Effect of Planet Size and Initial Water Content on the Formation of Anorthosite Crust. R. Sakai[1] and, H. Nagahara[1] and K. Ozawa[1], [1]Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, JAPAN (rsakai@eps.s.u-tokyo.ac.jp).

Introduction: The terrestrial planets and some of planetesimal likely have experienced significant melting by the radiogenic heating from short-lived radioisotopes and/or the conversion of kinetic energy to heat with energetic accretionary impacts [1-3] during the late-stage of formation of the planetary-system. The Moon has a clear evidence of magma ocean with the product of anorthositic crust, which was likely formed by flotation of plagioclase through a Magma Ocean [4]. It is, however, difficult to know whether other planets or planetesimals were differentiated through magma oceans. Once anorthosite crust (or lid) was formed at the surface of a planet like the Moon, thermal regime of the magma ocean would have changed from by convection to by conduction, which changed the cooling rate of the magma ocean by orders of magnitude. Therefore, formation of anorthosite crust would play a crucial role on the thermal history of terrestrial planets.

The purpose of this study is to determine the physical and chemical conditions for the anorthosite crust formation of a small terrestrial planet and planetesimal.

Model: In present work, differentiation of magma ocean is investigated by developing an incremental fractional crystallization model [5] based on MELTS program with parameters of planet size and the initial water content, and we evaluated the possibility of anorthosite crust formation by comparing the density of plagioclase and that of residual melt. The model assumes that (1) the bulk composition of a planet is Vesta-like composition [6]; (2) the planet was totally molted at the beginning; and (3) the efficiency of separation of crystallized minerals from magma ocean treated as a parameter in our model, represented by between the maximum fractional crystallization and equilibrium crystallization. We set the planet radius of 500, 1000 or 1500 km and the initial water content of 0, 0.023, 0.1 or 0.25 wt%.

Results: The differentiation calculations showed that: (1) the degree of crystallization of a magma ocean reaches ~70-80 vol% at the time of plagioclase crystallization after differentiation of mainly olivine and pyroxenes, (2) the H_2O content of residual magma ocean at the beginning of plagioclase crystallization is about five times more than the initial H_2O content, (3) the pressure of the center of residual magma ocean at the first time of plagioclase crystallization is ~0.04 GPa for a 500 km planetesimal and ~0.3 GPa for a 1500 km planetesimal.

Figure 1 shows the density of the residual magma ocean at the beginning of plagioclase crystallization. The density of residual melt increases as the planet radius is larger and the initial water content is lower. Taking the plagioclase density of ~2.7-2.8 g/cm^3 into account, a planetesimal of < 500 km cannot form anorthositic crust regardless of the initial water content because the density of melt is too low. The same calculation with the BSE composition [7] showed that the densities of melt at the time of plagioclase crystallization were lower than the results of Vesta-like composition by 0.1-0.15 /cm^3 for all the conditions investigated. This implies that planetesimals with the Earth mantle composition hardly form anorthosite crust compared to chondritic composition.

The present quantitative work supports the discussion by Elkins-Tanton et al. (2011) [8] that the Moon has a radius suitable for total melting and anorthosite crust formation.

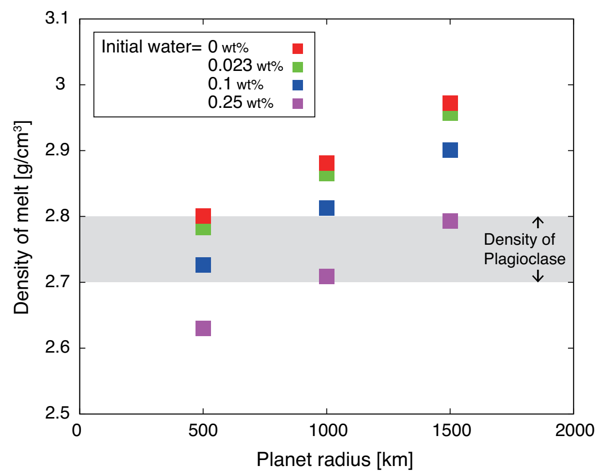

Fig. 1. Density of magma ocean at the beginning of plagioclase crystallization as a function of planet radius and the initial water content. The shaded area represents the density of plagioclase. The calculation was carried out for the initial bulk composition of Vesta mantle [6].

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