MINERAL INCLUSIONS IN DIAMONDS FROM THE RIVER RANCH KIMBERLITE

Kopylova, M.G., Gurney, J.J., Daniels, L.R.M.[1]

Geological Department, University of Cape Town, Rondebosch, 7700, Cape Town, RSA
1. Auridium, PO Box 62, Harare, Zimbabwe

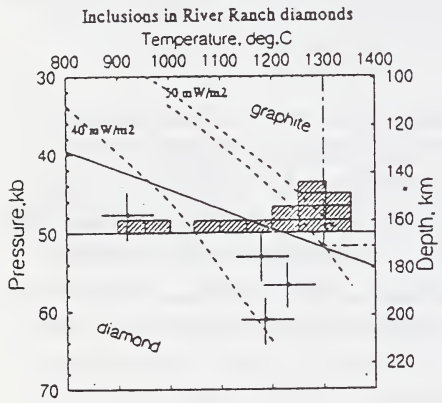
A suite of diamond inclusions from the River Ranch diamonds has been investigated. River Ranch is a newly discovered pipe in the Archean Limpopo Mobile Belt (LMB), north of the Kaapvaal craton. The River Ranch kimberlite may have been emplaced 530-540 Ma ago, simultaneously with the adjacent Venetia cluster of kimberlite pipes (Allsopp and Smith, in press).

Among 600 available diamonds (sieve class +6-9) with inclusions 99.7% are harzburgitic, containing olivine (Fo92-93), orthopyroxene (#Mg=93), G10 garnets and chromites. No clinopyroxenes were found. The rest 0.3% of the diamond population came from eclogitic paragenesis and contain orange garnets. Magnesio-wustite, pyrrhotite, pentlandite, a pure silica phase, amphibole, perovskite, Cr-Sr-loparite, Cr-chevkinite, iron hydroxide and serpentine inclusions we also found. Compositions of diamond inclusions differ from those for the River Ranch kimberlite, where higher proportion of garnets are lherzolitic G9 and spinels contain less Cr and more Al and Fe^{+3}.

Numerous diamonds with coexisting minerals in them made it possible to calculate temperatures, pressures and oxygen fugacities. Estimated values are the first for the mantle beneath the LMB. For plotting equilibrium conditions we used the MacGregor (MacGregor, 1974) barometer together with the Harley (1984) temperature estimates (Fig 1). Diamond inclusions from the River Ranch kimberlite equilibrated at temperatures of 1200-1350°C and pressures of 47-61 kb .The majority of the Ol-Gar temperature estimates (O'Neill and Wood, 1979) is substantially hotter than those for Finsch and Koffiefontein diamonds and compatible with those for Roberts Victor and for the Premier diatreme, varying between 1250° and 1400°C. Temperature estimates beneath the Limpopo Mobile Belt lie slightly below a 50 mW/m^2 geotherm (Fig. 1), whilst beneath the Kaapvaal craton they in general correspond to a 40 mW/m^2 geotherm; and beneath Proterozoic mobile belts to a 80 mW/m^2 geothermal gradient (de Wit, 1992). Temperatures of 1300°C are reached at the depth of 180 km within the Limpopo mobile belt, compared to 180-190 km beneath the Kaapvaal craton, and 150 km beneath western and southeastern mobile belts (Boyd and Gurney, 1986). Thus, the Limpopo Mobile Belt is hotter than some localities within the Kaapvaal craton and cooler than adjacent Proterozoic mobile belts with barren kimberlites.

Oxygen fugacities were calculated for olivine - spinel + orthopyroxene assemblages by two methods due to O'Neill and Wall (1987) and to Ballhaus et al, (1991). The River Ranch inclusions are all confined to a range of oxygen fugacities between WM and IW buffers according to O'Neill and Wall (1987) and between WM and QFM according to Ballhaus et al.,

(1991). All diamond inclusions from the Kaapvaal craton (Fig. 2) fit within narrow areas between corresponding buffers indicating that the Kaapvaal deep harzburgitic mantle as a whole was well-buffered and relatively homogeneous in f O_2 at the time of harzburgitic diamond formation. The O'Neill and Wall (1987) equation seemed to yield more realistic results than Ballhaus (1991). The O'Neill oxygen fugacities place our samples in the wustite stability field, which is true, since we have wustite as a diamond inclusion. The O'Neill, Wall (1987) estimates define the oxygen fugacities for the River Ranch mantle as lying well within a stability field for a pure carbon phase and equilibrated with reduced (H_2O-CH_4 mixture) fluids.



