THE ROLE OF CARBON IN EXOTIC CRUST FORMATION ON MERCURY.

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Introduction: The terrestrial planets that comprise our inner Solar System, including the Moon, are all rocky bodies that have differentiated into a crust, mantle, and core. Furthermore, all of these bodies have undergone various igneous processes since their time of primary crust formation. These processes have resurfaced each of these bodies, at least in part, resulting in the production of a secondary crust, to which Mercury is no exception. From its first flyby encounter with Mercury on January 14, 2008, the MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) spacecraft collected data on the structure, chemical makeup, and density of the planet among other important characteristics [1]. The X-Ray Spectrometer on board MESSENGER measured elevated abundances of sulfur and low abundances of iron [2, 3], suggesting the planets oxygen fugacity (fO_2) is several $\log_{10}$ units below the Iron-Wüstite buffer [4-6]. Similar to the role of other volatiles (e.g. sulfur) on highly reducing planetary bodies, carbon is expected to behave differently in an oxygen starved environment than it does in an oxygen enriched environment (e.g., Earth).

Carbon on Mercury: Until recently, the extremely dark nature of the mercurian surface was enigmatic. However, the results from sink-float experiments on a synthetic composition representative of the largest volcanic field on the surface of Mercury suggested that mercurian melts are extremely buoyant, mainly due to the low fO_2 resulting in limiting amounts of iron in the silicate portion of the planet, and therefore a plagioclase flotation crust like seen on the Moon isn't viable [7]. Given these results, [7] suggested the possibility of a primary flotation crust on the planet composed of graphite (Figure 1), which, due to the low density of graphite compared to mercurian melts, would have floated to the surface in a mercurian magma ocean. Occurring simultaneously with this experimentally derived hypothesis, results from the MESSENGER spacecraft showed elevated abundances of carbon on the surface of Mercury [8, 9]. Furthermore, the low reflectance material on the planet, typically found within craters, is also consistent with the presence of coarse grained graphite, which would act as a darkening agent on the planet without reddening the spectral slope and is also consistent with a primary graphite crust now exposed after bombardment and crater formation [10]. The thickness and extent of such a crust would be dictated by the amount of C allocated to the silicate portion of the planet and the efficiency of graphite flotation.

Role of Graphite in the Magmatic Evolution of Mercury: A primary graphite flotation crust on Mercury, albeit exotic, is supported by the dark color of Mercury's surface and the existence of low reflectance material covering at least 15 % of its surface (> 4 million km^2) [11]. Following planetary differentiation and the formation of a primary crust on Mercury, partial melting in the mantle along with subsequent volcanism has resurfaced the majority of the planet (Figure 1c) [e.g., 12]. The primary crust, secondary crust, and upper mantle have since been excavated and mixed by impact processes as evidenced by the large number of craters observed on Mercury's surface [13], leading to the chemically complex and darkened surface that is observed today (Figure 1d).

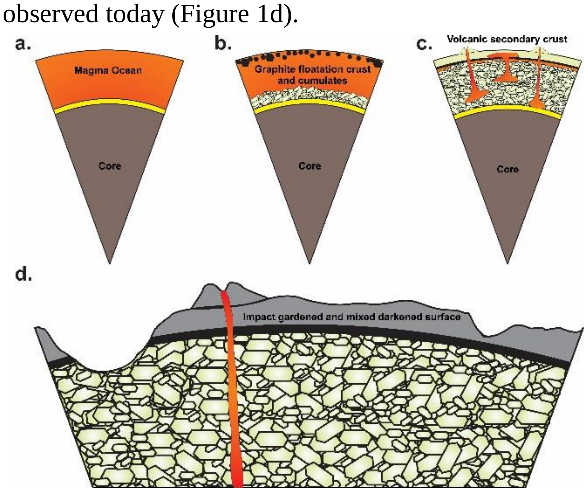

Figure 1. *Cartoon illustrating the stages of a mercurian magma ocean and subsequent primary and secondary crust formation. Full details are provided in [7]*

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