Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *The origin of the oceans.*

OK - whatever you do, if your next pub trivia quiz includes a question about where all the water came from - don't say comets. There will be a gasp followed by a kind of embarrassed hush, before someone walks up to you with a kind smile, pats you on the shoulder and thanks you for your contribution - acknowledging that a lot of people used to think that back in the 20th century.

I'm not sure the issue is fully settled - but at least for now, the comet story is a bit on the nose. Based on a small number of comet observations we have accumulated in recent years, their water content is just too heavy - meaning it's more $deuterium_2O$, than our familiar H_2O found here on Earth. Indeed, there seems to be a distinct gradient of deuterium enrichment as you move out through the solar system. So it seems our oceans must have formed from stuff which was much closer to the Sun.

To explain, first think about a comet. It's at least partly water ice - even if it's heavy water ice - and if it gets near the Sun, water (or at least sublimated ice) starts being blown off by the solar wind.

But in an accretion disk, it's thought that free water can attach to dust grains and not get blown away - so as the accretion process proceeds, you start building rocks which have quite a high water content. For example, some carbonaceous asteroids have a water content approaching 30% and we think asteroids are objects which accreted to a certain size, but then managed to avoid further accretion into rocky planets.

At least in our solar system, it's estimated that the likely water content of accreting rocky material equivalent to one Earth mass would have been enough to produce 50 hydrospheres - that is fifty times the full current volume of Earth's water supply.

Now, let’s travel to Hawaii where you can watch sea water coming into direct contact with molten lava - and, by and large, it just vaporises into steam. You need temperatures around 3000 degrees Celsius to split an appreciable amount of water into its constituent hydrogen and oxygen atoms - and molten rock rarely exceeds 2000 degrees Celsius. And really that's probably about as much heat as Earth's early water content was ever exposed to.

So when Earth began to form, it started as a small conglomeration of rocks which got bigger and bigger and massive enough to generate self-gravity - so that right at the centre of the conglomeration, density begin to increase and the rocks trapped there got hot. If you heat rocks until they are molten, they release volatiles - notably CO_2, nitrogen and of course water.

As the proto-Earth continued to get bigger, the size of its hot, molten core got bigger and so continually pushed this growing shell of volatiles further outwards. Then, as the proto-Earth approached planet size, this growing shell of volatiles burst out from the surface of what was by then a relatively dense sphere. And by this time, it was a sphere with an iron/nickel core - because these were abundant high atomic weight elements and hence tended to sink to the centre - displacing outwards lighter but still abundant elements like silicon (or really silicate, being oxygenated silicon molecules) which began to form a molten mantle over that dense iron nickel core. So you had something really starting to look like Earth - with a metallic core, a molten rocky mantle, a surface layer of cool drying crust - above which hovered an atmosphere of CO_2, nitrogen and water vapour - also known as steam.

Now in the very early stages of planetary growth, a lot of that atmosphere might have just floated off into space - but as Earth became planet sized, its gravity was strong enough to hold this atmosphere to the surface. Any steam collecting out near the edge of space cooled, liquefied and hence fell back to the ground - which might have still been hot enough to turn it back into steam, but after a few cycles of this - where the surface was cooled each time steam was formed again - well, eventually the rain just fell and stayed there.

Now at some point in this story, along came Theia, the Mars-sized object that collided with Earth Mark I - to form Earth Mark II - and a rather large Moon. This impact no doubt blew away much of the water that might have been accumulating on the surface of Earth Mark I.

But, in any case, such cosmic-scale impacts are a large part of the story as to why Earth's raw ingredients might have started with the equivalent of 50 hydrospheres - but ended up with just one. Interestingly, the Moon which everyone assumed would have virtually no water since it formed from the ejecta arising from the Earth-Theia collision – seems to have about 3% water content - at least in its surface rocks - which is quite a lot. It's theorised that this may be new water arising from interaction between the oxygen in silicate oxide - and hydrogen ions (that is protons) delivered in the solar wind. Another theory has it that the Moon’s water might actually come from comets. Well, maybe.

Anyway, Earth's ability to retain its one hydrosphere of water since its formation results from a fortunate confluence of factors not shared by the other rocky planets - Mercury, Venus and Mars - even though these may have all had an equivalent proportional water content when they formed.

For Mercury - well, it's smaller - so less gravity - and although it does have a bit of a magnetic field - it's only about 1% the strength of Earth's. So, Mercury could never really hang on to an atmosphere and any free water it started with just blew away with the solar wind.

Mars has more gravity and may have had at least seas in the past - but its magnetic field died away about 4 billion years ago - which along with its weaker gravity - meant most of its atmosphere got blown away too. But on Mars, it is cold enough that ice can form, so it does seem to have retained a small proportion of its original water that way.

Venus is different again. Much like Earth it probably started with an atmosphere of steam, nitrogen and carbon dioxide. But being a bit too close to the Sun for water to remain in a liquid state, its CO_2 content could not be dissolved out of the atmosphere the way it happened on Earth - and without liquid water it could not undergo plate tectonics which is what takes dissolved carbon out of circulation on Earth. So for Venus, run-away greenhouse effect.

While Venus does have a roughly Earth equivalent gravity, it - like Mars, has almost no magnetic field - and it's probably the case that its atmosphere is regularly blown away (which is where the water and the nitrogen went) - but it keeps being constantly replaced by more outgassing from the planet itself - which lacking plate tectonics, just gets hotter and hotter until volcanoes break out all over its surface - resurfacing the whole planet with a fresh layer of lava and pumping out more CO_2 and methane to replace the atmosphere that is continually being lost to space. Well maybe, these theories do tend to get updated quite regularly.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we try to do science stuff on the cheap. No ads, no profit, just good science. Bye.