THE IMPORTANCE OF REDOX STATE TO THE COMPOSITION AND FRACTIONAL CORE SIZE OF IRON-RICH PLANETESIMALS WITH APPLICATION TO 16 PSYCHE. T.-A. Suer[1], E.S. Steenstra[2], S. Marchi[3], [1]University of Rochester, NY, USA, [2]Institute of Mineralogy, WWU, Muenster, Germany, [3] Southwest Research Institute, CO, USA.

Introduction: The origin and evolution of iron-rich asteroids and meteoritic parent bodies is a topic of rich debate [1, 2]. Investigating whether these are the core remnants of differentiated bodies and/or formed in a highly reduced environment and the potential role of pebble accretion or gas drag on their formation dynamics are key issues for early solar system science [3, 4]. Based on its high density, asteroid 16 Psyche was hypothesized to be an exposed protoplanetary core. More recent measurements suggest that it has a lower density (3400 to 4100 kg/m^3) than that of meteoritic metal (7000 to 8000 kg/m^3) [3]. Although Psyche could still contain up to 60 volume % metal (for a maximum porosity of 20 %), its density could also be explained by low-Fe silicates and/or sulfides and/or carbon-bearing compounds. High metal content and low-Fe silicates could be an indication that Psyche formed at relatively reducing conditions [4]. Oxygen fugacity (fO_2) varies strongly throughout the solar system and can have a profound effect on planetesimal evolution. In particular, the distribution of elements between the core and silicate mantle or silicate phases are strongly influenced by redox state. This in turn affects the metal or core mass fractions of planetesimals. Whereas, the role of bulk composition and S contents on Psyche-like bodies have been explored in recent works [5], the effects of $fO_2$and highly reduced initial bulk compositions remain largely unexplored. Here we explore the effects of redox state on the composition and relative core size of a Psyche-like body.

Approach: We explored the effects of fO_2 on parent body differentiation for four end-member compositions with significantly different Si, Fe, S and C contents [6]. A range of core masses are derived as a function of fO_2 for the different bulk compositions. Using a simple mass balance approach we calculated how the silicate fraction would develop for different core mass fractions. We then calculated the relationship between the FeO content of the silicate fraction and the fO_2, for a specific core composition. This yields the correlation between relative core mass and fO_2 that were used to assess potential metal fractions in a Psyche-like planetesimal. Metal-silicate partition coefficients ($D^{met-sil}{}_i$, where D_i is defined as the ratio between the concentrations of element *i* in the metal liquid and of element *i* in the silicate melt) were used from the literature [7–10], in conjunction with the simple mass balance models [7] to calculate how the composition of the metal fraction would change for different initial fO_2 values. The core compositions were derived using internally consistent models, where the relationships between fO_2, core mass and composition are all simultaneously taken into account. One set of *P-T* conditions were considered for all of our models (*P* = 0.1 GPa; *T* = 1900 K), for a body with an assumed radius of roughly 100 km. It should be noted that derived core compositions hardly change with the set of *P-T* conditions considered in our models.

Results: The large influence of fO_2 can be seen in the metal-silicate partition coefficients calculated for key elements S, Si, and C (Fig. 1). Here, some interesting features become apparent. First, accretion of Psyche at reduced conditions would result in partitioning of some Si in the metallic core. The presence of Si in the metal phase would subsequently greatly limit the amount of carbon that could be dissolved in this metal. Interestingly, the modeled core C contents are much higher than the modeled solubility limit (CCGS - carbon content at graphite saturation) of C in the metal phase [11, 12] at realistic *P-T* conditions This implies that graphite or carbides must have been stabilized if C was not significantly lost due to volatility related fractionation. This is a robust conclusion that is obtained for all of the considered bulk compositions if condition are highly ($-6 \leq IW \leq -2$) reduced. These results suggest that if Psyche accreted at highly reduced conditions, graphite could constitute an important low-density phase. The results also show that S contents of the silicate fraction can be quite high, up to the point that the silicate melt/fractions could have experienced sulfide saturation, potentially resulting in the formation of an immiscible FeS layer within Psyche's interior. Such immiscibility could have resulted in core layering in reduced planetesimals [12].

