BASIC MINERALOCICAL MODELS FOR SILICATE- AND CARBON-RICH MEGA-EARTHS CONSIDERING COMPOSITIONAL AND GEOPHYSICAL CONSTRAINTS. P. Futó[1], A. Gucsik[2] [1] University of Debrecen, Cosmochemical Research Group, Department of Mineralogy and Geology, Debrecen, Egyetem tér 1. H-4032, Hungary (dvision@citromail.hu); [2] University of Debrecen, Cosmochemical Research Group, Department of Mineralogy and Geology, Debrecen, Egyetem tér 1. H-4032, Hungary

Introduction: In the last few years, at least a half dozen of terrestrial-like planets with masses higher than 10 $M_{\oplus}$ have been discovered. These planets, with no extended atmospheres and having relatively high mean densities, are the so-called mega-Earths. The circumstances of the formation of the very massive rocky planets have not yet completely been cleared up but they thought tend to form in massive protoplanetary disks. The main compositionally determined types for solid planets with masses over 10 $M_{\oplus}$ might be silicate-dominated, carbon-rich and icy bodies, which have been transition objects between Neptune-like and terrestrial planets. Their properties depend on the compositional characteristics of protoplanetary disk and the final location after the formation. Recent studies have suggested that post-perovskite phases of $MgSiO_3$ are need to exist in the deep interior of silicate-rich massive terrestrial bodies such as super-Earths and the rocky cores of gas giants [2]. I suggest that an icy or a gaseous planet is terrestrial-type then if its silicate+metal mass fraction larger than the 75 % of the total planetary mass. The main purpose of this study is to make planetary models to present the plausible compositional characteristics of mega-Earths for the case of silicate-and carbon-rich compositions.

Model: Simple compositional models have been made for modeling the possible basic planet-types for a twenty-earth-mass theoretical planets with Earth-like structural properties (for the case of cored planets). For the super dense cores of gas giants, the physical conditions of their highly-pressurized deep interiors have been expected to be extreme with the dominance of high pressure silicate mineral phases. In the modeling I have focused on two basic bulk compositions.

1.For the one of the theoretical basic types of mega-Earths, the mantle consisted of terrestrial analog materials in the upper mantle (olivine, ol; wadsleyite , wdl; plus ringwoodite, rwd; post-perovskite, pv and post-post-perovskite, ppv) and ultrahigh-pressure (UHP) mineral phases of $MgSiO_3$ in the deeper mantle regions. According to the one of the predicted mantle mineral compositions in multi-megabar pressure conditions, ppv phase of $MgSiO_3$ dissociates into CsCl (B2)-type MgO and P_21/C -type $MgSi_2O_5$ at 0.9 TPa and the further transition yields CsCl-type MgO and Fe_2P-type SiO_2 at 2.1 TPa, respectively. Umemoto et al. 2017 and Wu et al. 2014 and [3] [4] suggest the three-stage dissociation for $MgSiO_3$ from TPa to multi-TPa pressures, yielding phase transitions from ppv (dissociates into $I\bar{4}2d$-type Mg_2SiO_4 + $P2_1/c$-type $MgSi_2O_5$-0.75 TPa-UHP1) through the second transformation (being UHP1 transform into $I\bar{4}2d$-type Mg_2SiO_4 + Fe_2P-type SiO_2-1.31 TPa-UHP2) up to the final-stage of the dissociation (UHP2 dissociated into CsCl-type MgO + Fe_2P-type SiO_2-3.09 TPa- UHP3). The highly-oxidized $MgSi_3O_{12}$ may composed of the lowermost of mantle in mega-Earths with masses above 20 $M_{\oplus}$. For the O-rich silicate-dominated planets MgO_3, SiO_3, $MgSi_3O_{12}$ and possibly $MgSiO_6$ can be the essential planet-forming minerals[5]. It has been supposed that MTPs may have iron-rich cores under pressures in the multiterepascal range. Hexagonal-close-packed (hcp) iron is the stable form of iron from 0.1 TPa to multi-TPa pressures, between 7-21 TPa the face-centred-cubic (fcc) phase is slightly more than the hcp-iron. Pickard and R J Needs have found a transition to a body-centred-tetragonal (bct) phase at 34 TPa and the bcc-phase also becomes more stable than the hcp above 35 TPa [6]. For the case of mega-Earths the hcp and the fcc may be the dominant iron phases in their cores.

2.Mega-Earths might have been built up from carbon-rich compounds and these planets are thought to have formed in massive protoplanetary disks with a relatively high C/O ratio. Two main compositional types have been suggested with belonging to the carbon-rich planets, based upon the C/O ratio: carbon-planets (C/O > 1) (silicon-carbide mantle and iron-dominated core with high carbon-content) and carbon-silicate planets. Silicon carbide, silicates and silicon oxycarbides (SiO_xC_{4-x}) [7] can also be found in the mantles of so-called carbon-silicate planets, which constitute a transition planet-type between carbon and silicate-rich planets [8]. Carbon-silicate planets (CSP) are thought to have formed in protoplanetary disks, in which the C/O ratio is between 0.8-1. Shock compression studies for silicon carbide with cubic symmetry (3C-SiC, β-SiC) shows that 3C-SiC transforms from the ZnS-structure (B3) to the rock salt-structure (B1) at 90 GPa. Interestingly, radii of theoretical pure SiC planets are greatly similar to those of planets made entirely of silicates [9]. In this manner, the diameter of massive solid carbide-planets may also approaches to those of same mass silicate-dominated planets, which also have a similar core mass fraction.

Basic compositional models for mega-Earths: The five basic compositional models, which have been made by considering geophysical and cosmochemical-considerations, are summarized in Tables 1, and 3 are illustrated in Figure 1., respectively. Most of the currently-known mega-Earths are need to have a relatively small CMFs based on their mean densities. It provides an evidence for that a large population of the super-massive terrestrial bodies are need to have been cored, as opposed to being coreless.

