Precambrian Research 186 (2011) 28–50

Contents lists available at ScienceDirect

Precambrian Research

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

Volcanic evolution of the upper Onverwacht Suite, Barberton Greenstone Belt, South Africa

Harald Furnes[a,b,*], Maarten J. de Wit[c], Brian Robins[a], Nils Rune Sandstå[d]

[a] Department of Earth Science, University of Bergen, Allegt. 41, 5007 Bergen, Norway
[b] Centre for Geobiology, University of Bergen, Allegt. 41, 5007 Bergen, Norway
[c] AEON and Department of Geological Sciences, University of Cape Town, Rondebosch 7701, South Africa
[d] Norwegian Petroleum Directorate, Post Box 600, 4003 Stavanger, Norway

ARTICLE INFO

Article history:
Received 11 December 2009
Received in revised form 4 August 2010
Accepted 18 November 2010
Available online 25 November 2010

Keywords:
Barberton Greenstone Belt
Volcanic products – pillowed and massive lava
Volcanic stratigraphy and architecture
Tectonic setting

ABSTRACT

The volcanic stratigraphy of the upper Onverwacht Suite in the southeastern part of the Paleoarchean Barberton Greenstone Belt has been investigated in 18 sections through parts of the Hooggenoeg, Kromberg, and lower Mendon Complexes. The ca. 2700 m thick volcanic sequence of the lowest tectonostratigraphic unit – the Hooggenoeg Complex (HC) – can be subdivided into 9 stratigraphic units representing major eruptive phases, each separated by silicified sedimentary and volcaniclastic rocks. The thicknesses of the units vary from <100 m to ∼700 m. Some units are wedge-shaped and die out over distances of a few kilometre along strike. The volcanic rocks are predominantly basaltic lavas, with minor basaltic komatiite and komatiite in the middle part of the HC. The basaltic lavas of the overlying tectonostratigraphic unit, the Kromberg Complex (KC), occur as screens within intrusives, or are in tectonic contact with adjacent rocks. The basal part (Ncakini section) of the tectonostratigraphically uppermost Mendon Complex (MC), consists of Mg-rich basalt lava.

The lavas of the HC and KC are predominantly pillowed and massive flows, whereas those of the Ncakini section are exclusively massive. The massive and pillowed lava are commonly organized in cyclic units from 3 m to 32 m thick, and consisting of massive lava or large pillows that are succeeded by progressively smaller pillows. Cyclic units are inferred to have resulted from individual eruptions with decreasing rates of effusion. The pillow lavas of both the HC and KC contain <3–5% vesicles indicating eruption at greater depths than ∼2000 m. In general vesicular pillows occur in the lower part of both the HC and KC, and non-vesicular (and variolitic) lavas are found at the top, suggesting increasing water depths, and hence eruption in a subsiding basin. The chert layers within the HC include silicified tuffs derived from explosive subaerial or shallow-marine eruptions distant from the deep-water lavas of the HC and KC.

1. Introduction

There are a large number of greenstone belts worldwide (de Wit and Ashwal, 1997), and about 260 of Archean age (de Wit, 2004). As the name implies, they consist dominantly of basaltic volcanic and intrusive rocks of low-metamorphic grade (e.g. de Wit and Ashwal, 1995).

The Paleoarchean (3600–3200 Ma; Walker and Geissman, 2009) Barberton Greenstone Belt within the Kaapvaal Craton of South Africa (Viljoen and Viljoen, 1969) (Fig. 1) contains well-preserved volcanic rocks. The stratigraphy, structural evolution, geochemistry, petrology, geochronology and tectonic setting of these rocks have been investigated by many workers (Armstrong et al., 1990; de Wit et al., 1987, 1992; Lopez-Martinez et al., 1992; Kröner et al., 1996; Parman et al., 1997; Lowe and Byerly, 1999; Lowe et al., 1999; Byerly, 1999; Vennemann and Smith, 1999; Chavagnac, 2004). However, apart from the detailed studies by Dann (2001) and Dann and Grove (2007), mainly of the lower tectonostratigraphic part of the Barberton volcanics, relatively little attention has been paid to the volcanological development of the sequences.

