Near-acoustic wave speed of diamond bearing eclogite extraction caused by buoyancy-driven crack propagation from the Earth's mantle to the surface

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Diamond-bearing eclogite xenoliths from the Kaapvaal craton formed 170–220 km deep in the Earth's mantle at high temperature and pressure conditions. Diamonds are metastable at surface conditions and the phase transition to the stable graphite is extremely slow at low temperatures, which makes diamonds an important mineralogical reference material. During their ascent from the Earth's mantle to the surface, diamonds are subjected to temperature and pressure conditions that would lead to graphitization within a couple of minutes to a few hours. Therefore, their existence at the Earth's surface implies that a fast extraction mechanism must take place, which allows the diamonds to cool down before the graphitization is complete. We proposed that a buoyancy-driven crack could be a possible high-speed extraction mechanism.

We have used ultra-high-resolution Fourier-transform infrared spectroscopy at the ANKA synchrotron to measure hydrogen diffusion profiles around totally embedded cracks in strongly chemically zoned garnet crystals from diamond-bearing eclogite xenoliths. Here, we show hydrogen diffusion profiles that are indicative of uplift velocities as high as 333 m/s. We compared these uplift velocities with several limit calculations based on the condition of viscous laminar flow, full conversion of gravitational potential, drag coefficient and resorption time of diamonds in the kimberlitic melt.

The concentration in LREE and HFSE strongly increase in the outermost rims of the investigated garnet crystals, especially around or on the totally embedded microcracks. The same feature can be seen in ^{18}O isotopes, which increase from core ($\delta^{18}O$ = 4.64) to the outermost rim ($\delta^{18}O$ = 6.10). The change in chemical composition from core to rim in the studied garnets is probably caused by a melt derived aqueous mantle fluid (metasomatism). This metasomatic event can also be seen in the formation of phlogopite rimming the investigated garnets. The inferred speed of up to 333 m/s of xenolith extraction shows that extreme mechanisms must exist, which potentially start as a melt filled buoyancy-driven crack in the asthenosphere. These cracks, accelerate during ascent through bubble feedback into its final explosive state. This challenges our understanding of the basic mechanisms that can generate deep and fast cracks within the Earth.