CRUST-MANTLE RESERVOIRS OF RADIOGENIC ISOTOPES OF MARS AND EARTH: WHERE CAN WE SEE A MIXING? 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 Earth is still a dynamic planet, with mantle convection sufficient to drive the tectonic plates and outer core convection strong enough to produce a magnetic field. Mars started its geological life almost as the Earth and had in the past a liquid core, able to generate a strong magnetic field. But today, Mars has lost this internal magnetic dynamo and its mantle is probably slowly convecting. The study of radiogenic isotopes in the Martian meteorites (SNC), reveals that their parent body "must be frozen" in its planetary evolution.

$^{129/132}$Xe systematic: From the observed higher $^{129}Xe/^{132}Xe$ ratio in the Martian atmosphere compared to the interior of Mars [1, 2, 3] we postulated an efficient extraction of the halogens from the interior into the crust. The enrichment of $^{129}Xe_{rad}$ in the Martian atmosphere, produced by the decay of ^{129}I with a half-life of 15.7 Ma, points to a very early extraction of iodine into the crust; the $^{129}Xe_{rad}$ was released into the present atmosphere over geological time. In contrast, the $^{129}Xe/^{132}Xe$ ratio in terrestrial rocks is equal or higher than the atmospheric ratio, because of a continuous recycling of the crust and mantle.

Rb-Sr isotopic systematic: All whole rock data of the Rb-Sr isotopes cluster in 3 groups close to the meteoritic isochron of 4.55 Ga. Starting with the Rb-Sr systematic of only 6 SNCs we postulated about 10 years ago the existence of 3 isotopically distinct reservoirs on Mars, which remained isolated for a period of 4.3 ± 0.2 Ga [4]. Since then, more than 20 SNC meteorites have been found in hot and dry deserts. New isotope data from these recently recovered SNCs confirm the three isotopically distinct reservoirs.

The first group, the basaltic shergottites Shergotty, Zagami and Los Angeles have relatively high abundances of radiogenic Sr, which might originate from a planetary crust enriched in incompatible elements. The in situ measurements of the Martian surface by Viking [5], Phobos [6], and Mars Pathfinder [7], thousands of kilometres apart, reveal similar compositions of the Martian soils and the basaltic shergottites. Of course, we have to neglect in this comparison the extremely high S- and Cl-concentrations of the soil, which derived probably from volcanic exhalations [8]. The K contents of the soil measured by Phobos [6] and Mars Pathfinder [7], with 0.3 % and 0.55 % respectively, are higher than the 0.18 % K content in the basaltic shergottites. This higher K concentration on the Martian surface might indicate crustal reservoirs, which are more radiogenic in Sr as found in the shergottites. However, compared to the Earth's upper continental crust, with 2.8 % K [9], the Martian surface has a moderate K inventory.

A second group of Martian meteorites, characterized by non-radiogenic Sr, consists of the mafic cumulates nakhlites and Chassigny, the olivine rich shergottites DaG 476, SaU 005, Dhofar 019, and the basaltic QUE 94201 and may represent the depleted mantle. This and the first group are chemically complementary, suggesting that crust formation has caused the mantle depletion, which must have taken place during a very early process. This can be derived from the primitive Sr isotopes and the excess Nd-142, the daughter product of the extinct Sm-146, found in Chassigny, the nakhlites, SaU 005, DaG476, and QUE 94201 (E42 group). The observed correlation of ^{142}Nd with ^{182}W in SNC meteorites by Lee and Halliday [10] points to the same incompatible behaviour of Nd and W during magmatic processes and an early core formation (about 30 Ma). Core formation must have occurred concurrently with the rapid accretion of Mars, which is inferred from excess ^{182}W in Martian meteorites.

A third meteorite group with intermediate Sr isotopic composition, represented by the olivine gabbroic LEW 88516, ALHA77005, and Yamato793605, might originate from a primitive, unfractionated mantle. However a mixing process of crust and depleted mantle cannot be excluded [11].

The lack of plate tectonics can keep the obvious 3 distinct reservoirs untouched. On Earth, plate tectonics might be responsible for the homogenization of the terrestrial Rb-Sr reservoir. Today, only one Rb-Sr isotopic reservoir exists on Earth. The terrestrial crust and depleted mantle are developed from an isotopic homogeneous mantle at about 2 Ga while on Mars crust and depleted mantle developed at 4.3 Ga.

Sm-Nd systematic: The Sm-Nd systematic of terrestrial samples reveals also a crust-mantle differentiation from a chondritic Sm/Nd reservoir 2 Ga ago. In the terrestrial samples of crust and mantle the Sm/Nd ratio changes by a factor of 2. The SNC meteorites, however, have strongly fractionated Sm/Nd ratios and large variation of the $^{143}Nd/^{144}Nd$ ratio particularly among the rocks from a depleted mantle reservoir: Nakhla, Chassigny, DaG 487, SaU 005, Dhofar and QUE 94201. In the Sm-Nd isotope plot only the data of the minerals and the whole rock of ALHA84001 fall on the 4.55 Ga meteoritic internal isochron. All other SNCs are far away from this isochron due to their strongly fractionated Sm/Nd ratio. In the Sm-Nd system we cannot find the 3 distinct initial isotopic reservoirs as found for the case of the Rb-Sr systematic.

Pb-Pb systematic: The Pb isotopes of all measured SNCs show a similar pattern as the Sr isotopes. The present study of the Pb isotope systematic might give the strongest indication for an early differentiation of Martian mantle and crust. The initial Pb from hand-picked ultra clean plagioclase separates Los Angeles, Shergotty, Zagami, and the new shergottite Dhofar 378, from the enriched crustal reservoir, and of nakhlites and SaU 005, from the depleted mantle reservoir, plot close to the 4.5 Ga Pb-Pb isochron. 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.

Summary: The ^{129}I-^{129}Xe ($T_{1/2}$ 16 Ma) and the ^{146}Sm-^{142}Nd ($T_{1/2}$ 103 Ma) isotope systems indicate a rapid accretion and a very early formation of the crust with its enrichment of volatile and highly incompatible lithophile elements. The absence or at most very limited plate tectonic activity on early Mars excludes an extensive crustal recycling back to the mantle and preserves the Rb-Sr and U-Pb isotopes systems derived from the early crustal differentiation. The observed correlation of radiogenic ^{182}W with radiogenic ^{142}Nd by [10] points also to a close relationship between core formation and mantle melting in the first ~30 Ma after formation of the Mars. Contrary to Mars, on Earth a relationship exists between the Sr- and Nd-isotope systems. Because of the remixing of the crust into the Earth's mantle and the homogenization of the isotopes through plate tectonics a "common isotopic reservoir" exists from which about 2 Ga ago crust and depleted mantle differentiated.

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