ORIGIN OF THE MAIN GROUP PALLASITES FROM AN UNDIFFERENTIATED CHONDRITIC ASTEROID: WHAT ARE THE POTENTIAL MISSING LINKS?.

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Introduction: Primitive chondritic meteorites provide direct constraints on the early solar nebular composition. Ordinary chondrites (OCs) are undifferentiated extraterrestrial specimens that make their way from the asteroidal belt to the Earth. Recent advancements in long-distance observational techniques [1] and sample-return missions [2] have provided important constraints on asteroid compositions. OCs are mineralogically identical to that of the S-type asteroids [2], however, main group pallasites (MGPs) represent chunks from differentiated asteroids and generally are associated with A-type asteroids given their abundance of forsteritic olivine [3]. The slope-1 lines on an oxygen isotope diagram have been reported to describe the primitive oxygen isotope reservoirs based on the analyses of various carbonaceous and non-carbonaceous chondritic materials [4]. We plotted the oxygen isotope compositions of OCs [5], SNCs [6], and MGPs [7] along with the gas-solid mixing (i.e., GSM-C/O=0.5) line − constructed from the oxygen isotope values derived by mixing the ^{16}O-rich solid component (i.e., CAIs; δ^{17}O = -41.9 ‰, δ^{18}O = -40.6 ‰) [8] and estimated ^{16}O-poor gas component (i.e., δ^{17}O = 23.6‰; δ^{18}O = 25.0‰) [9] using the C/O = 0.5 [10] − to compare the trends on the oxygen isotope plot.

Results and Discussion: Mass-dependent oxygen isotope fractionation trends are observed in different meteorite groups that are likely linked either with thermal metamorphism [5] or igneous differentiation [11] processes on their parent bodies. All slope-1/2 lines (e.g., H5 [5], L6 [5], SNCs [6], and MGPs [7]) originating from the slope-1 GSM-C/O=0.5 line [4] show most of the data fall on the right side of the primitive oxygen isotope line. The slope-1/2 lines meet at slope-1 line at δ^{17}O & δ^{18}O values of 2.9‰ & 4.3‰ (H5), 3.6‰ & 5.0‰ (L6), 2.1‰ & 3.5‰ (SNCs), and 1.2‰ & 2.5‰ (MGPs). These isotope compositions with reference to the slope-1 line [4] demonstrate that the parent bodies of H5, L6, SNCs, and MGPs possibly accreted from the gas (mass%) : solid (mass%) mix in the proportion of 30.5:69.5, 31.6:68.4, 32.8:67.2, and 34.3:65.7 respectively. The parent bodies of these meteorite types inherited the isotopic heterogeneities from distinct isotopic reservoirs given their different locations in the protoplanetary disk [2]. As a possibility, a large scale igneous differentiation (e.g., development of magma ocean) on undifferentiated asteroids cannot be ruled out [12]. For example, parent bodies of angrites, aubrites, and MGPs are said to be differentiated after the development of magma oceans [13]. It is also suggested that 45-70% partial melting of an H-chondritic starting material could produce pallasite-like olivine-metal fabric after the removal of pyroxene by gravitational separation [13]. Here, we propose that non-carbonaceous chondritic material, probably similar to the S-type asteroids (i.e., parent bodies of OCs), may have undergone an igneous differentiation process that possibly resulted into the formation of a protoplanet. Later, hit-and-run collision stripped of most silicates (i.e., mantle) from the protoplanet exposing core-mantle materials and the core [14-15]. This catastrophic event could have generated the remnants of the protoplanet in the form of asteroids such as pyroxene-rich S-type (e.g., 115 Thyra and 532 Herculina [16]), Fe-Ni metal-rich M-type (e.g., 16 Psyche [17]), and olivine-rich A-type (i.e., potential parent bodies of MGPs). We have shown that oxygen isotope compositions of the MGPs fall on a slope-1/2 line [7] and they are generally considered as core-mantle materials. Therefore, oxygen isotope data of the corresponding mantle material of a differentiated body must fall on the same slope-1/2 line as expected from the mass-dependent fractionation lines observed for Earth, Mars, and some asteroids. So far, we have not yet discovered a separate pl-px-ol-rich meteorite to represent the missing complementary member of the MGPs, hence we hypothesize that it could probably have originated from the 115 Thyra- or 532 Herculina-like asteroids. Similarly, core material is required to complete all the major components of a protoplanet and that could possibly be identical to 16 Psyche asteroid which is considered as may be the remnant of a protoplanet that has been stripped of most silicates by a hit-and-run collision [15]. The confirmation of these missing links in our triple oxygen isotope canvas of MGPs awaits new discovery of pl-px-rich meteorites having oxygen isotope compositions that fall on MGPs slope-1/2 line [7] and a close investigation of 16 Psyche by NASA mission set to start in 2023 [17].

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