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Granodiorite and alkaline suite at Gale crater: continental crust on early Mars

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Abstract

The Curiosity rover landed at Gale, an early Hesperian age crater formed within Noachian terrains on Mars. The rover encountered a great variety of felsic igneous float rocks ranging from granodiorite to trachy andesite and trachyte during the first part of the traverse up to sol 550. They are the first in-situ evidence of low density early Noachian crust on Mars, sampled by Peace Vallis river cross-cutting the crater wall over a 2-3km thick vertical section, below the basaltic regolite.

1. Introduction

Fifty three igneous float rocks were identified along the Curiosity's traverse at Gale crater between sol 13 and 550 [1-3]. Textural and compositional analyses using MastCam, ChemCam Remote Micro Imager (RMI) and Laser Induced Breakdown Spectroscopy (LIBS) allow recognition of 29 mafic and 24 felsic igneous targets (over 95 locations totaling 2850 laser shots). At Bradbury rise (sol 13 to 45), located at a distal portion of the alluvial fan derived from Peace Vallis, a fluvial channel cutting through the northern rim of Gale crater, 3 light-toned rocks were initially observed (Blanchet, Stark and Thor Lake) [1]. Since the rover left the fluvio lacustrine deposit of Yellow Knife Bay on sol 326, 21 additional feldspar-rich rocks were recognized within Hummocky plains and Rugged Units on our way to Aeolis Mons up to sol 550.

2. Methodology

Grain size, shape and distribution were first assessed using MastCam (450 and 150 µm /pixel) and RMI cameras (14 µm/pixel). The smallest visible grain with RMI is 95 µm at 2.4m, and 140 µm at 3.6m. Moreover, ChemCam LIBS offers the first opportunity to assess mineralogical diversity at grain-scales with its ~300-500µm laser spot and, from this, lithological diversity. Key element ratios (Al/Si, (Fe+Mg)/Si) and oxide concentrations are derived from the spectra using univariate analysis [4], a method that quantifies the peak areas of well-chosen LIBS lines that are related to concentration thanks to calibration curves using on-board calibration targets (CCCTs: 3 basaltic glasses 1 felsic macusanite glass and 4 ceramics). Whole rock estimates are obtained by averaging large rasters (> 9 points) on fine-grained homogenous targets. For heterogeneous targets such as phenocrysts in fine-grained mesostasis, whole rock compositions are calculated using modal proportions of felsic and mafic phases and their respective molecular compositions.

3. Rock morphology and texture

Felsic rock are mainly float faceted by wind erosion (Fig.1). Some targets form 8-10 cm clasts in polymict conglomerates (Fig.1D) associated with the Peace Vallis alluvial fan system. From morphology, color, grain size, and patina, 3 different classes of rocks have been identified: (1) Class 1 (9 targets) are light-toned coarse granular rocks dominated by leucocratic minerals (≈ 80% of the rock volume). Pearly coarse crystals (>5mm) are locally intergrown with finer (1mm) rectangular translucent gray grains in a graphic texture (Fig. 1A, C). Some of these targets are chunky when weathered (Fig.1B); (2) Class 2 (6 targets) are aphyric leucocratic rocks with no visible grains (less than 100 µm at 2.5 meters, Fig.1F). They sometimes have shiny scoriaceous surfaces; (3) Class 3 (11 targets) are porphyritic with light-toned, euhedral white crystals 1-20 mm in length (48 to 65% of the rock volume) set in a dark gray

mesostasis (Fig.1D,E). Porphyritic targets of class 3 and aphanitic to glassy rocks of class 2 are effusive whilst class 1 has granoblastic textures corresponding to intrusive rocks..

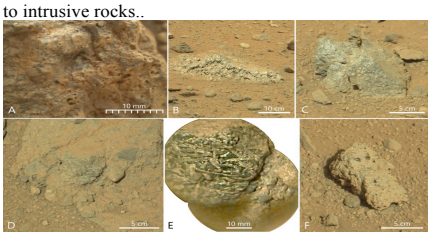


Figure 1: Rock texture from MastCam, MAHLI and RMI: A) coarse intrusive: Clinton (MAHLI); B) chunky weathered Little Wind River (MAHLI); C) coarse intrusive Sparkle, D) porphyritic clast Harrison of porphyritic class in a polithic conglomerate (MastCam); E) Harrison; F) vesiculated: Becraft (RMI).

4. Chemical composition and mineral inference

The 24 anhydrous targets have been plotted in Al/Si vs. (Fe+Mg)/Si (mole %) diagrams (Fig. 2). For the light-toned rocks such as Clinton (Class 1: red symbols), 80% of the points plot on a mixing line between oligoclase-albite (Al/Si: 0.48-0.30; An30-0) and a silica-rich component and less than 20% correspond to mafic composition. Vesiculated light-toned rocks such as Becraft (Class 2: brown symbols) have compositions close to the macusanite CCCT, a rhyolitc glass (Al/Si < 0.33), indicative of silica satured rocks mixed with alkali-feldspar needle including more than 1500ppm Ba. Porphyritic class such as Harrison (Class 3: green symbols) plot on a basaltic mixing line between oligoclase (Al/Si 0.38-0.44; An 10-28) and augitic composition [2].

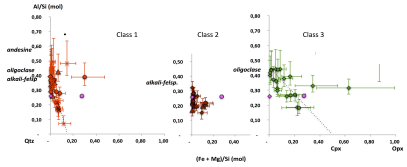
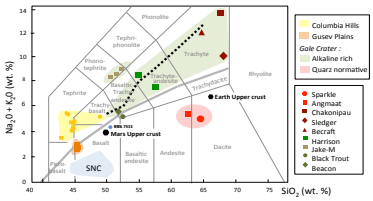


Figure 2: Al/Si vs. (Fe+Mg)/Si Purple symbols are the CCCTs

Whole rock estimations distinguish quartz-normative intrusive rocks of class1 (red symbols, Fig.3) with dioritic to granodioritic composition, from effusive rocks (class 2- 3) that plot in the alkali domain. Porphyritic effusive (class 3) rocks plot in the trachyandesitic field (Fig. 3) whilst felsic targets of class 2 with SiO_2>64% and Na_2O+K_2O>10% are consistent with trachytic composition. These liquids could be related to basanites [2] and trachyandesites of class 3 along liquid line of descent from 1-bar primary basalt produced by 6% melting of the mantle at1GPa



5. Summary and Conclusions

This work provides the first in situ detection of low density leucocratic igneous rocks on Mars. They comprise two distinct geochemical series: (i) alkali-K-feldspar bearing effusive suite including porphyritic and aphyric members; (ii) quartz-normative intrusives close to granodioritic composition. The former looks like felsic clasts recently described in two SNC meteorites (NWA 7034/7533 [5-6] the first Noachian breccia sampling the martian regolite. The latter rock-type is unlike anything proposed in the literature for Mars but resembles Archean TTG's encountered on Earth related to the building of continental crust. Our finding would be consistent with quartzo-feldspathic material detected locally from orbit in the southern thus felsic material should be widespread in Early Noachian terrains

References

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