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Lithospheric mantle structure and the diamond potential of kimberlites in southern D.R. Congo

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ABSTRACT

Mantle-derived peridotitic garnet xenocrysts from kimberlites in the Mbuji Mayi and Kundelungu areas and from heavy-mineral concentrates collected in the Luebo area, D.R. Congo, have been analysed for major- and trace-element compositions in order to understand the structure and composition of the subcontinental lithospheric mantle (SCLM) and the diamond potential of the kimberlites. The lithosphere beneath the Kundelungu Plateau is ca 175 km thick and has been affected by pronounced melt metasomatism. Garnets from the Kundelungu Plateau indicate an initially cool geotherm (~35 mW/m^2), which was disturbed by asthenospheric melts that penetrated the SCLM shortly before kimberlite intrusion ca 32 Ma ago. Harzburgitic garnets are very rare, but some lherzolitic garnets display compositions similar to garnets included in diamond. Garnets from the Mbuji Mayi region indicate a cool geotherm (35 mW/m^2); the SCLM is ~210 km thick and was affected by melt-related and phlogopite-related metasomatisms. Harzburgitic garnets form about 33% of the analysed population. The garnets from the Luebo region indicate a cool lithospheric geotherm (35 mW/m^2) typical of cratonic areas. The SCLM from which the garnets were derived was relatively thick (205 km), affected by melt-related and phlogopite-related metasomatisms and characterised by the presence of a ~80-km thick harzburgite-rich layer. In terms of peridotitic diamond potential, Mbuji Mayi and Luebo are more prospective than Kundelungu. The initially cool conductive geotherm, the presence of some garnets with compositions similar to garnets included in diamond and the presence of sporadic diamond in the Kundelungu Plateau suggest that diamond initially was present in the lithosphere and the observed paucity of diamond may be due to the melt-related metasomatism that affected the lithosphere in the region. We suggest that the lithospheric mantle beneath Kundelungu is a strongly modified Archean cratonic lithosphere that has survived beneath the area during Proterozoic tectonism.

1. Introduction

Our knowledge of the nature and composition of the subcontinental lithospheric mantle (SCLM) is largely based on the study of xenoliths brought to the Earth's surface by volcanism (mostly basaltic to kimberlitic). The distribution of elements between different mineral phases in the xenoliths allows the estimation of the conditions of equilibration at the time of entrainment (pressure, temperature) and an understanding of chemical processes that have affected the part of the SCLM from which the xenolith was derived. However, the distribution of such xenoliths (in which most of the mineral phases are preserved) is very restricted in space and time (O'Reilly and Griffin, 2006). Minerals (xenocrysts) such as garnet and chromite represent the products of the disaggregation of the xenoliths; they commonly are well preserved and may be abundant in kimberlites, partly due to their resistance to alteration compared with other mantle minerals such as olivine and pyroxene. These minerals may thus be used for the study of the SCLM in areas where xenoliths are rare or absent.

Two kimberlite fields are known in the Democratic Republic of the Congo (hereafter referred to as the Congo) at Mbuji Mayi located in the south-central part of the country (Kasai Province) and Kundelungu in the southeastern part (Kundelungu Plateau (Pivin et al., this issue)). In this study, xenocrystic peridotitic garnets from Mbuji Mayi and Kundelungu kimberlites and from heavy-mineral concentrates collected in drainages in the Luebo, Mbuji Mayi and Kundelungu regions are used to map and understand the nature of the SCLM in the southern part of the Congo and to assess its peridotitic diamond potential. This study provides an opportunity to compare the composition and structure of the lithospheric mantle and kimberlite diamond potential in two different geological settings.

