

DIAMONDS AND THEIR SYNGENETIC MINERAL INCLUSIONS FROM THE 2 GA BIRIMIAN DEPOSITS, GHANA, WEST-AFRICA

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The Birimian Supergroup (about 2 Ga) of south-west Ghana was emplaced within a series of volcanic belts and intercalated basins, within which mostly fine-grained sedimentary/volcaniclastic rocks were deposited (Leube et al. 1990). Originating from the Birimian Supergroup diamonds are recovered from alluvial sources. We examined in excess of 10,000 cts of diamonds and recovered over 600 inclusion-bearing diamonds in four different size ranges between 1 and 4 mm. Here we present the first detailed study of the carbon and nitrogen isotopes, infrared analyses and inclusion chemistry of these diamonds.

Throughout the diamond size range under consideration, the syngenetic inclusion content is almost exclusively peridotitic, with only one eclogitic diamond being found. The inclusions are dominated by olivine, which is present in about 80% of the diamonds examined, followed by garnet (18%), orthopyroxene and chromite (both about 10%), and clinopyroxene (1%). Olivine-pyrope and olivine-chromite are the most common coexisting mineral pairs. In addition, there occur associations like olivine-pyrope-cpx or olivine-pyrope-chromite, which provide multiple constrained geothermobarometric data on their growth environment. Within the peridotitic paragenesis, inclusion chemistry is very harzburgitic (>90%), but there is a minor lherzolitic presence.

Olivine compositions range in forsterite content from 91-94 mol%, with a peak at 93 mol%. This marks a shift towards lower forsterite contents compared with the peak at 94 mol% (Harris 1992) for harzburgitic olivines from worldwide sources (Fig. 1). Forsterite contents below 92 mol% were observed only in the few olivines occurring together with inclusions which form part of the lherzolitic paragenesis. Concentrations in minor and trace elements generally conform with our worldwide database (MnO 0.04-0.14 wt%, CaO <0.02-0.07 wt%) with NiO (0.24-0.47 wt%) and Cr₂O₃ (<0.03-0.33 wt%), however, reaching in part unusually high concentrations.

Orthopyroxene from the Birimian diamonds has molar Mg-numbers between 92.8-94.7, with a maximum at 93.5 (Fig. 2). Similarly to the olivines this marks a significant shift towards lower Mg-numbers, compared with the peak at 95 for harzburgitic orthopyroxenes from worldwide sources. The minor and trace element contents of the orthopyroxenes, however, coincide very well with worldwide observations (Al₂O₃ 0.44-1.19 wt%, Cr₂O₃ 0.03-0.69, NiO 0.10-0.19 wt%, CaO 0.13-0.66 wt%).

Chrome diopside, plotted in terms of Ca-Mg-Fe_{total}, falls within the ultramafic field defined by Meyer (1987). Within the trace elements K₂O (0.05-0.72 wt%) is in part unusually high and NiO (<0.05-0.10 wt%) also tends to be generally high. On the other hand Na₂O (0.21-0.62 wt%) and particularly TiO₂ (<0.04-0.06 wt%) are low compared to other locations.

Apart from the presence of one single pyrope-almandine inclusion, the observed garnet compositions may be subdivided into subcalic pyropes of the harzburgitic paragenesis (CaO 1.2-4.6 wt%, Cr₂O₃ 5.6-15.2 wt%) and lherzolitic paragenesis pyropes, the latter, in several cases, coexisting with cpx-inclusions. The lherzolitic pyropes are unusual in composition (Fig. 3) with high Cr₂O₃

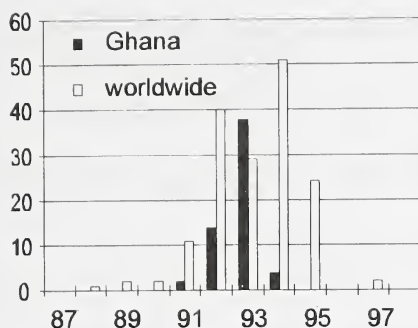


Fig.1: Forsterite content (molar) in olivines from Ghana and from worldwide sources.

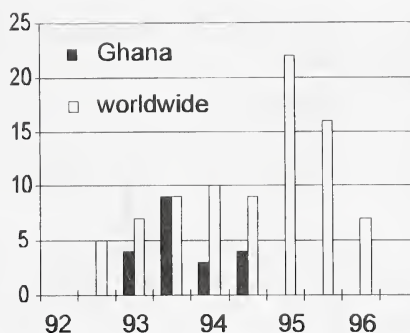


Fig.2: Mg-number (molar) for orthopyroxenes, from Ghana and from worldwide sources.

(5.3-14.2 wt%), CaO (5.1-7.7 wt%), and $\text{FeO}_{\text{total}}$ (5.7-9.2 wt%) together with a correspondingly low MgO-content (16.7-21.8 wt%). Regarding their trace elements lherzolitic and harzburgitic pyropes correspond well with other worldwide occurrences, with only MnO (Fig.3) being somewhat high (harzburgitic 0.27-0.49, lherzolitic 0.28-0.57 wt%).

Picrochromites (Cr_2O_3 61-68 wt%) differ from other locations by having high MnO (0.69-1.10 wt%) and NiO (0.09-0.19 wt%) and in one case a TiO_2 -content of 2 wt%. ZnO contents are low and vary between 0.04-0.05 wt%, thus indicating rather high temperatures of formation.

