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S1. Modal olivine abundances of diogenites

Most diogenites contain some olivine, usually <5 vol%[31], but some contain much more. Recognition that some diogenites are olivine-rich[32] ultimately led to subdivision of diogenites into three subclasses of increasing olivine content: orthopyroxenitic diogenites have <10 vol% olivine, harzburgitic diogenites have between 10 and 90 vol%, and dunitic diogenites have >90 vol% olivine[2,23]. Extended Data Table 1 gives the modal mineralogy for diogenites compiled from literature sources, and Extended Data Fig. 1 shows the proportions of orthopyroxene, olivine and high-Ca clinopyroxene for the meteorites. Most diogenites are orthopyroxenitic and are thought to be representative of the lower crust of Vesta. Relatively few are harzburgitic and only one dunitic diogenite has been well characterized. The modal mineralogy of available harzburgitic diogenites has been determined and an average olivine content for the subclass has been estimated[33]. Most olivine-bearing diogenites have very little olivine (few%) but the full range of olivine content is found up to dunites.

S2. Olivine detection by ground-based and space-based observations

The occurrence of olivine on Vesta was postulated using rotational spectral variations observed with ground-based telescopes[3] and two possible maps of the major lithological were derived. In both scenarios, the surface consists mainly of howardite or polymict eucrite with local regions of diogenite, olivine and possibly basaltic eucrite. The extent and locations of such areas vary for the two scenarios. Multispectral images obtained with Hubble Space Telescope (HST) have been used to derive surface compositional maps[4,5].The first maps[4] show a longitudinal variability, with one hemisphere more likely dominated by one pyroxene component, and the other being two pyroxenes or a mixture of pyroxene and olivine. The combination of ground based and HST results led to the conclusion of a hemisphere with a eucrite-like composition with spectra

dominated by a single pyroxene with a modest calcium component and the other hemisphere with the presence of a diogenite-like component and an olivine component. However, the presence of olivine was not confirmed by the first disk-resolved spectroscopic observations of an asteroid surface from the ground[36], that found Vesta's composition to be mostly compatible with howardite meteorites, although the presence of a small region of diogenite was suggested. The disk-resolved images of Vesta obtained with HST Wide Field Planetary Camera 2 (WFPC2) through four filters centered at 439 nm, 673 nm, 953 nm, and 1042 nm were used to construct surface albedo and color maps in a limited range of latitude[5].These maps show that overall the western hemisphere of Vesta is darker than the eastern hemisphere and dominated by more diogenitic minerals.

S3. Exogenic source

Delivery of olivine by impacts is unlikely for several reasons: first, the impactor is commonly completely disaggregated in hypervelocity impacts, and it is well mixed with the much larger volume of target material excavated by the impact. In this respect, a low impact velocity - possible among main belt asteroids- may help preserve impactor materials. But even so, for the average impact angle of 45°, the surviving material is mostly expected to be found within the rim of the resulting crater[38], contrary to the observed olivine-rich terrains on Vesta. In addition, olivine-rich materials have not been detected on other asteroids visited by spacecraft. Furthermore, Olivine-rich bodies (also called A-types) are rare[25,37] among current main belt asteroids and is unlikely that the observed olivine-rich materials on Vesta may have been delivered by an A-type impactor.

Moreover, the study of olivine grains in impact melt breccia clasts and the calculated bulk compositions of the impact melts of the paired PCA 02 howardites indicate that the target rock was likely olivine-rich, i.e. dunitic or harzburgitic diogenites[22] . The occurrences of plagioclase with relatively Fe-rich pyroxene and olivine in the melt matrices of PCA 02 impact melt breccia clasts suggest that the target rock also contained a eucritic component, that was mixed with dunitic or

harzburgitic diogenites in the impact melting process. Although these howardites sample only one location on Vesta, they do demonstrate that olivine was present in the near-surface environment. Furthermore, these impact melts are non-uniform in composition, implying that they formed in separate, small impact events[22]. Impact melt generated from a large impact event, such as the Rheasilvia basin, would crystallize from a melt sheet, and thus would be close to uniform in composition.

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