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2.46 Ga kalsilite and nepheline syenites from the Awsard pluton, Reguibat Rise of the West African Craton, Morocco. Generation of extremely K-rich magmas at the Archean–Proterozoic transition

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ABSTRACT

The Awsard pluton in the Moroccan part of the Reguibat Rise, West African Craton, contains the oldest kalsilite-bearing rocks discovered to date, with a SHRIMP zircon U/Pb age of 2.46 ± 0.01 Ga. The pluton is composed of nepheline syenites, kalsilite syenites and minor silica-saturated syenites, all with the same primitive Sr and Nd initial isotope compositions and Nd model age that cluster around $^{87}Sr/^{86}Sr_{2.46Ga} \approx 0.7029$, $\varepsilon Nd_{2.46Ga} \approx -1.4$, and $T_{DM} \approx 2.75$ Ga. Silica-saturated syenites are in fact contact fenites that grade into nepheline syenites, but the two feldspathoidal syenites are true magmatic rocks that crystallized from two coeval highly fractionated K-rich magmas with sharply different chemical compositions. Chemical, isotopic and textural evidence suggests that the two magmas originated by liquid immiscibility within an already fractionated alkaline potassic magma of asthenospheric origin that split in two phases, a nephelinitic melt rich in HFSE + REE, and a kalsilitic melt poor in HFSE + REE. The Awsard pluton, spatially associated to carbonatites and other alkaline rocks, does not mark a Late Archean fossil subduction zone but represents the first manifestation of a Paleoproterozoic alkaline province located in the Reguibat Rise, the full extent and importance of which is yet to be determined.

1. Introduction

Kalsilite syenites are a rare case of silica-subsaturated alkaline magmatic rocks with extremely high potassium and low sodium concentrations ($K_2O > 16\%$, $Na_2O < 1.5\%$). To date, these rocks have only been described in the Paleozoic to Mesozoic alkaline complexes of the Baikal-West Aldan Potassic provinces, Russia (Mitchell, 1996 and references therein), and in the Rischorr Complex of the Paleozoic Khibine Massif, Russia (Arzamastsev et al., 2001; Ageeva and Borutzky, 2004). We have found that the Reguibat Rise of the West African Craton hosts an intrusive complex, the Awsard pluton (Fig. 1), mainly consisting of nepheline syenites and kalsilite syenites formed at 2.46 Ga (see Section 5). Awsard is, therefore, the oldest kalsilite-bearing pluton known on Earth, more than 2 billion years older than any other massif of similar composition. Accordingly, it might provide with important information on the origin of extremely K-rich magmas and their early appearance in the geological record.

This paper summarizes the first modern study of the Awsard syenites. Here we report their crystallization age (SHRIMP zircon U–Pb, whole rock Rb–Sr) and the field relationships, mineralogy, major and trace element composition, and Sr and Nd isotope compositions of the main rock types. From these data we discuss their petrogenesis and the probable geodynamic environment, and highlight the possible occurrence of a Paleoproterozoic alkaline province in the West Reguibat Rise with no equivalent in the Archean terranes of northeast Africa (Bea et al., 2011, and references therein).

2. Geological setting

The Awsard pluton (22°35′N 14°17′W) is a 12 km × 10 km NW-SE elongated intrusive body mostly composed of felsic feldspathoidal syenites which crops out in the Moroccan part of the Reguibat Rise, West African Craton (Rjimati et al., 2009) (Fig. 1), a region that is geologically poorly known because of military restrictions.

The Awsard pluton is easily identifiable because it forms abrupt high reliefs in the sandy flatland of the desert. It intrudes into a suite of TTG gneisses with SHRIMP zircon U–Pb ages of 2.9–3.0 Ga (authors' unpublished data) and is cut by a network of pre-Panafrican tholeiitic dykes, that are probably of Paleoproterozoic age (E. Rjimati, 2012, pers. comm.). The Awsard pluton is unlikely to be unique. The 1:1 000 000 geological map of Morocco (Bronner

