Supplementary Information for

Lunar primitive mantle olivine returned by Chang'e-6

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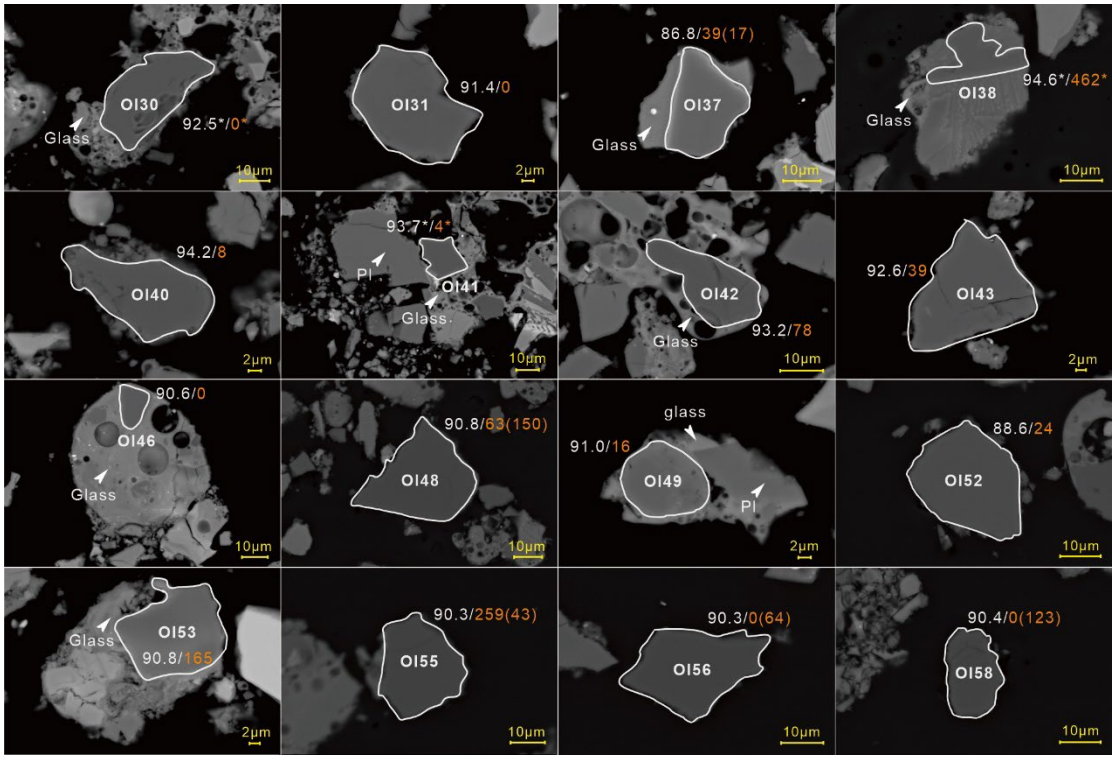
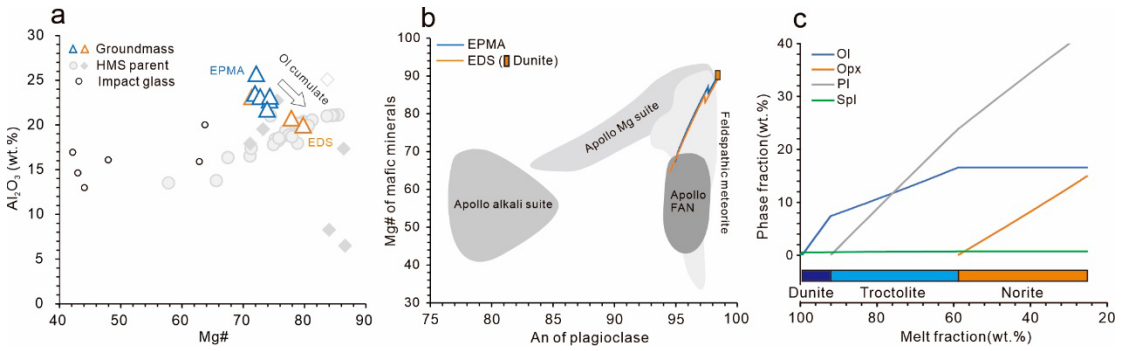
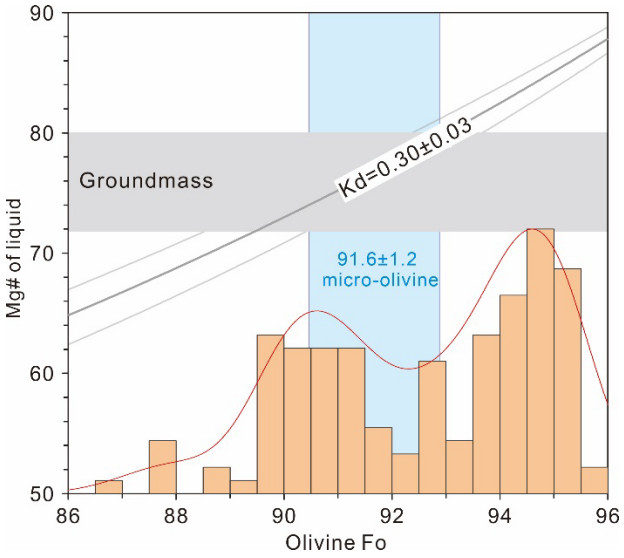


