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Detrital pyrope garnets from the El Kseibat area, Algeria: A glimpse into the lithospheric mantle beneath the north-eastern edge of the West African Craton

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ABSTRACT

Pyrope garnet grains found in Cretaceous and Quaternary alluvial sediments in the El Kseibat area (Algeria) suggest the presence of kimberlites along the NE margin of the West African Craton. The garnets have been studied using major- and trace-element chemistry to obtain information about the composition and thermal properties of the lithospheric mantle beneath this area. Most of the garnet grains are lherzolitic in composition (group G9), but range up to high Cr contents (>10% Cr_2O_3); two grains are harzburgitic (G9/G10). Three differently metasomatised groups of pyrope garnets were distinguished: (1) depleted grains that have low Sr, Ti, and Zr contents; (2) grains having low Sr and Ti and high Zr contents; and (3) grains with high Ti and Zr contents. Each group reflects a different stage and intensity of metasomatism. A range of chondrite-normalised rare earth element (REE_n) patterns also reflects several styles of metasomatism. Based on geochemical features, most grains appear to be derived from Archean to Proterozoic mantle. The geotherm estimated from the garnet compositions is typically cratonic (*ca* 40 mW/m^2), but somewhat higher than that estimated for the interior of the Craton using heat flow constraints (33 ± 8 mW/m^2). Depleted garnets give *P–T* estimates up to 950 °C, 40 kbar; those showing melt-related metasomatism (high Ti, Zr) go up to 1400 °C and >50 kbar. Nearly all garnet grains were derived from the graphite stability field at depths of 100–170 km, but some may be derived from the diamond stability field. The pyrope garnets of the El Kseibat area indicate that their lithospheric-mantle source has a lherzolitic composition as a result of several stages of metasomatism.

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1. Introduction

Little is known about the lithospheric mantle of the north-eastern part of the West African Craton (WAC). There are no deep-seated seismic or geoelectric profiles in this region, and only small-scale surface wave tomography is available (Pasyanos and Nyblade, 2007; Priestley et al., 2008). The age of its cratonisation is disputable. In contrast to the Archaean Reguibat Rise, the Eglab Shield was considered to be Palaeoproterozoic, Eburnean (*e.g.*, Bessoles, 1977; Schofield et al., 2006). The discovery of diamondiferous kimberlites in the Mauritanian part of the Reguibat area (Krymsky et al., 2003) was considered normal, while occurrences of placer diamonds in the Algerian Sahara are still enigmatic.

Archaean amphibolites intercalated with garnet–hornblende banded grey gneisses, dated at 2.73 Ga, were recently recognised in the south-western part of the Eglab Shield. The amphibolites were considered to be a relic of the Archaean core of the Eglab Shield (Peucat et al., 2005). Based on these findings, the sources of the Algerian diamonds were suggested to lie in the north-eastern part of the Eglab Shield (Kahoui et al., 2008). While the present material represents a very small sample, the Algerian diamonds and indicator minerals (pyrope garnet) may yield some information about the lithosphere in which they formed. This information may in turn be useful in evaluating the diamond prospectivity of the region.

In 1980s to 1990s, the sub-economic Djebel Aberraz diamond placer deposit was discovered in the Bled-el-Mas Valley approximately 30 km south of Reggane (Kaminsky et al., 1992a; Kahoui et al., 1998). The Djebel Aberraz diamond placer deposit is located near the border of the Sahara Plate and the WAC

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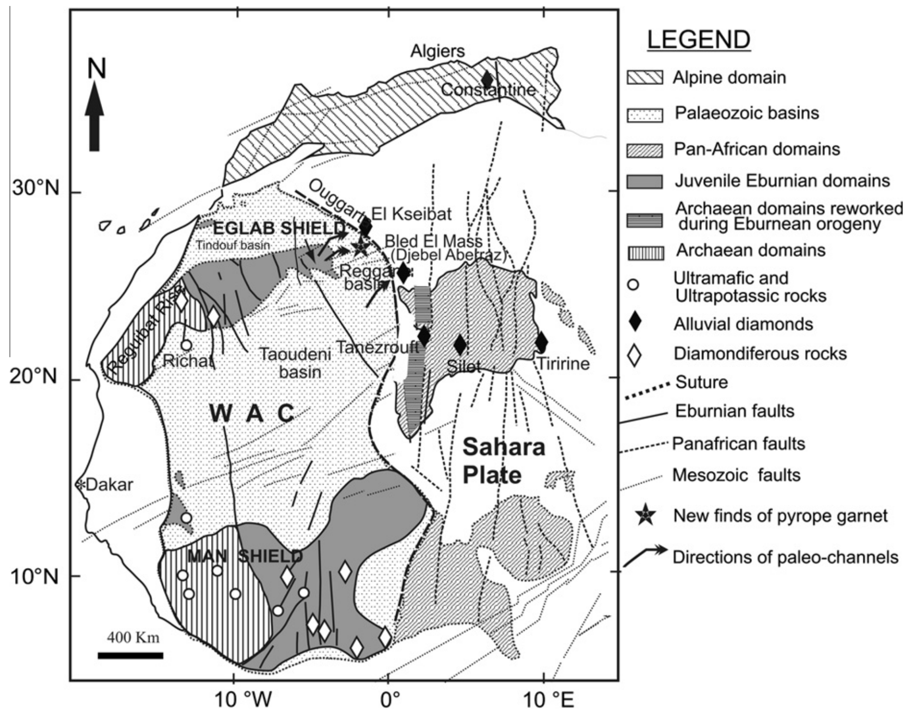

