Synthesis of Gusev crater analogue basalts, Mars: interest for astrobiology

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Reference

Introduction

The elemental composition of Martian basalts differs from that of terrestrial basalts: they are richer in Fe and Mg as indicated by in situ measurements on Mars. This enrichment shows up both in the altered surface rocks of the basalt, as indicated by the Pathfinder APXS analyses of the rock surfaces [1], as well as in the surface aerosols studied using the Rock Absorption Final (RAF) of the MER mission, for example at Gusev Crater [2] (Fig. 1). Thus, in order to have relevant analogues for studying Martian basalts, a number of experiments have been undertaken to produce artificial Martian basalts. Previous studies have synthesized Martian basaltic reference compositions of Pathfinder mission and/or martian geochemical databases [3,4]. In our present study, we used the geochemical data set from surface basalt samples of the MER at Gusev crater to produce primitive Martian basaltic analogues.

Synthetic basalt composition

We based our synthetic composition on the analyses of altered basaltic surfaces in Gusev Crater [4], assuming that the basalt was totally degassed (i.e. no CO2, NO, or N2). We included corrections for the chemical weathering on the Martian surface [5] as shown in Fig. 2.

Second synthesis experiment: large volume basalt synthesis

A second experiment was carried out to prepare a large quantity of synthetic material using 50 g of oxide powders (SiO2, Fe2O3, Al2O3, CaO, MgO, FeO, MnO, Na2O, K2O, and SiO2) that were placed into larger, more luminous crucibles (Fig. 8) and heated in an oven at atmospheric pressure (100 Pa) to 1400°C under reducing conditions (N2/CO2 = 90/10) gas mixture.

Results

Two synthetic basalt samples were made with identical geochemical compositions. As a result of the different cooling rates they exhibited different textures.

The slowly cooled sample (nAl10) is characterized by spinifex-like textures (Fig. 4, 56) formed by the dendritic texture exhibited by large pyroxene and smaller feldspathic crystals. These textures are distinct from those of intergranular or vesicle-like textures of clinopyroxene observed in MORB and resemble more the spinifex textures observed in komatiites (Fig. 3). Associated with the major mineralogical phases are minor phases of well crystallized oxides (e.g., spinel). Despite the initially slow cooling rate, the material contains small areas of augitic glass associated with the two types of dendritic crystals.

The rapidly cooled sample (nAl11) contains large areas of augitic glass and has the same mineralogical composition as the slowly cooled material, including unshaded (globular) olivine phases (Fig. 4). Sample nAl11 is more vesicular than sample nAl10 because the fast-ri-iger-quickening prevents outgassing of carbonate-derived CO2.

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Discussion

Spinifex-like texture similar to komatiites (Fig. 4), Komatiites on Mars [5].

Preliminary results

Optical observations show that there is a vertical and radial gradient in the texture (Fig. 9) caused by the differential cooling rates between the core and surface of the samples.

SEM and Raman analyses

Synthesis of a larger volume results in the crystallization of pyroxene (augite) instead of olivine (forsterite) (Fig. 10) due to retrograde reactions. Furthermore, only occurs at the bottom of nAl10, where the crucible had been plunged into water.

Astrobiological implications

Komatiites and their spinifex textures are common on the early Earth because of the higher mantle temperature and possibly on early Mars [7]. Basaltic materials are ideal habitats for chemoautotrophic types of microorganisms that obtain their energy from redox reactions at the surfaces of the reactive volcanic material, as well as their nutrients through dissolution of the basalt [8-10] (Figs. 6–7). Microbial and organic compounds could be preserved in the aqueous alteration products of basalts, including spinifex textures, making these kinds of rock and minerals interesting targets for astrobiological investigations.

Conclusion & perspectives

Synthetic Martian basalts are included in the ISAR collection to provide an analogue of basaltic material with a realistic Martian composition to test and calibrate instrumentation for in situ missions.

Four variations in cooling rate produce significant mineralogical and textural variations in compositionally homogeneous materials.

Martian synthetic basalts are astrobiologically interesting since they represent a source of energy and nutrients for chemolithotrophic microorganisms. These rocks and their alteration products are potential targets to search for organic molecules on the Martian surface.

References