14]

In October 2014, Adam Sarafian of the Woods Hole Oceanographic Institution released a study suggesting that water was on earth as the planet was forming. This conclusion was drawn after establishing a link between the oldest known carbonaceous chondrite meteorites and meteorites believed to be from Vesta (which formed in the same region as earth during the birth of the solar system), and noticing how their composition are similar, and both contained a lot of water.[15]

Role of organisms

Some terrestrial water may have had a biochemical origin, during the Great Oxygenation Event, via redox reactions and photosynthesis.[16]

In the early 1930s, Cornelis van Niel discovered that sulfide-dependent chemoautotrophic bacteria (purple sulfur bacteria) fix carbon and synthesize water as a byproduct of a photosynthetic pathway using hydrogen sulfide and carbon dioxide:[17]

$$CO_2 + 2H_2S \rightarrow CH_2O + H_2O + 2S$$

Few modern organisms use this method of photosynthesis, making their water contribution negligible. But on the hydrogen-sulfide-rich and oxygen-poor early Earth, a small but significant portion of Earth's water may have been synthesized biochemically through this pathway.

Extraplanetary sources

Comets, trans-Neptunian objects, or water-rich meteoroids (protoplanets) from the outer reaches of the asteroid belt colliding with Earth may have brought water to the world's oceans. Asteroids[18][19] may have been primarily responsible based on several studies, including measurements of the ratio of the hydrogen isotopes deuterium and protium, since similar percentage impurities as in

carbon-rich chondrites were found in oceanic water, whereas previous measurement of the isotopes' concentrations in comets and trans-Neptunian objects correspond only slightly to water on Earth.[20] In January 2018, researchers reported that two 4.5 billion-year-old meteorites found on Earth contained liquid water alongside a wide diversity of deuterium-poor organic matter.[21]

Large-enough planetesimals were heated by the decay of aluminium-26. This could cause water to rise to the surface.[22] Recent studies suggest that water with similar deuterium-to-hydrogen ratio was already available at the time of Earth's formation, as evidenced in ancient eucrite meteorites originating from the asteroid Vesta.[23]

That Earth's water originated purely from comets is implausible, since a result of measurements of the isotope ratios of deuterium to protium (D/H ratio) in the four comets Halley, Hyakutake, Hale–Bopp, and 67P/Churyumov–Gerasimenko, by researchers such as David Jewitt, is approximately double that of oceanic water. What is, however, unclear is whether these comets are representative of those from the Kuiper belt. According to Alessandro Morbidelli,[24] the largest part of today's water comes from protoplanets formed in the outer asteroid belt that plunged towards Earth, as indicated by the D/H proportions in carbon-rich chondrites. The water in carbon-rich chondrites point to a similar D/H ratio as oceanic water. Nevertheless, mechanisms have been proposed[25] to suggest that the D/H-ratio of oceanic water may have increased significantly throughout Earth's history. Such a proposal is consistent with the possibility that a significant amount of the water on Earth was already present during the planet's early evolution.

Recent measurements of the chemical composition of Moon rocks suggest that Earth was born with its water already present. Investigating lunar samples carried to Earth by the Apollo 15 and 17 missions found a deuterium-to-hydrogen ratio that matched the isotopic ratio in carbonaceous chondrites. The ratio is also similar to that found in water on Earth. The findings suggest a common source of water for both objects. This supports a theory that Jupiter temporarily migrated into the inner Solar System, destabilizing the orbits of water-rich carbonaceous chondrites. As a result, some of the bodies could have fallen inwards and become part of the raw material for making Earth and its neighbors.[26] The discovery of water vapor out-gassing from Ceres provides related information on water-ice content of the asteroid belt.[27]

See also

- Water on terrestrial planets of the Solar System

Notes

- Jörn Müller, Harald Lesch (2003): Woher kommt das Wasser der Erde? - Urgaswolke oder Meteoriten. Chemie in unserer Zeit 37(4), pg. 242 – 246, ISSN 0009-2851
- Parts of this article were translated from the original article from the German Wikipedia, on 4/3/06