Fig. 1. Tectonic map of Northwestern Africa, showing the position of the El Kseibat area.

(Fig. 1). In the deposit, below a few metres of eolian sand, a 12–15 m-thick layer of Lower–Upper Quaternary alluvial sediments overlies Palaeozoic sedimentary rocks. About 1500 diamond grains were recovered from exploration pits in the alluvial sediments. Numerous kimberlite indicator mineral grains, such as pyrope garnet, chrome spinel and picroilmenite, also were identified in the deposit. Such indicator minerals were also found in Lower Cretaceous sediments of the Tidikelt Plateau to the north of Djebel Aberraz (Kaminsky et al., 1992b; Sobolev et al., 1992).

Besides the Djebel Aberraz deposit, diamonds were found north and south of Reggane within a large area extending over 1000 km from Tanezrouft, Silet, and Tiririne in the southeast to El Kseibat in the northwest (Fig. 1). The El Kseibat area is located at the suture zone between the West African Craton and the Sahara Plate, which runs NW of the towns of Djebel Aberraz and Adrar. The first diamond was recovered during geological mapping (Wilczynski, 1989), and 19 more diamonds (mostly less than 1 mm in size) and indicator minerals have been found in this area since then (Hamlat, 1999; Labdi and Zénia, 2001; Acheraiou, 2008). In 2005, as a result of the work organised by the ORGM (Office National de la Recherche Géologique et Minière), several dozen pyrope garnet grains were found in the El Kseibat area (ORGM, 2008). The primary source(s) of both diamonds and pyrope garnets have not yet been found.

The objective of this work was to use the geochemistry of the pyropes from the El Kseibat area to characterise the structure and composition of the lithospheric mantle beneath the area.

2. Analytical methods

Thirty-nine pyrope grains from El Kseibat were studied at GEMOC, Department of Earth and Planetary Sciences, Macquarie University, Sydney, Australia for their major and trace elements.

The major-element compositions of the pyropes were analysed using a Cameca SX-100 electron microprobe. The analyser has a 50-keV gun; a focus beam diameter of 1–2 μm, a 15 kV accelerating voltage, and a 20 nA beam current. Counting times were 10 s for peaks and 5 s for background each side of the peak. The detection levels for major oxides were less than 0.2 wt.% with precisions better than 2% rsd for the concentrations over 1 wt.%. Three points were analysed in each grain and averaged.

Trace-element concentrations were measured using a New Wave 266 nm laser connected to an Agilent series 7500c ICPMS. Samples were ablated using 5 Hz, a beam energy of about 0.17 mJ per pulse, and a spot size of 60 μm. The NIST 610 standard glass was used as the external standard. Quantitative results for trace elements were obtained through normalisation of each analysis to the electron-probe data for Ca as an internal standard. Typical detection limits are at the ppb levels for REE, Y, U, Th, Nb, Ta, Hf, Ti, Zr, V, Co and at the ppm levels for Li, B, P, Ca, Sr, Ba. The precision and accuracy of the NIST 610 standard glass are 2–4% at the ppm concentration levels and up to 10% for elements with concentrations less than 1 ppm. Analytical technique, accuracy and precision are outlined in more detail by Norman et al. (1998). The time-resolved data was processed using the GLITTER software (Griffin et al., 2008), which allows the selection of stable parts of the signal, compares them with the standards, calculates the concentrations, and carries out the chondrite-normalising and plotting of the data.

3. Pyrope from the El Kseibat area

3.1. General characteristics

The El Kseibat area is composed mainly of Lower Cretaceous (Continental Intercalaire) sandstones and gravels that discordantly overlie Palaeozoic formations (*e.g.*, Fabre, 2005). Above their eroded surface are continental Neogene (Mio-Pliocene) Hamada Chammar deposits (sandy sediments, gravels, calcareous and dolomitic sandstones with a basal conglomerate or altered basal zone) followed by Pliocene and Lower Quaternary (Plio-Villafranchien) unconsolidated sands and gravels. The latter fill erosional paleochannels oriented predominantly NE; pyrope grains were found in these sands and gravels. The modern relief is defined by late

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