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Geochemical signatures of uranium oxides in the Lufilian belt: From unconformity-related to syn-metamorphic uranium deposits during the Pan-African orogenic cycle

Aurélien Eglinger [a,*], Anne-Sylvie André-Mayer [a], Olivier Vanderhaeghe [a], Julien Mercadier [a], Michel Cuney [a], Sophie Decrée [b], Jean-Louis Feybesse [c], Jean-Pierre Milesi [c]

[a] GeoRessources, CNRS–CREGU, Université de Lorraine, France
[b] Royal Museum of Central Africa, Tervuren, Belgium
[c] AREVA, BU Mines Paris, France

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ABSTRACT

The Pan-African Lufilian belt (Zambia and Democratic Republic of Congo) is known for its world-class copper and cobalt deposits. In addition, the Lufilian Copperbelt hosts several uranium occurrences concentrated within deformed siliciclastic rocks of the basal Neoproterozoic Katanga Supergroup. We report LA-ICPMS and EMP analyses of the rare earth element (REE) and yttrium (Y) abundances (designated as the REY signatures) of uranium oxides from two uranium mineralizing events of the Lufilian belt previously dated at 652 ± 8 Ma and 530 ± 6 Ma by the U–Pb method on uraninite. Uranium oxides dated at ca. 650 Ma from the External fold-and-thrust belt are characterized by (i) bell shape REE patterns centered on middle REE (MREE), (ii) positive europium (Eu) anomalies and (iii) relatively low Y contents. In contrast, uranium oxides dated at ca. 530 Ma from the Domes region are characterized by (i) REE patterns but with a less pronounced light REE (LREE) fractionation, (ii) negative Eu anomalies and (iii) higher Y contents. Moreover, the External fold-and-thrust belt also contains uranium mineralization dated at ca. 530 Ma having the same characteristics as the ca. 530 Ma uranium oxides from the Domes region (a moderately fractionated REE pattern and a negative Eu anomaly).

As REY signatures are known to reflect mineralizing processes, the distinct geochemical signatures of the two uranium oxide generations (ca. 650 Ma and ca. 530 Ma) provide meaningful information about the uranium cycle during the Pan-African orogeny. Compared to the REY signatures of the known worldwide uranium deposit types, the REY signature of uranium oxides dated at ca. 650 Ma of the External fold-and-thrust belt is similar to the REE patterns from unconformity-related U deposits (Athabasca in Canada and Kombolgie in Australia). Uranium oxides of the Domes region and some of the External fold-and-thrust belt display similar characteristics to syn-metamorphic U deposit (Mistamisk in Canada). Accordingly, we propose that the two stages of uranium oxide crystallizations within the Lufilian belt, at ca. 650 and ca. 530 Ma, occurred under distinct physico-chemical conditions. The first stage, at ca. 650 Ma, may be related to late diagenesis hydrothermal processes, at the basement/cover interface, with the circulation of highly saline basinal brines linked to evaporites of the Roan Group. This Pan-African unconformity-related uranium deposit is the youngest of this type described to date. The second stage may be connected to metamorphic fluid circulations, at about 530 Ma, during the Lufilian orogeny in the Domes region and also in the External fold-and-thrust belt.

1. Introduction

The Pan-African Lufilian belt is known for its world-class sediment-hosted Cu–Co ore deposits with a proposed multiphase origin (Cailteux et al., 2005; De Waele et al., 2006; El Desouky et al., 2009; Hitzman et al., 2010; Key et al., 2001; Muchez et al., 2008; Fig. 1). This belt also hosts some Pb–Zn–Cu ore deposits and significant uranium mineralization (Cosi et al., 1992; Kampunzu et al., 2009; Mendelsohn, 1961; Meneghel, 1981; Fig. 1). In total, about 42 uranium occurrences (mines and showings) have been discovered in the Lufilian belt and are distributed within the External fold-and-thrust belt in Democratic Republic of Congo (DRC) and within the Domes region in Zambia (Fig. 1). Uranium occurrences were first discovered in the External fold-and-thrust belt in 1915 by UMHK (*Union Minière du Haut Katanga*; Derriks and Vaes, 1956) and much later in the northwestern part of the Domes region in 1972 by AGIP (Meneghel, 1981). The first uranium mining in the Katanga Copperbelt, the Shinkolobwe deposit exploited from 1921 to 1960 and, in 1939, yielded a large part of the ore used

* Corresponding author at: UMR GeoRessources 7359, Université de Lorraine, F-54506 Vandœuvre-lès-Nancy Cedex, France. Tel.: +33 6 73 87 59 88.
E-mail address: aurelien.eglinger@univ-lorraine.fr (A. Eglinger).