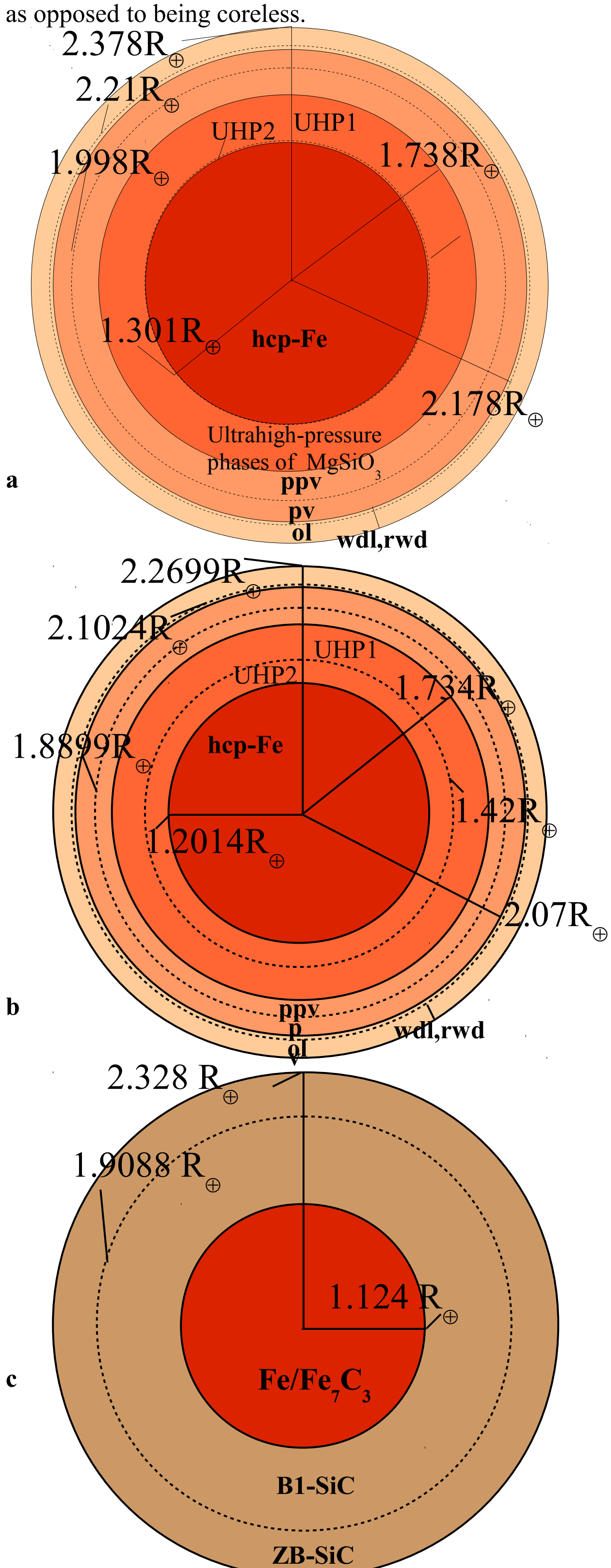

Figure 1. Schematic representations for twenty-Earth-mass planets with two-(a) and three-stage (b) dissociations of $MgSiO_3$ and a carbon composition (c), respectively.

	C/O< 0.8		C/O=0.8-0.1	C/O> 0.8	
Planet	O-rich terrestrial planet **O-TP**	Si-rich terres-trial planet **TP**	Carbon-silicate planet **CSP**	Carbon planet **CP**	Si-rich carbon planet **Si-CP**
Mantle	MgO_3, SiO_3, $MgSi_3O_{12}$ $MgSiO_6$	Sili-cates	Silicates, Silicon-oxycarbid-es, C, SiC	C,SiC, TiC	SiC
Core	Fe,Fe- Ni alloy, FeO	Fe, Fe-Ni alloy	Fe,Fe-Ni alloy, Fe_7C_3	Fe, Fe_7C_3	Fe_7C_3,Fe_3Si,FeSi,Fe

Table 1. Possible mineral compositions for the main planetary spheres of the massive solid planets. The core of TPs contains O, Si in several percent [12] and C in several ppt [13]

Summary: The specific observations of the massive protoplanetary disks may help the researhers to better understand the details of the formation processes of mega-Earths.

References: [1] Fortney J. J. et al. (2006): *Astrophysical Journal*. 642. 495-504. [2] Umemoto K. et al. (2011): *Earth and Planetary Science Letters,* 311, 225-229. [3] Umemoto K. et al. (2017): *Earth and Planetary Science Letters,* [4] Wu S. Q. et al. (2014): *Journal of Physics: Condensed Matter*, **26.** 035402 [5] Niu H. et al. (2015): *Nature Scientific Reports,* 5, 18347. [6] Pickard C.J, Needs R. J . (20xx): *Journal of Physics: Condensed Matter,* 21, 452205. [7] Sen S. et al. (2013): *Proceedings of the National Academy of Sciences,* 110. 15904–15907. [8] P. Futó (2014): LPSC. XLV. # 1046. [9] ElkinsTanton, L. T., Seager S., (2008) : *Astrophysical Journal,* 688, 628. [10] McWilliams R.S. et al. (2012): *Science.* 338, 1330-1333. [11] Vilim R. et al. (2013): *Astrophysical Journal*. 768. L30. [12] Rubie D.C. et al. (2015): *Icarus,*248, 89-108. [13] Zhang Y., Yin Q.Z. (2012):*Proceedings of the National Academy of Sciences,* 109. 19579-19583.