

CHEMICAL AND ISOTOPIC CONSTRAINTS FOR THE MARTIAN CRUST. G. Dreibus and E. Jagoutz, Max-Planck-Institut f. Chemie, P.O. BOX 3060, D-55020 Mainz, Germany, dreibus@mpch-mainz.mpg.de).

Introduction: The Martian meteorite whole rock Rb-Sr isotopic compositions and the initial Pb data from plagioclase separates suggest strongly that the crust of their parent body originated from an ancient planetary global differentiation process about 4.5 Ga ago. The absence of plate tectonic activity on early Mars excludes a crustal recycling and preserves the isotopic systems derived from the early crustal differentiation. Together with geophysical and geochemical data from spacecraft missions, the Martian meteorites provide constraints on the nature of the crust. Based on element correlations observed in the Martian meteorites and the measured K content of the Martian surface we propose an estimate of the Rb-Sr systematics of the crust.

Isotopic reservoirs of the crust: All whole rock data of the Rb-Sr isotopes cluster in 3 groups close to the meteoritic isochron of 4.55 Ga. Borg et al [1, 2] interpreted the Rb-Sr whole rock isochron as a mixing line of an ancient depleted mantle and an old evolved crust. We favored an early crust-mantle differentiation forming 3 distinct isotopic reservoirs, which remained isolated since 4.3 ± 0.2 Ga. [3, 4]. The representatives of the isotopically enriched crustal reservoir are the basaltic shergottites: Shergotty, Zagami and Los Angeles. They have relatively high abundances of radiogenic Sr, which might originate from a planetary crust enriched in incompatible elements. The Pb systematic on the SNCs reveals also that U was enriched in the crust and depleted in the mantle ~ 4.5 Ga. The conformity of the U-Pb and Rb-Sr isotopic systematics reflects similar magmatic fractionation behaviour of Rb and U during the evolution of curst and mantle.

Inventory of incompatible elements in the crust: The in situ measurements of the Martian surface by Viking [5], Phobos [6], and Mars Pathfinder (MPF) [7], thousands of kilometers apart, reveal similar chemical compositions of the surface. This similar chemical composition indicates a thorough mixing of surface material on a global scale, and, for a first approach, can be taken as the average composition of the near surface crust on Mars. Neglecting the extremely high S- and Cl-concentrations of the soil, which derived probably from volcanic exhalations [8], the similarity in the chemical composition of the soil and the basaltic shergottites is remarkable. However, the K contents of the calculated MPF rock (1.1 %) [7] and the soil measured by Phobos (0.3 %) [6] and MPF (0.5 %) are higher than the K content in the basaltic shergottites (0.18). This higher K concentration on the Martian surface might suggest an enrichment of Rb in the crust, which should result in more radiogenic Sr in the Martian crust, as found in the shergottites. Assuming a chemically homogeneous Martian crust, we estimated the Rb and Sr content of the crust from observed K/Rb and K/Sr in Martian meteorites and the postulated crustal K content. For all Martian meteorites, independent of their rock type, we found a good correlation between the highly incompatible elements K and Rb. Suggesting the same K/Rb systematic for the Martian crust, we calculated with the known K concentrations from the MPF and the Phobos missions the respective Rb contents (Fig.1, Table 1).

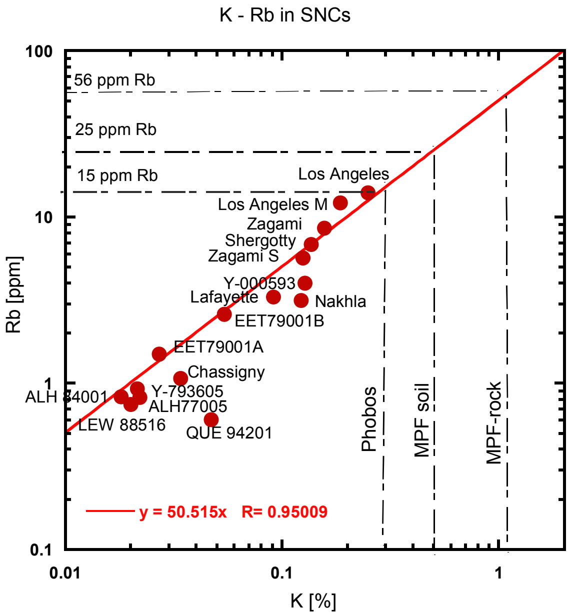

Fig. 1: K – Rb correlation of the SNC meteorites

Furthermore, Sr and Nd abundances in the crust can also be derived from the observed K/Sr and K/Nd systematics in SNCs and the K contents of the Martian surface (Table 1).