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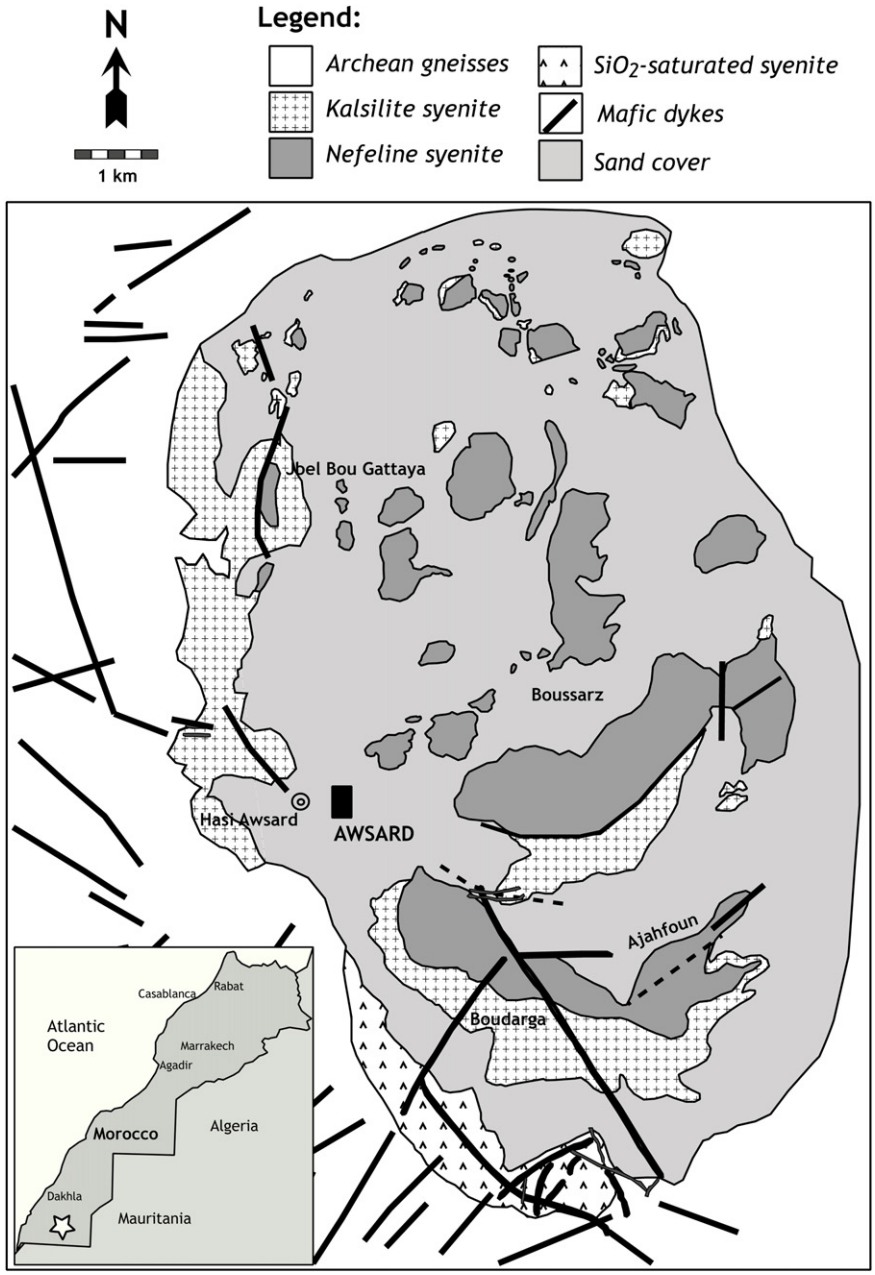

Fig. 1. Geological sketch of the Awsard massif, after Rjimati et al. (2009).

et al., 1985) depicts another syenitic pluton about 40 km to the southeast, in the military exclusion area bordering Mauritania, which to the authors' knowledge has never been studied. Aerial photographs suggest that deeply eroded plutons with similar shape and size might exist a few km to the south, and carbonatite massifs with a Nd model age close to 2.0 Ga (author's unpublished data) are known in the neighboring Glibat Lafhouda region and in the Ahaggar, Algeria (Ouzegane et al., 1988; Bernard-Griffiths et al., 1988). It seems, therefore, that Awsard forms part of an alkaline province located in the Reguibat Rise, the importance and extent of which are just beginning to be appreciated.

3. Field relations and petrography

The Awsard pluton (Fig. 1) is composed of three syenite types which in decreasing order of abundance are: nepheline syenites, kalsilite syenites, and silica-saturated syenites. Nepheline syenites are pale greenish medium- to fine-grained rocks. Kalsilite syenites are pale grayish coarse-grained rock, locally pegmatitic, which intrude the nepheline syenites and form small apophyses penetrating the host gneisses. Silica-saturated syenites are fine-grained rocks that grade into the nepheline syenites and contain abundant small veins and dikes. They are limited to the southwest margin of the pluton and, as discussed below, might represent fenitised Archean gneisses.

The major minerals in the nepheline syenites are K-feldspar, nepheline, green clinopyroxene, biotite, and occasional melanitic garnet. K-feldspar is microcline. It appears commonly as large grid-twinned anhedral to subhedral crystals which either form a granoblastic framework (Fig. 2A) or are cemented by K-rich nepheline plus albite (Fig. 2B). Nepheline ($Na_{3.05}K_{0.94}Al_{3.89}Si_{4.05}O_{16}$) is abundant; it appears as interstitial anhedral crystals (Fig. 2A), as subhedral inclusions in K-feldspar (Fig. 2C), or as graphic intergrowths with K-feldspar and albite. The percentage of nepheline in