Appendix A1: Description of the localities and samples included in this study.

This study investigates olivine grains from komatiites that represent a wide range of cratons (i.e. Yilgarn, Kapvaal, Zimbabwe and Superior), ages (i.e. 2.69, 2.72, 3.26, 3.48 Ga), geochemical affinities (i.e. Al-depleted (Barberton-type) and Al-undepleted (Munro-type)), and degrees of metamorphism (i.e., prehnite-pumpellyite to amphibolite facies). The key characteristics of each locality are summarized in Table 1 of the main text.

Barberton Greenstone Belt / Kapvaal Craton

The Barberton greenstone belt in the Kapvaal Craton, South Africa, is the type locality for komatiitic rocks (Viljoen and Viljoen, 1969). Three main units are distinguished, i.e. the mostly volcanic Onverwacht Group, and the overlying, mostly sedimentary, Fig Tree and Moodies Groups (Lowe and Byerly, 1999; Lowe and Byerly, 2007). This study includes samples from the Komati and Weltevreden Formations, both situated within the Onverwacht Group.

The 3.48 Ga Komati Formation consists of a succession of komatiites, komatiitic basalts and tholeiitic basalts (Armstrong et al., 1990; Dann, 2000; Viljoen et al., 1983). It is subdivided into the 1.8-km-thick, primarily komatiitic, Lower Komati Formation, and the 1.3-km-thick Upper Komati Formation, which is mostly composed of komatiitic basalts. Five samples from a 120-m-thick sequence of differentiated komatiite flows from the Lower Komati Formation were investigated. These are the same samples previously described by Puchtel et al. (Puchtel et al., 2013) who investigated the bulk rock lithophile isotope and trace element systematics of these flows. Every analyzed sample represents a different Barberton-type (Al-depleted) komatiite flow, with flow thicknesses between <1 and >10m; all samples are from the olivine cumulate portions of the respective flows and have undergone greenschist facies metamorphism.

The 3.3 Ga Weltevreden Formation is a several km thick sequence of komatiites, komatiitic basalts, tuffs and ultramafic intrusions (Connolly et al., 2011; Lowe and Byerly, 1999). This study includes two samples from a differentiated, 65-m-thick, komatiite flow in the Pioneer Complex within the Weltevreden Formation (Connolly et al., 2011; Kareem, 2005; Stiegler et al., 2012). As discussed in the main text, the studied Weltevreden komatiites are considered Al-undepleted and have undergone lower greenschist facies metamorphism (Kareem, 2005; Puchtel et al., 2013; Stiegler et al., 2012)

Belingwe greenstone belt / Zimbabwe Craton

The Belingwe greenstone belt is located in the southern part of the Zimbabwe Craton and is divided into the 2.9 Ga old lower Mtshingwe Group and the upper 2.7 Ga old Ngezi Group (Nisbet et al., 1987; Nisbet et al., 1977; Wilson et al., 1995). The Ngezi group, which is part of this study, is an up to 8-km-thick volcanic and sedimentary sequence that can be subdivided from bottom to top into the sedimentary rocks of the Manjeri formation (< 100 m), mafic and ultramafic rocks of the Reliance formation (~ 1 km), dominantly basaltic rocks of the Zeederbergs Formation (up to 5 km) and shallow water sedimentary rocks of the Cheshire formation (up 2 km (Bickle et al., 1975; Nisbet et al., 1977)). Komatiites in the Ngezi Group are restricted to the Reliance Formation (Nisbet et al., 1977); one sample was studied from the olivine cumulate zone of Tony’s Flow, a remarkably fresh 10-m-thick, Munro-type (Al-undepleted) komatiite lava flow that occurs in the central portion of the Reliance Formation and contains abundant fresh olivine (Nisbet et al., 1987; Renner et al., 1994). The analyzed olivines are from the same sample previously discussed by Puchtel et al. (Puchtel et al., 2009), who studied the bulk-rock Pt–Re–Os and Sm–Nd isotope and highly siderophile element and rare earth element abundances of Tony’s Flow.

Abitibi Greenstone belt / Superior Craton

The 2.7 Ga old Abitibi Greenstone Belt in Ontario/Quebec, Canada, is located in the south-eastern part of the Superior Craton and comprises a range of komatiitic to felsic volcanic and sedimentary rocks, and mafic/ultramafic and granitic intrusions (Jackson and Cruden, 1995; Pearson and Daigneault, 2009; Wyman and Kerrich, 2009). One sample was investigated from the Alexo area near the Alexo Ni-Cu-(PGE) mine in Dundonald Township. The sample was taken from drill core ALX-49-98 (Puchtel et al., 2004), which intersects a series of 5- to 18-m-thick, differentiated komatiite flows that are intercalated with thin sedimentary layers. The sample (ALX-19) is from the olivine cumulate portion of a ~18-m-thick, Munro-type (Al-undepleted) komatiite flow that has undergone prehnite-pumpellyite facies metamorphism (Jolly, 1982). The lithophile trace element and HSE abundances of sample ALX-19 have previously been analyzed by Puchtel et al. (Puchtel et al., 2004).