Preliminary geothermobarometric data for the peridotitic inclusion suite based on gt-opx, gt-ol, cpx-ol, and ol-chr equilibria suggest that the diamonds formed between 50-65 kbar and 1050-1350 °C

The carbon isotopic composition ($\delta^{13}\text{C}$ -6.6 to -2.6 ‰, n=81) of the inclusion-bearing Ghanaian diamonds falls in the range typically expected for peridotitic samples. Compared to the carbon isotopic composition of worldwide peridotitic occurrences (Fig.4), however, the diamonds from Ghana show a shift in mode towards isotopically heavier compositions (from -5.5 towards about -4.0 ‰). This observation for a predominately harzburgitic assemblage contrasts with the data of Deines et al. (1984) for Finsch and Premier Mines, which suggest that the isotopic heavy end of the peridotitic range normally represents the lherzolitic paragenesis.

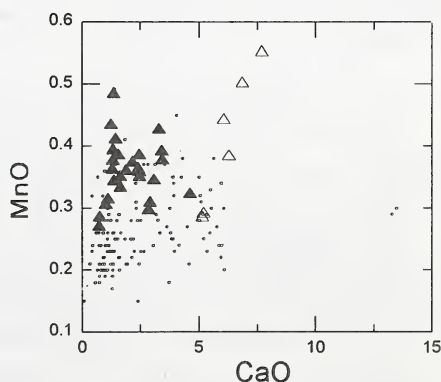
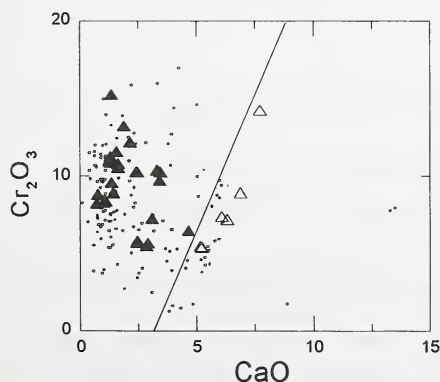


Fig.3: Lherzolitic (open triangles) and harzburgitic (solid triangles) garnet inclusions from Ghana compared with peridotitic garnets from worldwide occurrences.

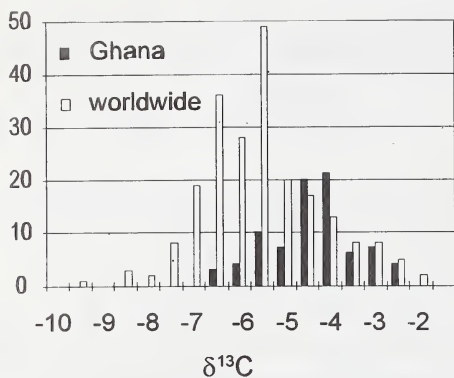


Fig. 4: Carbon isotopic composition (‰ vs. PDB) of diamond samples from Ghana compared with peridotitic diamonds from worldwide sources.

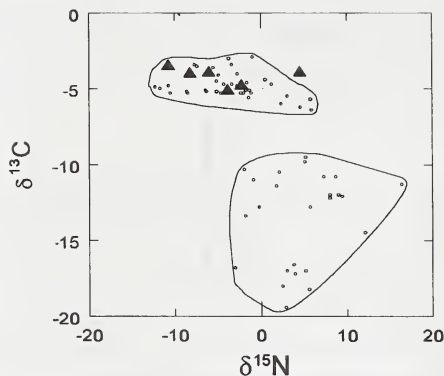


Fig. 5: Carbon and nitrogen (‰ vs. air) isotopic composition of diamond samples from Ghana (triangles) compared with the data-set of Boyd & Pillinger (1994).

Nitrogen contents in the Ghanaian diamonds are very low, with the vast majority of stones being either Type-II diamonds (no nitrogen) or Type-IaA with less than 100ppm nitrogen. However, there exists a minor proportion of stones with well defined A and B-centers, that may contain up to 600 ppm nitrogen. Nitrogen characteristics are non-specific to both inclusion chemistry and $\delta^{13}\text{C}$ -values.

Nitrogen isotopic compositions, at present determined only for 6 samples containing inclusions of the peridotitic paragenesis, fall into the non-paragenetic "high- $\delta^{13}\text{C}$ " field (Fig. 5) characterized by Boyd & Pillinger (1994).

The predominantly harzburgitic paragenesis, the narrow carbon isotopic signature, the generally low nitrogen contents with restricted nitrogen aggregation states, all indicate an origin for these Ghanaian diamonds from a fairly homogeneous, isotopically unmodified upper mantle source.

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- Boyd, S.R. and Pillinger, C.T. (1994) A preliminary study of $^{15}\text{N}/^{14}\text{N}$ in octahedral growth form diamonds. *Chemical Geology*, 116, 43-59.
- Deines, P., Gurney, J.J. and Harris, J.W. (1984) Associated chemical and carbon isotopic composition variations in diamonds from Finsch and Premier kimberlite, South Africa. *Geochimica et Cosmochimica Acta*, 48, 325-342.
- Harris, J.W. (1992) *Diamond Geology*. J.E. Field, Ed., The properties of natural and synthetic diamond, p. 345-393. Academic Press, London.
- Leube, A., Hirdes, W., Mauer, R. and Kesse, G.O. (1990) The early Proterozoic Birimian Supergroup of Ghana and some aspects of its associated gold mineralization. *Precambrian Research*, 46, 139-165.
- Meyer, H.O.A. (1987) Inclusions in diamond. In P.H. Nixon, Ed., *Mantle xenoliths*, p. 501-522. John Wiley & Sons Ltd (New York).