OK but that still doesn't really answer our question. Right, it doesn't really explain, how did Venus get this way. Why is Mars this way? And why has Earth persisted in this habitable region even though there have been fluctuations over history? And to answer that we really have to think about what is it that controls greenhouse gases in the atmosphere and carbon dioxide in particular. And a long time, scales of millions of years, we're talking about planetary evolution now. We actually have to think about where the CO2 in the atmosphere comes from.

It turns out that the carbon dioxide in the air ultimately comes from the inside of the Earth, either through volcanism or though releases of gases associate with metamorphic events, but essentially the internal processes in the Earth give rise to venting of carbon dioxide into the atmosphere. Now this is a tiny amount, I don't want anybody to worry about a volcano going off right, the amount of carbon dioxide coming out of volcanos is less than 1% of what we put into the air each year from burning of fossil fuels. So volcanos are not going to change the climate through carbon dioxide emissions anytime soon.

But here's the thing, they persist for a very long period of time. So if you let this go for millions of years we would end up like Venus, right so this tiny trickle of carbon dioxide, if it were to persist for millions and millions of years would end up building up carbon dioxide, the higher and higher and higher levels and then we would be essentially so hot that life couldn't survive.

So there has to be something that balances this release of carbon dioxide to the atmosphere and results in taking it out of the atmosphere and on the Earth, one of these important things, the most important process that does this is a chemical reaction. This chemical reaction is an interesting one because it actually has three parts. The first part is just dissolving that carbon dioxide in water. That could happen in clouds, it could happen in rain water, it could happen in groundwater, but the result is carbonic acid you guys have probably looked at that in elementary school.

Carbon dioxide you know in seltzer water you know is an acid, it's not a very strong acid, so that's why we can drink it, you can drink soda because of that, but it is mildly acidic. And when the acid reacts with the rocks on the Earth's surface, igneous rocks that have come from melting of the Earth's crust, what happens is a chemical reaction that occurs that we call weathering. And the net result of that reaction is that it produces calcium carbonate - limestone, chalk.

Now this reaction isn't often talked about when you learn science in high school. But what’s interesting is this is probably the most important chemical reaction on the surface of the Earth. This is the reaction that has kept Earth habitable for most of Earth history. It's a very simple reaction where essentially you have carbon dioxide plus an igneous mineral, in this case the mineral anorthite and water going to a clay mineral and calcium carbonate. You can see a picture of what granite looks like, anorthite is the common mineral in a granite or in a salt for that matter.

And clay for that matter, this is the clay kaolinite which is a very common clay, it's a soft mineral that you see on the Earth's surface in mud or other weathered regions. What's interesting about this reaction, the reason it works as a thermostat is that it's temperature dependent. I want to take you guys quickly, I know this isn't a chemistry lecture, but I want to take you a little bit through the chemistry of this just to show you how this works and explain that these are three separate chemical reactions that occur at different places on the Earth's surface, and yet when you combine them all together they yield this wonderful result.

So the first is simply the solubility of carbon dioxide in water, so it's just saying carbon dioxide plus water produces hydrogen ions, that's acid, and a bicarbonate ion. Ok? This is a very simple chemical reaction.

The second is the weathering reaction, and this is the critical one. This is the one that's probably most important in terms of its temperature dependence and this is the mineral anorthite, you could substitute in other igneous minerals as well, but this is one of the most common ones, plus two of those protons, hydrogen ions, plus water, and essentially that chemical reaction produces this clay mineral, kaolinite, and a calcium ion. And so when you actually combine these two reactions you can actually see that these weathering reactions on land produce river water. So rain falls on the rock, weathers the rock, produces clay and then what ends up in the river is the mixture of bicarbonate ion and calcium, or other ions like magnesium and sodium. And that's the composition of river water predominantly.

And the final reaction actually occurs completely separately in the ocean, where the calcium and the bicarbonate gets washed in from the rivers and then combines to make calcium carbonate. And this is the material that corals use to make their skeletons, it’s in the form of araginite, or foraminera use to make their skeletons, that's calcite, but it's the same mineral, it's carbonate. The same chemical composition.

So actually if we do a little math and just cross out the things that cancel on the left and right hand sides of these equations you can actually see that the net reaction when we add all of this together is the one we just showed. Carbon dioxide plus anorthite goes to clay mineral plus calcium carbonate.

So these three reactions that occur in different places, one is occurring in rain, or in groundwater. The second is occurring as the rain washes over the rock and reacts with the rock and chemically weathers it. And the third is actually completely separate as the rivers wash the water into the ocean and then ultimately in the ocean, animals grow, organisms grow and precipitate calcium carbonate as their skeletons. These are three separate chemical reactions, but the net result is to take carbon dioxide out of the atmosphere and into the ocean and onto the ocean floor.