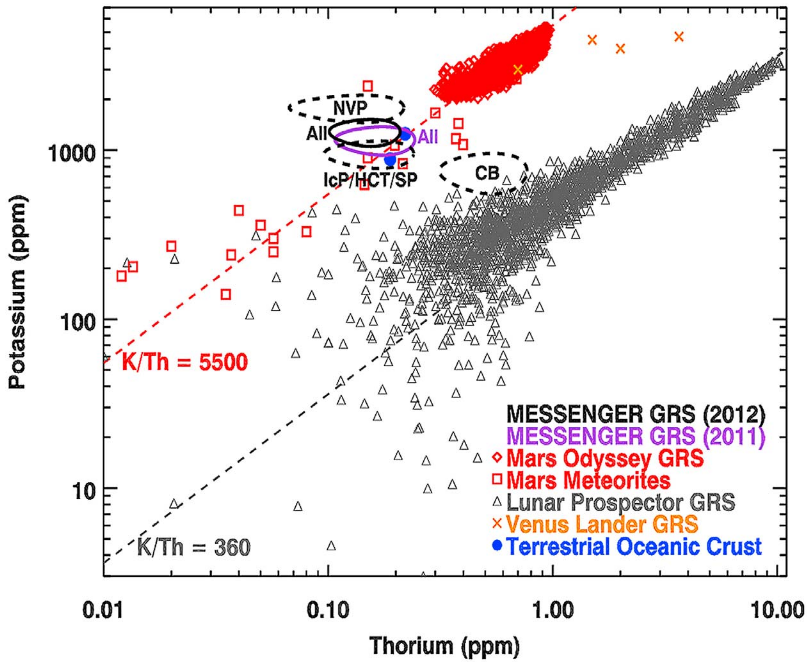

Figure 9. K abundances plotted against Th abundances for Mercury [*Peplowski et al.*, 2011b], the Moon [*Prettyman et al.*, 2006], Mars [*Taylor et al.*, 2006], Venus [*Surkov et al.*, 1987], and Earth [*Lodders and Fegley*, 1998]. Measurements of spatially resolved abundances of K and Th corresponding to GRS data collected when the spacecraft sub-nadir point was within the boundaries of the northern volcanic plains (NVP), Caloris basin (CB), and regions outside of the NVP and CB (denoted IcP/HCT/SP, see Table 4) are also included and suggest the possibility of variations in K/Th over the surface of Mercury (see Table 4). The ellipses for K and Th abundances on Mercury represent the one-standard-deviation statistical and systematic errors of the measurements. Values originate from both orbital gamma-ray spectroscopy (GRS) and laboratory measurements (see legend). Lines of constant K/Th for the Moon and Mars are shown for comparison. The K/Th value for Mercury is found to be consistent with that of Mars and an order of magnitude larger than for the volatile-depleted Moon, suggesting that Mercury is not depleted in volatiles. The absolute abundances agree with the values from Martian meteorites and terrestrial oceanic basalts, both of which represent products of partial melting of mantle material depleted in incompatible elements from volatile-rich planets.

partial melting, as both concentrate in the melt phases; and the K/Th ratio in volcanic material tends to reflect the ratio in the mantle source region of those magmas.

[33] Abundances of K (1150 ± 220 ppm) and Th (175 ± 68 ppb; see section 4.4), along with the K/Th ratio (6600 ± 2800; see section 4.4) for Mercury were reported by *Peplowski et al.* [2011b] as globally averaged values for all regions northward of 20°S. These values are consistent with the northern-hemisphere average K and Th abundances obtained in this analysis (Table 4). A comparison of the K and Th abundances for Mercury to those for the Moon, Mars, Venus, and Earth is shown in Figure 9. The agreement between the Mercury northern-hemisphere averaged K/Th ratio to that of Mars (K/Th ~ 5500), which is an order of magnitude larger than the volatile-depleted Moon (K/Th ~ 360), were found to be inconsistent with the predictions of most of the pre-MESSENGER formation theories for Mercury [e.g., *Taylor and Scott*, 2003] that called for extreme heating of the planet or its precursor materials [*Peplowski et al.*, 2011b]. *McCubbin et al.* [2012] have questioned the inference of a volatile-rich Mercury from the K/Th ratio, but this conclusion was supported by the discovery of higher than expected abundances of the volatile element S by the MESSENGER XRS [*Nittler et al.*, 2011] and the geologic evidence for recent volatile-related activity on the surface [*Blewett et al.*, 2011]. Additional evidence is found in the high Na abundance presented in a companion paper by Evans et al. (submitted, 2012).

[34] The regional K and Th abundances (Table 4) derived in this work are also included in Figure 9 for the purpose of characterizing the behavior of the K/Th ratio over the surface. The ratio for each region is distinct from the others at the one-standard-deviation level. These differences raise the possibility that the K/Th ratio is not constant over Mercury's surface, in contrast to the general situation on the Moon and Mars (see section 5.3). Alternatively, a secondary process may have modified the abundance of one or both of these elements at Mercury's surface (see section 5.4).

5.3. The K/Th Ratio at Low Th Abundances

[35] Following *Peplowski et al.* [2011b], we compare in Figure 9 MESSENGER GRS measurements of the K and Th abundances on Mercury to orbital gamma-ray measurements of the surfaces of the Moon and Mars. These orbital gamma-ray spectrometer measurements, and the derived K/Th ratios, are biased toward regions with higher abundances of these