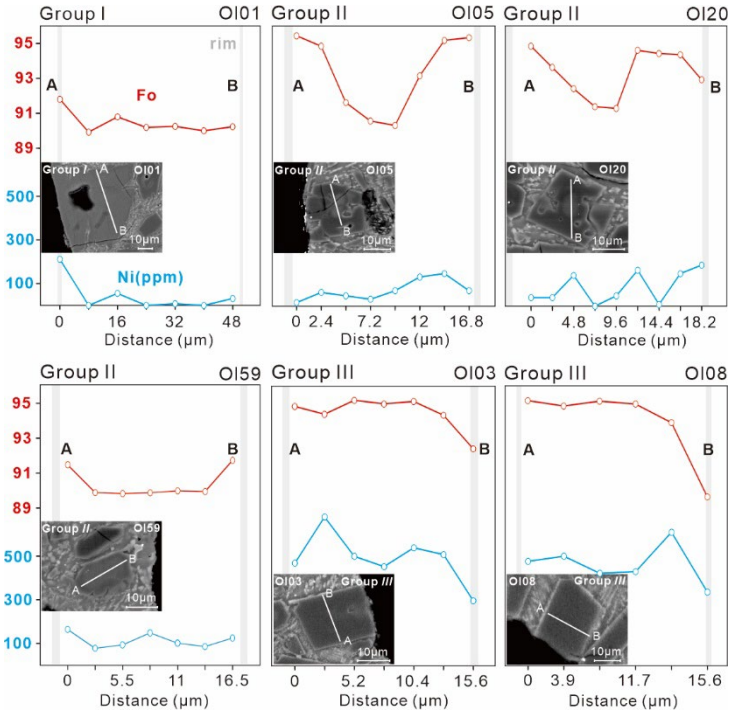
Supplementary Fig. 1. Representative backscattered electron (BSE) images of the CE-6 olivine fragments. Pl, plagioclase. Numbers are the Fo values (white) and Ni contents (orange) of olivines (* stands for average values from multiple analyses on a single olivine grain). LA-ICPMS data are shown in parentheses if analyzed.