Eastern Goldfields Superterrane / Yilgarn Craton

The Eastern Goldfields Superterrane (EGST) is located in the eastern part of the Yilgarn Craton in Western Australia. Sampling focused on the Agnew-Wiluna Domain (informally also referred to as the Agnew-Wiluna belt) that forms the northern third of the Kalgoorlie Terrane and contains some of the world's largest komatiite hosted Ni-Cu-(PGE) sulfide deposits (Barnes, 2006; Hronsky and Schodde, 2006). The Agnew-Wiluna Domain comprises a sequence of felsic-to-intermediate volcanic and volcaniclastic rocks, sulfidic cherts and carbonaceous shales with komatiites and komatiitic basalts (Hill et al., 1995; Kositcin et al., 2008). This study includes a series of 2.7 Ga old, Munro-type (Al-undepleted) komatiites from the localities of Betheno, Mount Clifford, Perseverance, and The Horn in the Agnew-Wiluna Domain. In addition, two samples were studied from the Murphy Well komatiite flow, which is located in the southern half of the Eastern Goldfields Superterrane.

Betheno is an approximately 500 m thick meso-adcumulate dunite body that occurs in a sequence of metabasalts and dacites or dacitic volcanisclastic sediments (Barnes et al., 2011). Seven samples were taken from a diamond drill core (MKT-528) that intersects the central portion of the dunite and hosts disseminated nickel-sulfide mineralization. Olivine grains are abundant in all samples and only weakly serpentinized, despite the fact that the Betheno dunite has undergone greenschist-to-amphibolite facies metamorphism (Barnes et al., 2011; Locmelis et al., 2013).

At Mount Clifford, finely disseminated sulfides exist throughout a 1000-m-thick adcumulate dunite body. The base of the dunite body is marked by a chilled margin in contact with a chloritic metasedimentary rock that overlies a tholeiitic footwall. The dunite is overlain by a series of olivine orthocumulates, pyroxenites and gabbros (Donaldson et al., 1986). The Mount Clifford dunite reached sulfide-saturation in an early stage of the emplacement, but most sulfides have been redissolved by a later batch of a sulfide-undersaturated magma (Locmelis et al., 2009). The dunite has undergone extensive greenschist-to-amphibolite facies metamorphism and olivine is generally completely replaced by olivine. Therefore, sampling was restricted to one, only moderately serpentinized sample that contains relict olivine grains large enough to obtain data for this study.

Perseverance is a large, up to 2-km-thick near-pure olivine adcumulate dunite body (Barnes et al., 1988; Duuring et al., 2010). Stratigraphically, the dunite body overlies a sequence of porphyritic felsic volcanics, tuffs, schists and komatiites, whereas the top is marked by a series of komatiites, high-Mg basalts and metasediments (Barnes et al., 1988). Four chromite-free, olivine adcumulate samples were taken from a drill core that intersects the central portion of the dunite (drill core LSD-896). Although the Perseverance dunite has undergone extensive amphibolite facies metamorphism, coarse grained, adcumulate textured olivine grains up to 2 cm in size are well preserved in all samples.

The Horn contains massive nickel-sulfide mineralization at the base of a cumulate-rich unit, probably a layered komatiite flow within a heavily deformed and faulted sequence of komatiites and basalts (Locmelis, 2010; Locmelis et al., 2013). Three samples were taken from an olivine meso-to-adcumulate unit that was intersected by drill core LWDD-794. The rocks have undergone greenschist-to-amphibolite facies metamorphism; however, olivine grains in the three analyzed samples are remarkably fresh with abundant meso-to-adcumulate textured olivine up to 1 cm in size.

Murphy Well is a 160-m-thick layered komatiite flow of a notably homogenous bulk-rock composition that does not contain any sulfide mineralization (Locmelis et al., 2013; Siégel et al., 2014). A characteristic feature of this flow is the occurrence of unusual dendritic olivine textures in the uppermost 20 m. The Murphy Well komatiite has undergone extensive greenschist facies metamorphism, resulting in the near complete replacement of olivine by serpentine, although the primary cumulus and dendritic textures are well preserved. Two samples from an exposed outcrop (MW-2303-3 and MW-2303-8 (Locmelis et al., 2013)) contained relict olivine grains that were investigated in this study.

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