

THE IMPORTANCE OF THE MODERATELY SIDEROPHILE AND VOLATILE GERMANIUM IN CHONDRITES AND PLANETARY RESERVOIRS TO RECONSTRUCT PLANET FORMATION.

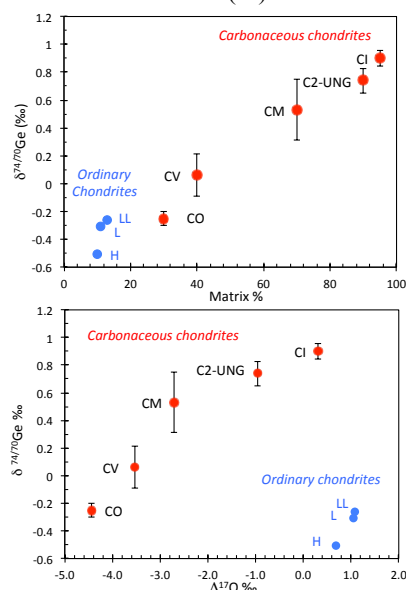
B. Luais¹, G. Florin², D. Cividini¹, ¹CRPG-CNRS, University of Lorraine, BP 20, 54501 Vandoeuvre-lès-Nancy Cedex, France, luais@crpg.cnrs-nancy.fr, ²Freie Universität Berlin, Institute of Geological Sciences, Malteserstraße 74-100, 12249 Berlin, Germany, g.florin@fu-berlin.de

Introduction: The moderately siderophile and volatile elements are strong tracers of condensation, accretion-collision and metal-silicate differentiation processes in the earliest history of the solar nebula, and of terrestrial planets, the Moon, and asteroids, respectively. Among them, germanium, with $T_{50\% \text{ cond}} = 825 \text{ K}$ and metal-silicate partition coefficient of 17 for the Earth, show significant isotopic fractionation ($\Delta^{74}\text{Ge}_{\text{metal/silicate}}$) at two scales, namely (1) at a meteorite scale between metal and silicate phases in ordinary chondrites or pallasites, and (2) at reservoir scales, between iron meteorites taken as proxies for core and the silicate Earth. Establishing the isotopic budget of planetary mantles (e.g. Earth, Mars, Vesta) and the Moon implies to determine the isotopic composition of chondrites as proxy for undifferentiated parent bodies.

Here we present new high precision germanium isotopic data obtained on (1) bulk carbonaceous (CC) and ordinary chondrites (OC), (2) Howardite-Diogenite meteorites though to originate from Vesta, (3) Martian meteorites (shergottite, nakhlites) and (4) lunar basalt meteorite, They will be compared with Ge isotopic composition of iron meteorites and Earth silicate mantle (peridotites, basalts) [3,4] to assess parent bodies composition.

Samples and methods: Variable quantities of sample, from 80 mg for CC (CI, CM, CV, CO), OC (H, L, LL) and martian meteorites (shergottite, nakhlites), to up to 2 g for Ge-depleted HED (unbrecciated and brecciated eucrites, diogenite) and lunar basalt, were analyzed for Ge concentrations at the SARM (ICP-MS, CRPG-Nancy), and for bulk Ge isotopic compositions by using Ge chemistry and MC-ICPMS techniques (Hydride Generator System coupled to NeptunePlus) developed at CRPG ($\delta^{74/70}\text{Ge}_{\text{NIST3120a}} \leq 0.1\%$, $2\sigma\text{SD}$) [1,2,3].

Results and discussion: OC and CC type chondrites present fundamental Ge isotopic dichotomy that follow O and Cr isotopic anomalies [4]. Bulk ordinary chondrites values display negative values from $-0.51 \pm 0.16 \%$ in H OC, $-0.29 \pm 0.05\%$ in L to $-0.33 \pm 0.14\%$ in LL, that agree within error with data on metal phase of OCs (Florin et al., 2020), then confirming that the metal phase hosts the Ge isotopic budget. By contrast, carbonaceous chondrites have positive $\delta^{74}\text{Ge}$ values and show exceptional large variations of $\approx 1\%$, from CI (Orgueil) with the heaviest composition ($\delta^{74}\text{Ge} = 0.901 \pm 0.06\%$) toward lighter composition in CV (Allende) ($\delta^{74}\text{Ge} = +0.096 \pm 0.12\%$). The $\delta^{74}\text{Ge}$ values and matrix fraction (%) of OCs and CCs are positively correlated and describe a mixing line between CI composition and expected chondrule composition (Fig. 1).



In addition large Ge isotopic composition in CC are exceptionally well correlated with $\Delta^{17}\text{O}$ (Fig. 1) and $\varepsilon^{54}\text{Cr}$, then constraining the origin and/or processes that lead to Ge isotopic signatures in the Solar System.

Planetary mantles, except the Moon, have Ge isotopic compositions that are lighter than the iron meteorites, thus confirming the positive $\Delta^{74}\text{Ge}_{\text{metal/silicate}}$ during core formation [2]. In addition, distinct Ge isotopic signatures are recorded: Mars has $\delta^{74}\text{Ge}$ values that overlap terrestrial mantle and crustal values, and reveals a dichotomy between shergottites with higher $\delta^{74}\text{Ge}$, lower Ge contents ($+0.84\%$, 0.73 ppm) than nakhlites ($+0.35\%$, 2.2 ppm), thus emphasizing degazing processes [6]. The highly depleted HED and lunar samples (Ge = <0.03 to 0.17 ppm ; 0.2 ppm , respectively) have higher $\delta^{74}\text{Ge}$ values than the Earth: the $\delta^{74}\text{Ge}$ of $+1.07\%$ of the non-brecciated HED samples would be consistent with evaporation during intense impact activity identified on Vesta, and the highest $\delta^{74}\text{Ge} = +1.74\%$ of the lunar sample could also include volatile loss during Moon formation.

Figure: Variations in Ge isotopic compositions versus matrix fraction and Oxygen isotope anomalies in chondrites (from [3,5]).

All these data show that Ge isotopic compositions of CC are either lighter or heavier than planetary mantles, and emphasize that there is no unique chondritic Ge isotopic signature to establish the isotopic budget of planetary reservoirs.

References: [1] Luais B. (2007) *Earth and Planetary Science Letters* 262:21-36. [2] Luais B. (2012) *Chemical Geology* 334:295-311. [3] Florin G. et al. (2020) *Geochimica Cosmochimica Acta* 269: 270-291. [4] Warren P. (2011) *Earth and Planetary Science Letters* 311: 93-100. [5] Clayton and Mayeda (1999) *Geochimica Cosmochimica Acta* 63: 2089-2104. [6] Humayun M. et al. (2016) *LPS XLVII*, Abstract#2459.