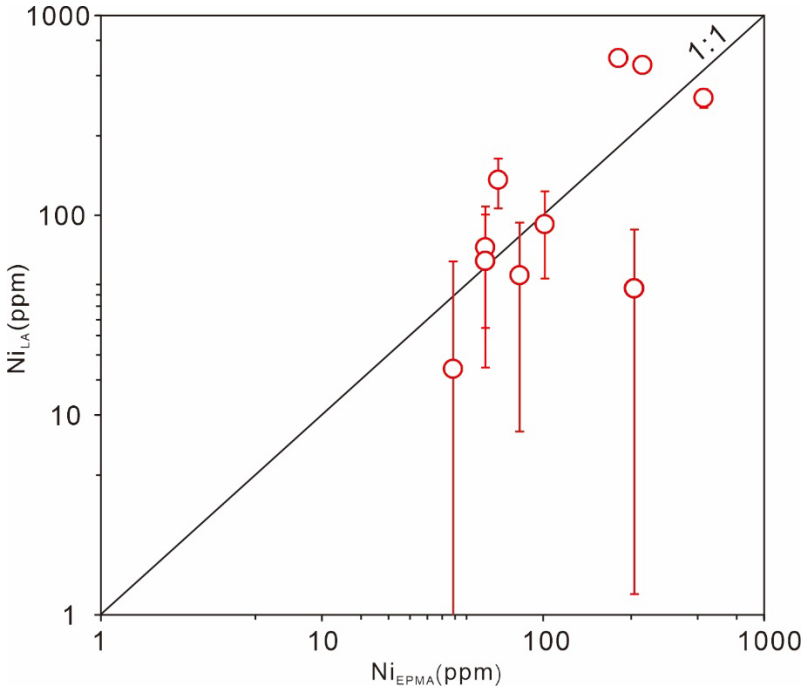
Supplementary Fig. 2. Geochemistry of the groundmass. **(a)** Compositions of the troctolitic groundmass determined by electron microprobe (EPMA, blue triangles) and energy dispersive spectroscopy (EDS, orange triangles) analyses compared to the parental liquid of lunar high Mg suite (HMS) by experiments [1](solid circles) and modeling[2-5] (diamonds). Also shown are compositions of impact glasses adjacent to single olivine fragments in the CE-6 soils (unfilled circles). **(b)** An-Mg# plot showing the crystal fractionation of the average composition of groundmass by EPMA and EDS at 1 bar. The composition of dunite, produced before plagioclase crystallized in the case of groundmass by EDS is illustrated as an orange rectangle. Compositional fields for the Apollo samples and feldspathic meteorites are from ref. 6 and ref. 7 (after ref. 8) respectively. **(c)** Cumulate mineral proportions as a function of residual melt fraction produced by the crystal fractionation of the groundmass at 1bar. Rock types identified by mineral assemblages are shown beneath. Ol, olivine; Opx, orthopyroxene; Pl, plagioclase; Spl, spinel.



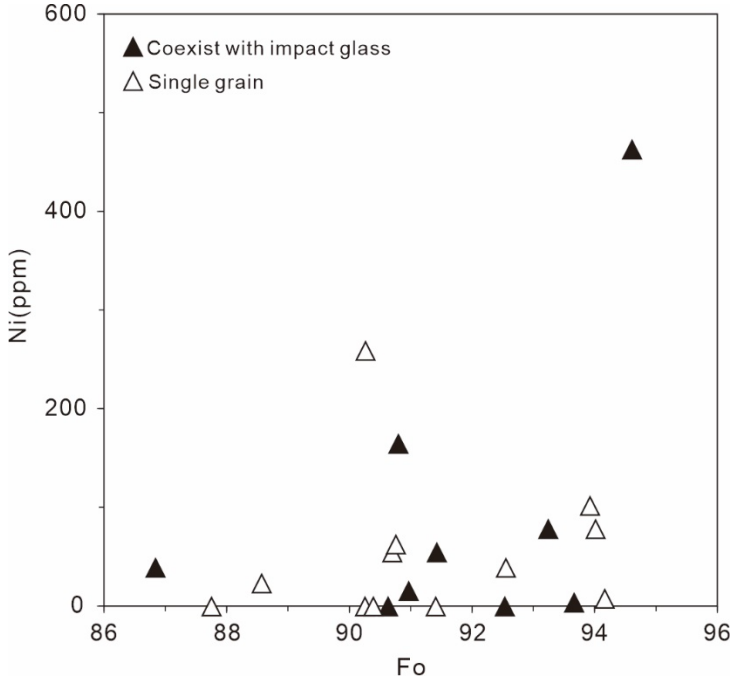
Supplementary Fig. 3. Calculated Mg# of liquid equilibrated with olivine grains in this study, using Kd= 0.30 ± 0.03 [9]. Fo content of olivine is shown as a histogram with a Kernel Smooth curve. Also shown are the compositional field of the groundmass (grey) and average composition of the micro-olivine (blue) in this study.