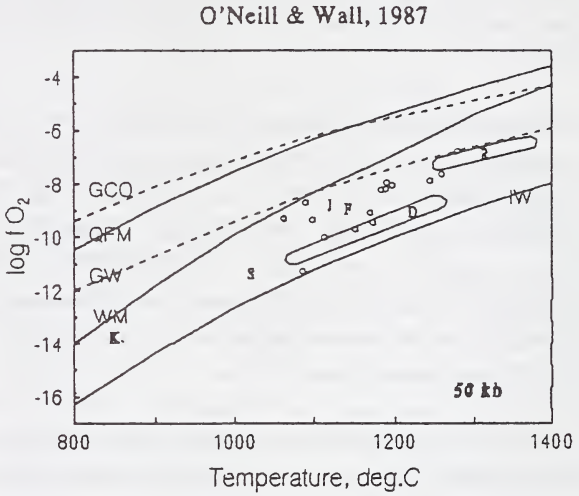


Figure captions:

Fig.1. Estimated equilibrium conditions (MacGregor, 1974; Harley, 1984) for the River Ranch diamond inclusions compared with the diamond - graphite equilibrium curve (Kennedy and Kennedy, 1976), a continental geotherm calculated for the heat flow of 40 mW/m^2, a geotherm for the heat flow of 50 mW/m^2 (Pollack, Chapman, 1977), and a geotherm which fits the River Ranch P-T values best. Shown also is a histogram for temperature (O'Neill, Wood, 1979) distribution at 50 kb.

Fig.2. Oxygen fugacities (O'Neill and Wall, 1987) recorded by harzburgite inclusions in the River Ranch diamonds plotted against temperature (O'Neill and Wall, 1987) at 50 kb. Letters indicate oxygen fugacities for diamond inclusions from other South African localities: K-Koffiefontein, S-Star, J-Jagersfontein, F-Finsch. Letters inside fields mark oxygen fugacities fields for Roberts Victor (R) and Dokolwayo (D) (Daniels and Gurney, 1991). Also shown is the position of some common oxygen buffers and the maximum mole water fraction (GW).

Mineral chemistry of the River Ranch harzburgitic mantle is identical to that of granular, low-temperature lithospheric garnet peridotites. Beneath the Limpopo Mobile Belt the River Ranch diamonds sample chemically depleted, thick, relatively cool lithosphere - absolutely identical to that beneath the Kaapvaal craton. In other words, the Kaapvaal "mantle root" stretches northward beneath the Limpopo Mobile Belt as well.

This fact can be explained with a help of recent tectonic and geophysical data. The data showed the LMB as a thin allochthon tectonic flake lying on totally alien mantle (de Wit et al., 1992, 1993). Thin crust here has been displaced from its original position many times. The Limpopo Mobile Belt is a superficial tectonic structure and is not rooted in mantle.

References:

Allsop, H.L., Smith, C.B. et al, (1995) The emplacement age and geochemical character of the Venetia kimberlite bodies, Limpopo belt, Northern Transvaal. South Afr J Geol, in press

Ballard, S., and Pollack, H.N.(1987) Diversion of heat by Archaean Cratons: a model from southern Africa. Earth Planet Sci Lett 85: 8-14

Ballhaus, C., and Berry, R.F. et al. (1991) High-pressure experimental calibration of the olivine-orthopyroxene-spinel oxygen geobarometer: implications for the oxidation state of the upper mantle. Conrib Mineral Petrol 107: 27-40.

Boyd, F.R., and Gurney, J.J. (1986) Diamonds and the African lithosphere. Science 32: 472-477

Daniels, L.R.M., and Gurney, J.J. (1991) Oxygen fugacity constraints on the southern African lithosphere. Contrib Mineral Petrol 108: 154-161

de Wit, M.J., and Roering, C. et al, (1992) Formation of an Archean continent. Nature 357: 553-562

de Wit, M.J., and Hart, R.A. (1993) Earth's earlest continental lithosphere, hydrothermal flux and crustal recycling. Lithos 30: 309-335

Harley, S.L. (1984) The solubility of alumina in orthopyroxene coexisting with garnet in FeO-MgO-Al_2O_3-SiO_2 and CaO-FeO-MgO-Al_2O_3-SiO_2. J Petrol 25: 697-712

Harley, S.L., and Green, D.H. (1982) Garnet-orthopyroxene barometry for granulites and peridotites. Nature 300: 697-701

MacGregor, I.D. (1974) The system MgO-Al_2O_3-SiO_2: solubility of Al2O3 in enstatite for spinel and garnet peridotite compositions. Amer Miner 59: 110-119

O'Neill, H.S.C., and Wall, V.J. (1987) The olivine-orthopyroxene-spinel oxygen geobarometer, the nickel precipitation curve, and the oxygen fugacity of the Earth's upper mantle. J.Petrol 28: 1169-1191

O'Neill, H.S.C., and Wood, B.J. (1979) An experimental study of Fe-Mg partitionong between garnet and olivine and its calibration as a geothermometer. Contr Miner Petrol 70: 59-70

Taylor, W.R., and Green, D.H. (1989) The role of reduced C-O-H fluids in mantle partial melting. In J. Ross, A.L. Jaques et al, Ed., Kimberlites and related rocks, vol 1: Their composition, occurence, origin and emplacement., p 1054-1062, GSA Spec. Publ., No 14, Blackwell Scientific Publications.