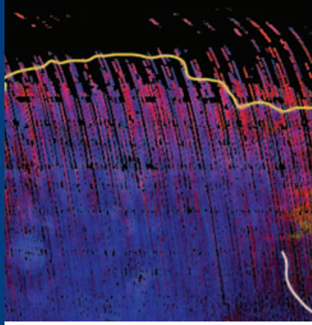

The Orbital Search for Altered Materials on Mars

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The Martian surface is dominated by primary igneous minerals common in basaltic rocks. Limited chemical alteration exists in fine-grained dust, and is likely in sands and rocks at high latitudes and in the northern lowland plains where materials have interacted with ice and snow. Evidence for extensive production of secondary phases is revealed at higher spatial resolutions, where alteration effects of unique, and perhaps time-limited, aqueous environments are observed. The distribution of ice on Mars thus appears to have a global influence on the production of alteration materials, whereas the effects of water are discovered in unique and locally diverse geological settings.

INTRODUCTION

Recent observations by the Mars Global Surveyor (MGS) TES, Mars Odyssey (MO) THEMIS, and Mars Express (MEX) OMEGA instruments (see glossary on page 138 for acronyms in text) have greatly improved knowledge of the abundances and distributions of Martian minerals and have provided insight into past geological environments. This paper summarizes major discoveries about surface compositions from orbital experiments, focusing on investigations of altered materials and their implications for the history of water on Mars. The search for chemically derived secondary phases on Mars is driven, in large part, by physical evidence of surface–volatile interactions in the form of ancient, fluvial, dissected channels and surfaces recently modified by ice. The search began over four decades ago with the use of Earth-based telescopes and early robotic explorers. Only recently, however, have observations from TES, THEMIS, and OMEGA been used to construct global surface-composition maps and search for local exposures of altered materials at high resolution. The production of secondary phases depends on a number of factors, including the compositions of precursor igneous minerals and glasses, the nature of the alteration environment (gas, aqueous, solid), temperature, pH, and time. Global variations in surface mineralogy are crucial to understanding the dynamic interaction between the atmosphere, hydrosphere, and crust.

GEOLOGICAL SETTING

A globally projected simple-cylindrical image (Fig. 1a) made from MOC and MOLA datasets provides the geological context for the distributions of Martian mineral abundances. The regolith consists of a mixture of bright (high-albedo), globally homogeneous, fine-grained dust and dark (low-albedo), locally derived, sand drifts and dunes atop variably indurated soil, rock fragments, and layered bedrock exposures. The ancient southern highlands are of Noachian to Hesperian age, whereas the northern lowlands are composed of younger Hesperian to Amazonian materials covering a Noachian basement. The white line in Figure 1a approximates a 40 km crustal-thickness dichotomy separating thinner crust to the north from thicker crust to the south (Zuber et al. 2000), and the yellow line marks the boundary of the Vastitas Borealis Formation (VBF) (Tanaka et al. 2003). VBF materials have been interpreted as sediments reworked by near-surface, in situ volatile-driven processes (Tanaka et al. 2003) and as a sublimation residue from frozen bodies of water (Kreslavsky and Head 2002).

There is a bimodal distribution of near-surface H_2O ice measured by the Gamma Ray Spectrometer (GRS) (e.g. Boynton et al. 2002) and MOC- and THEMIS-observed ice-rich mantles (Fig. 1b). Mantles have been interpreted as meter-thick, ice-rich sediments (Mustard et al. 2001) or remnant snowpacks (Christensen 2003) and are thought to form during phases of high obliquity. Development of near-surface ice is likely connected to surface ice deposition as abundances are too high to be accounted for by vapor diffusion alone (e.g. Mustard et al. 2001; Christensen 2003; Head et al. 2003).

EARLY SEARCHES FOR ALTERATION

Investigations of high- and low-albedo surfaces with visible/near-infrared (VNIR) spectra from Earth-based telescopes and early Mars spacecraft provided a framework of Martian compositions (reviewed by Bell 1996). Spectral observations in the VNIR are sensitive to electron transitions of metals, especially iron, and molecular vibrational transitions in minerals, which can be used to determine chemical and mineralogical compositions. Figure 2a shows composite, telescopic-orbital (Phobos-2 Imaging Spectrometer for Mars) VNIR spectra representative of Martian high- and low-albedo surfaces (Mustard and Bell 1994).

High-Albedo Surfaces

VNIR observations of high-albedo surfaces are consistent with highly oxidized, fine-grained materials characterized by poorly crystalline iron oxides and a small amount of crystalline iron oxides (e.g. Morris et al. 1997). Subtle spectral differences in high-albedo surfaces suggest small variations in the abundance, and possibly composition, of crystalline iron oxide materials. A weak spectral band in the 2.2 μm

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