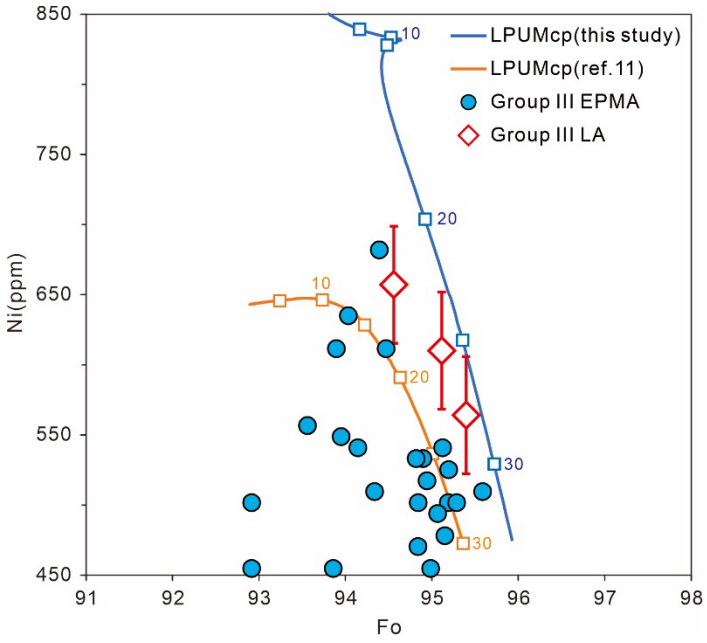
Supplementary Fig. 4. Detailed Electron probe traverses across different groups of olivine crystals in the lithic fragment. Note that the rim of olivine grain is too narrow for actual analyses (grey bars).



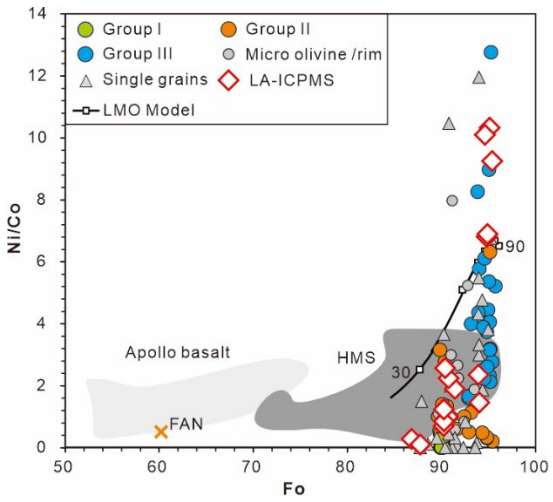
Supplementary Fig. 5. Comparison of Ni contents of CE-6 olivines analyzed by EPMA and LA-ICPMS. Error bars represent 2se of LA-ICPMS analysis.



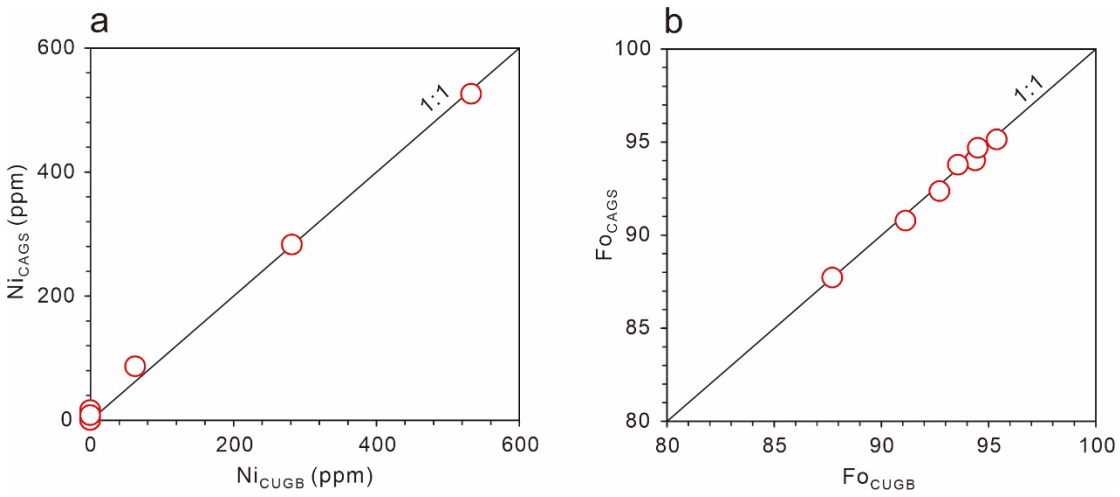
Supplementary Fig. 6. Fo versus Ni content of the single olivine fragments coexist with the impact glass (filled) compared with those do not (unfilled).



