THE KUNDELUNGU KIMBERLITES (SHABA, ZAIRE) PETROLOGY AND GEOCHEMISTRY (TRACE ELEMENTS AND RADIOGENIC ISOTOPES) : A REVIEW

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Zaire has been one of the main diamond producers in the world since the beginning of this century. Diamonds are related to the Mbuji Mayi kimberlites of Kasai (first province), which intrude the Archean Congo Craton. The second kimberlite province of Zaire, occurring on the Kundelungu Plateau, has been poorly studied since the pioneering work of Verhoogen (1938) because it is very poor in diamond.

Twenty four pipes are known on the plateau, over on area of 4500 km^2. They are arranged along two N-S trending alignments, 14 rather clustered pipes in the Western group and 10 in the Eastern group. The kimberlites intrude a basement belonging to the south-western extension of the 1.9 Ga Bangweulu block. The intrusion age is not known: stratigraphically, the pipes are post-Kundelungu (Upper Precambrian) and pre-Miocene (Miocene sands contain the typical kimberlite minerals); they are possibly of Upper Cretaceous age as many African kimberlites, in particular the Mbuji Mayi kimberlites.
Ten pipes (5 from each group) have been recently studied in detail (Kampata PhD Thesis, 1993): most of them are made of rare, unaltered and unbrecciated fresh kimberlites.
The two groups are very similar in terms of petrography and mineralogy: the textures of the rocks are porphyritic with macrocrysts of olivine (Fo85-91), garnet, pyroxene and ilmenite in a dark, fine-grained matrix consisting of olivine, spinel, perovskite, serpentine and calcite. Following the classification of Clement and Skinner (1985), the rocks correspond to macrocrystic hypabyssal kimberlites. Monticellite occurs only in the western group; two different habits of monticellite of the same composition (Mo74-85 Ki11-79 Fo2-7; Kampata et al.,1994) characterize the Gwena pipe: small (5-10 µm) euhedral grains in the matrix and overgrowths (rims) over serpentinized olivine microphenocrysts.

The kimberlites contain ultramafic nodules (lherzolite, harzburgite, wehrlite and dunite) with granular texture; only one sheared lherzolite was found. Eclogite nodules are rare. P-T equilibrium conditions deduced from the mineral assemblages define a fairly large range, from 770 to 1100°C and from 28 to 51 kbars for the granular lherzolites. In a P-T diagram, these data plot along the Precambrian shield geotherm of Pollack and Chapman corresponding to a surface heat-flow of 40 mW/m^2 The sheared lherzolite

equilibrated at higher P-T conditions (1380° C, 61 kbars) distinctly above the geotherm.
The megacryst suite comprises: 1) olivine (Fo90-93); 2) Ca-rich (>4.5 wt % CaO) garnets, some rich (>2.5 %) and some poor in Cr_2O_3 (low-Ca garnets have never been found neither in the diamond-poor Kundelungu kimberlites nor in the diamond-rich Mbuji Mayi kimberlites); 3) two types of clinopyroxenes: a sub-calcic (Ca/Ca + Fe = 0.36-0.39) Cr-poor type and a calcic (Ca/Ca + Fe = 0.41-0.45) Cr-rich (1.5-2.7 % Cr_2O_3) type. Application of the 20 kbars pyroxene solvus of Lindsley and Dixon (1976) gives a wide range of crystallization temperature (1000-1450°C); 4) ilmenites plot along the magmatic Mg-enrichment trend of Haggerty et al. (1979); non-magnetic ilmenites are rich in the geikielite end-member (up to 60 mol% $MgTiO_3$); 5) orthopyroxenes (up to 8 cm long) are Ca-poor (0.07-0.42 % CaO) enstatites or Ti-bronzites; 6) phlogopite occurs in some pipes only.

Thirty fresh kimberlites from 10 pipes have been analysed: their compositions are very similar. They appear primitive on the basis of their high MgO (28-34 %), Ni (950-3000 ppm) and Cr (1400-1750 ppm) contents. When compared to other "group I" kimberlites (Smith, 1983), they are among the most highly enriched in LREE (La_N = 300-400) but depleted in HREE (Yb_N = 2-3). Absolute REE contents cover a remarkably small range (~15 % around mean values). Two altered samples show extreme REE enrichment (La_N = 3000-9000, Yb_N = 70-100) except Ce, resulting in an apparent negative Ce anomaly. Chondrite-normalized spidergrams show important enrichment (200 to 3000) for most incompatible elements (except K).

