"ICE CAPS ON VENUS?"

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ABSTRACT

The Venus data obtained by the Mariner 5 and Venus 4 probes are interpreted as evidence for giant polar ice caps which hold the water which must have come out of the volcanos with the observed CO_2 on the assumption that the earth and Venus are of similar composition. Life would seem to be a distinct possibility at the edge of the ice sheets.

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I. INTRODUCTION

The almost exact correspondence of the large amount of carbon dioxide found in the atmosphere of Venus by the Russian probe[1] Venus 4 with the total CO_2 on earth suggests that the earth and Venus may have very similar over all composition. The total amount[2] of limestone on earth is $9.2 \cdot 10^{22}$ grams of CO_2 equivalent which would amount to 18 atmospheres pressure if it were all present as gas, and this figure agrees very well with the Venus 4 result for the atmosphere of Venus. This similarity leads us to ask "Why doesn't Venus form $CaCO_3$?" and "Where is Venus' water?".

II. DISCUSSION

If Rubey's excellent argument[2] for the gradual simultaneous liberation of terrestrial CO_2 and H_2O by volcanic action applies to Venus we need to understand where the water has gone. We can readily see that oceans cannot have formed since they would have caused $CaCO_3$ to precipitate and lowered the CO_2 pressure below that observed. And the water cannot be in the atmosphere since the Venus 4 measurements gave an upper limit of 1.2 per cent or .24 atmospheres.

There are various possibilities to consider but let us first review the facts for the earth as given by Rubey.[3] The ratio of H_2O to CO_2 (or rather to the sum of all forms of surface compounds of CO_2 as well as the gas itself) is large, 18:1 by mass. So we need to see what could be different about Venus in its disposal of and reaction to steam issuing from its depths over the long billions of years.

Let us begin with the water gas reaction

$$(1) \quad CH_4 + 2H_2O = CO_2 + 4H_2$$

which occurs (in analogous form) for all forms of organic compounds at temperatures of hundreds of degrees centigrade such as have been reported on the surface of Venus. The hydrogen formed might escape from the planet; and thus we would remove two water molecules for each CO_2 made, and this might reduce the ratio substantially. But the earth has had the same experience presumably and still has a seventeen fold water excess. Since H_2O molecules cannot escape from Venus at any appreciable rate, it seems to be very unlikely that the water has disappeared. We are left seriously perplexed as to why the planet Venus should be so different.

There seems to be only one possibility worth consideration (assuming the two planets to be similar in composition) -- ice caps at the poles. The thought is that the water is trapped in this way in great caps perhaps 10 or more kilometers thick. Is it reasonable that a planet rotating as slowly as Venus appears to do[3] -- once every 243 days -- and lying 30% closer to the sun than the earth should have polar caps, particularly when the mid-latitude temperatures are so high? The angle of inclination of the axis of rotation with respect to the normal to the ecliptic is small[3]. Is it possible that Venus has polar areas cold enough to store the vast quantities of ice needed to keep her seas dry and thus to prevent limestone formation?

In order to answer this question let us consider the problem of the circulation of the atmosphere of Venus and try to understand the consequent patterns of heat flow from the sunlit mid-latitude regions to the poles and the dark night side. Suppose, as a start, that the planet doesn't rotate at all. Then the day will be one Venus year long or 225 of our days with the sun rising in the west. Actually as we have said there is some evidence of an east to west rotation of Venus with about the same period. This means the day is about halved to 125 terrestrial days again with the western sunrise and eastern sunset. The solar constant will be 3.8 cal/cm^2/min at the equator with an albedo[4] of about .71. If we suppose the CO_2 content is 20 atmospheres or

460 moles per cm^2, the time constant for solar heating at the equator with perfect vertical mixing will be about 4700 minutes per degree centigrade, a very sluggish rate.

This very readily explains the hot night side as found, because even after 112 days (terrestrial) the law of radiative loss limits the night cooling. The calculated cooling with perfect vertical stirring would be only 10 degrees for a perfect black body at 235°K (the cloud top temperature reported[4]).

The equatorial atmosphere could be very hot and stay hot throughout the night, the source of heat being the visible sunlight which is transmitted to the ground and absorbed there after which the hot surface in turn heats the air and causes vigorous local vertical mixing up to the cloud tops. The Venus 4 report[1] was 280°C on the dark side surface at the equator with a vertical gradient of about 10°per kilometer so the radar altimeter reading of 26 km. at 30°C and a pressure of about 1.5 atm. shows excellent vertical mixing to extend to 26 km. and quite probably to the cloud tops. The linear variation of temperature with altitude when combined with the pressure data and assuming the atmosphere to be essentially pure CO_2 give the relation

$$\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^{4.6}$$

Thus, if the cloud temperature were 0°C the altitude would be 29 km at a pressure of 1 atm. and if -40°C (as observed radiometrically), 33 km and the pressure 0.4 atm. Of course, these are extrapolations since the highest altitude actually measured was 26 km. but these data appear to rule out CO_2 clouds and leave water as the leading possibility. At -40°C the vapor pressure of CO_2 liquid is 10 atmospheres.

What should we expect to be the temperatures at the poles in the light of the above? Does it follow that the poles could not have ice when the equatorial atmosphere is so hot?

We suggest that it is indeed possible to have ice caps since the planet Venus rotates very slowly.[5] From our knowledge of terrestrial winds we suspect that the rotational forces (Coriolus) are extremely important for north and south energy transport and that this transport will be smaller on Venus.

III. CONCLUSION

The Venus data seem to fit the Rubey model for the earth and bolster the thesis that the earth and Venus were made of very similar material with about the same amount of carbon probably as primeval organic compounds as well as carbides, carbonates, graphite et al. These are converted to CO_2 and emitted as volcanic gases together with excess water.

At the edge of the glaciers melting will occur and streams and small oceans and fresh water lakes may exist. No extensive oceans exist because the equatorial surface is too hot, but it is our suggestion that above certain latitudes in both hemispheres small bodies of water bordering on extensive polar regions capped with great sheets of ice exist and that evaporation from these bodies due to the hot winds that do find their way to the high latitudes continually replenishes the clouds which we take to be mainly water which are precipitating over the polar areas.

It seems that any forms of life which can exist in high concentrations of carbon dioxide may well exist on Venus in the semi-polar regions where the temperatures may well be mild enough.

REFERENCES

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3. Von R. Eshleman, Science 158, 585-(1967).

4. W. R. Koenig, F. W. Murray, C. M. Michaux, and H. A. Hyatt, "Handbook of the Physical Properties of the Planet Venus". National Aeronautics and Space Administration (NASA SP-3029), U. S. Government Printing Office.

5. Y. Mintz, Icarus 1, 172-(1962).
   In this reference with a synchronously rotating planet (Venus day = 224 earth days with counter clockwise rotation when looking down from above the north pole), a surface pressure of 50 atmospheres and a surface temperature of 400°K the winds were extremely light, about 0.2 miles per hour at the terminator.