References

1. "The World Factbook" (https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html#Geo). *www.cia.gov*. Retrieved 2016-03-17.
2. Brandon Schmandt, Steven D. Jacobsen, Thorsten W. Becker, Zhenxian Liu, Kenneth G. Dueker (13 June 2014). "Dehydration melting at the top of the lower mantle" (http://science.sciencemag.org/content/344/6189/1265). *Science*. **344** (6189): 1265–1268. Bibcode:2014Sci...344.1265S (http://adsabs.harvard.edu/abs/2014Sci...344.1265S). doi:10.1126/science.1253358 (https://doi.org/10.1126%2Fscience.1253358)
3. "Could an 'Ocean' of Water Be Trapped Within the Earth? - Science Friday" (https://www.sciencefriday.com/segments/could-an-ocean-of-water-be-trapped-within-the-earth/)
4. "Earth's Rocks Contain a Hidden Ocean's Worth of Water - NBC News" (https://www.nbcnews.com/science/environment/earths-rocks-contain-hidden-oceans-worth-water-n130961)
5. "Archived copy" (https://web.archive.org/web/20151125185854/http://live.huffingtonpost.com/r/highlight/scientists-discover-where-earths-water-originated/564ba93d99ec6d09c3000126). Archived from the original (http://live.huffingtonpost.com/r/highlight/scientists-discover-where-earths-water-originated/564ba93d99ec6d09c3000126) on 2015-11-25. Retrieved 2015-12-10.

6. Drake, Michael J. (April 2005). "Origin of water in the terrestrial planets". *Meteoritics & Planetary Science*. John Wiley & Sons. **40** (4): 519–527. Bibcode:2005M&PS...40..519D (http://adsabs.harvard.edu/abs/2005M&PS...40..519D). doi:10.1111/j.1945-5100.2005.tb00960.x (https://doi.org/10.1111%2Fj.1945-5100.2005.tb00960.x)
7. Drake, Michael J.; et al. (August 2005). "Origin of water in the terrestrial planets" (https://www.cambridge.org/core/journals/proceedings-of-the-international-astronomical-union/article/origin-of-water-on-the-terrestial-planets/733A36CB767229E4D403E165198611E3). *Asteroids, Comets, and Meteors (IAU S229)*. 229th Symposium of the International Astronomical Union. **1**. Búzios, Rio de Janeiro, Brazil: Cambridge University Press. pp. 381–394. Bibcode:2006IAUS..229..381D (http://adsabs.harvard.edu/abs/2006IAUS..229..381D). doi:10.1017/S1743921305006861 (https://doi.org/10.1017%2FS1743921305006861). ISBN 978-0521852005.
8. "Solar System Exploration: Science & Technology: Science Features: View Feature" (https://www.webcitation.org/69kxiqRQz?url=http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=446). Solarsystem.nasa.gov. 2004-04-26. Archived from the original (http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=446) on 2012-08-08. Retrieved 2009-08-20.
9. N. H. Sleep; K. Zahnle & P. S. Neuhoff. "Inaugural Article: Initiation of clement surface conditions on the earliest Earth - Sleep et al. 98 (7): 3666 - Proceedings of the National Academy of Sciences" (http://www.pnas.org/content/98/7/3666.full). Pnas.org. Retrieved 2009-08-20.
10. Wilde S.A., Valley J.W., Peck W.H. and Graham C.M. (2001). "Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago" (http://www.geology.wisc.edu/%7Evalley/zircons/Wilde2001Nature.pdf) (PDF). *Nature*. **409** (6817): 175–8. doi:10.1038/35051550 (https://doi.org/10.1038%2F35051550). PMID 11196637 (https://www.ncbi.nlm.nih.gov/pubmed/11196637).
11. "ANU - Research School of Earth Sciences - ANU College of Science - Harrison" (https://archive.is/20060621100255/http://wwwrses.anu.edu.au/admin/index.php?p=harrison). Ses.anu.edu.au. Archived from the original (http://wwwrses.anu.edu.au/admin/index.php?p=harrison) on 2006-06-21. Retrieved 2009-08-20.
12. "ANU - OVC - MEDIA - MEDIA RELEASES - 2005 - NOVEMBER - 181105HARRISONCONTINENTS" (http://info.anu.edu.au/mac/Media/Media_Releases/_2005/_November/_181105harrisoncontinents.asp). Info.anu.edu.au. Retrieved 2009-08-20.
13. "A Cool Early Earth" (http://www.geology.wisc.edu/%7Evalley/zircons/cool_early/cool_early_home.html). Geology.wisc.edu. Retrieved 2009-08-20.
14. Chang, Kenneth (2008-12-02). "A New Picture of the Early Earth" (https://www.nytimes.com/2008/12/02/science/02eart.html?8dpc). *The New York Times*. Retrieved 2010-05-20.
15. Andrew Fazekas, Mystery of Earth's Water Origin Solved (https://news.nationalgeographic.com/news/2014/10/141030-starstruck-earth-water-origin-vesta-science/). *Nationalgeographic.com*, 30 October 2014
16. "The oxygenation of the atmosphere and oceans" (http://rstb.royalsocietypublishing.org/content/361/1470/903.full.pdf) (PDF), *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 29 June 2006
17. van Niel, C.B. (1931). "Photosynthesis of bacteria". *Arch. Mikrobiol.* **3** (1).
18. Daly, R. Terik; Schultz, Peter H. (25 April 2018). "The delivery of water by impacts from planetary accretion to present" (http://advances.sciencemag.org/content/4/4/eaar2632). *Science Advances*. **4** (4). doi:10.1126/sciadv.aar2632 (https://doi.org/10.1126%2Fsciadv.aar2632). Retrieved 16 May 2018.
19. Gorman, James (15 May 2018). "How Asteroids May Have Brought Water to Earth" (https://www.nytimes.com/2018/05/15/science/asteroids-water-earth.html). *The New York Times*. Retrieved 16 May 2018.
20. Altwegg, K.; Balsiger, H.; Bar-Nun, A.; Berthelier, J. J.; Bieler, A.; Bochsler, P.; Briois, C.; Calmonte, U.; Combi, M. (2015-01-23). "67P/Churyumov-Gerasimenko, a Jupiter family comet with a high D/H ratio" (http://science.sciencemag.org/content/347/6220/1261952). *Science*. **347** (6220): 1261952. Bibcode:2015Sci...347A.387A (http://adsabs.harvard.edu/abs/2015Sci...347A.387A). doi:10.1126/science.1261952 (https://doi.org/10.1126%2Fscience.1261952). ISSN 0036-8075 (https://www.worldcat.org/issn/0036-8075). PMID 25501976 (https://www.ncbi.nlm.nih.gov/pubmed/25501976).
21. Chan, Queenie H. S. et al. (10 January 2018). "Organic matter in extraterrestrial water-bearing salt crystals" (http://advances.sciencemag.org/content/4/1/eaao3521). *Science Advances*. **4** (1, eaao3521). Bibcode:2018SciA....4O3521C (http://adsabs.harvard.edu/abs/2018SciA....4O3521C). doi:10.1126/sciadv.aao3521 (https://doi.org/10.1126%2Fsciadv.aao3521). Retrieved 11 January 2018.
22. "How Earth was watered" (https://phys.org/news/2014-02-earth.html). Retrieved 2016-08-19.

