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Oxidant activity in soils from the Pampas de La Joya, Atacama Desert in southern Peru, under conditions of the Labeled Release experiment

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Abstract

Mars-like environments on Earth provide an important tool to prepare for the search for life on future missions to Mars, and/or a better understanding of the geological, geochemical and microbiological process that could have occurred on the Red Planet [1]. Different studies showed evidence for different soil types in Mars, suggesting a range of formation conditions and alteration mechanisms [2, 3]. Because of this heterogeneity, it is necessary to identify a soil analogue that is suitable for the study required. An analogue to Mars extensively studied and of great scientific interest is the Atacama Desert, located in northern Chile and southern Peru, which lies on the west slopes of the central Andes between 15 to 30°S at elevations between sea level and 3500 m. a. s. l. [4]. This desert is considered one of the most, if not the most, arid regions on Earth [5] and the arid core of the Atacama near Yungay Chile contains Mars-like soils [6].

Navarro-González et al. (2003) described soils from Yungay as ‘‘Mars-like’’ based on three main criteria: very low levels of organic matter in soil, levels of soil microorganisms below the detection limits, and equal decomposition levels of both a biotic organic mixture (L-alanine and D-glucose) and an abiotic mixture (D-alanine and L-glucose) that was added to soil samples. The last criterion was made using a modified version of the Labeled Release (LR) experiment, one of the Viking biology analysis used on Mars, which is not comparable to the method of the Viking LR [7].

Labeled Release (LR) experiment monitored the radioactive gas evolution after the addition of a 14C-labeled aqueous organic substrate into a sealed test cell that contained a Martian surface sample [8, 9]. This experiment was designed to test Martian surface samples for the presence of life by measuring metabolic activity and distinguishing it from physical or chemical activity. Interestingly, the interpretation of the Viking LR experiment was that the tested soils were chemically reactive and not biologically active [10], and that at least two oxidative processes with different kinetics were required to explain the observed decomposition of organics [11].

Recently, the decomposition of organics added in aqueous solution to Yungay “Mars-like” soils under the conditions of Viking LR experiment protocol was evaluated and compared with the Viking LR results [7]. The results of this study showed that the mechanisms for the oxidation of organics added to these soils were different from the processes observed in the Viking LR experiment.

On other hand, although there are areas considered hyperarid in more than 3000 km along the desert [4], the vast majority of studies have focused on studying the Yungay region from northern Chile. However, other area named Pampas de La Joya, located in the Atacama region of southern Peru between 15ºS to 17ºS, recently, has had an astrobiological interest because it exhibits hyperarid soils with the lowest levels to organics - even lower than those presented in Yungay [12, 13] and it showed high oxidant activity depending of organics content and mineralogy composition [14, 15]. In addition, the nature of oxidant(s) present in the soils from Pampas de La Joya is still unknown, suggesting that this region might also contain Mars-like soils.

In this work, we conducted similar experiments under Viking LR protocol to test the decomposition kinetics of organic compounds in aqueous solution added to 7 types of soil samples from the Pampas de la Joya desert and compared with both of the LR experiments in Yungay soils and Viking results.

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13C-labeled organic compounds were used: sodium formate, L-alanine, and D-alanine. The different enantiomers helped to distinguish biotic from abiotic responses, with the assumption that biological activity would preferentially utilize L-alanine over D-alanine. The labeled organic solutions were prepared in a laminar-flow hood using autoclaved utensils and glassware. The aqueous organic solutions were introduced into the sample vial using a sterile syringe and needle. Syringe-extracted headspace samples was analyzed for the production of $^{13}CO_2$ using an gas chromatograph with a mass selective detector. Measured levels of $^{12}CO_2$ were used to correct for the natural abundance of $^{13}CO_2$ present in the sample cells.

Our results show that the 13C-labeled formate and DL-alanine are oxidized to $^{13}CO_2$ when added in aqueous solution to soils collected from the Pampas de La Joya region. The observation of similar $^{13}CO_2$ initial releasing by soils treated with L-alanine, compared to soils treated D-alanine, indicates the presence of one or more nonbiological chemical decomposition mechanisms similar to Yungay soils [7] and the Viking LR experiment [8, 9]. An increase in the decomposition rates of L-alanine compared to the rates of D-alanine decomposition was observed on ~5-7 d, indicating the presence of microorganisms in these soils. When treated with an sodium formate solution, some of the soils tested released $^{13}CO_2$ gas in a manner similar to kinetics of the gas release observed in the Viking LR experiment and similar to Yungay soils. A second rapid CO_2 release by La Joya soils, when additional formate was injected into the sample cell (day 6th), is consistent with biological processes. However, soil samples II, V, and VI did not show a second rapid release until day 11th (Figure 1). Viking LR experiment after a second injection of organic solution on day 7th, did not release CO_2. These results indicate that the $^{13}CO_2$ produced in La Joya soils is consistent with an initial phase of nonbiological oxidation followed by biological decomposition of added organics.

Heating the soil to 160°C for 3 h did not totally eliminate the decomposition of formate and alanine. The initial rapid CO_2 release was not eliminated by heating in the LR experiment; the secondary, apparently catalytic, CO_2 release was significantly diminished, while in the Viking LR experiment, the initial rapid CO2 release was eliminated by heat treatment, but a slower secondary CO2 production was not. The results of LR experiment in Yungay soils eliminated both the biological and nonbiological decomposition of added organics. Finally, our data indicate that the mechanisms for the oxidation of organics added (in aqueous solution) to Pampas de La Joya soils are different from the processes observed in the Viking LR experiment, and they are not completely similar to Yungay process.

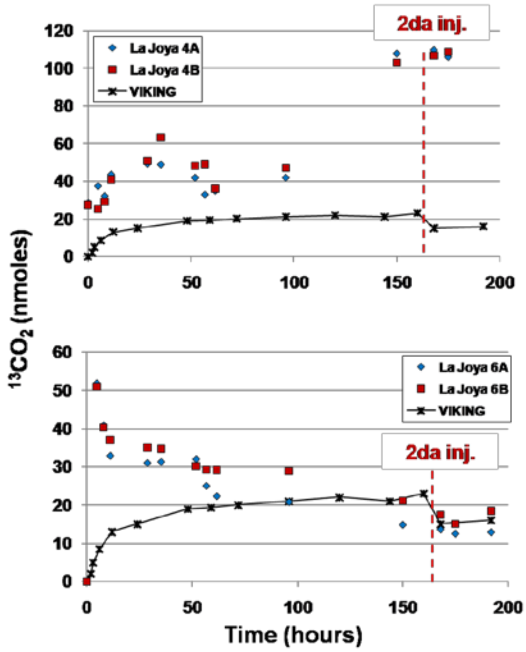

Figure 1: A comparison of the Viking LR exp. CO_2 release with Pampas de La Joya soil samples (IV and VI) wetted with 0.25 mM sodium formate solution. 2da inj.: *second injection*.

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