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APRON HEIGHTS AROUND "STEPPED MASSIFS" IN THE CYDONIA MENSAE REGION: DO THEY RECORD THE LOCAL PALEOBATHYMETRY OF "OCEANUS BOREALIS"? T. J. Parker and D. S. Gorsline, Department of Geological Sciences, University of Southern California, Los Angeles CA 90089-0740, USA.

Over the past several years a number of investigators have described geomorphic evidence for and paleoclimatic significance of large standing bodies of water or ice sheets within the northern lowland plains of Mars [e.g., 1–14]. The details of the timing, emplacement mechanisms, and sizes of these bodies differ markedly from one group of investigators to another, however. For example, Jöns [1,2] envisioned a "mud ocean" covering much of the northern plains, with sediment slurries derived from a variety of peripheral sources, including the fretted terrains and outflow channels. Lucchitta et al. [4] pictured an ice-covered ocean, fed by large circum-Chryse ice streams, analogous to those in Antarctica. Parker et al. [10,11] indicated two or more highstands of a sea or ocean that, most recently, would have been charged by catastrophic floods, but may have existed more or less permanently during Noachian and Hesperian time. Interestingly, the shorelines of Jöns' "mud ocean," Lucchitta et al.'s ice-covered ocean, and Parker et al.'s most recent sea, or "interior plains" [11], coincide almost precisely around the northern lowlands, though the details of the mechanisms by which key boundary morphologies are thought to have been produced differ. Baker et al. [12] pictured a plainswide ocean emplaced by the major outflow channels relatively late in martian history, and coined the term "Oceanus Borealis" for this ocean.

Taking a more conservative approach to the question of standing water in the northern plains, Rotto and Tanaka [14] have relied on volume estimates of maximum discharge from the circum-Chryse outflow channels, which they feel limits any standing water to one or a few large, ephemeral lakes. The locations of these lakes are based on the identification of broad, shallow topographic basins on the present martian topographic maps [15]. Similarly, Scott et al. [13] have indicated evidence for several large lakes across the northern plains, some exhibiting connecting spillways, that were fed by a variety of channel sources peripheral to the plains. Delineation of these lakes is based on a similar assessment of the topography, but also included the identification of shore morphology.

All the above studies would have benefited greatly from the advent of the high-resolution topography afforded by the Mars Observer Laser Altimeter [16], which would have produced global topographic maps beginning in early 1994. For example, basin volume estimates in Parker et al. [11] are loosely based on the available topography with its very large vertical errors. These estimates, when compared to estimates by others of the water discharged by the Chryse outflow channels, suggest the possibility that the volumes required to fill the basin may be at or beyond the high end of the estimated volumes available from the channels. High-resolution topography is needed to sort out the common modifiers of shoreline elevation, such as tectonism, isostatic rebound, and sediment desiccation and compaction, that probably altered the topography of the northern plains after the putative surface water was lost, so that the original topography can be reconstructed. Until a reflight of the laser altimeter or some similar instrument, elevations derived using the currently available high-resolution topographic tools—photoclinometry and shadow measurements—cannot be accurately tied to the global datum. It is not possible, therefore, to be certain that basin volumes based on the current global topography provide better than a crude approximation of the volume of ancient standing bodies of water in the northern plains. Until they do, such estimates cannot, by themselves, either point to nor preclude the presence of surface water or ice within the northern plains prior to the latest catastrophic floods; the uncertainties are still too large relative to the flood volume estimates.

Can photoclinometry and shadow measurements be used to determine the volume of the basin without having to link the measurements to a global datum? Since the boundary, or shoreline of the basin cannot be tied to the datum and typically has no useful local relative height to measure, what is needed are a number of measurements of the height of the paleoshoreline(s) distributed across the basin—soundings, in effect.

Parker et al. [9,11] described a type of small knob in the northern plains that resembles terrestrial and lunar steptoes (volcanic apron) and terrestrial wave-cut islands, and applied the nongenetic term "stepped massifs" to the martian knobs. If these are upland outliers that had been abraded through wave action in an unfrozen ocean, or through ice-shoving in an ice-covered ocean, then the height of the apron above the surrounding plains could provide a measure of the local basin depth in the vicinity of the knob. Since stepped massifs are distributed over broad expanses in several places in the northern plains, it should be possible to measure the variation in basin depth regionally. With the exception of those regions where the available image scale is insufficiently small, it should be possible to measure the heights of the aprons to within a few tens of meters.

As a feasibility test of this approach, photoclinomettic profiles are being compiled from Viking Orbiter images of the Cydonia Mensae region, which includes images with high Sun elevations (necessary to avoid shadows) and images with low Sun elevations (to enable the use of shadow measurements as an independent check) at high resolution (40–100 m/pixel). Both asymmetric and symmetric photoclinometic profile models are being used, and the results cross checked with one another to minimize the errors. An apron-height map, potentially a paleobathymetric map of part of the margin of "Oceanus Borealis," will be compiled of this data to determine whether variations in apron height are consistent with a lacustrine interpretation.