The initial (at 70 Ma) Sr and Nd isotopic compositions of the kimberlites display a narrow range of values: $^{87}Sr/^{86}Sr$ = 0.70393-0.70487 and $^{143}Nd/^{144}Nd$ = 0.51266-0.51277 (ϵNd = +2.1 to +4). These values are comparable to those of Mbuji Mayi kimberlites (Weis and Demaiffe, 1985) and to group I kimberlites. These compositions imply a time-integrated LREE-depleted mantle source-region comparable to the OIB-type source and could indicate an asthenospheric (convective) origin for the kimberlitic magma.
One altered sample, highly enriched in REE (1515 ppm Nd, 202 ppm Sm), has a slightly negative ϵNd (-1) with a "normal" $^{87}Sr/^{86}Sr$ ratio (0.70447).
Two crustal xenoliths (a micaschist and a gneiss) have been analysed: their isotopic compositions at 70 Ma are very radiogenic in Sr (0.717-0.770) and very unradiogenic in Nd (ϵNd = -16 and -30).
The Sr-Nd isotope systems of the kimberlites do not show any crustal influence, except maybe for the altered, REE-rich samples. Several megacrysts (Cr poor cpx, opx, garnet) and two mantle xenoliths (one lherzolite and one eclogite) have also been analysed: except the opx megacryst with ϵNd = -2.8, all these samples have positive initial ϵNd values (+1.1 to +2.6) comparable to, but slightly less positive than their

host kimberlites. Cpx have low $^{87}Sr/^{86}Sr$, close to 0.7040 while opx and garnet have higher values, up to 0.7072 and 0.7111 respectively.
Initial Pb isotopic data for the fresh kimberlites are in the range $^{206}Pb/^{204}Pb$ = 18.51-19.8 and $^{207}Pb/^{204}Pb$ = 15.64-15.72. The REE-rich sample has higher ratios: 20.35 and 15.75 respectively. These data plot to the right of the geochron. The initial $^{207}Pb/^{204}Pb$ are significantly higher than those reported for MORB and OIB but are comparable to those of many group I kimberlites. It is interesting to note that recent East African rift volcanics have still higher $^{207}Pb/^{204}Pb$ (up to 15.82) for comparable $^{206}Pb/^{204}Pb$ (Davies and Lloyd,1988).
Although high $^{207}Pb/^{204}Pb$ ratios are often ascribed to contamination by old crustal material, the only measured crustal xenolith (a micaschist) has much less radiogenic Pb isotopic composition ($^{206}Pb/^{204}Pb$ = 16.29 and $^{207}Pb/^{204}Pb$ = 15.59); this type of material is obviously not responsible for the high $^{207}Pb/^{204}Pb$ of the kimberlites. In the 207/204-206/204 Pb diagram, the data points for the Kundelungu kimberlites and cpx megacrysts display a linear array. If considered as a secondary isochron, this line corresponds to an "age value" of roughly 400 Ma which has no geological meaning. On the other hand, the array points towards the St Helena field, the HIMU component of the oceanic mantle; this array could then tentatively be interpreted as a mixing line between a group I kimberlite component and the HIMU component.

Very few diamonds have been collected in the alluvial deposits: most of them are grey stones (cubic, octaedral, irregular). The range of $\partial^{13}C_{PDB}$ for 5 stones is rather narrow: -5.28 to -8.42 °/oo (Kampata et al., in press) which is similar to the range of P-type diamond. One diamond has a $\partial^{13}C_{PDB}$ value of -22.8 °/oo, comparable to E-type diamond. A composite diamond made of two crystals has been found in the Gwena pipe: each part has a distinct isotopic signature (-8.5 °/oo and -14.4 °/oo) which suggests complex crystallization and growth history.

The fresh Kundelungu kimberlites are very homogeneous for their mineralogical, geochemical and isotopic compositions. They formed by very uniform magmatic processes (degrees of melting and/or fractional crystallization). This suggests that the whole kimberlite province may have been formed by a single magmatic event that extracted the magma from an homogeneous source region within the mantle. The Nd-Sr isotopic signature of the kimberlites suggests that the kimberlitic magma originated in the depleted asthenospheric (convective) mantle and not in the thickened, possibly enriched, lithospheric mantle beneath the Archean Congo Craton.