In this study we present the results of detailed stratigraphic logging of sections through volcanic sequences in the southeastern part of the Barberton Greenstone Belt carried out in 2004–2009 (Fig. 2). Altogether 18 sections, in total 2257 m thick, were logged through the most continuous exposures of the Hooggenoeg and Kromberg Complexes, as well as the lower part of the Mendon Complex that we have named the Ncakini section (Figs. 1 and 2). These sections have enabled us to reconstruct the nature of the volcanic activity and the architecture of the volcanic products, to estimate the eruption depths (based on the vesicularity of pillows), as well

* Corresponding author at: Department of Earth Science, University of Bergen, Allegt. 41, 5007 Bergen, Norway. Tel.: +47 5558 3530; fax: +47 5558 3660.
E-mail address: harald.furnes@geo.uib.no (H. Furnes).

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doi:10.1016/j.precamres.2010.11.002

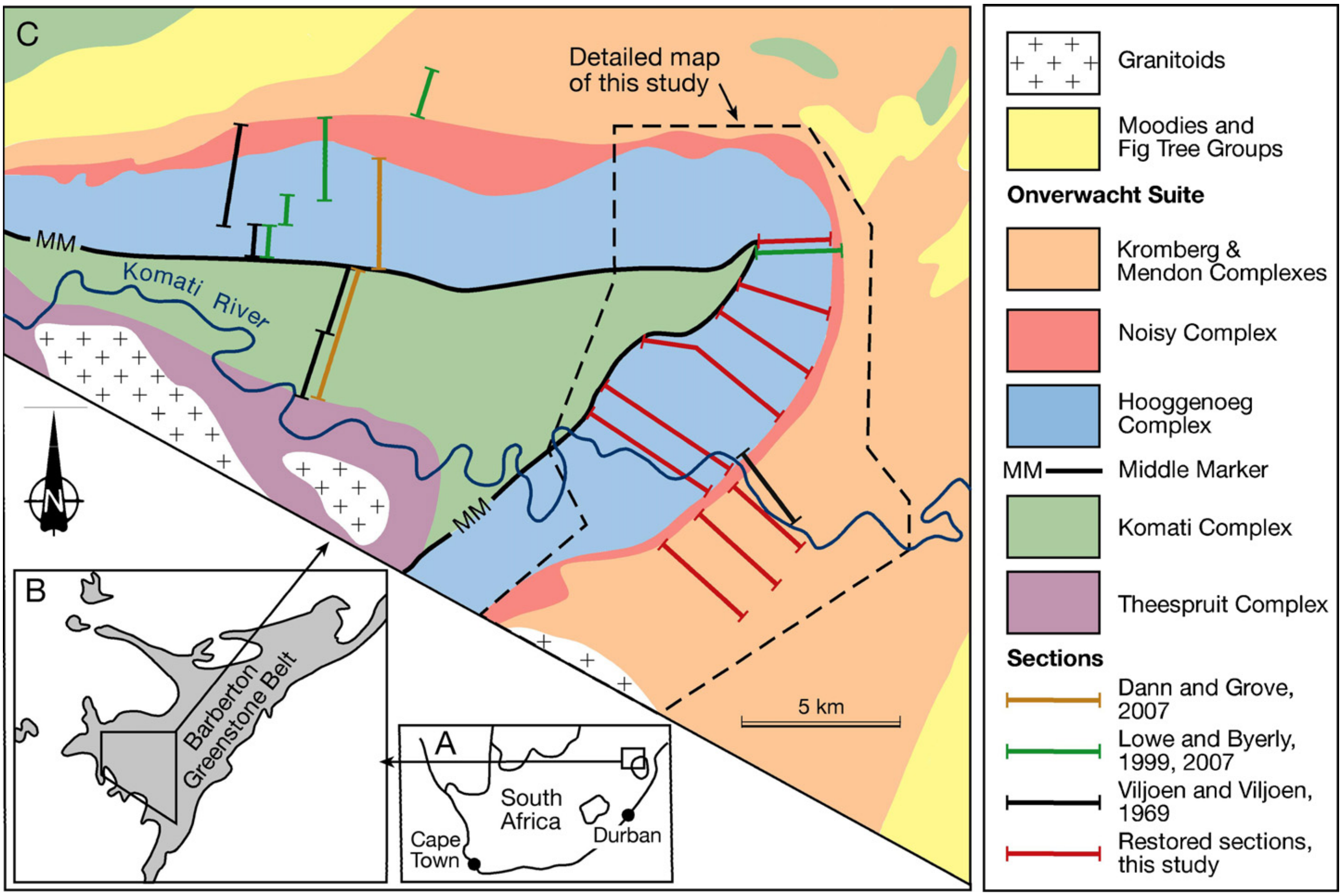

Fig. 1. Maps showing the geographic location of the Barberton Greenstone Belt in South Africa (A), the outline of the greenstone belt (B), and a very simplified geological map (C) showing the distribution of different units within the south-eastern part of the Barberton Greenstone Belt. Different coloured lines mark the type sections described by previous authors (Viljoen and Viljoen, 1969; Lowe and Byerly, 1999, 2007; Dann and Grove, 2007), as well as the locations of the sections that form the basis of the present account. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

as to make some inferences as to the tectonic setting in which the complexes were formed.

2. General geology of the Onverwacht Suite

The Paleoarchean Barberton Greenstone Belt consists of volcanic, intrusive and sedimentary rocks belonging to the Onverwacht, Fig Tree and Moodies Groups (see overview paper by Lowe and Byerly (1999)). The largely volcanic sequence, first defined as the Onverwacht Group by Hall (1918) and later subdivided into the Sandspruit, Theespruit, Komati, Hooggenoeg, Kromberg, and Swartkoppie Formations (Viljoen and Viljoen, 1969) comprises basaltic and subordinate komatiitic extrusives and intrusives, as well as minor silicified sedimentary and volcaniclastic horizons. The Onverwacht Group has been interpreted as a