Air and Space this Week

Item of the Week

Venus: Earth's Fraternal Twin

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Understanding why two planets as similar to one another as Earth and Venus have such radically different surface environments is one of the most important questions facing planetary geologists, and the rest of us, too! Was Venus once like Earth? More importantly, with Earth someday be like Venus?

This week's Item topic will be Venus, Earth's "fraternal twin," for two reasons. First, there are a number of anniversary events this week relating to our exploration of Venus:

- *Vega 1* dropped probe during fly-by to get to Comet Halley (35 years ago)
- Launch of *Venera 9* 45 years ago
- Launch of *Venera 4* in 1967
- Launch of *Mariner 5* in 1967

Second, Venus and its climate have been in the news a bit lately. More on that later. But, first, a little background.

Venus is very similar to the Earth in its bulk physical properties. It is almost the same size and mass as the Earth, meaning that the bulk density, hence bulk composition, of the two planets is similar. We would expect the surface environment of Venus to be somewhat higher than the Earth's because Venus is closer to the Sun.

However, the surface environment of Venus is radically different from the Earth's. The surface temperature, ~800° F is hot enough to melt lead, and the atmospheric pressure is 90 times that of Earth's.

Question 1: If the two planets are so similar in their bulk properties, why are their surface environments so radically different?

Follow-up question 1: Has the surface environment of Venus always been the way it is today?

Follow-up to the follow-up of question 1: If not, was the surface environment of Venus ever more Earth-like?

Follow-up to the follow-up of the follow-up of question 1: If so, what happened to change the venusian surface conditions from Earth-like to those at present? Was there some sort of "tipping point" were naturally-changing conditions triggered a massive and irreversible set of conditions like those now present on Venus?

Here's another fact in play. The atmosphere of Venus is mostly carbon dioxide with some nitrogen. On Earth, most of the carbon dioxide in the surface environment is locked up in rocks like limestones, biological tissue such as bones, coral, and shells. If all of that locked up CO_2 were released to the atmosphere, the Earth's atmosphere would be 90 times denser, too!

That Human activity can affect the local micro-climate is a well-known established fact. For example, the "heat island" of cities has been studied for decades, and exploited by sailplane pilots just as long. City-dwellers are intimately familiar with changes in air quality and other environmental parameters with changes in the weather, travel, and/or local industrial activity.

The CO_2 content of Earth's atmosphere has varied naturally over millions of years. Addition of CO_2 to the air by volcanoes is countered by sequestration of CO_2 by sedimentation and other geologic processes. But we now know that Human activity has been slowly increasing the Earth's atmosphere's CO_2 content steadily for decades. Is there a tipping point ahead were, if there is too much CO_2 in the Earth's atmosphere, conditions will suddenly shift to be more Venus-like? One that would kill us all?

More and better radar imaging and topography became available with later missions. Radar revealed many large volcanoes and large-area volcanic terranes, but the radar did not reveal the number of craters on those terranes we would expect to see if those terranes were really old, like those on our Moon. Instead, it seems that the emplacement of the volcanic plains buried a lot of the craters that had formed on the plain surface. It wasn't clear if there were only one re-surfacing event, or a number of them in a relatively-modest time interval, but it was clear that the venusian surface had evolved with time and that the present surface was but a few hundred million years old.

Recent studies suggest that Venus *did have a more Earth-like surface environment* in the distant past, one that changed for the worst a few hundred million years ago, a time the researchers link to when the large igneous provinces were emplaced. They contend that the eruptions triggered a severe and irreversible change in climate. Summary: https://eos.org/research-spotlights/how-long-was-venus-habitable. Modeling Venus' Climate Paper Abstract: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019JE006276

Do harsh venusian surface conditions preclude exploration by robotic spacecraft? Russian landers worked until their electronics cooked in the harsh heat of the venusian surface; the stoutest lasted a few tens of minutes. Can anything be engineered that could make it possible to more effectively explore this hostile place?

Long-time fans of A+StW might recall my touching on this particular topic before. NASA's Glenn Research Center outside of Cleveland has been involved in engineering studies in support of possible direct exploration of Venus. They have a test chamber capable of operating a full-up venusian conditions and an aggressive materials science program underway to develop robust technologies that can withstand venusian conditions.

[ASIDE: Operating at full venusian conditions is no mean feat. Steel loses most of its strength at those temperatures, so building a safe pressure containment vessel was a real problem. Back in

the day, my dissertation research involved the study of wind-blown sand under venusian conditions (motivated by the observation of dunes and other wind-related features in radar images of the Venus surface). We were lucky in the fact that we didn't have to have full Venus conditions; our controlling parameter was atmospheric density. It turns out that about 300 PSI of CO_2 at room temperature had a similar density to that prevailing on the Venus surface. Just getting that much pressure safely under control, and creating and measuring a gentle wind inside it, was super difficult. I can only imagine the difficulties the GRC guys have dealt with over the years!]
Imagine no more, the Glenn Extreme Environments Rig is in the news. See: https://eos.org/articles/venus-exploration-starts-in-the-lab?utm_source=eos&utm_medium=email&utm_campaign=EosBuzz060320 and https://geer.grc.nasa.gov

The recent 40th anniversary of the eruption of Mt. St. Helens, plus a number of different types of volcanoes over the past few decades, remind us that volcanic activity is ongoing and can cause significant changes on the local and even regional level. But we haven't experienced a really big eruption in recorded history. Expanding the time horizon to hundreds of thousands of years and more, brings many larger volcanoes into play, including very explosive volcanoes, such as Yellowstone, Taupo, and large-scale but not explosive outpourings of lava, such as that forming the Columbia River Plateau in the northwestern USA and the Deccan Traps in India.

Lots of carbon dioxide is released during large-scale eruptions, especially the non-explosive ones, so much so that the climate changes induced by the emplacement of the Deccan Traps is the second leading theory, after the Chicxulub impact, for the ultimate demise of the dinosaurs.

And don't discount the environmental damage and attendant suffering that smaller (but still large) eruptions can cause. An example is the eruption of the Laki volcano on Iceland in 1783. The erupted material had a high fluorine content, and that, along with acids and other pollutants, collapsed much of the food chain on the island, both on and off shore. At the time, Iceland had about 60,000 inhabitants, but over a third of them died in the famine resulting from the eruption.

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