THE ROCKY PLANETS WITH MAGNESIUM - RICH MANTLE COMPOSITION. P Futó[1] [1] University of Debrecen, Cosmochemical Research Group, Department of Mineralogy and Geology, Debrecen, Egyetem tér 1. H-4032, Hungary (dvision@citromail.hu)

Introduction: Rocky planets may have chemical compositions, which are largely different from that of the Earth. The efficiency of geodynamics and plate tectonics is highly influenced by the mineral composition of the mantle and the lithosphere.

According to the spectroscopic observations of the stellar abundances in the Solar neighbourhood, most of the FGK stars have been determined to have Mg/Si ratios in the range of 1 - 2. If they have rocky planets, most of those have bulk Mg/Si ratio than that of the Solar System planets. A small fraction of rocky worlds may build up in high - Mg/Si protoplanetary disks, in which "olivine planets" having been allowed to form. These planets, having a more Mg-rich mineral composition than that of the Earth, may have upper mantles with transition zones dominated by olivine, and ferropericlase (Fp) or magnesiowustite (mw) at larger depths.

The main purpose of this study is to calculate the molar percent of the relevant mineral constituents in the Mg-rich planetary mantles. A possible crustal mineralogy has also been explored for high-Mg/Si rocky planets and several accessory minerals in the mantles are being proposed for the major fraction of Mg-rich rocky exoplanets. The Mg/Si and O/Si elemental ratios have been determined for the structural units of the Earth's mantle taking into account the assumed major mineral compounds. Moreover, I focuses on a much higher pressure range corresponding to the deep mantles of super-Earths (1-10 $M_\oplus$) and mega-Earths (M >10 $M_\oplus$) ranging from 3 GPa to > 3 TPa.

Model: The modeled composition in the uppermost region of the UM are (α) Mg_2SiO_4 (75 vol %) + high majoritic garnets (25 vol %). In transition zone, the major mineral compounds are β- Mg_2SiO_4 (wdl) and γ - Mg_2SiO_4 (rwd) (60 vol %); majoritic garnet (40 vol %). In addition to this, the garnet structures were also calculated assuming Ca, Fe^{2+} and Fe^{3+}, Al cation substitutions in small amounts. In the deep interior of Earth, bridgmanite (Bdg), ferropericlase (Fp) and perovskite-structured $CaSiO_3$ (Ca-pv) are expected to build up the bulk mineralogy of the lower-mantle. The calculations of Mg/Si and O/Si ratio of the Earth are partially based on that the lower mantle is generally thought to consist mainly of $(Mg,Fe)SiO_3$ perovskite and (Mg,Fe)O magnesiowüstite (Fp) containing 7-8 volume % $CaSiO_3$ perovskite [1, 2].

For planets with Mg/Si ratio ranging from 1-2 and for the Earth, the boundary between the transition zone and the lower mantle is in the pressure range of 23-26 GPa, assigned by the dissociation of rwd into pv plus Fp and the mj-pv transition in $MgSiO_3$.

In very massive rocky planets (MRP) the Mg-rich compositional models for the lower mantle are based on the ultra-high pressure (UHP) phases of $MgSiO_3$ [3] similarly to that of the lower Mg/Si planets.

In this model, the effect of other mineral compounds on the Mg/Si ratio has not been considered assuming that the value of the ratio is almost constant throughout the lower mantle. The molar percent of Mg-pv + Fp and Mg-ppv + Fp have also been investigated in the pressure ranges of mid-mantle region and the lower mantle of rocky planets at elevated Mg/Si ratio.

I have analyzed compositions of G-type stars taken from the Hypatia Catalog [4] to examine possible relationships between the calculated Mg/Si and O/Si elemental ratios.

A rocky planet with higher bulk silicate planet (BSP) Mg/Si value relative to the Earth is thought to have a thicker melilite and calcium dominated crust [5]. In fact, the mantle and crust of high-Mg/Si planets may have a highly complex mineral composition, but this study focuses on relatively simple magnesium-rich mineralogies.

Plausible compositions for Mg-rich planetary mantles: The mj-rich mineral composition of the Earth's UM is consistent with the silicon-depleted pyrolitic UM models, while the Ca-pv bearing conception is being consistent with the silicon-rich chondritic compositional models for the LM of the Earth.

