METASOMATIC REEQUILIBRATION OF MANTLE XENOLITHS FROM THE GIBEON KIMBERLITE PROVINCE (NAMIBIA)

Franz, L.[1], Brey, G.P.[2] and Okrusch, M.[3]

1. GeoForschungsZentrum Potsdam, Telegrafenberg, D-14473 Potsdam, FRG
2. Institut für Geochemie, J.W. Goethe Universität, Senckenberganlage 28, D-60054 Frankfurt, FRG
3. Mineralogisches Institut, Am Hubland, D-97074 Würzburg, FRG

The Gibeon Kimberlite Province of Southern Namibia comprises more than 90 kimberlite dykes and pipes, numerous associated carbonatites and the ultrabasic massif of the Blue Hills (Janse, 1964, 1971). The volcanism may have been triggered about 70 Ma ago by the socalled Vema hot spot, now active under the Atlantic ocean (Spriggs, 1988; Kurszlaukis, 1994). The diatremes are located within shales and quartzites of the Precambrian to Cambrian Nama Subgroup and are underlain by Proterozoic metamorphites of the Rehoboth Subprovince. The kimberlites of the Gibeon Province are non-diamondiferous which can be related to the "off-craton"-character of the area and its lower crustal thickness compared to the adjacent Kaapvaal Craton. We report here on results on peridotite xenoliths from the pipes Hanaus and Anis-Kubub and compare them with former results on peridotites from the Hanus pipe and the Louwrentsia pipe (Mitchell, 1984) as well as the Gibeon Townsland 1 pipe (Franz et al., 1995).

The Hanaus diatreme is a big polyintrusive kimberlite pipe which contains garnet-lherzolites and also garnet-spinel- and spinel-lherzolites. Most samples are intensly ("mosaic-porphyroclastic") or partly sheared ("porphyroclastic") and some are granular ("coarse equant", textural classification after Harte, 1977). PT-estimates using different thermobarometers mostly plot along an elevated geothermal gradient of about 50mW/m^2, similar to the findings for the Gibeon Townsland 1 pipe. All samples originate from the stability field of graphite with the deepest samples corresponding to PT-conditions of more than 1300°C and 45 kbar (Fig. 1). The coarse equant and the porphyroclastic nodules from Hanaus do not contain equilibrium assemblages since Al and Ca in Opx as well as Ca in Ol increase from the core to the rim, pointing towards transient heating in the upper mantle. The mosaic-porphyroclastic nodules lack any mineral zonation and yield consistent PT-estimates with different methods. This indicates complete reequilibration during ductile shearing in the mantle.

The small Anis-Kubub diatreme at the Northern border of the Province displays numerous crustal and mantle nodules. Except for one ilmenite-phlogopite-lherzolite, all mantle xenoliths are garnet-lherzolites with coarse equant and porphyroclastic textures while mosaic-porphyroclastic textures are rare.

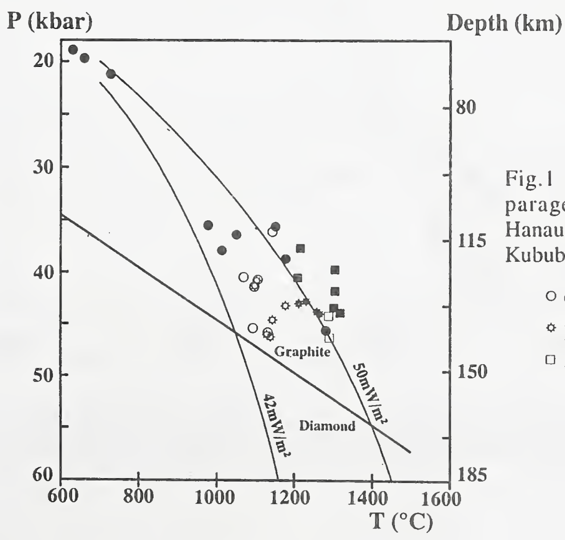

Fig.1 PT-estimates for the primary parageneses of the xenoliths from Hanaus pipe (filled symbols) and Anis Kubub pipe.

- ○ coarse equant
- ✲ porphyroclastic
- □ mosaic-porphyroclastic

Thermobarometry of the primary parageneses gives PT-estimates of 35-45 kbar at temperatures of 1050-1300°C (Fig. 1). This spans the range from a conductive geotherm of about 44 mW/m^2 (coarse equant) to an elevated gradient of up to 50 mW/m^2 (porphyroclastic and mosaic-porphyroclastic).The primary parageneses of the coarse equant and porphyroclastic xenoliths from Anis Kubub pipe show distinct zonation patterns: Similar to the Hanaus pipe, Ca as well as Al in Opx increase from core to rim. Garnets reveal increasing XMg values towards the rim and olivines display strong enrichment of Ca in the outer rim sections, a fact which is even observed within the mosaic-porphyroclastic xenoliths.

Beside mineral zonation, severe secondary alterations affected the primary parageneses of the Anis Kubub xenoliths: Garnets are mantled by phlogopite and/or coronas of spinel and secondary pyroxenes due to the reactions

2 Pyp + En + 4 H_2O + 2 K_2O (in fluid phase) <==> Phl,

Pyp + Fo <==> 2 En + Sp and

Pyp + Grs + 3 Fo <==> Di + Sp.

