The Tl content and Tl isotope composition constraints on the magnitude of late-accretion of Earth and meteorite type

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Introduction: The contents of highly siderophile elements (HSEs) of mantle were used to estimate how much materials were delivered during the late accretion period (Day et al. 2007; Walker 2014). By using the average Tl concentration of 500 ng/g for the continental crust, 200 ng/g for the oceanic crust and 0.7 ng/g for the mantle, the content of Tl in bulk silicate Earth (BSE) has been estimated to be about 3.03 ng/g (Shaw 1952; McDonough and Sun 1995; Salters and Stracke 2004; Nielsen et al. 2006c; Nielsen et al. 2014). Because Tl is a highly volatile element and its abundance is extememly low (less than 0.02 ng/g) in magmatic iron meteorites (Andreasen 2012), we can assume that most of the Tl would be volatilized and lost during the accretion of proto-Earth. The low Tl concentration of current BSE can be assumed that it was almost entirely delrivered by the late veneer.

There are very similar Tl isotopic compositions between BSE and chondrites (Baker et al. 2010; Palk et al. 2018) (see Fig. 1). We also checked the possible Tl isotope fractionations, especially with the inclusion of the nuclear volume effect, during core-mantle differentiation and vaporization. We find that vaporization can significantly change the Tl isotope composition of BSE, but no observed signal of it at all. The core segregation, however, may slightly lower the Tl isotope composition of BSE.

If BSE's Tl was delivered by the late-accretion, considering the similar contents of the Tl of enstatite chondrites (EC) and carbonaceous chondrites (CC) (Baker et al. 2010; Palk et al. 2011; Palk et al. 2018) (Fig. 1), we use the an average value (50 ng/g) of to represent EC and CC with 60 ng/g. Meanwhile, the average concentration of Tl in ordinary chondrites (OC) is 6 ng/g (Andreasen et al. 2009). We can set x as the fraction of material from CC and EC added delivered in the early mantlelate veneer stage relative to the total mass of the Earth, and the fraction of OC is y. If we assume that the material of late-stage accretion had constituted the entire Tl concentration of BSE, which was defined as nBSE (ng/g), then 60x + 6y = nBSE and nBSE = 3.03 x 67.4% = 2.04 (ng/g). It turns out that needs more chondritic materials, especially CC and EC to satisfied the above equation. Therefore, the amount of 0.5 wt.% late veneer estimated by HSEs is not enough to explain the Tl content in BSE. It needs at least 5 more times of materials.

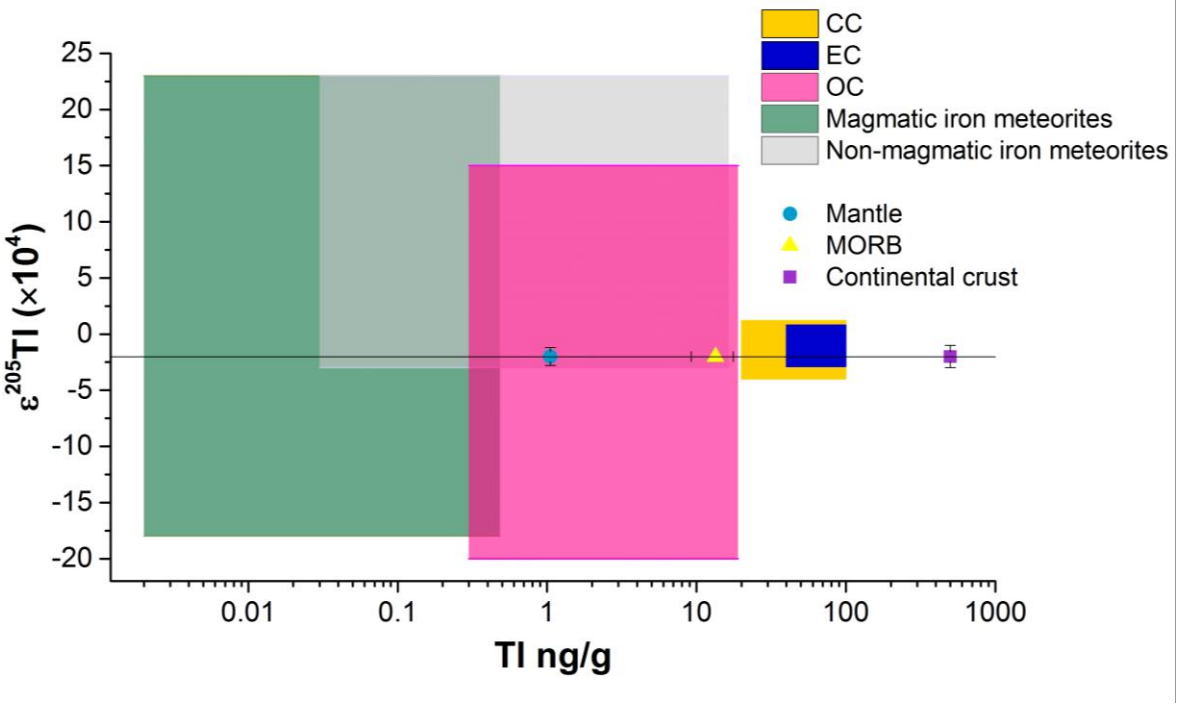

Figure 1