Recently Nyquist et al. [9] and Borg et al. [2] favored a more evolved Martian crust, which should be partly assimilated by the basaltic shergottites during their emplacement. In their assimilation model Nyquist [9], proposed that the basaltic shergottite Los Angeles is a mixture of 20% crust + 80% of a basaltic component like QUE 94201. The results of this estimate are listed in Table 1. Compared to our work the model of Nyquist et al. [9] calculated a high enrichment of Nd in the crust. The reason for the high estimate could be the extremely high Nd content of 11.8 ppm, which they found in their sample of Los Angeles [9]. An aliquot of Los Angeles analyzed in our lab has only 7.4 ppm Nd and a Sr/Nd ratio of 12 matching the Sr/Nd ratio of 11 from our estimated crustal composition (Table 1). A possible explanation for the high Nd of 11.8 ppm could be a higher portion of phosphates in the sample of [9].

Table 1:

Estimated Martian crust					
Constraints	K [%]	Rb[1)] [ppm]	Sr[2)] [ppm]	Nd[3)] [ppm]	Sr/Nd
K: MPF-soil	0.5	25	180	16.5	11
*% in crust**	*39*	*41*	*26*	*43*	
K: Phobos	0.3	15	110	10	11
*% in crust**	*24*	*25*	*16*	*26*	
K: MPF-rock	1.1	56	405	36	11
*% in crust**	*87*	*93*	*57*	*94*	
Nyquist [9]	1.1	*46*	203	53	3.8
*% in crust**	*87*	*76*	*29*	*138*	

** Thickness of the crust: 30 km*
1) K/Rb = 200; 2) K/Sr = 27; 3) K/Nd = 308

The abundances of the large ion lithophile (LIL) elements in the Martian crust in this model depend on the assumed crustal K content (0.3 – 1.1 %) and the thickness of the crust. Geophysical data determined by Mars Global Surveyor derived crustal thickness values of ~50 km [10] and 30 – 100 km [11]. A mass balance model based on Nd isotopic compositions and REE abundances in Martian meteorites by Norman [12] gives a value of 20 – 30 km crustal thickness and a Nd concentration of about 34 or 23 ppm respectively. This would imply that 55 % of the total Nd is in the crust. Table 1 reports our calculations of the proportions of K, Rb, Sr, and Nd for a 30 km thick crust. For these estimates the bulk Mars composition of [13] was used. It can be assumed, that U and Th have a similar enrichment in the crust as estimated for K and Th [14, 15]. As a consequence, all the radiogenic heat production would be stored in the K-rich (1.1 %) crust of 30 km thickness for 4.5 Ga, which was also recently discussed by McLennan [14].

Assuming for Mars a similar distribution of heat producing elements between crust and mantle of about 50 %, as found for the Earth, the estimated crustal composition based on the MPF-soil [7] provides with 0.5 % K and 17 ppm Nd reasonable values.

Estimated Sr isotopes for Martian crust: From the assimilation model, Nyquist [9] calculated a $^{87}Sr/^{86}Sr$ for the Martian crust of 0.74, whereas our calculations with a constant Rb/Sr ratio of 0.14 ($^{87}Rb/^{86}Sr = 0.39$) yield a $^{87}Sr/^{86}Sr$ of 0.725. The dashed lines in the Rb-Sr isochron (Fig. 2) indicate the estimated crustal Rb-Sr isotopic compositions, which match the isotopic data of Shergotty. The Rb-Sr systematics, developed from a combination of Martian surface spacecraft measurements and element correlations among SNCs, imply a basaltic Martian crust with high radiogenic Sr.

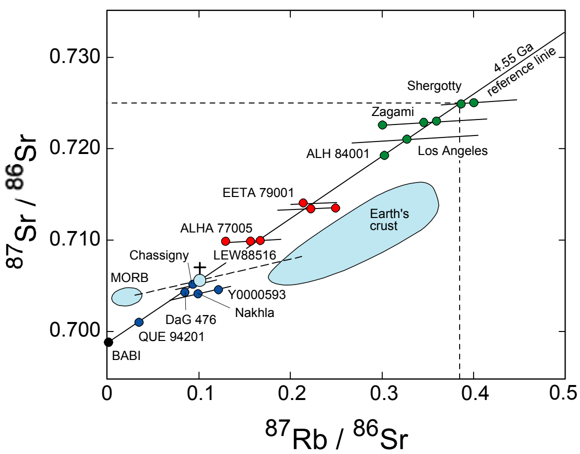

Fig. 2: Rb/Sr isochron diagram for SNC meteorites. Dashed lines shows the estimated Sr isotopes for the-Martian crust.

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