KEPLER-145B AND K2-66B: A KEPLER- AND A K2-MEGA-EARTH WITH DIFFERENT COMPOSITIONAL CHARACTERISTICS. 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: The sub-Neptune-sized planet Kepler-145b, having an orbital period of 22.951 days, has been detected in the original observing field (K1) of Kepler Space Telescope. Its host star is also being orbited by a Jovian-planet with a mass of 0.25 $M_{Jupiter}$, a radius of 0.385 $R_{jupiter}$ and an orbital period of 42.882 days. Based on its measured mass (37.18 $M_{\oplus}$) and radius (2.648 $R_{\oplus}$) [1] Kepler-145 b may be belonged to the mass category of mega-Earths, making it the one of the largest terrestrial planets that has been known, up to date.

K2-66 is a G1 subgiant star, which is located in the C3 field of Kepler K2 Mission. The field of C3 can be found in the direction of Constellation Aquarius and it had been monitored by Kepler from 14 November to 03 February 2015. It hosts an extremely hot sub-Neptune-sized (2.49 $R_{\oplus}$) planet in the „photoevaporation desert" with an orbital period of 5.06963 days and a semi-major axis of 0.05983 AU. K2-66b has a mass of 21.3 $M_{\oplus}$ [2]. The mean densitiy is calculated to be 7.609 g $cm^{-3\ -1}$, which indicates that this planet has no a large mass fraction of gaseous envelope, likely due to the high level of irradiation from its parent star. Accordingly, K2-66-b needs to have a predominantly rocky composition and it can be categorized into the planet class of mega-Earths. Its mantle composition may be similar to that of BD+20594b (K2-56b).

The main purpose of this study is to constitute possible compositional and interior structure models, which are limited to the measured mass and radius of Kepler-145 b and K2-66-b.

Model: Terrestrial analog silicate mineral phases constitute the upper mantles-olivine (ol), wadsleyite/ringwoodite (wdl/rwd)-and the uppermost zone of lower mantles-silicate-perovskite (pv) and post-perovskite (ppv). In terms of the examination of Umemoto [3,4], three-stage dissociation of $MgSiO_3$ occurs in the TPa to multi-TPa pressure range. Post-pv dissociates into $I\bar{4}2d$-type Mg_2SiO_4 + $P2_1/c$-type $MgSi_2O_5$ at 0.75 Tpa (UHP1). The second transformation is being UHP1 transform into $I\bar{4}2d$-type Mg_2SiO_4 + Fe_2P-type SiO_2 at 1.31 Tpa (UHP2). The final-stage of the dissociation is UHP2 phase dissociated into CsCl-type MgO + Fe_2P-type SiO_2 at 3.09 Tpa (UHP3). Accordingly, the ultra-high pressure (UHP) phases of $MgSiO_3$ constitute the significant volume of the lowermost mantle for the case of both planets.

Vinet EOS [5, 6] has been used for computing the material properties in the upper mantle and in the pv belt in the lower mantle. Murnaghan equation of state [7] is being suited at the calculation for pressure/density relation in the ppv and the ultra-highpressure silicate mineral phases. The utilized zero-pressure densities of hcp-Fe[1], fcc-Fe [2], UHP silicate phases [3][3] [4][4] ,[8][5] MgO [6], ppv[7], pv[8], wdl/rwd[9] and olivine[10] are 8.255[1] [8], 8.06[2] [9], 3.67727[6] (calculated for MgO by the data of Strachan et al. 1999)[10], 4.27[7] [11], 4.152[8] [12] , 3.644[9] [12] and 3.347[10] [12] g cm^3.

K2-66b needs to have a silicate-dominated interior, however, it is likely to have been overlaid by a relatively small fraction of a steam atmosphere. Therefore, in this model I focus on a composition with a CMF of 10 percent by total mass and a thick silicate-mantle plus a thin steam atmosphere.

It has been assumed, that a significant fraction of metals had been oxidized before the accretion of the planet or a relatively small core could only formed. Therefore, the enhanced Fe/Mg ratio for perovskite and post-perovskite structured Mg, $FeSiO_3$, the FeO content in the UHP1 and UHP2 phases have also been considered, through exploring the lower-mantle conditions.

Possible interior model for Kepler-145b: Massive terrestrial planets with masses over 30 $M_{\oplus}$ might moderately be rare, they are proposed to have been belonged to a new subgroup inside the mega-Earth category: supermassive terrestrial planets (SMTP). Accordingly, Kepler-145 b is an SMTP in this terminology.

Its globally averaged surface gravity is more than five times larger than on Earth, it is obtained to be 52.06 m s^{-2}. (5.3 g_{Earth}). The central pressure has been calculated to be 10.15318 TPa.

