9<sup>th</sup> International Kimberlite Conference Extended Abstract No. 9IKC-A-00155, 2008

# Hydrous Silicate Melts: A new Growth Medium for Diamond?

Andrew J Fagan & Robert W Luth

C.M. Scarfe Laboratory for Experimental Petrology, University of Alberta, Edmonton, Alberta, Canada

Natural peridotitic diamonds form in the 'diamond window', an area of the upper mantle bounded by temperatures of 1000-1400°C and pressures between 5 and 7 GPa. This study has experimentally tested and shown the viability of a hydrous, halidebearing silicate melt, as a possible diamond growth medium.

#### Diamond Formation Studies:

Many mechanisms have been suggested for diamond growth in the Earth's mantle, and despite much work in the last 40 years, this issue is still unresolved. Experimental petrology can help to determine the effect of different chemical constituents on diamond Many systems have growth. been investigated, including - carbonate, sulphide and silicate (Arima et al., 2002; Tomlinson et al., 2004; Gunn & Luth, 2006; Sokol & Pal'Yanov, 2008). We have conducted experiments in the system MgO-SiO<sub>2</sub>-C-H<sub>2</sub>O to test the efficacy of a hydrous silicate melt (HSM) in nucleating and growing diamond, in a C-saturated system. Natural diamonds have been found to contain alkali halides within their fluid inclusions (Klien-BenDavid et al., 2004); these trapped 'brine-like' mantle fluids have been cited as 'diamond forming fluids' (Klien-BenDavid et al., 2004). For this reason, we have evaluated the effect of alkali halides in catalysing diamond-forming reactions by investigating the addition of KCl and NaCl. Previous studies in carbonatebearing systems have concluded that alkali halides have a catalytic effect on diamond formation reactions; this study tests the extension of this proposal to silicate melts.

### This Study:

Experiments were conducted in sealed Pt capsules in a multi-anvil apparatus housed within the C.M. Scarfe Laboratory for Experimental Petrology at the University of Alberta. In these experiments, diamond was successfully grown on seed crystals at temperatures of 1400-1600°C and pressures of 6-7 GPa, over 4 hour durations. See Fig 1.



Fig 1: **Top**) SEM image of growth on experimental seed crystal. Run conditions 1500°C, 7GPa, and 4hrs. MgO-SiO<sub>2</sub>-H<sub>2</sub>O-C-KCl system - Alkali halide catalyzed. 10µm scalebar.

Middle) SEM image of diamond growth in SiO<sub>2</sub>-MgO-H<sub>2</sub>O-C system, without the addition of alkali halide catalysts. 1500°C, 7Gpa, 4hrs. Produces diamonds of vastly smaller diameter than seen above. 1µm scale bar.

**Bottom**) SEM image of diamond seed growth. Run conditions 1600°C, 7GPa, 4hrs. MgO-SiO<sub>2</sub>-H<sub>2</sub>O-, no additional catalyst included. 10μm scalebar.



## Results:

Complete spontaneous nucleation of diamond was not observed during the course Ρ of these experiments; however, the growth r e of single octahedral diamonds on the surfaces of the seeds was very prevalent. We u observed the beginning of diamond coats, <10µm thick, created by the amalgamation of numerous single octahedral crystals. The addition of KCl and KCl + NaCl, to the HSM system enabled diamond to form 200°C cooler than the previously published minimum experimental temperature (Sokol & We Pal'Yanov, 2008). observed that temperature is critical to the formation of diamond. We agree with other authors (Tomlinson et al., 2004) that the halide likely affects the diffusion rate of carbon, allowing diamond growth to proceed at a lower temperature. By lowering the pressure from 7GPa to 6GPa we observed no diamond growth, although no long duration runs (>24hrs) were conducted at this lower pressure. The HSM precipitated diamonds alongside stable solid enstatite and forsterite crystals in a simplified upper mantle assemblage. H<sub>2</sub>O plays an important role in the diamond forming reaction. The presence of a small volume of H<sub>2</sub>O lowered the silicate solidus and allowed melting to occur at lower temperatures. This is especially relevant for bounded by experiements the physical conditions within the diamond window.

KCl shows a clear effect on diamond growth. producing larger crystals at a lower temperature compared to an unfluxed system (fig 1). The NaCl system is different; in these experiments the diamond seed crystals show triangular etch pits, a common feature of resorbtion on natural stones and facets with small dissolution holes spread homogeneously over the surface of the seeds. Thus we suggest that NaCl is a possible diamond growth inhibitor within a silicate growth system.



Fig 3 – Pressure–Temperature diagram showing various experimental systems testing 'diamond growth'.

#### Implications:

Fig 3, above, shows the results of this experimental study compared to previous workers results. Only one other silicate system has been tested to date (Sokol & Pal'yanov, 2008), shown in blue, all others were conducted in carbonate systems. Purple crosses denote the various P-T conditions that were tested during this study but proved to be non-diamond producing. Purple diamonds shows where we achieved diamond growth and the red box represents the natural diamond formation window - the target P-T conditions for this study. Also shown is the simplified harzburgitic mantle assemblage Fo+En+H<sub>2</sub>O solidus, after Stalder et al., 2001. The introduction of the alkali halides can clearly been seen in Fig 3, where diamond was produced at the upper end of the diamond formation window. The first time this has occurred in a silicate system.

There are wider implications for diamond formation from halide-rich hydrous silicate melts. Experimental evidence shows that by partially melting carbonated harzburgite at high temperatures (1600°C), it is possible to precipitate diamond without the addition of any other elements. However, the presence of KCl will promote diamond growth at the reduced temperatures observed within the diamond formation window. The availability of the various components – alkali halides,



water and carbon at the correct P-T conditions would define regions in the mantle where it is possible to form diamond using a HSM. One of these places would be within a subduction zone. Alkali halides are observed as volatile phases deriving from the deep dehydration of serpentine and sedimentary units commonly associated with the subducting slab. These halide-rich phases would be ideal candidates as a 'trigger-fluid', lowering the silicate solidus and promoting partial melting of the overlying mantle wedge harzburgite, Within a carbonated wedge assemblage, the influx of a halide-HSM would begin the precipitation of diamond.

This experimental study demonstrates that hydrous silicate melts, especially containing alkali halides, are a viable medium for diamond growth in the Earth's upper mantle. We suggest that the mantle wedge above a subduction zone is the ideal locality within the diamond formation window where the necessary components used in this study are stable and can easily interact.

### References:

Arima, M., Y. Kozai, et al. (2002). "Diamond nucleation and growth by reduction of carbonate melts under high-pressure and hightemperature conditions." Geology **30**(8): 691-694.

Gunn, S & Luth. R.W, (2006). "Carbonate reduction by Fe-S-O melts at high pressure and high temperature." American Mineralogist **91**: 1110-1116.

Klein-BenDavid, O., E. S. Izraeli, et al. (2004). "Mantle Fluid evolution-a tale of one diamond." Lithos **77**: 243-253.

Sokol, A. G. and Y. N. Pal'yanov (2008). "Diamond Formation in the system MgO-SiO2-H2O-C at 7.5GPa and 1600 C." Contributions to Mineralogy and Petrology **155**(1).



Stalder, R., P. Ulmer, et al. (2001). "High Pressure fluids in the system MgO-SiO2-H2O under upper mantle conditions." Contributions to Mineralogy and Petrology **140**: 607-618.

Tomlinson, E., A. Jones, et al. (2004). "Highpressure experimental growth of diamond using C-K2CO3-KCl as an analogue for Clbearing carbonate fluid." Lithos **77**(1-4): 287-294.