Metallogenic mechanism of leucogranite-type uranium deposit in the Gaudeanmus area, Namibia

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1 Introduction

As an important type of uranium deposit associated with plutonic rocks, the leucogranite-hosted deposit has become a significant research objective for uranium ore geology. It draws great attention from the industry not only due to the significance of the deposit type, the variety of compositional minerals, and great potential on mineral resources, but also the fact that the source of hydrothermal fluids and the uranium genesis are still in debate. This paper discusses on the characteristics of uranium mineralogy, main ore controlling factors, metallogenic chronology and uranium source etc., and then analyzes on the metallogenic mechanism of leucogranite-type uranium deposit.

2 Regional geological background

In Namibia, the Damara Orogen has been divided into Northern Platform, Northern Zone, northern Central Zone, southern Central Zone, Okahandja Lineament Zone, Southern Zone, Southern Margin Zone and Southern Foreland by the lithostratigraphical, structural and metamorphic criteria (Figure 1) (Corner, 1983; Nex, 1997; Kinnaird, & Nex, 2007; Kitt, 2008). Uranium-bearing leucogranites in Namibia occur within the Central Zone of the Damara Orogen (Roesener and Schreuder, 1992). The Gaudeanmus area locates in the southern Central Zone. The strata in the Gaudeanmus have been divided into Abbabis Complex, Etusis Formation, Khan Formation, Rössing Formation, Chuos Formation, Karibib Formation, Kuiseb Formation from bottom to top (Miller, 1983). There are six type leucogranites (Nex, 1997), which have different petrological characteristics. There are domes, faults and ductile shear zones within the mining area. The axial direction of elliptoid domes is North East; ductile
shear zone also shows North East. According to strike, the fractures can be divided into four directions: NE, NW, EW, NS, the main fault is NE-trending Welwitschia Lineament.

3 Deposit geology

In the Gaudeanmus area, the uranium ore body are mostly stratiform, lenticular, extended stably, 100–200 m thickness, the mineralization significantly enriched in the swollen part of ore body. Three stages of alteration of U ore could be generally observed: (1) the first stage is late magmatic autometasomatism alteration, including albitionation, little potash feldspathization, muscovitization, silicification and little fluoritization, associated with the formation of idiomorphic coffinite and uranothorite; (2) The second stage is mesothermal-epithermal alteration, mainly including chloritization, kaolinization, sericitization, pyritization, silicification, illitization and hematization, closely associated with the formation of vein coffinite and pitchblende and (3) the third stage is supergene oxidation alteration, including limonitization, tightly associated with uranotile, carnotite and other secondary uranium minerals. Uranium of Gaudeanmus area mainly exists as independent uranium minerals, and partially exists in zircon, titanite, monazite, apatite and thorium minerals as isomorphic form. The uranium minerals are uraninite, thor-uraninite, coffinite, uranothorite, brannerite, betaftite, pitchblende, uranophane and carnotite. Thus, the alaskite-type uranium deposit of Gaudeanmus is a comprehensive product of crystallization differentiation of protomagma, superimposed reformation of late hydrothermal fluid and supergene infil-

Figure 1  The inland branch of the Damara Orogen showing the different zones and bounding lineaments (after Miller, 1983).
4 Ore controlling factors

In this area, the main ore controlling factors are tectonic, lithology, stratum, basic rock veins and latter fluids. The ore body mainly occurs in NNE ductile shear zone, fold corner, dome edge and structure variation positions (twist or expand), and these structures provide ample space for uranium mineralization. At the same time, the Welwitschias regional faults provide the way for uranium remobilization. Mineralization is exclusive to leucogranite, just D, E type leucogranite are mineralization leucogranite. Another four leucogranite and Salem granite contain no uranium ore, because D3 tectonic deformation and dome formation lead to the uranium-rich basement remelting in the deep, while unmineralized leucogranite and Salem granite formed before D3, and also with different material source. For stratum, mineralization leucogranite intruded into Rössing Formation, Khan Formation, Chuos Formation, Karibib Formation (under the situation of Rössing Formation lost or reduced) as veins or net veins. Because when magma arrived Rössing Formation or Khan formation, it causes decarburization reaction with marble, with increasing contents of CO2 in the ore forming fluids, which lead magma easy to boil, and uranium easy to precipitation (Fan, et. al, 2014). The latter fluids can superimpose modification the uranium mineralization, the new discovery of this dissertation, happen in the fault fracture zone, making mine alteration strong, and mineralization grade increasing obviously. The intrusion of Jurassic basic vein provides not only the necessary energy but also the channel for the hydrothermal remove. At the same time the large amount of reduced gas containing in basic magma is the necessary reluctant for uranium precipitation in imposed modification stage (Fan, et. al, 2003).

5 Metallogenic mechanism analysis

A deposit is formed by multiple geology process, which can be divided into three phases- metallogenetic prophase, metallogenetic phase, and metallogenetic anaphase. In the metallogenetic prophase it mainly provides space and physical and chemical conditions for uranium precipitation. The based mixtite of Abbabis Fomation in Gaudeannmus area of Namibia provide resource for uranium mineralization, and ductile shear zone, dome and Welwitschias regional faults provide space and channel for uranium remobilization. Leucogranite mineralization is a multiple process with constantly superimposition of metallogenic matter.

The collision of Kalahari craton and Congo craton happens in 550 Ma, forming a lot of syntectonic granite; At about 502 Ma, uranium rich basement melts partially forming the granite magama migrating upward through Welwitschias regional faults produced D, E type leucogranite rich in uranium which mainly intrude in schist, gneiss and marble of Khan Formation, Rössing Formation and Karibib Formation; and uraninite, brannerite, uranothorite, coffinite and so on formed in the process of crystallizaiton differentiation. In late Jurassic the intrusion of diabase vein and crust plifting provide energy for deep fluid, through faults, cracks, joints, mixing with me-
teoric water, super imposing to the mineralization leucogranite, pitchblende and vein like coffinite form. In the late metallogenic phase, mineralized matter effected by climate, secondary uranium minerals such as uranophane, carnotite form. Sum up all the above, the leucogranite-type uranium deposit in Gaudeanmus area of Namibia, is a product of multiple period, multiple phases and multiple geology factors.

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