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Geochemical constraints of the petrogenesis of the O'okiep Koperberg Suite and granitic plutons in Namaqualand, South Africa: A crustal source in Namaquan (Grenville) times

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Abstract

The Namaquan (Grenville) Orogeny (late Mesoproterozoic) in the O'okiep District is characterized by two tectono-magmatic episodes: the O'okiepian Episode (1210–1180 Ma) with the intrusion of batholitic granites, and the Klondikean Episode (1040–1020 Ma), which includes the intrusion of the copper-bearing Koperberg Suite and the Rietberg Granite. This study focuses on the geochemistry (major and trace elements, Sr and Nd isotopes) of intrusive rocks of the O'okiep terrane to provide better constraints on their source rock characteristics and on their petrogenesis. The O'okiepian Granites belong to the K-rich granite kindred, with shoshonitic affinities. The Concordia Granite results from dehydration melting of a pelitic source. The Rietberg Granite shows geochemical similarities with post-collisional magmatic series. The anorthosites and related rocks of the Koperberg Suite are cumulates; their REE distribution is controlled by their apatite content. A new rock type, jotunite, has been identified in the Koperberg Suite; it is analogous to the Rogaland chilled jotunite, a characteristic which gives strong evidence that the Koperberg rocks belong to the massif-type anorthosite suite. Inversion modelling of plagioclase REE compositions from anorthosite permits the reconstruction of melt compositions and places constraints on the melting process and on the characteristics of the source rocks. The occurrence of jotunite in the Koperberg Suite is strong additional evidence for a crustal source, because jotunite is produced by remelting of gabbronorite under dry conditions. The various intrusions in the Koperberg Suite show distinct isotopic signatures, which resulted from isotopic heterogeneities of the crustal source and from minor contamination with the country rocks. The characteristic negative $\varepsilon_{\mathrm{Nd}(1030\,\mathrm{Ma})}$ values (−5 to −11) can be explained by remelting at 1030 Ma of a 1900-Ma-old oceanic crust protolith with an enriched MORB REE distribution. The large range in Sr initial ratios (0.709–0.748) may reflect hydrothermal alteration of the oceanic crust, a process which may also explain the Cu enrichment. The Koperberg intrusions were produced by forceful injection of cumulate crystal mush, which were differentiated in deeper magma chambers or in conduits.

Keywords: Granite plutonism; Anorthosite; Jotunite; Cu sulphides; Namaquan orogeny; Sr and Nd isotopes

1. Introduction

The O'okiep intrusive rocks of Namaqualand, South Africa, include the Koperberg Suite and a number of

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important granite suites which intrude a basement of crystalline rocks, made up of granite gneiss with remnants of supracrustal rocks. These crystalline rocks were deformed and metamorphosed during the Namaquan (=Grenville) Orogeny (late Mesoproterozoic) (Clifford et al., 1981, 2004). The Koperberg Suite includes Cu-bearing sulphide deposits that have been mined for 150 years, and because of its economic importance, the O'okiep District has been the subject of detailed studies for the last 50 years (see e.g. Gibson et al., 1996). A number of recent publications have been devoted to the timing and interpretation of metamorphic and intrusive events (Clifford et al., 1995, 2004; Gibson et al., 1996; Robb et al., 1999). Fewer studies have, however, been concerned with the geochemistry of the intrusive rocks (Conradie and Schoch, 1988; Brandriss and Cawthorn, 1996; Van Zwieten et al., 1996; Geringer et al., 1998).

Several granites, including the Concordia and Kweekfontein Granites, were emplaced around 12000 Ma (Clifford et al., 2004) and were, in turn, intruded at *ca.* 1030 Ma (Clifford et al., 1995, 2004; Robb et al., 1999) by the Koperberg Suite of rocks, consisting of andesine anorthosite and various members of the charnockitic suite (*sensu* Streckeisen, 1974). In the present work, we show that most Koperberg Suite rocks are cumulates and we focus on the jotunite rocks that have the characteristics of melts which can be parental to andesine anorthosite and related rocks (Duchesne, 1990). The isotopic characteristics of the crustal source of this parental magma (Clifford et al., 1995; Geringer et al., 1998) may be explained by the melting of a mafic (gabbronoritic) rock, a process supported by experimental work (Longhi et al., 1999; Longhi, 2005); this protolith was an hydrothermally altered oceanic crust with associated Cu-sulphide deposits. Finally, the overall K-rich nature of the enclosing granitoids, whatever their age and evolution, is compatible with a post-collisional geodynamic setting (Liégeois et al., 1998).

2. Regional setting

The Namaquan orogenic belt in north-western South Africa and southern Namibia is made up of a series of terranes which have been grouped in subprovinces (Fig. 1; Hartnady et al., 1985): (1) the Gordonia subprovince, (2) the Richtersveld subprovince, and (3) the Bushmanland subprovince. The Gordonia subprovince is composed of several terranes between the Kaapvaal craton and the other two subprovinces. Among them the Areachap terrane, made up of greenstones generated *ca.* 1300 Ma ago (Cornell et al., 1990), is the only juvenile terrane in the Namaquan orogen. The Richtersveld subprovince is interpreted as an Eburnian, 1700–2000-Ma-old island arc complex remobilized along an active continental margin (Reid and Barton, 1983; Hartnady et al., 1985). Finally the Bushmanland subprovince com-

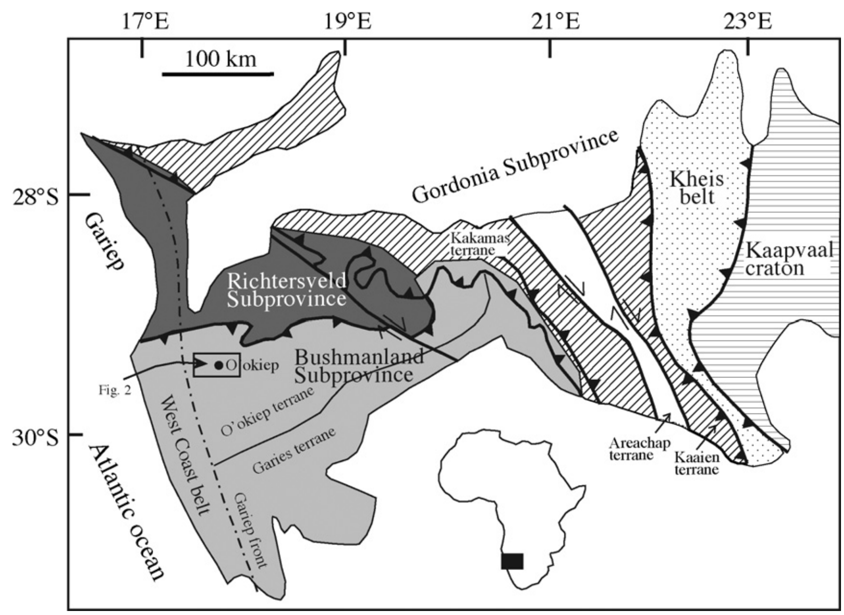

Fig. 1. Terrane map of the Namaquan orogen modified after Hartnady et al. (1985) and Thomas et al. (1994). The Gordonia subprovince (eastern Namaqua), which possesses rocks with active margin characteristics, the Richtersveld subprovince, made of preserved 2000–1700 Ma rocks, and the Bushmanland subprovince (south-western Namaqua) made also of an early Palaeoproterozoic basement but heavily reactivated during the Namaquan orogeny (1200–800 Ma).