Smectite Clays in Mars Soil: Evidence for Their Presence and Role in Viking Biology
Experimental Results

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Summary. Various chemical, physical and geological observations indicate that smectite clays are probably the major components of the Martian soil. Satisfactory ground-based chemical simulation of the Viking biology experimental results was obtained with the smectite clays nontronite and montmorillonite when they contained iron and hydrogen as adsorbed ions. Radioactive gas was released from the medium solution used in the Viking Labeled Release (LR) experiment when interacted with the clays, at rates and quantities similar to those measured by Viking on Mars. Heating of the active clay (mixed with soluble salts) to 160°C in CO₂ atmosphere reduced the decomposition activity considerably, again, as was observed on Mars. The decomposition reaction in LR experiment is postulated to be iron-catalyzed formate decomposition on the clay surface. The main features of the Viking Pyrolytic Release (PR) experiment were also simulated recently (Hubbard, 1979) which the iron clays, including a relatively low ‘1st peak’ and significant ‘2nd peak’.

The accumulated observations on various Martian soil properties and the results of simulation experiments, thus indicate that smectite clays are major and active components of the Martian soil. It now appears that many of the results of the Viking biology experiments can be explained on the basis of their surface activity in catalysis and adsorption.

Key words: Mars soil — Viking biology — Viking simulation — Labeled release (LR) experiment — Smectite clays — Montmorillonite — Nontronite — Adsorbed iron — Formate decomposition — Surface reactions of clays

Introduction

The meaning of the findings of the biology experiments conducted by the Viking Landers (VL) have not been resolved yet (Klein, 1977, 1978). It can be said, however, that the prevailing opinion is that almost certainly, biological activity of the types we
recognize on Earth was not the cause and that the results were due to chemical reactions. The nature and mechanisms of these reactions, however, are still far from being clear. Since mineralogical measurements were not conducted by the Viking instruments we have no direct clue regarding the types of minerals present in the Martian soil and can not use such information for understanding the causes of the soil chemical activity. Nevertheless, a number of hypotheses have been proposed to explain the results of the biology experiments. Of these, three major ideas can be summarized, as follows:

1. The soil contains a spectrum of oxidized compounds, including superoxides, which release oxygen upon contact with water (the Gas Exchange (GEX) experiment); \( \gamma \text{-Fe}_2 \text{O}_3 \) (or some similar metallic oxide), and hydrogen peroxide which cause the release of \( \text{CO}_2 \) by catalytic oxidation of organic acids (the Labeled Release experiment), and (in one variant of this hypothesis) carbon suboxide polymers which account for the second peak in the Pyrolytic Release (PR) experiment. This hypothesis thus presumes that the surface of Mars is essentially anhydrous and self-sterilizing (Oyama et al., 1977; Oyama and Berdahl, 1977).

2. The unweathered fraction of the soil contains chemisorbed \( \text{OH}^- \) and \( \text{CO}_3^{2-} \) formed by a proposed photochemical weathering process (Huguenin, 1976a,b). The adsorbed \( \text{OH}^- \) is released to solution once water is added to the soil, forming \( \text{H}_2\text{O}_2 \) that subsequently decomposes releasing \( \text{O}_2 \) (the GEX experiment). The \( \text{CO}_2 \) released in the GEX experiment is then apparently due to formate oxidation by the \( \text{H}_2\text{O}_2 \) in solution, as is the case presumably for \(^{14}\text{CO}_2 \) release in the LR experiment. The PR results are attributed to incorporation of \(^{14}\text{C} \) in the form of \( \text{CO}_3^{2-} \) adsorbed on soil particles, some carry-over of the soil particles into the 'firebrick' column, and then release of \(^{14}\text{C} \) upon heating to 650°C. In a variant of this hypothesis (Huguenin et al., 1978) the source of \( \text{H}_2\text{O}_2 \) in the soil is water-frost acting on a freshly weathered surface of a primary mineral.

3. The soil contains a substance whose grains are permeated with micropores which were formed, presumably, by migration and accumulation of gases released from the crystal itself by radiation. The gases \( \text{O}_2 \) and \( \text{CO}_2 \) are occluded in the pores and can only be released after wetting of the sample (Nussinov et al., 1978). When released these gases can oxidize the organics in the LR medium and account for the gas release measured in the GEX experiment. No explanation is proposed for the PR results.

A common feature of the first two hypotheses is that they explain the results on the assumption of the presence in Martian soil of small amounts of extremely active chemical ingredients taking no account of the major mineral components of the soil. Furthermore, all three hypotheses, in essence, suggest a completely waterless, self-sterilizing Mars soil.

In a previous paper (Banin and Rishpon, 1978) we proposed and brought experimental evidence to support another hypothesis that may explain the Viking biology results. We suggested that since smectite clay minerals are probably some of the major components of the Martian soil, then, due to their extensive and active surface area, they are capable of adsorbing and releasing gases and catalyzing the decomposition and/or synthesis of organics as was observed by Viking on Mars. In the present paper we will review in brief the evidence at hand for the presence of these clays in Mars soils and report the results of additional work simulating the Viking biology experimental results with certain active clays.