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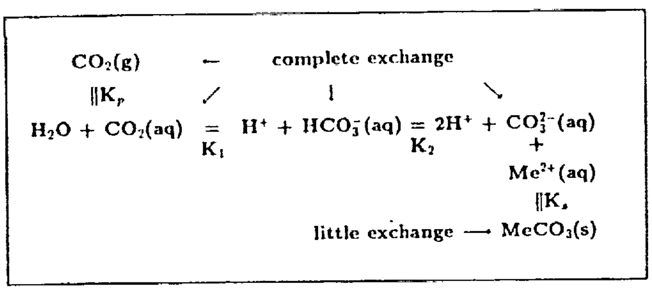
THE pH OF MARS. R. C. Plumb[1,2], J. L. Bishop[2], and J. O. Edwards[2], [1]Worcester Polytechnic Institute, Worcester MA 01609, USA, [2]Brown University, Providence RI 02912, USA.

The Viking Labeled Release (LR) experiments provided data that can be used to determine the acid-base characteristics of the regolith. Constraints on the acid-base properties and redox potentials of the martian surface material would provide additional information for determining what reactions are possible and defining formation conditions for the regolith. A number of chemical models [1] and simulation experiments [2–8] attempted to explain the LR results. A recent chemical model suggests that nitrates are present, as well as a carbonate with a solubility similar to that of calcite [9].

During the LR experiments after the oxidation process was complete (~5 days) the magnitude of the LR signal was controlled by the distribution of $^{14}CO_2$(g) between the gas phase and the moist solids in the LR cell. That distribution was controlled by chemical equilibria that are sensitive to acid-base conditions. Levin and Straat [10] demonstrated that the second injection reabsorption occurs as a result of a shift in chemical equilibria involving CO_2(g), water, and soil. Calculations devised to determine the pH of Mars must include (1) the amount of soluble acid species or base species present in the LR regolith sample and (2) the solubility product of the carbonate with the limiting solubility [11].



(1) mass balance

$$P_o V/RT + K_s M[H^+]^2/K_1K_2K_pP = PV/RT + K_pPM + K_1K_pPM/[H^+] + K_1K_2K_pPM/[H^+]^2$$

(2) charge balance

$$[H^+] + 2K_s[H^+]^2/K_1K_2K_pP + F_{OA}[H^+]/(K_{OA} + [H^+]) - m_o/M = K_1K_pP/[H^+] + 2K_1K_2K_pP/[H^+]^2 + K_w[H^+] + K_{AA}F_{AA}/(K_{AA} + [H^+])$$

P_o ≡ initial pressure of CO_2
M ≡ mass solvent
P ≡ equilibrium pressure of CO_2
F_{OA} ≡ concentration of organic acids (formate, glycolate and lactate) in nutrient
K_{OA} ≡ average dissociation constant of organic acids
F_{AA} ≡ concentration of amino acids (alanine and glycine) in nutrient
K_{AA} ≡ average dissociation constant of amino acids
m_o ≡ moles of soluble acid (m_o>0) or soluble base (m_o<0) in regolith sample

Fig. 1. Chemical and isotopic exchange equilibria in labeled release experiment.

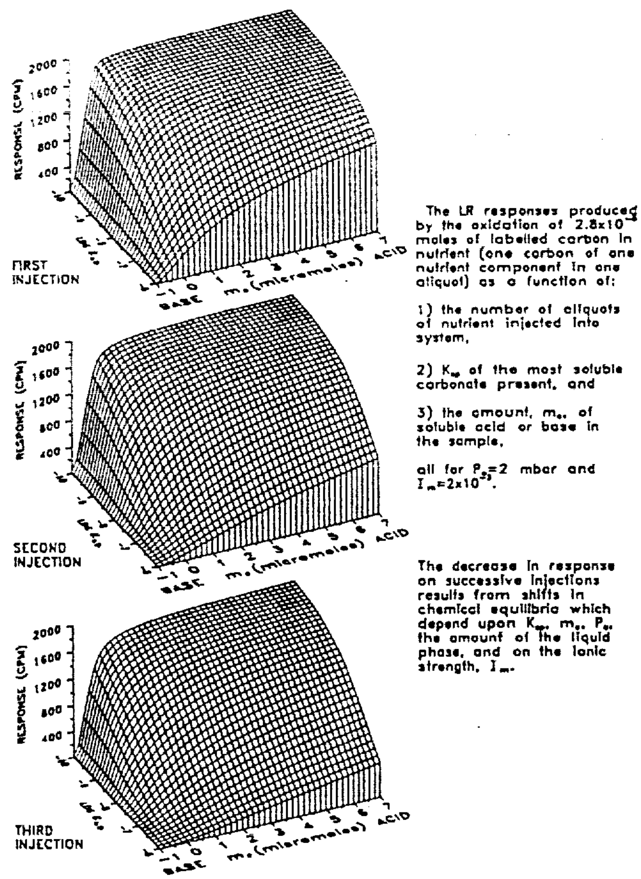


Fig. 2.

Results and Discussion: The equilibria for CO_2 in a heterogeneous system are shown in Fig. 1. This equilibrium system as represented is completely general. Several metal carbonates may be present. $MeCO_3$(s) refers to the particular metal carbonate that is the most soluble of those that do not dissolve completely. Less soluble carbonates, if present, do not enter into the equilibria; more soluble carbonates dissolve completely and are not present as solids in the system after wetting. The limiting case of no metal carbonates present corresponds to a vanishingly small K_s, i.e., a K_s that does not enter into the equilibria.

Exchange of $^{14}CO_2$ among the soluble species and CO_2(g) occurs rapidly, but the $MeCO_3$(s) does not enter into the exchange pool, except for the surface layer, which is a negligibly small quantity.

It was observed in the Viking studies that successive injections of nutrient decreased the magnitude of the response. This is what