Stellar Metamorphosis: The Phases of Sillimanite, Andalusite and Kyanite in Uranus's Atmosphere, and Thoughts on Ocean World Stage Beginnings

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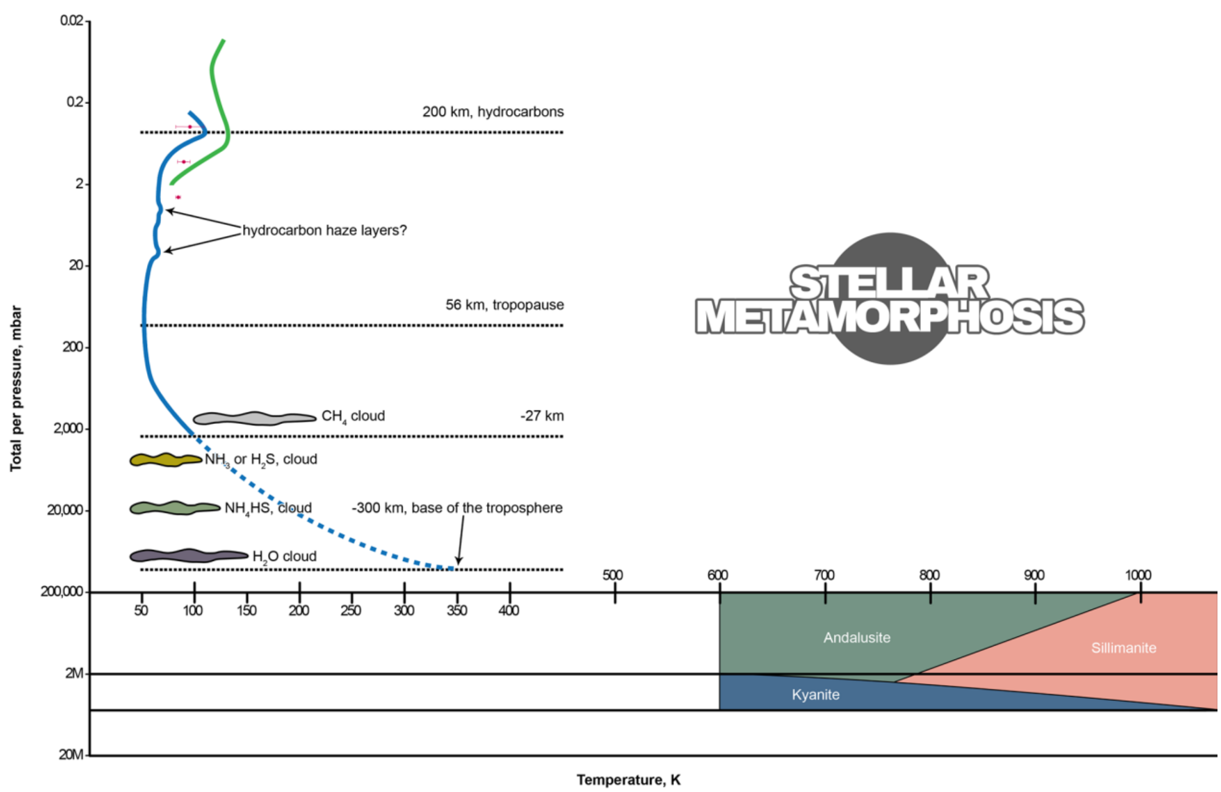
Abstract: The phases of sillimanite, andalusite and kyanite are placed in reference to the deep atmosphere of Uranus. This is to show that Uranus has the temperatures and pressures that can form rocks and minerals exactly like the Earth. As well some thoughts as to how we can pin point the exact moment in time the Earth moved into its own ocean world stages of evolution.

The bottom graph is a representation of the layers and pressures that exist in the interior of the star Uranus in its current stage of evolution, at ~1.23 billion years old.



200,000 mbar on the y-axis represents ~200 Earth atmospheres of pressure, so could be corrected in the future. That is not the interesting part though. The kyanite could only have formed in at least 2,000 Earth atmospheres of pressure, and these pressures exist deep in the atmosphere of Uranus, as well as all stars that are in a Uranium stage of evolution. The pre-ocean worlds that are termed "ice giant" are forming kyanite, andalusite and sillimanite in their interiors as we speak.

