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Microbialite–sediment interactions on the slope of the Campbellrand carbonate platform (Neoarchean, South Africa)

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ABSTRACT

Microbialite–resedimented dolostone cycles form a prominent part of slope facies for the 2.6–2.5 Ga Campbellrand carbonate platform, Transvaal Supergroup, South Africa. Microbialites are typically transitional between four end members: (1) cuspate microbialites, (2) plumose microbialites, (3) stratiform, domal and columnar microbialites, and (4) incipient microbialites. Resedimented facies include (1) dolarenites, (2) massive to laminated dolostones, (3) dolomite laminites, and (4) lumpy dolostones with roll-up structures. On a cm- and dm-scale, microbial and resedimented facies are arranged into symmetric or asymmetric *microbialite cycles* with resedimented facies commonly grading upward into microbialite facies. Cycles are transitional between a microbialite-dominated end member with almost no evidence for clastic carbonate sedimentation, and a sediment-dominated end member where microbialite relief is strongly subdued and resedimented carbonate makes up most of the cycle thickness. The microbialite-dominated cycles are remarkably uniform on the platform slope. Systematic variation in cycle architecture leads to dm-scale *stacked microbialite cycles*, which in turn form the main building blocks of m-thick *microbial units*. On the scale of decameter-thick sequences, microbial units pass upwards to progressively thicker units dominated by resedimented slope carbonates.

Microbialite cycles show a distinct inverse relationship between the development of microbial structures and the abundance of detrital carbonate sediment in cycles. Thus, cyclicity is interpreted as primarily controlled by variations in sediment influx. On the largest scales, sediment influx may be controlled by sediment export off the platform margin and upper slope, which was influenced by sea level change. Due to the deep depositional environment and stratigraphic distribution of cycles, dm-scale cycles are interpreted as primarily controlled by allocyclic processes.

1. Introduction

Cyclic carbonate sedimentation is an important component of carbonate platforms and reflects allocyclic factors (e.g., relative sea level, tectonics) as well as autocyclic factors (e.g., carbonate production and progradation of tidal flats) (Fischer, 1964; Ginsburg, 1971; Pratt et al., 1992). Such sedimentary cycles have been traced back until Neoarchean time (e.g., Grotzinger, 1986; Sami and James, 1994; Sumner and Grotzinger, 2000; Hofmann et al., 2004), suggesting that the physical and chemical processes governing carbonate deposition remained relatively unchanged throughout Earth history. Carbonate cycles, in particular Precambrian examples, commonly have a microbialite component (e.g., Sami and James, 1994; Johnson and Grotzinger, 2006), and this association has the potential to shed light on the relative importance of microbial versus environmental processes in the formation of microbialites (Grotzinger and Rothman, 1996; Grotzinger and Knoll, 1999). Studies of such microbialite–carbonate cyclicity typically focus on shallow-water environments, although cycles have been reported from slope and slope-basinal environments as well (e.g., Hoffman, 1989). Deeper-water microbialite–carbonate cycles can be expected to form under more homogeneous environmental conditions, thus eliminating some of the more rapidly changing environmental effects, such as localized differences in flow dynamics and sediment reworking.

This contribution examines carbonate–microbialite cycles in sub-storm-wave base environments in the Neoarchean Transvaal Supergroup in South Africa. Cyclicity is described on several orders of scale and along a slope transect, followed by an examination of the processes involved in cycle formation.

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2. Geological setting

The studied rock succession belongs to the Campbellrand Subgroup of the Transvaal Supergroup in the Griqualand West basin (Figs. 1 and 2; Beukes, 1987; Sumner and Grotzinger, 2004; Sumner and Beukes, 2006). Deposition of the Campbellrand Subgroup occurred between ~2600 and 2500 Ma, but many intermediate age dates remain unreliable due to zircon inheritance and analytical complications (Fig. 2) (see discussion in Altermann and Nelson, 1998; Sumner and Beukes, 2006). The Campbellrand Subgroup conformably overlies the mixed carbonate–siliciclastic rocks of the Schmidtsdrif Subgroup (Beukes, 1978), and is in turn conformably overlain by iron formations (Asbestos Hills Subgroup) (Fig. 2; Beukes, 1978, 1984).

The sedimentary succession studied here records deposition on a passive margin (Sumner and Beukes, 2006). The Schmidtsdrif rocks form a mixed carbonate–siliciclastic ramp, which is overlain by an aggradational rimmed carbonate platform, represented by the Campbellrand Subgroup. Rocks of the Campbellrand Subgroup represent two distinct paleogeographic domains. In the northeast of the study area, oolitic and stromatolitic platform carbonates constitute the (informal) Ghaap Plateau Facies, which is up to 1900 m thick (Fig. 1; Beukes, 1978, 1987; Sumner, 1997a; Sumner and Grotzinger, 2004). The platform margin coincided with a northwest-trending sedimentary growth fault located near Griquatown (Fig. 1). Interbedded microbialites, resedimented carbonates, siliciclastic mudstones, cherts and iron formations of the Prieska Facies (≤650 m thick) were deposited in the basin and on the slope southwest of the platform margin (Figs. 1 and 3; Beukes, 1978, 1987). The gradual transition from the carbonates of the Campbellrand Subgroup to the chert and BIF of the Asbestos Hills Subgroup represents drowning of the platform (Klein and Beukes, 1989; Sumner and Grotzinger, 2004).

