Solid Earth Discuss., 5, C1041–C1045, 2014
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Solid Earth
Discussions
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Interactive comment on "The morphology and surface features of olivine in kimberlite lava: implications for ascent and emplacement mechanisms" *by* T. J. Jones et al.

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Received and published: 20 February 2014

The aim of the project described in this manuscript was to study the surface features of olivine grains in order to gain a better understanding of how kimberlites were emplaced. A combination of optical and laser microscopy and SEM imagery reveals differences between the surfaces of kimberlitic olivines and those of reference samples from a basanite lava and a peridotite xenolith. These features are attributed to two processes that acted during the transport of the olivines in the kimberlite: 1) "penetrative flaking from micro-tensile failure induced by rapid decompression" and 2) abrasion during transport. In terms of its relatively restricted aims and methods, the study is a success it that it demonstrates the rounded form of olivine grains in many kimberlites is due to a combination of the two processes, with erosion predominating. However, had the approach been more general, and had the authors made better use of recent literature, the project could have been far more fruitful. It would have been greatly improved by the incorporation of information about the compositions of the olivines. A one-day session on a microprobe would have been extremely instructive; for example, it would have allowed the authors to provide more quantitative information than "(the composition of the IHV olivine crystal is) . . . close to the forsterite end member of the olivine solid solution". Microprobe analyses would probably have revealed the presence of rims of Fe-rich olivine that crystallized from the kimberlite magma, as recognized by Brett et al. (2008), Kamenetsky et al. (2008), Arndt et al. (2010) and Pilbeam et al. (2013). In a recent paper, we illustrated and described morphological and chemical features that provide very useful information about the way olivine behaves during its transport in kimberlites (Arndt et al. 2010). Deformation structures and grain boundaries within multigrain olivine "nodules" or "ellipsoids" reveal the following features: that the material entrained into the kimberlite was dunite, not peridotite; that euhedral grains (tablets) within these dunite xenoliths recrystallized during ascent of the kimberlite; that Fe-rich olivine rims crystallized from kimberlite magma during ascent; and that the rounded borders of the ellipsoids cut indiscriminately across all these olivine morphologies. Key observations such as the partial removal of both the kimberlite-derived rims and the margins of olivine tablets indicate clearly that abrasion was the main mechanism that produced the rounded shapes. This conclusion agrees with that of the authors of the present manuscript. If an inspection of the outer surfaces of Fe-rich rims showed textures indicative of abrasion, this would clearly rule out chemical abrasion because the olivine of the rims was clearly in equilibrium with the kimberlite. As anonymous reviewer #1 points out, the proportions of minerals observed in kimberlites are not easily reconciled with the hypothesis that the olivine grains were derived from four-phase peridotite: relicts of opx, cpx or gt are rare to absent in kimberlites. Arndt et al (2010) argued that these phases were removed during metasomatism in the lithosphere, and that the entrainment of xenoliths of dunite, not peridotite, explains the abundance of olivine and the absence of the other minerals in most kimberlites. The authors could make a very useful contribution if they addressed directly the question of how opx, cpx or gt could be removed during transport in kimberlite. These minerals make up about 50% of normal mantle peridotite – if they were removed during transport, how did the remaining olivine grains aggregate to form the large and commonly multigrain ellipsoids observed in kimberlites worldwide? It would be very interesting to see a quantitative comparison of grainsize in peridotite xenoliths, where the olivine grains are rarely larger than 4 mm, with the seemingly larger grains illustrated in Figs 1 and 2.

Some other aspects of the manuscript warrant discussion: Page 2285, line 1: the degree of alteration can be independent of age: the Proterozoic Kangamuit (Majuagaa) kimberlite is as well preserved as the 10 ka Igwisi Hills kimberlite.

Page 2287, line 25: the subgrains illustrated in Fig 2c are rather like the recrystallized grains described by Arndt et al. It is not clear what is meant by the phrase "The peripheral olivine grains are randomly oriented but still retain the overall rounded shape, suggesting that recrystallization post-dates and conforms to the rounded structure". A simple explanation of these textures is that abrasion has removed the outer portions of both lithosphere-derived and recrystallized olivine grains.

Page 2289. It is surprising that no mention is made here of the work of Holden et al (2008). As reviewer #1 points out, the conclusion that the grains are very well sorted is surprising. First, the sorting coefficient is in fact rather large; second, the results have been biased by the exclusion of smaller grains by the manual method that was used to outline grain boundaries. Why wasn't an automatic image analysis technique like that of Holden et al used?

Page 2291. The quality of Figure 6c is not high enough to observe that the layering exists below the surface. It is not clear why the hemispherical structures are ascribed to impact. They are very small (<50 microns) and it is not evident that such structures would result from impacts of mm-sized olivine grains. In this context it would be interesting to see a more detailed exploration of erosion mechanisms and intensities in the kimberlite system where olivine grains are transported within a relatively viscous fluid. Some information might come from comparison with better-understood situations such as abrasion of cobbles or sand in fluvial or eolian settings. Intuitively it would seem that inertial forces of mm-sized olivine grains within a silicate liquid would be small and that abrasion would occur mainly in zones of shearing where olivine grains were brought into contact by differential movement of the fluid. Do such zones exist in the kimberlite conduits?

Page 2292. Do data exist to show that the flakes have the same "chemistry" as the surrounding fresh olivine?

Page 2293. It would be interesting to try to relate the theory of decompression-related flaking at the surface of olivine grains with the reworking of peridotite (removal of px and garnet, aggregation of olivine grains) that is assumed to take place during transport to the surface.

Page 2294. The discussion of abrasion is very qualitative. More explanation is needed to explain how the figure of 25-45% volume loss was obtained. Comparison to erosion in fluvial systems would be interesting in this context. The experiments in which the surfaces were etched with HF seem to provide only a very crude approximation of reaction of olivine with silicate liquid. Other observations argue far more strongly for mechanical abrasion.

Page 2296. What is meant by the phrase "decompression makes the olivine more susceptible for abrasion"? More susceptible than what? The key observation is that olivine is far more abundant in kimberlites that might be expected if the source was mantle peridotite. A mechanism must be sought to explain the persistence of olivine in a system in which other minerals are supposed to be selectively removed.

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Interactive comment on Solid Earth Discuss., 5, 2283, 2013.