fragment of Archean oceanic crust, termed the Jamestown Ophiolite Complex (de Wit et al., 1987), that developed in association with subduction and island-arc magmatic activity 3480–3220 Ma ago (Armstrong et al., 1990; de Wit, 2004). The Hooggenoeg and Kromberg Formations contain some of the world's oldest and best-preserved subaqueous lavas (de Wit et al., 1987; Brandl and de Wit, 1997). The magmatic sequence of the Onverwacht Group is locally unaffected by penetrative deformation. The Fig Tree and Moodies Groups (Fig. 1) consist of chert, banded iron formation (BIF), shale and sandstone (e.g. Lowe and Byerly, 1999; Heubeck and Lowe, 1999). In general, stratigraphically downward there is an increase in the metamorphic grade from zeolite to amphibolite facies in the tectonostratigraphically lowest igneous rocks that are adjacent to, or surrounded by granitoid plutons (Fig. 1) (de Wit et al., 1987; Dziggel et al., 2002; Diener et al., 2005; Moyen et al., 2006). The metamorphic grade of the volcanic rocks within the studied area (Figs. 1 and 2) is prehnite-pumpellyite to greenschist facies.

On the basis of detailed mapping carried out by one of us (M.J. de Wit), as well as the present work, we infer that contacts between the formal subdivisions of the Onverwacht Group established earlier (Viljoen and Viljoen, 1969) are tectonic rather than stratigraphic, and furthermore, the radiometric ages of the stratigraphic sequences are poorly known. We contend that the relative ages, with the Sandspruit Formation as the oldest, followed by the Theespruit, Komati, Hooggenoeg, Kromberg and Mendon Formations, as generally accepted since the work of Viljoen and Viljoen (1969), is not justified. A companion paper (de Wit et al., this volume), presents the arguments supporting this contention. Thus, we employ the informal term "complex" instead of "formation". As a consequence we replace the "Onverwacht Group" with the "Onverwacht Suite" consisting of the Sandspruit, Theespruit, Komati, Hooggenoeg, Noisy, Kromberg and Mendon Complexes. The magmatic and sedimentary rocks, previously included in the uppermost part of the Hooggenoeg Formation (Viljoen and Viljoen, 1969) and the lower part of the Kromberg Formation (Lowe and Byerly, 1999), are re-assigned to the Noisy Complex (see de Wit et al., this volume).