A LARGE BURIED FELSIC/ANORTHOSITIC COMPONENT IN THE ANCIENT MARTIAN CRUST. D. Baratoux1,2 and M. Monnereau3,4, H. Samuel3,4, C. Michaut5, M. A. Wieczorek6. 1Université de Toulouse, UPS-OMP, GET, Toulouse, France (david.baratoux@get.obs-mip.fr), 2IRD/Institut Fondamental d’Afrique Noire, Dakar, Senegal, 3Université de Toulouse, UPS-OMP, IRAP, Toulouse, France, 4CNRS; IRAP; 14, avenue Edouard Belin, F-31400 Toulouse, 5Institut de Physique du Globe de Paris, Université Paris Diderot, Sorbonne Paris Cité, France

Introduction: Mars has a long and rich volcanic history [1] and has preserved old crustal material, exposed essentially in the southern hemisphere. The nature of these ancient igneous rocks is debated. It is not clear if Mars has preserved a significant proportion of its primary (magma-ocean related) crust or if the crustal growth through the subsequent addition of partial mantle melts accounts for most of the crustal volume. Initially seen as the components of a primary crust [2], the low-calcium-pyroxene-rich composition of these ancient rocks appears now to be compatible with a period of intense volcanism (secondary crust) associated with relatively shallow melting of a primary mantle source [3].

The crust thickness is estimated to be in the range of 50 ± 12 km [4]. However, it should be noted that a range of average crustal density limited to 2700–3100 kg/m³ was generally used for crustal thickness inversions using gravity and topography data, whereas Martian meteorites are known to be generally denser than 3200 kg/m³. The assumptions for density values were influenced by the silica-rich composition from Pathfinder analyses and the Martian meteorites were considered to be a nonrepresentative set of samples of the Martian crust biased toward young ages.

Then years later, the characteristics of the Martian crust may be revised in light of newly available petrological constraints. We confirm here that the basaltic component of the Martian crust has a density above 3100 kg/m³. If this density is representative of the entire crust (i.e., crust is essentially basaltic in composition), it would imply a threefold reduction of the density contrast with the mantle in comparison to previous studies. However, when compared to geophysical constraints, our results imply the presence of a large and buried felsic component in the Martian ancient crust [5]. We discuss the possible origins of such of feldspar-rich component, such as magma ocean crystallization, or crustal differentiation.

Density from the Martian meteorites: Straightforward constraints on crustal density come from direct measurements of the density of Martian meteorites. However, such analyses are surprisingly rare and provide values for only a few samples [6,7,8]. Alternatively, it is possible to estimate the density from the bulk chemistry through CIPW norm calculations [9]. Such densities are represented in increasing order (Figure 1), and the laboratory measurements are shown for comparison. The densities of Martian meteorites calculated in this way (at 1 bar and 25°C) range from less than 3200 kg/m³ to more than 3600 kg/m³ with values around 3300–3500 kg/m³ for most of the basaltic shergottites. This calculation confirms, with no exception, that the Martian basalts are dense.

Density of surface rocks: The same approach may be applied to available surface compositions. CIPW/density calculations were achieved on both in situ measurements (Pathfinder, MERs, MSL, Figure 2) and remote sensing observations (geochemical maps from the Mars Odyssey/Gamma Ray Spectrometer, Figure 3). Density values calculated in this way range between 3200 kg/m³ and 3450 kg/m³ with a single peak at 3350 kg/m³ [5]. This range of density is also consistent with the expected density if the primary melts of the iron-rich mantle of Mars [5].

Constraints from geophysical data: evidence for a large buried felsic component. A dense crust is compatible with the mass and moment of inertia factor of Mars, but should be > 100 km. Such a thick crust appears to be inconsistent with the analysis of geoid-
topography ratios [4] and crustal thickness in excess of ∼100 km might lead to lower crustal flow and destruction of crustal thickness variations [13].

Therefore, the comparison of petrological and geophysical constraints implies the crust may be not entirely basaltic in composition. The existence of a light crustal component buried under subsequent volcanic products in the southern hemisphere (highlands) is necessary to reduce the average crustal density to values lower than 3100 kg/m³. As the existence of highly porous materials is unlikely given the pressure-temperature conditions prevailing within the Martian crust, this light component may be composed of felsic or anorthositic material similar to the lunar anorthosites. The findings from visible/NIR spectroscopy of outcrops associated with excavated felsic or anorthositic material [10,11] and the identification of feldspar-rich rocks at Gale crater [13] support this hypothesis. It should be also noted that felsic lithologies were already identified by Pathfinder.

Discussion - The origin of the felsic/anorthositic crust: magma ocean or crustal differentiation?

The recently identified felsic/anorthositic outcrops are seen as either remnants of an ancient anorthositic crust, the result of local igneous differentiation of plutonic bodies. The same questionning may apply to the inferred buried felsic component. Local igneous differentiation is currently the preferred hypothesis as early Mars conditions should not be compatible with the formation of a plagioclase floatation crust [2]. However, in light of the geophysical and petrological constraints discussed above, and given the absence of abundant light material at the surface, the existence of a mostly hidden anorthositic crust on Mars should be considered. The conditions (depth of magma ocean, role of volatiles) for the abundant crystallization and buoyancy of plagioclase during magma ocean crystallization will be examined again.