The present study focuses on two cores, 24 km apart, which were drilled through the platform slope southwest of Griquatown (Figs. 1 and 4). Core GKP01 was drilled in a distal position and covers the stratigraphy from the base of the Schmidtsdrif Subgroup to the base of the Asbestos Hills Subgroup. The second core, GKF01, represents a more proximal position on the platform slope (Figs. 1 and 4), and the succession from the Boomplaas Formation of the Schmidtsdrif Subgroup to the base of the Asbestos Hills Subgroup is present (Fig. 3).

3. Slope lithofacies

In the above lithostratigraphic framework, the slope succession to the Campbellrand carbonate platform belongs to the Nauga Formation of the Campbellrand Subgroup (Fig. 4; Beukes, 1987). Several slope lithofacies were recognized in the cores, in particular microbialites and resedimented carbonates, which are discussed below. Additional subordinate lithofacies include dark grey massive or laminated siliciclastic mudstones, chert, banded iron formations and tuff beds (Schröder et al., 2006).

3.1. Microbialite facies

Microbial structures are typically transitional between four end members: (1) cuspate microbialites, (2) plumose microbialites, (3) stratiform, domal and columnar microbialites, and (4) incipient microbialites (cf. Sumner, 1997b; Sumner and Grotzinger, 2004). Cuspate microbialites are characterized by vertically oriented support structures with draping concave upward laminae, creating a generally tented morphology (Fig. 5A). The size of the microbialite structures varies between millimetric and decimetric. The supports have a smooth texture and are commonly folded. The draping mm-scale laminae vary in texture between smooth and crinkly. Laminae are commonly deformed into sand-sized lumps and roll-up structures (see below). Supports and laminae create a framework surrounding mm- and cm-scale ovoids that are filled by sparite. Cuspate microbialites include the tented, cuspate *sensu strictu*, and

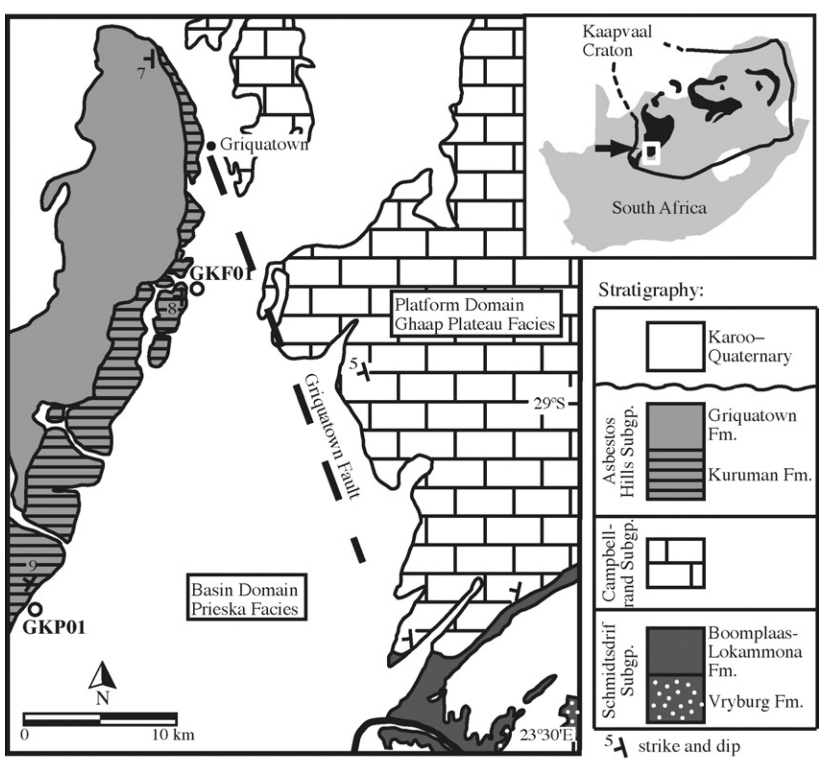

Fig. 1. Detailed geological map of the study area with outcrops of the main depositional units and location of the two drill cores. The Griquatown Fault separates the platform domain in the NE from the basin domain in the SW. The small inset map shows location of study area relative to the outcrop belt of the Transvaal Supergroup (black). Subgp. = subgroup; Fm. = formation.