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Extracting scientific results from robotic arm support operations: A technique for estimating the density and composition of rocks on Mars

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Abstract

Background: Robotic arms on landed spacecraft are typically designed to either (a) retrieve surface samples for analyses by the main spacecraft or (b), bring a mobile instrument package into contact with surface components. Yet the engineering data returned by a robotic arm while conducting these science support operations can themselves be used to investigate the physical properties of surface materials. The Viking Lander 2 (VL2) displaced several nearby rocks with its sampling arm to obtain regolith samples from the protected environment beneath them.

Method: The masses of displaced rocks are estimated using measurements of the pushing force exerted by the sampling arm by assuming a basic block-sliding model. Rocks densities are estimated by dividing the mass estimates by rock volumes determined from stereo pairs of images.

Conclusion: Although the precision of the VL2 sampling arm motor current records is insufficient to derive unambiguous results, the bulk densities of pushed rocks appear to be low (≤2.6 g/cm^3), consistent with rocks that are vesicular throughout their volumes (*i.e.*, vesicular impact or volcanic glasses). If the bulk density and vesicularity are known with high enough precision, the method demonstrated here can roughly constrain rock composition. Although the Viking measurements are ultimately inconclusive, the robotic sampling arm on the Mars Phoenix lander could execute a similar pushing strategy on nearby rocks to obtain more accurate density and compositional estimates.

Introduction

The primary purpose of a robotic sampling arm on a planetary lander is to provide support for other instruments, for example by excavating trenches, acquiring surface samples, sieving material, and delivering samples for further analyses. At the Viking 2 Lander (VL2) site in Utopia Planitia, a rock pushing campaign was undertaken to obtain samples of Martian fines from beneath rocks (rock pushing activities were also undertaken at the Viking 1 Lander site but were generally less successful than at VL2; Moore et al. 1987). These sub-rock regolith samples, which were shielded from the harsh ultraviolet radiation environment at the Martian surface, were considered prime biological targets in the search for living organisms or organic molecules (Shorthill et al. 1976). Although no definitive evidence of biologic activity was detected (*e.g.*, Biemann et al. 1977), the rock pushing activity can be used to provide information about the nature of the rocks themselves.

The Physical Properties Team of the Viking mission made detailed analyses of the position, topography, and burial state of the candidate rocks. A bulk density of 3.0 g/cm^3 was assumed for the rocks to assess the engineering feasibility of rock pushing (Moore et al. 1978). Once the pushing sequences were executed, the actual bulk densities of the rocks were not back calculated. Rock density is a fundamental geologic parameter that has yet to be determined *in situ* on Mars. In this work, we calculate both the bulk densities and densities of the silicate portions of rocks, and we show how the latter could be used to estimate their compositions. Unfortunately, the precision of these measurements precludes us from making any firm