2. Geological setting

The Mbuji Mayi kimberlite field and the Luebo exploration area (~200 km NW of Mbuji Mayi) are located inside the Congo-Kasai

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Craton whereas the kimberlites in the Kundelungu Plateau intruded rocks belonging to the Neoproterozoic Katangan Supergroup inside the Katangan Belt (Fig. 1). The Congo-Kasai Craton consists of granulite, gneiss, granite and amphibolite, a gabbro-noritic and gabbro-charnockitic complex, and a migmatitic complex. The ages of these rocks range from 3.4 to 2.6 Ga (Delhal and Ledent, 1973; Delhal and Liégeois, 1982; Walraven and Rumvegeri, 1993; Batumike et al., 2009). The youngest Archean age in this part of the craton was found in the Malafundi granites from the Dibaya complex which gave 2648 ± 22 Ma (Rb/Sr; Delhal et al., 1976) and 2595 ± 92 Ma (Rb/Sr; Cahen et al., 1984). Paleoproterozoic, Mesoproterozoic and Neoproterozoic rocks within this craton are poorly studied, but represent parts of the Paleoproterozoic Ubendian, Mesoproterozoic Kibaran and Neoproterozoic Katangan orogenic belts. The Mbuji Mayi Supergroup, intruded by the Mbuji Mayi kimberlites, consists of 1.3–0.95 Ga sedimentary rocks, covered in places by 0.95 Ga basaltic lavas and Cretaceous sandstones (~120 Ma, Schärer et al., 1997).

Kimberlites occur in two clusters in the Mbuji Mayi region: the northern Mbuji Mayi cluster is formed of elliptical bodies along an E–W-striking crustal fissure (e.g. Fieremans, 1977; Demaiffe and Fieremans, 1981; Demaiffe et al., 1990) and the southern Tshibwe cluster (Schärer et al., 1997). Because the kimberlites intrude Cretaceous sandstones with an estimated age of 120 Ma, this age has been taken as the maximum age of known kimberlite occurrences within the craton. Davis (1977) dated a megacrystic zircon from Mbuji Mayi at 71 Ma (TIMS $^{206}Pb/^{238}U$). U–Pb analysis of zircon and baddeleyite megacrysts from Mbuji Mayi yielded discordant data with concordia intercepts at 69.8 ± 0.5 Ma and 2528 ± 452 Ma (Schärer et al., 1997), and Kinny and Meyer (1994) reported an age of 628 ± 12 Ma for a zircon included in diamond from the same area.

The Luebo region is characterised by the presence of abundant diamonds and kimberlitic indicator minerals in streams and rivers. The region has been subjected to intensive exploration for search of local sources for the diamond, but no primary sources such as kimberlite have yet been found (e.g. Bhebhe, Z., pers. comm., 2008). Our morphological examination of garnet grains from heavy-mineral concentrates suggests that these grains may have not travelled long distances, and might be derived from local kimberlitic sources, although formally the source(s) for the grains studied are indeterminate. U–Pb, Hf isotope and trace-element data for zircons from the same Luebo-area heavy-mineral concentrates suggest that kimberlites were emplaced inside the Congo-Kasai Craton in Late-Archean, Neoproterozoic and Cretaceous time (Batumike et al., 2009), though the location of such sources remains to be determined.