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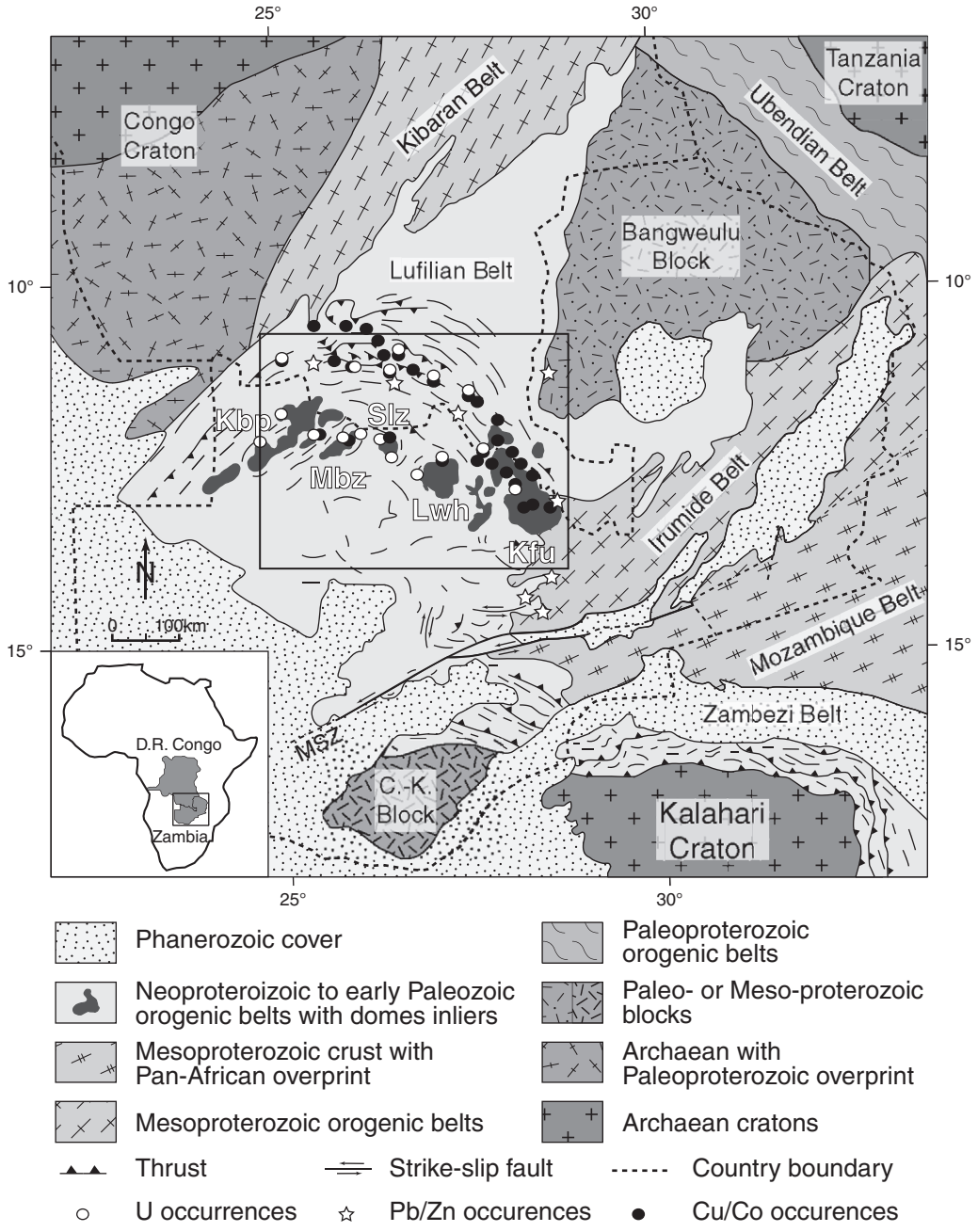

Fig. 1. Geological map of the Pan-African Lufilian belt indicating the main structural trends and mineral occurrences (modified after De Waele et al., 2008). Abbreviations: Kbp = Kabompo Dome; Mbz = Mwombezhi Dome; Slz = Solwezi Dome; Lwh = Luiswishi Dome; Kfu = Kafue Anticline; C.-K. = Choma Kalomo block; MSZ = Mwembeshi Shear Zone. (Black rectangle: study area enlarged in Fig. 3).

for production of the first nuclear bombs deployed at the end of the Second World War (Derriks and Vaes, 1956; Ngongo, 1975). Mineralization occurs mainly as uranium oxides within a basal sedimentary sequence, known as the Roan Group and attributed to the Neoproterozoic (Cailteux, 1983, 1994; Porada and Berhorst, 2000). The host rocks are dolomitic shale in the External fold-and-thrust belt, and carbonaceous quartzite/quartz micaschist in the Domes region (Cosi et al., 1992; Meneghel, 1981). The Shinkolobwe uranium deposit, in the External fold-and-thrust belt, was initially assigned to a magmatic origin, although no magmatic rocks were described in this area (Derriks and Oosterbosch, 1958). More recently, uranium mineralization in the External fold-and-thrust belt has been interpreted as being of syngenetic/early diagenetic origin because of the strong lithostratigraphic control, such as identified for copper and cobalt ore deposits (Cailteux, 1983, 1997; François, 1974; Loris, 1996; Meneghel, 1981; Ngongo, 1975). Recent work suggests that uranium has been re-concentrated during the Lufilian orogeny leading to epigenetic deposits (Loris et al., 2002).

U–Pb ages on uranium oxides from the Lufilian belt yield a wide range of ages from 706 to 235 Ma based on concordant $^{207}Pb/^{206}Pb$, $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ages or on upper intercept of discordia lines (Begemann et al., 1952, 1953; Cahen and Snelling, 1984; Cahen et al., 1961; Ledent, 1958; Loris, 1996; Meneghel, 1981; Richards et al., 1988). These geochronological data have been recently reassessed based on new U–Pb dating by SIMS (Decrée et al., 2011), yielding a discordia with an upper intercept at 652.3 ± 7.3 Ma for uranium oxide from the External fold-and-thrust belt (Shinkolobwe, Swambo and Kalongwe; Fig. 3) and a discordia with an upper intercept at 530.1 ± 5.9 Ma for uranium oxide from the Domes region (Musoshi and Nkana, Fig. 3) and from the External fold-and-thrust belt (Kolwezi and Luiswishi, Fig. 3). Other uranium oxides from the Kawanga occurrence in the Domes region yield 542 ± 12 Ma