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Growth-fault structure and stratigraphic architecture of the Buck Ridge volcano-sedimentary complex, upper Hooggenoeg Formation, Barberton Greenstone Belt, South Africa

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Abstract

The ∼3.45–3.42 Ga Buck Ridge volcano-sedimentary complex (BR-vsc) forms the uppermost part of the Hooggenoeg Formation, in the early Archaean Onverwacht Group of the Barberton Greenstone Belt, South Africa. The complex consists mainly of massive and pillowed basalts and felsic, quartz-plagioclase porphyritic rocks, which are capped by pervasively silicified sedimentary rocks. Deposition of the felsic extrusive and (volcani-)clastic sedimentary rocks occurred in shallow water to emersion, during an extensional tectonic regime. The extensional regime is expressed by a number of listric normal faults that transect the entire ∼2 km thick complex. The syndepositional (i.e. growth fault) character of the faults is indicated by variations in thickness and facies of rock units across the faults, and by systematic rotation of the fault blocks. Broadly contemporaneous with the faulting, felsic rocks intruded the complex into the highest levels. The geometry of these intrusive bodies was controlled by the major growth faults. Extension also created space for the intrusion of approximately bedding-perpendicular felsic and mafic dykes, and black chert veins. The new field observations and U–Pb zircon SHRIMP data have pinned the timing of events during and after deposition of the BR-vsc. The growth-fault model accounts well for previously unexplained structural observations that include both extensional and compressional features. Recognition of an early extensional phase of deformation demonstrates further similarities between the tectonic histories of the Barberton Greenstone Belt and the greenstone belts of the east Pilbara in Australia.

Keywords: Early Archaean; Early extension; Syndepositional normal faulting; Geochronology; Onverwacht Group; Barberton Greenstone Belt

1. Introduction

Sedimentary rocks of the ∼3.42 Ga Buck Ridge Chert (BRC, also referred to as Buck Reef Chert; Lowe and Byerly, 1999a) of the upper Hooggenoeg Formation are amongst the oldest preserved clastic deposits in the Barberton Greenstone Belt (South Africa). The sedimentary rocks are well preserved and have experienced little deformation. Therefore, they form a good target for early Archaean basin studies. Knowledge of the tectonic regime during which these basins were formed, and hence the timing of the earliest phase of crustal deformation, is essential. Despite the fact that the Barberton Greenstone Belt has been intensively studied, the tectonic regime during deposition of the upper Hooggenoeg Formation is still not well known. Extensional faults (Viljoen and Viljoen, 1969; de Wit, 1982, 1986; Lowe and Fisher Worrell, 1999) as well as compressive features (de Wit, 1982, 1983; de Wit et al., 1987a; Lowe et al., 1985, 1999) have been reported. However, it

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remains unclear whether basin formation was controlled by an extensional or a compressive tectonic regime, and what the temporal relationship between these tectonic regimes was. Some conspicuous features in the upper Hooggenoeg Formation, such as the Geluk disturbed zone, described by Lowe et al. (1985, 1999) as a zone of rotated and overturned blocks, remained largely unexplained, and were not attributed to a particular tectonic regime. We present new field and geochronological data that allow for a more detailed interpretation of the structural control during deposition of the upper Hooggenoeg Formation. In this study it was found that observations of syndepositional deformation provide the most useful clues about the structural control in this basin. Attention will also be paid to the structure of the area immediately to the north of the BRC, because the connection between the BRC and the overlying stratigraphic units is relatively poorly known.

2. Geological framework

2.1. Stratigraphy

Stratigraphically, rocks of the Archaean Barberton Greenstone Belt belong to the Swaziland Supergroup, which is divided into the dominantly volcanic Onverwacht Group and the overlying sedimentary Fig Tree and Moodies Groups. The intact stratigraphic section of the Onverwacht Group consists of four units: the ∼3.48–3.27 Ga Komati, Hooggenoeg, Kromberg, and Mendon Formations (e.g. Viljoen and Viljoen, 1969; Armstrong et al., 1990; Kröner et al., 1991; Kamo and Davis, 1994; Byerly et al., 1996; Lowe and Byerly, 1999b).

The Hooggenoeg Formation dominantly consists of mafic and ultramafic rocks that occasionally include thin layers of silicified sedimentary rocks. The uppermost part of the formation is made up of a 1–2 km thick succession of basalt with several layers of felsic volcanic and volcaniclastic rocks, and a minor amount of felsic intrusive rocks (e.g. Viljoen and Viljoen, 1969; de Wit, 1982; Lowe et al., 1985; de Wit et al., 1987a; Lowe and Byerly, 1999b). The extrusive felsic rocks are capped by up to 570 m of sedimentary rocks of the BRC. The Kromberg and Mendon Formations consist of mafic to ultramafic volcanic and volcaniclastic rocks, and include thin layers of silicified sedimentary rocks (e.g. Viljoen and Viljoen, 1969; Lowe and Byerly, 1999b).

Opinions differ about whether the BRC belongs to the Hooggenoeg Formation or to the Kromberg Formation. The BRC was originally placed at the top of the Hooggenoeg Formation (Viljoen and Viljoen, 1969). This interpretation was widely adopted until Byerly et al. (1996) re-interpreted the BRC as the basal unit of the Kromberg Formation. These authors regarded the BRC to be the lateral equivalent of several thin cherts in the Kromberg Formation on the southern limb of the Onverwacht Bend. Since then, there has been a debate about which formation the BRC should be assigned to. Brandl and de Wit (1997) regard it as the uppermost unit of the Hooggenoeg Formation, whereas Lowe and Byerly (1999a) continued to interpret it as the base of the Kromberg Formation. In our study area, the contact of the BRC with the underlying layers of the Hooggenoeg Formation is generally transitional (cf. Viljoen and Viljoen, 1969; Lowe and Fisher Worrell, 1999). Local unconformities are present, but there is no regional unconformity at the base of the BRC. The transitional contact of the BRC with the underlying rocks, and the fact that further west the BRC splits up in an alternation of chert, shale and Hooggenoeg Formation basalt, indicate that the BRC should be regarded as part of the latter formation (cf. Viljoen and Viljoen, 1969). For the assemblage of interrelated basalts, felsic volcanic rocks and intercalated cherts in the upper part of the Hooggenoeg Formation a new term is introduced: the Buck Ridge volcano-sedimentary complex (BR-vsc). The BRC forms the silicified, uppermost part of this complex. The base of the BRC is taken where the uppermost felsic volcanic rocks of the BR-vsc grade into pervasively silicified, black-and-white-banded sedimentary rocks.

2.2. Structural setting

The rock succession of the Barberton Greenstone Belt has undergone several phases of intense folding and faulting, which have resulted in a generally vertical to subvertical orientation of the bedding. Main phases of deformation that led to the folding and thrusting of the greenstone belt succession are interpreted to be D1 and D2, at ∼3445 and 3230 Ma (Table 1). Deformation phases D3 and D4 led to further folding and faulting. During D3, the entire southern part of the greenstone belt was folded into the steeply east-plunging Onverwacht Bend (Fig. 1). The study area is located on the northern limb of this antiform, where the overall younging is to the north (dating by e.g. Armstrong et al., 1990; Kröner et al., 1991; Kamo and Davis, 1994; Byerly et al., 1996).

There has been debate about the stratigraphic continuity in the study area on a smaller scale. Viljoen and Viljoen (1969) provided one of the first maps and a systematic description of the stratigraphic succession of the area (Fig. 2a). They regarded the Hooggenoeg Formation as an essentially continuous, north-younging