Melt pockets around garnet, which contain secondary pyroxenes and spinel point to a reaction of Pyp + Grs + Fo + fluid phase <==> Opx + Cpx + Sp + melt.

Fine, angular grains of secondary olivine with high Ca contents and felt-like aggregates of K-richterite as well as Mg-arfvedsonite developed at the expense of primary ortho- and clinopyroxene due to metasomatic overprint at high temperature by the reactions:

4 En + Di + H_2O +0.5 Na_2O + 0.5 K_2O (in fluid phase) <==> K-Ri + Fo and

10 En + Fs + H_2O + K_2O + 2 Na_2O (in fluid phase) + 0.5 O_2 <==> 2 Mg-Arf + 6 Fo.

A PT-estimate for this overprint can be performed using different calibrations of the two pyroxene thermometry (Brey and Köhler, 1990) on secondary pyroxenes within the coronas around garnet. The three calibrations (TBKN, TCaOpx and TNaOpx) point to temperatures of 1100-1250°C with their reaction curves intersecting at about 20 kbar (Fig. 2). Similar pressures are indicated by the spinel forming reactions calculated with the TWEEQ-programm of Berman (1991) and also by the Ca in Ol barometry of Köhler and Brey (1990; see Fig. 2). Judging from these data and from PT-estimates of lower crustal xenoliths (Rupprecht et al., 1995), this metasomatic overprint must have occured within a magma chamber located close to the boundary of upper mantle to lower crust.

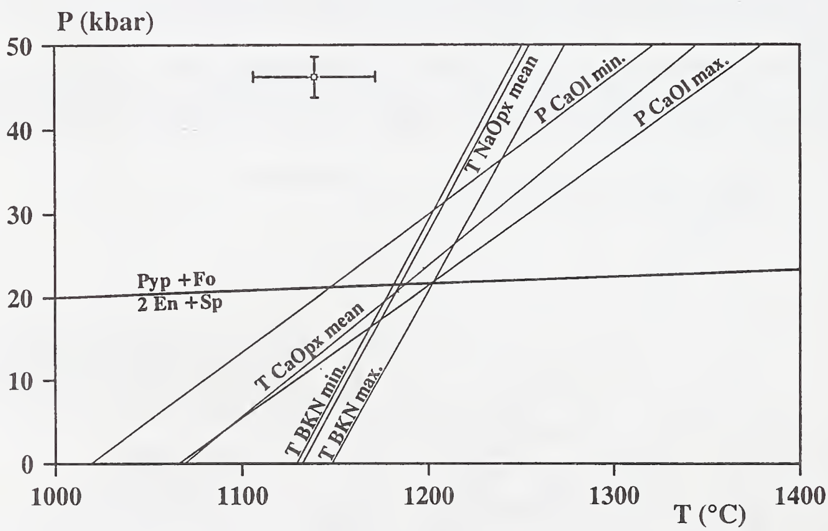

Fig. 2 PT-estimates for the metasomatic overprint of the Anis Kubub xenolith KAK31; the error bars indicate the PT-estimate for the primary paragenesis using the TBKN and PBKN calibrations of Brey and Köhler (1990).

Zonation of Ca in olivine is always present in the mantle xenoliths from Anis Kubub pipe and therefore, an estimate for the duration of the overprint can be performed using the diffusion rates for Ca in olivine of Jurewicz and Watson (1988) and the diffusion equation of Crank (1975). Assuming an fO_2 near the QFM buffer (10^{-8} atm), a diffusion along the C-axis of olivine and temperatures of 1150°C, the duration of the overprint would be 60 (±20) days.
As demonstrated above, the xenoliths of the Gibeon Kimberlite Province suffered a polyphase overprint in the upper mantle and - in case of the Anis Kubub pipe - in a magma chamber at the boundary of upper mantle to lower crust. The first thermal perturbation affected the xenoliths in situ, which is indicated by the isobaric heating processes. The fact, that a perfect thermobarometric reequilibration to the perturbed geothermal gradient of 50 mW/m^2 is only present within the intensly sheared mosaic-porphyroclastic xenoliths shows that heating was connected with a severe dynamic recrystallization. Such an anomalously high geothermal gradient is thermally instable and must have developed shortly before the eruption of the kimberlites because otherwise, retrograde zonation patterns of elements with high diffusion rates (e.g. Ca in olivine and orthopyroxene) would have developed during subsequent cooling. These observations are in accordance with our former results on mantle xenoliths from the Gibeon Townsland 1 pipe (Franz et al., 1995) and the data of Mitchell (1984) for the Hanaus and the Louwrentsia pipe.
The absence of diamonds in the Gibeon Kimberlite Province results from the shallow position of the asthenosphere in Southern Namibia as well as from the elevated geothermal gradient. A further reason for the lack of diamonds could be a thermal and metasomatic reequilibration of the kimberlite as well as its xenoliths within a deep-seated magma chamber as observed at the Anis Kubub pipe. An overprint in such a shallow level under elevated temperatures and high fluid activity would probably have oxidized any present diamonds within the kimberlite.

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