Planetary mantles with Mg/Si ratios over 2 are proposed to make up mostly of UHP Mg-rich silicates and Fp (Fig.1). Over the value of Mg/Si ratio of 1, the molar fraction of Fp in the lower mantle increases with the increasing Mg/Si ratio. The mid-lower mantle composed mostly of the high-pressure form of M_2SiO_4 having $I\bar{4}2d$- type structure.

The higher ratio of Fp may lead to a more vigorous mantle dynamics. However, the Mg-rich crust may be thick on high Mg/Si planets and it is not able to fracture into tectonic plates under given conditions. Under the thick lithosphere, excess heat may arises in the mantle, which affects the mantle driven tectonic processes and plume activity, leading to episodic resurfacing. It has a great impact on the planetary habitability on high Mg/Si planets.

Using the data of Hypatia Catalog, I have found that the examined high Mg/Si values (Mg/Si >1.05) correlate with the high O/Si values. The O/Si ratios higher than the Solar O/Si value for the case of more than 70 percent of high-M/Si values.

The calculated average O/Si molar ratio values for Earth are between 3 and 4 (Fig, 2).

Elevated oxygen abundances are being observed in planet-harboring stars [6]. Magnesium peroxide (MgO_2) may be stable under high pressure conditions of O-rich planetary interiors [7]. Accordingly, MgO and the MgO_2 phase may be present in the deep mantles of a major fracton of Mg-rich rocky super-Earths under highly oxidized conditions.

CaO_2 may be formed over CaO in an oxygen-rich environment of planetary interiors. Calcium peroxide is a thermodynamically stable oxide at temperatures and pressures in the upper zone of the lower mantle reaching its peak stability at the CaO B1–B2 phase transition at 65 Gpa [8]. Hence, CaO_2 may also plays a role in the mantle mineralogy of oxygen-rich high-Mg/Si rocky planets.

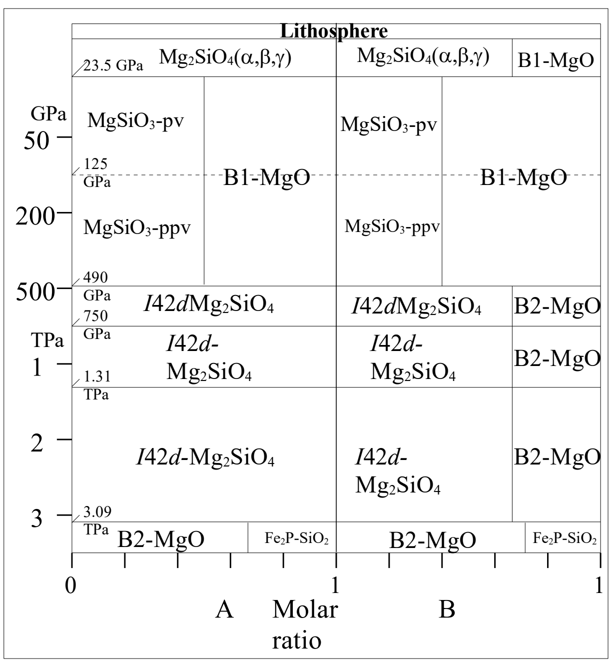

Figure 1. Mineral compositions for mantles of high-mass rocky planets for the case of 2 and 2.5 Mg/Si molar ratios.

Earth		Mg/Si			O/Si
Upper mantle	Uppermost upper mantle	BSE (M+C) 1.15	1.35	1.43	3.6
	Transition zone			1.27	
Lower mantle			1.08		3.18

Figure 2. The calculated Mg/Si and O/Si elemental ratios in molar percents for the Earth mantle. If the averaged crustal Mg/Si value has also been considered, the Mg/Si ratio is 1.15 for bulk silicate Earth.

If the bulk elemental composition of a rocky planet is richer in Mg than that of Earth then the crustal mineralogy of the high-Mg/Si planet can be characterized by a higher ratio of plagioclase feldspars and a lower ratio of alkali feldspars, SiO_2 compared to the terrestrial crust. Additionally, gehlenite – $Ca_2A1[(Si,Al)_2O_7$ - may be the one of the most abundant mineral constituents in the crust of a Mg-rich rocky planet.

It is likely that plagioclase feldspars can be moderately dominant minerals in the crust of Mg-rich rocky planets, and anorthite may be the most abundant mineral constituent in the feldspar-rich crustal rocks.

Summary: It has been found that the evolution of massive Mg-rich rocky planets can merely be different from that of high-mass Si–rich planets similarly to the low-mass rocky planets. In most cases, an increase in the Mg/Si ratio correlates with the increase in the O/Si ratio.

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