It should be noticed that the phase diagram of the minerals is representative of the temperatures and pressures that Al_2SiO_5 solidifies at. This meaning they are probably under more pressure and heat at Uranus's current stage of evolution. This diagram is simply to show that when Uranus loses its thick atmosphere and the oceans start thinning, the anhydrous aluminum silicate minerals will solidify and crystalize. This means as the pressure decreases and the temperature lowers, it will be the andalusite that is formed first, alongside sillimanite, then the kyanite last. This means when you look at phase diagrams, it is the andalusite that is the oldest mineral out of the three, then sillimanite shares in age due to left over heat making it a tad bit older in some spots, then finally it is the kyanite that cools and crystallizes into large chunks. Kyanite out of the three is therefore the youngest material.

It should also be noted that kyanite, andalusite and sillimanite are anhydrous. This means that they cooled and solidified before the young Earth reached ocean world stages, as they contain no water or hydroxide (OH). This means the minerals did not crystalize in a solution of water or settle out of a solution. This is telling because it means they pre-date chronologically the ocean world stages of the Earth's evolution as the Earth was forming certain regions of its crust. Looking at the diagram it is also quite interesting, as the H2O clouds are listed as being at about ~100-200 atmospheres of pressure. The thick clouds do not even touch the temperatures or pressures at which the aluminum silicates solidify at. So this could mean the ocean world interface did help cool the interior, but was a secondary driving factor for the cooling as it did not directly contact the crystallizing rocks and minerals. The largest driving factor of internal cooling was the loss of pressure, due to mass loss (the atmosphere being ripped away or dissipating back into interstellar space). It is well known that an expanding gas cools and a contracting gas heats up, so internal cooling is also facilitated by the water's volatile nature, it simply is explosive at extreme temperatures. It wants to escape, and since it has a high thermal heat capacity, it carries heat with it, further cooling the star. The difference in total density between Neptune and Uranus further elaborates this fact. Uranus has cooled down more because it is both wider, and less dense than Neptune.

The hydrous minerals are the ones that formed at the interface of ocean world stages of evolution, and are even continually formed to this day though in much smaller amounts due to a much calmer, lower temperature and lower pressure water cycle. Water is also strange, in that it happens to be lighter per mole than the very oxygen gas we breathe. It can exist in three distinct phases under just 1 bar of pressure and standard temperature. Though, in the interior of Uranus as it is now, that water is super-heated and "trapped" by the even higher thermal heat capacity of the upper atmosphere, which consists of hydrogen gas and ammonia.

The specific heat of hydrogen gas is extremely high too, so that easily acts as a giant celestial blanket preventing the heat loss of ocean worlds in formation. You have to remove that blanket before any long term mineral/rock formation can occur. More work will be done to make more connections in the future between the phase transitions of minerals and the evolving star that is forming them internally.

Finally, most importantly, this connection also means that the vast majority of rocks and minerals on the Earth that are anhydrous are probably older than Earth's beginning ocean world stages of evolution. The majority of Earth's rocks (given most are anhydrous) formed before the thick water oceans could touch the surface. What this means is that we can take the D/H ratios of the oldest hydrous (water, OH containing) rocks and minerals, to figure out when the water of the Earth finally touched the surface, and made the very first crystal/water barrier. This is different from lava entering the ocean where the lava is a viscous fluid interacting with another fluid to cool. I'm referring to the first time an anhydrous rock becomes fully crystallized, and becomes a solid even before it touches the water. I guess that would signal the very beginning of a genuine "ocean world" stage.

What this all means is that when we begin exploring the exo-systems and objects in our own system, we can determine how advanced those bodies are and when their ocean world stages began. Even cooler is that we can determine how old the hydrous minerals are, by measuring their d/h ratios in relation to the star itself. For instance, if the d/h ratios of the hydrous rocks/minerals match the atmosphere, then that star was ripped apart to its bare bones really quickly, and probably didn't have an ocean world stage. It might have skipped completely over it.