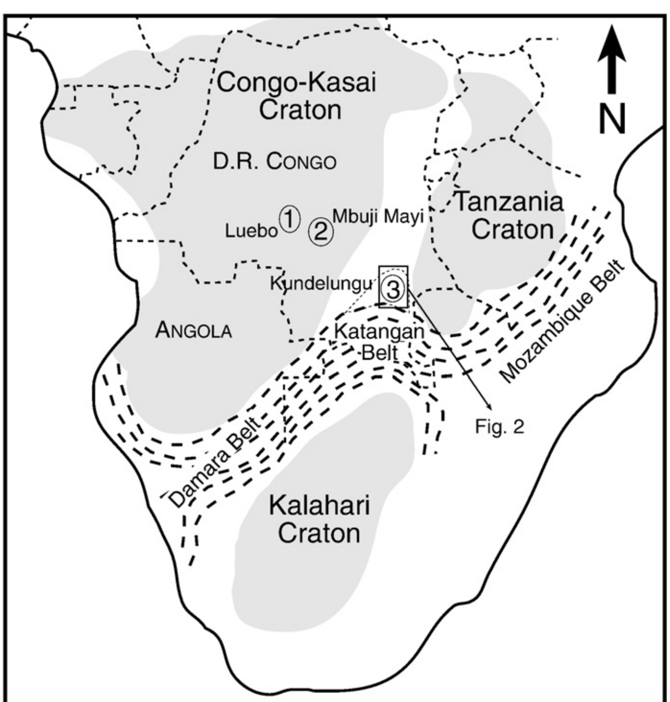

Fig. 1. Geological sketch map showing the position of the Congo-Kasai, Tanzania and Kalahari Cratons in Africa (grey areas), and study areas. Small dashed lines are political boundaries. Names of countries are in small capitals.

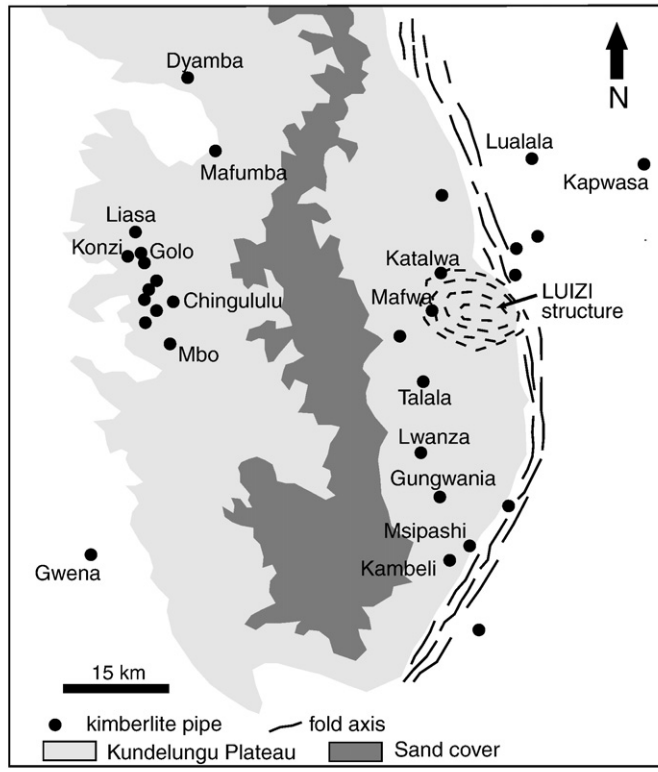

Fig. 2. Location of kimberlite pipes in the Kundelungu Plateau.

The Kundelungu Plateau is made up of sandstones, limestones and mudstones grouped as the Biano Subgroup, occurring stratigraphically at the top of the Neoproterozoic Katangan Supergroup. These rocks are subhorizontal and undeformed and were deposited in a foreland basin during the Lufilian orogeny (Kampunzu and Calteux, 1999; Batumike et al., 2007a). The kimberlites form two geographic clusters inside the Kundelungu Plateau: the eastern cluster has 16 pipes and the western has 14 pipes (Fig. 2). This division is mainly based on the presence of a thick sand cover in the central portion of the plateau that may obscure some kimberlite pipes. U–Pb analysis of perovskites indicates that there was only one magmatic kimberlite episode in the Kundelungu Plateau and this occurred at 32 ± 2 Ma, coincident with the initial stages of the East African Rift in Ethiopia and Kenya (Batumike et al., 2008).

3. Samples and methods

3.1. Sampling

The garnet xenocrysts studied were collected from three different locations: Kundelungu Plateau, Mbuji Mayi and Luebo. Data for garnets from Mbuji Mayi and some of the kimberlite pipes in the Kundelungu Plateau (e.g. Luanza, Golo, Mbo and Chingululu, Fig. 2) were provided by De Beers. Epoxy mounts of garnets from Luebo and their electron microprobe data were provided by Gravity Diamonds Ltd. These garnets were extracted from heavy-mineral concentrates prepared from stream samples collected during an exploration campaign. In the eastern part of the Kundelungu Plateau, stream sediment samples were collected in the Gungwania, Talala and Luanza