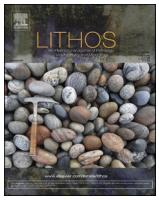
LITHOS 508–509 (2025) 108089

Contents lists available at ScienceDirect

LITHOS

journal homepage: www.elsevier.com/locate/lithos



Archean syenites by intracrustal processes: The Boesmanskop Alkaline Complex, Eastern Kaapvaal Craton

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ARTICLE INFO

Keywords:
Archean Alkaline rocks
Cumulus mechanism
High-temperature K-rich magmatism
Kaapvaal Craton

ABSTRACT

Alkaline rocks are volumetrically a minor component of the geological record, with Archean examples being remarkably rare. The oldest Archean syenites on Earth occur in the ca. 3.1 Ga Boesmanskop Alkaline Complex (BAC), located on the eastern margin of the Kaapvaal Craton, where they form part of a voluminous Granodiorite-Monzogranite-Syenogranite suite (GMS). The unique geochemical and isotopic characteristics of the BAC may provide key insights into early crustal differentiation processes and the nature of Archean magmatism. Understanding its petrogenesis helps to refine models of early continental stabilization and the evolution of high-K magmatism in the Archean. The rocks of the BAC include syenite, quartz monzonite, and leucogranite. This study draws upon newly acquired data, encompassing field observations, petrological analysis, mineral chemistry, whole-rock geochemistry including Rb—Sr and Sm—Nd isotope ratios, and phase equilibrium modeling, with the aim of better understanding the petrogenesis of the BAC rocks. These syenitic rocks display coarse-grained porphyritic textures with K-feldspar phenocrysts as cumulus phase and clinopyroxene, Ca-amphibole, plagioclase, titanite, and scarce quartz as the main intercumulus phases. The syenite is only deformed at the contact with the Tonalite–Trondhjemite–Granodiorite (TTG) basement, displaying SC fabrics and mineral lineation parallel with the pluton edges and concordant with the basement kinematic indicators. In other outcrops, the syenite intrudes the TTGs with sharp contacts and overlay syenitic dyke swarms connected to sill intrusions with hypabyssal textures, which suggest the shallow emplacement of the magmas along an active shear zone. The BAC rocks are silica-saturated with high $K_2O + Na_2O$ (< 11.2 wt%), low MgO (< 1.6 wt%) and low CaO (<3.41 wt%). They also have low transition element contents, high Ba and Sr contents and negative Nb, Ta, and Ti anomaly, indicative of crustal sources. The BAC rocks have Sr and Nd isotopic compositions that overlap those of the host TTG basement. The data obtained indicate that the syenites represent K-feldspar-dominated crystal cumulates left behind by the extraction of rhyolitic melts from the magma chamber, formed from magmas that crystallized high-temperature K-feldspar before plagioclase and quartz. The viability of this hypothesis has been tested by phase equilibrium modeling, which has demonstrated that a subset of GMS granite compositions with high $K_2O + Na_2O$ (> 9.3 wt%) do produce high-temperature K-feldspar as the first tectosilicate when cooling under low-pressure conditions. Thus, the syenitic cumulates are proposed to be produced by a structurally assisted accumulation of K-feldspar from hot granitic magma produced by fluid-absent anatexis of the lower crust, contributing to the craton stabilization by the transfer of radioactive elements to shallow depths.

1. Introduction

Alkaline igneous rocks comprise a compositionally broad group of rocks characterized by alkali concentrations that exceed the capacity of their feldspar to fully accommodate the alkali elements (Fitton and Upton, 1987; Frost and Frost, 2008). A broader, commonly applied classification that is also used in this study, classifies igneous rocks as either alkaline or subalkaline, based on the relationship between SiO_2 and the combined alkali content, as expressed in the Total Alkali vs Silica diagram (e.g., Fitton and Upton, 1987; Miyashiro, 1978; Sørensen,

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https://doi.org/10.1016/j.lithos.2025.108089
Received 21 September 2024; Received in revised form 3 April 2025; Accepted 5 April 2025
Available online 10 April 2025