23. Sarafian, Adam R.; Nielsen, Sune G.; Marschall, Horst R.; McCubbin, Francis M.; Monteleone, Brian D. (2014-10-31). "Early accretion of water in the inner solar system from a carbonaceous chondrite–like source" (http://science.sciencemag.org/content/346/6209/623). *Science*. **346** (6209): 623–626. Bibcode:2014Sci...346..623S (http://adsabs.harvard.edu/abs/2014Sci...346..623S). doi:10.1126/science.1256717 (https://doi.org/10.1126%2Fscience.1256717). ISSN 0036-8075 (https://www.worldcat.org/issn/0036-8075). PMID 25359971 (https://www.ncbi.nlm.nih.gov/pubmed/25359971).
24. Alessandro Morbidelli et al. Meteoritics & Planetary Science 35, 2000, S. 1309–1329
25. H. Genda, M. Ikoma, Origin of the Ocean on the Earth: Early Evolution of Water D/H in a Hydrogen-rich Atmosphere. Accessible at https://arxiv.org/abs/0709.2025
26. Cowen, Ron (9 May 2013). "Common source for Earth and Moon water" (https://www.nature.com/news/common-source-for-earth-and-moon-water-1.12963). *Nature*. doi:10.1038/nature.2013.12963 (https://doi.org/10.1038%2Fnature.2013.12963).
27. "Herschel discovers water vapour around dwarf planet Ceres" (http://www.esa.int/Our_Activities/Space_Science/Herschel/Herschel_discovers_water_vapour_around_dwarf_planet_Ceres). *European Space Agency*. Retrieved 10 February 2014.

External links

- Dr. C's Oceans Online website (archived copy)
- UniverseToday
- Nature