In the zone of post-ppv phases of $MgSiO_3$ (UHP1-UHP3) might be the most massive mineral belt in the K-145b 's mantle. At the ultrahigh-pressure of 1.31 Tpa, $I\bar{4}2d$-type Mg_2SiO_4 + $P2_1/c$-type $MgSi_2O_5$ (UHP1) transforms into $I\bar{4}2d$-type Mg_2SiO_4 + Fe_2P-type SiO_2 (UHP2 phase of $MgSiO_3$), which constitutes the lowermost zone of the mantle and it has been appeared as the most massive mantle sphere in the interior of K-145b from the depth of 1.799 $R_{\oplus}$ to 1.453 $R_{\oplus}$. The radius of the metallic core has been calculated to be 1.449 $R_{\oplus}$, which is 54.72 percent of the total planetary radius. It is an Earth-like structure for the case main structural units of terrestrial planets.

In terms of the geological evolution, Kepler-145b is a moderately young MTP (2.62 Gyr)[13], accordingly, a vigorous convective layer may be expected overlying the highly viscous deeper region of the mantle.

Plausible composition for K2-66b: The surface gravity is more than three times greater than on Earth: g_s =

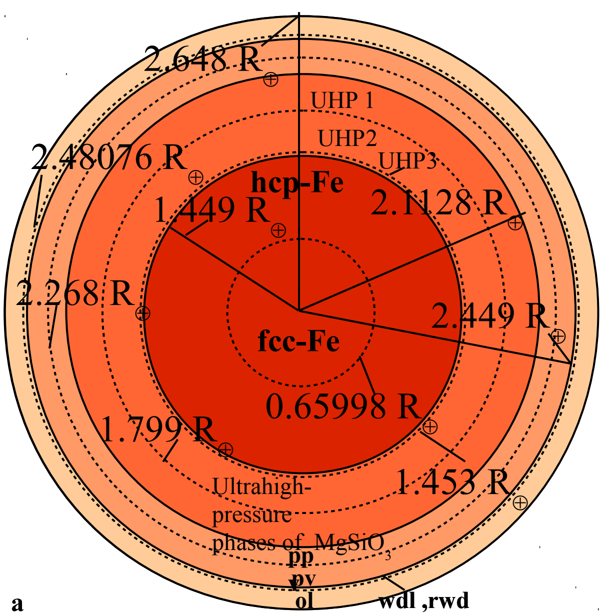
33.746 m s^{-2} (3.44 g_{Earth}). The central pressure is calculated to be 4.266 terapascal.

It is possible that K2-66b is not a coreless planet it need to have a relatively small metallic core fraction calculated to be 0.8019 $R_{\oplus}$. Nonetheless, it is believed that it can be belonged to the mega-Earths constituting a transition in composition between Neptune-like and true terrestrial planets. The planetary structure differs from that of a same mass planet with an Earth-like composition and a 32.59% CMF. K2-66b is likely to have been formed in the formational enviroment of ice or gas giants.

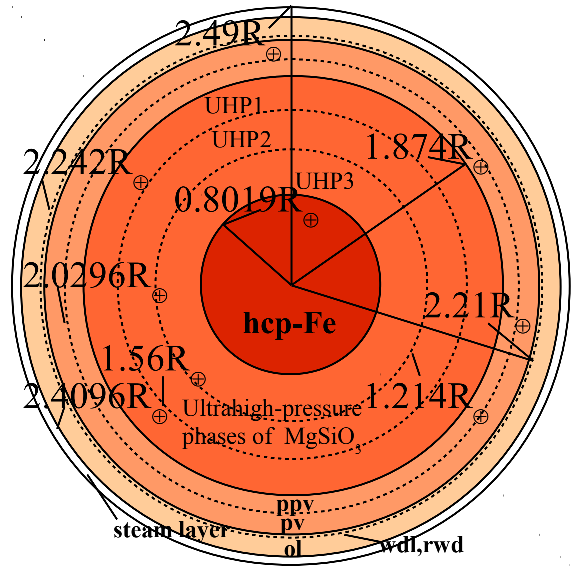
The modeling shows that the UHP phases of $MgSiO_3$ constitute a definitely thick zone in the deep mantle and the central region of the planet to the CMB. The thickness of the top layer is calculated to be ~500 km by assuming a mostly water steam atmosphere with metal-oxides (SiO, SiO_2, MgO, FeO) and hydroxide gases ($SiOH_{(2),(4)}$; $MgOH_{(2)}$; $FeOH_{(2)}$) presence of which are expected under adequate conditions is being reported by Fegley et al. [14].

According to a likely scenario, K2-66b could originally be an ice giant like Neptune. An essential amount of its original atmosphere (or possibly an ice layer) had been lost by means of the strong irradiation in the proximity of the star. Therefore, it is plausible that this planet has a coreless rocky interior or it has a small CMF overlaid by a dense water-steam bearing envelope.

It is likely to have a powerful geological activity in the upper mantle zone.



a



b

Fig.1
a: Schematic representation for K-145b. It has an Earth-like structure in the core/total planet radius ratio.
b: a simple two-component structure for K2-66b. The steam atmosphere that surrounds the rocky interior composed possibly of the combination of water steam, metal-oxides and hydroxide gases.

Summary: According to a likely scenario, Kepler-145b has an Earth-like interior, while K2-66b composed mostly of silicates with a small mass fraction of a steam layer, having a small metallic core. In the future, the study of mega-Earths can help for better understanding the planet formation.

References:

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