Discussions and implications: If formed in a highly reducing environment, Psyche's density could potentially be explained by the presence of significant amounts of carbon either as graphite or alloyed with iron. Furthermore**,** carbon could also be an important component of other M-type bodies formed under similar conditions. A sulfide layer could have also played a role in the internal structure of these bodies. Additionally, these results show that only the most reduced compositions, namely the CB suite, produce the required volume fractions of metal that are closest to the bulk properties of Psyche from the most recent estimates (Fig. 2). These combined results imply that Psyche could have formed elsewhere or possibly under highly reducing conditions. However, significant loss of the silicate fractions due to the collisional erosion cannot be ruled out. The required metal content could also be lower if the actual porosity of Psyche is much lower than current estimates. We plan to assess through Monte Carlo simulations the range of densities produced from a larger range of and combination of bulk compositions to further refine possible internal structure and compositions of Psyche and other M-type asteroids.

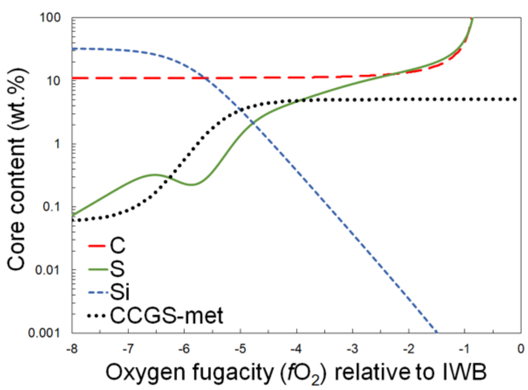

Figure 1: Light element core content in wt. % at different oxygen fugacities (fO_2) for CB bulk composition. Si and C are abundant at very reduced conditions. C remains abundant at more oxidizing conditions and eventually saturates. Si content drops off while that of S increases.

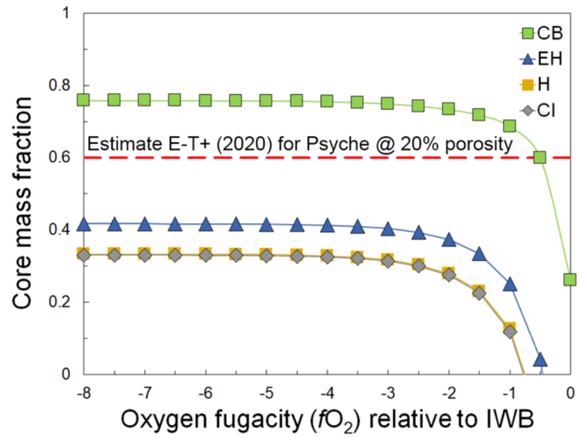

Figure 2: Core mass fraction at different oxygen fugacities (fO_2) for 4 possible parent body bulk compositions. Only the most reduced composition (CB) produces a core mass fraction compatible with current estimates of Psyche's density.

References: [1] Neeley et al. (2014) *Icarus* 238 [2] Hirschmann et al. (2021) *PNAS* 118 (13) [3] Elkins-Tanton *et al*. (2022) *Space Sci. Rev.* 218(3) [4] Johansen & Dorn (2022) *A&A* 662 [5] Bercovici et al. (2022) *Icarus* [6] Alexander (2019) *GCA* 254 [7] Steenstra *et al*. (2020) *Icarus* 335 [8] Boujibar *et al*. (2014) *EPSL* 391 [9] Suer *et al*. (2017) *EPSL* 469 [10] Chi *et al*. (2013) *GCA* [11] Buono *et al*. (2013) *GCA* 120 [12] Corgne *et al*. (2008) *GCA* 72