

IS REGOLITH ADSORPTION THE EXPLANATION FOR THE TRANSITION FROM EARLY TO PRESENT MARS CLIMATE?; F.P. Fanale, S. Postawko, A.P. Zent, and J.R. Salvail, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii.

The total degassed CO_2 inventory on Mars is currently thought to be the equivalent of ~ 1.0 bar or less (1). Using the highest of these estimates, several radiative transfer models for early Mars have been advanced (2) purporting to show that a significant greenhouse effect could have characterized the early Mars environment, possibly explaining the intense channeling of the most ancient Mars terrain. However virtually all the available CO_2 would be needed in the atmosphere to achieve a significant greenhouse effect (3).

We have reexamined those models with regard to the effect that regolith adsorption may have had. In our model, we take into account: 1) the atmospheric greenhouse effect, 2) the existence, mass and temperature of any cap and 3) the partition of CO_2 between the atmosphere-cap system and the regolith as required by the latitudinal temperature distribution and 4) atmospheric heat transport.

We solve simultaneously for all these interdependent variables for cases involving realistic total CO_2 inventories (< 2 bar equivalent), a variety of published greenhouse models, and both current and lower solar constants.

To describe regolith adsorption properties we use the mineralogically insensitive adsorption relationship developed by Zent et al. (4), which is based on laboratory measurements on palagonite, nontronite, and basalt, and which is normalized to be consistent with observed surface properties of Viking-sampled soil (5). We should point out that adsorption is relatively more effective under current Martian conditions than at the higher temperature and pressure conditions that may have characterized the early Martian environment. However the regolith currently has adsorbed 10-100 times the atmospheric CO_2 inventory, whereas in most models, the removal of only half the original atmospheric CO_2 inventory would be sufficient to destroy the strong greenhouse effect.

Resulting scenarios fall into several classes. Either: 1) The greenhouse effect is so weak that a cap exists throughout the period of growth of several hundred meters of regolith; in this case the surface environment is essentially unaffected by the development of any reasonably postulated regolith; or 2) A cap exists initially, but is sufficiently small that the growth of >100 m or so of regolith causes a significant repartitioning of CO_2 molecules among the three parts of the system and the equilibrium solution finally involves no cap. In this case the regolith has no effect on the atmospheric pressure and resulting temperatures until the cap disappears. However, once the cap disappears the effect of further regolith growth is to dramatically lower atmospheric pressure and hence surface temperatures; or 3) A substantial greenhouse effect exists initially, and there is no cap initially. In this case also, regolith growth to a depth of a few hundred meters dramatically lowers atmospheric pressures and surface temperatures, and the effect of the regolith is important from the outset.

In other words, in all realistic scenarios in which surface temperatures are both higher than at present and dependent on high CO_2 pressures,

high pressure and temperature conditions are truncated by the growth of only a few hundred meters of regolith, ultimately leading to present Mars conditions. It might be argued that while the development of a regolith a few hundred meters thick in early Mars history is likely in view of the existence of the ancient cratered terrain, it is unreasonable to postulate a much lower regolith thickness at the very outset. We point out, however, that it is not literally the thickness of the regolith that is the critical parameter, but rather its total surface area. Weathering products such as palagonites and nontronites typically exhibit specific surface areas for CO₂ adsorption of tens to hundreds of square meters per gram whereas basalts typically exhibit specific surface areas of a fraction of a square meter per gram to several square meters per gram. Thus, although we represent the "regolith growth" as a physical thickening (keeping the specific surface area equal to the Viking derived value), the actual case involves the product of both actual thickening and a great increase due to an increased abundance of weathering products. While the precipitation of carbonates has probably been an important process during Mars history (6), the rates at which this process could have taken place under early Mars conditions would have dropped sharply once liquid water was fairly scarce. Furthermore, conditions under which liquid water was available may have involved efficient recycling of carbonate so that steady state conditions rather than irreversible CO₂ removal prevailed. In contrast, the growth of regolith surface area demands corresponding and predictable CO₂ removal from the atmosphere cap system and is, as shown here, fully capable of terminating any enhanced temperature regime on early Mars in the absence of any other effects. To put it another way, total degassed CO₂ inventories of < 2 bar and the existence of substantially higher temperatures than present are compatible; total degassed CO₂ inventories of < 2 bar, substantially higher temperatures than present, and a regolith qualitatively comparable to the present one are not compatible.

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