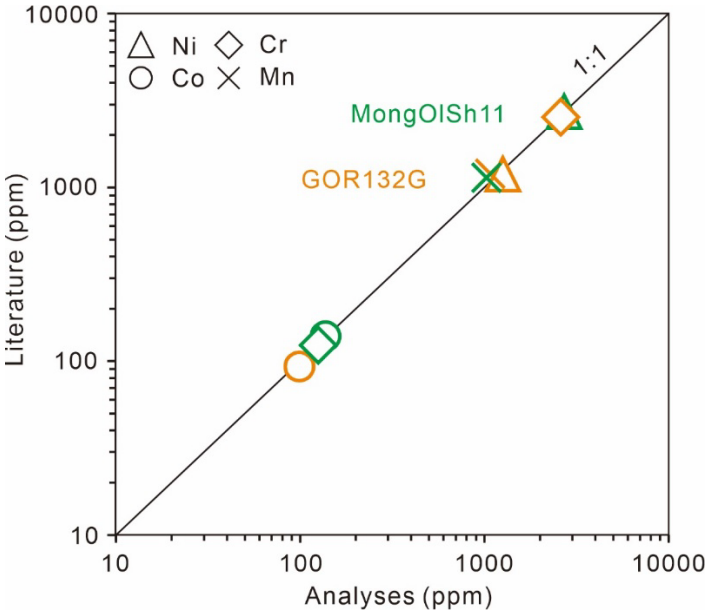
Supplementary Fig. 7. Thermodynamic modeling of Fo versus Ni content of olivine during equilibrium melting of the LMO cumulate pile (LPUMcp) at 50 PCS of the LMO with an initial composition of the LPUM[10] from this study (blue line) and ref. 11 (orange line). The squares stand for the melting degree (%). The EPMA/LA-ICPMS analyses of Group III olivines are shown as circles/ diamonds. Error bars represent 2se of LA-ICPMS analysis.



Supplementary Fig. 8. Ni/Co ratios versus Fo values of the CE-6 olivines. Olivines in lunar basalts[12], ferroan anorthosite[13] (FAN, cross) and Apollo Mg-suite rocks[13](HMS) are also shown for comparisons. The curves are modeled compositions of olivines crystallized from the LMO with an initial composition of the LPUM[10]. EPMA analyses of olivine grains in the particular lithic fragment are shown in circles and those of single olivine grains are shown in triangles. LA-ICPMS data are shown in diamonds. Modeled compositions of olivine crystallized from the LMO with an initial depth of 1000 km is shown in the solid line. The squares stand for the proportion of remaining LMO (30-90%). Modeling details are described in the Methods. Initial LMO composition: Ni = 415 ppm[14], Co =115 ppm[14].



Supplementary Fig. 9. Comparison of Fo values and Ni contents of a random set of olivines by EPMA at China University of Geosciences, Beijing (CUGB) versus at Chinese Academy of Geological Sciences (CAGS).



Supplementary Fig. 10. The accuracy of reference materials MongOlSh11-2 and GOR132-G in LA-ICPMS analysis. Data were calculated using ARM-1 as calibration material. The reference values of MongOlSh11-2 and GOR132-G are from ref. 15 and the GeoReM database (http://georem.mpch-mainz.gwdg.de/)[16,17], respectively.

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