Volatiles in the kimberlite melt – What drives ascent and causes explosive eruption?

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Existing reconstructions of the kimberlite melt emphasise carbonate-bearing ultramafic compositions with significant amounts of dissolved volatiles CO_2 and H_2O (10-20 wt%). These volatiles are considered to be a major factor in reducing viscosity of the kimberlite melt, governing fast ascent from mantle depths. The exsolution of these volatiles from the melt during ascent and emplacement is viewed as being responsible for violent eruption of the magma and related brecciation of country rocks and the kimberlite itself. Magmatic volatiles and groundwaters have an unequivocal role in present models of kimberlite emplacement (fluidisation and phreatomagmatism, respectively).

Studies of the diamondiferous Udachnaya-East pipe (Siberia) kimberlites [1-3] show that neither of major magmatic volatiles in the form of degassing fluids was responsible for well-known 'explosivity' of kimberlites. Exceptionally fresh kimberlites from the Udachnaya-East pipe have low H_2O (<0.5 wt%), but high CO_2 (up to 14 wt%), Cl and alkalis. The carbonatite-chloride composition of the Udachnaya-East kimberlite [1, 2] and similar compositions in olivine-hosted melt inclusions in other kimberlites worldwide [4] strongly support the previously assumed low viscosity and density of kimberlite magmas. Massive degassing of H_2O and CO_2 is unlikely in the case of the Udachnaya-East kimberlite, because the melt is poor in H_2O, whereas CO_2 is bonded in the carbonatitic melt. After crystallisation of olivine the kimberlite melt evolves towards essentially dry carbonate-chloride compositions [3]. The gravitational separation of silicate solids within the kimberlite pipes drives light, low viscosity carbonate-chloride melt to the top. The hydrogen species, such as H_2 and CH_4, some of magmatic origin, but mostly produced by post-magmatic serpentinisation of olivine in the kimberlite, are the main cause of explosions. Detonation of these gases at near-surface levels of the pipe can result in brecciation and even evacuation of already solid kimberlite and country rocks.

[1] Kamenetsky *et al.* (2004) *Geology* **32**, 845–848.
[2] Kamenetsky *et al.* (2007) *Chem. Geol.* **237**, 384–400.
[3] Kamenetsky *et al.* (2008) *J.Petrol.* **49**, 823–839.
[4] Kamenetsky *et al.* (2009) *Lithos* **112S**, 334–346.

Real composition of the Earth's lower mantle

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Real composition of the Earth's lower mantle is based on a study of mineral inclusions in lower-mantle diamond from Brazil, Guinea, Canada and Australia. Three associations were established among them: juvenile ultramafic, analogues to eclogitic, and carbonatitic. The juvenile ultramafic association strongly predominates; it is composed of ferropericlase, MgSi-, CaSi- and CaTi-perovskites, stishovite, tetragonal almandine-pyrope phase (*TAPP*), and some others. The mineralogical composition of the lower mantle is now understood to be more complex than had been suggested in theoretic and experimental works. The frequencies of the lower mantle minerals for all areas are similar to each other, deviating from the average by only 10-15 %.

These figures differ drastically from the composition of the lower mantle as suggested from experimental data. In that the most common mineral is ferropericlase, which comprises 48.0-63.3 % (average 55.4 %) of all minerals in the lower mantle. This is in contrast to an abundance of ~ 18 % as suggested by experimental data, i.e. approximately three times higher. In contrast to ferropericlase, MgSi-perovskite comprises, in all studied regions, only 5.0-10.2 % (average 7.5 %), i.e. approximately ten times lower than has been suggested as an average composition in the lower mantle (~ 77 %); and its composition is more iron-rich ($mg = 0.36$-0.90) as compared to experimental and theoretical data. CaSi-perovskite, according to geological data, is more than twice as common compared to experimental data (10.0-14.3 % with an average of 12.0 % against ~ 5 %). The most important feature of the real composition of the lower mantle is a permanent presence, in all regions and areas, of free silica (as stishovite), in the lower mantle. Stishovite frequency, among the lower mantle minerals, is 2.1-15.0 % (average 8.4 %). The other minerals (CaTi-perovskite, *TAPP*, a phase with the composition of that of olivine, spinel, ilmenites, titanite, native nickel and iron, magnetite, and sulphides), have frequencies 0.1-4.3 % each. These discrepancies suggest that the composition of the lower mantle differs to that of the upper-mantle, and experiments based solely on 'pyrolitic' compositions are not, therefore, applicable to the lower mantle. These data indicate a probability of an alternative to the CI-chondrite model of the Earth's formation, for example, an enstatite-chondrite model.