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3.2 Ga eolian deposits from the Moodies Group, Barberton Greenstone Belt, South Africa: Implications for the origin of first-cycle quartz sandstones

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ABSTRACT

The 3.2 Ga Moodies Group in Barberton Greenstone Belt, South Africa, contains the oldest recognized evidence for eolian processes on Earth. These eolian facies indicate that significant wind regimes existed in the Archean atmosphere. Eolian deposits are developed in the lower Moodies Group in the central part of the belt and consist of stacked inversely graded strata ranging in thickness from 2 to 10 mm.

Individual strata consist of fine- to medium-grained quartz sandstone at the base that passes vertically into very coarse- to coarse-grained quartz sandstone. Strata make up cross-bed sets up to 3–5 m thick. Sets of wind ripple strata are either tabular tangential or in the form of broad troughs. This type of inversely graded stratification is the product of wind-ripple migration. The coarse grain size of the sediment combined with the low-angle of inclination of the strata is best interpreted as the product of sand sheet or dune plinth preservation. Based on the geometry of eolian set boundaries, dunes were probably simple barchan form.

The tens-of-meters thick eolian deposits are underlain by braided stream deposits composed of subfeldspathic, pebbly sandstones. The vertical change from braided-stream subfeldspathic sandstones to eolian quartz arenites, highlights the underappreciated capacity of eolian processes to generate first-cycle quartz sandstones on landscapes pre-dating the advent of land vegetation.

1. Introduction

Observations on the migration of wind ripples on modern sand dunes has led to the identification of physical processes that produce inversely graded ripple stratification, the distinctive and unique product of wind-ripple migration (Hunter, 1977, 1981). Inversely graded strata generated by wind-ripple migration provide an unequivocal means for separating subaerial from subaqueous depositional processes at a centimeter scale in ancient stratigraphic successions and hence eolian processes in continental settings (Hunter, 1977, 1981; Kocurek and Dott, 1981).

The oldest reported evidence of eolian processes is recorded as wind erosion in ventifacts associated with placer deposits in the 2.9 Ga Witwatersrand Supergroup, South Africa (Minter, 1976, 2006). Sand sheet deposits composed of eolian stratification from the 2.6 Ga Minas Supergroup of Brazil are the oldest cited evidence of eolian deposition (Martins-Neto and Costa, 1985). Archean eolianites have not been identified and this probably reflects their limited development and/or preservation; significant growth of widespread dunefields did not occur until ~1.8 Ga (Eriksson and Simpson, 1998; Simpson et al., 2004).

This paper describes preliminary work conducted in the 3.2 Ga Moodies Group that has recognized sets of wind-ripple strata preserved in quartz-rich sandstones. These are the oldest eolian deposits on the Earth and we interpret the quartz sandstones as first-cycle, produced in part by eolian abrasion. This interpretation is consistent with Dott's (2003) hypothesis on mechanisms generating quartz sandstones in pre-vegetated continental systems.

2. Geological setting

The Moodies Group, the uppermost subdivision of the Swaziland Supergroup, outcrops in a series of tightly keeled synclines in the Barberton Greenstone Belt (Fig. 1). The Swaziland Supergroup consists of, from oldest to youngest: (1) the volcanic-dominated Onverwacht Group, (2) the quartz-poor sedimentary Fig Tree Group, and (3) the quartz-rich Moodies Group (Fig. 1). The Moodies Group is Mesoarchean with an age ~3.2 Ga. The maximum age of the Moodies Group strata is bracketed by ages of ignimbrites (3226+/−1 Ma), porphyries (3222+10/−4 Ma), and dacitic clasts

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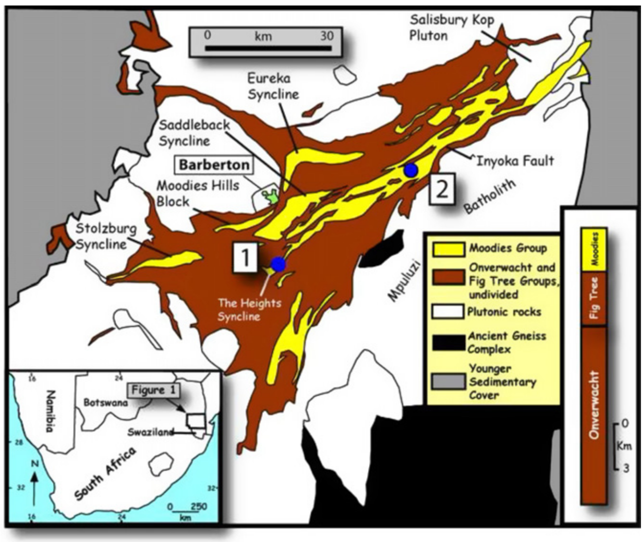

Fig. 1. Geological map of the Barberton Mountain Greenstone Belt. Note the study localitions 1 and 2. Modified from Heubeck and Lowe (1994).

contained in conglomerates (3225+/−3 Ma) at the top of the Fig Tree Group (Kröner et al., 1991; Kamo and Davis, 1994). A minimum age is constrained by the cross-cutting Salisbury Kop Pluton (3079+/−6 Ma) in the eastern part of the greenstone belt (Heubeck et al., 1993). The 3216+2/−1 Ma Dalmein Pluton (Fig. 1) cross cuts large-scale folds in the Onverwacht and Fig Tree groups and is similar in size, geometry, and orientation to post-Moodies Group folds (Kamo and Davis, 1994).

In the northern part of the Barberton Greenstone Belt, the ~3.2 km-thick Moodies Group is subdivided into mappable stratigraphic units MD 1–MD 5, from oldest to youngest (Eriksson, 1978). Unit MD 1 fines upward from a basal conglomerate into more quartzose sandstones and reflects a braided-river depositional setting (Eriksson, 1978; Heubeck and Lowe, 1994). Unit MD 2a in the southern Saddleback Syncline consists of feldspathic sandstones with conglomerates common along the northern flank of the syncline that includes the parasitic Dycedale Syncline. Unit MD 2b consists predominantly of fine- to coarse-grained sandstones and is best interpreted as a tidal shelf and tidal flat succession (Eriksson, 1977, 1978; Heubeck and Lowe, 1994; Eriksson and Simpson, 2000). In the Saddleback Syncline, conglomerates and coarse-grained sandstones characterize MD 3 and MD 4 and are of braided-alluvial origin. In contrast MD 3 and MD 4 consists of different paleoenvironments in the Eureka Syncline (Fig. 1). For example, MD3 in the Eureka Syncline consists of upward-coarsening successions of iron-formation, shale, siltstone, followed by sandstone, and interpreted as progradational shoreline-shelf deposits, whereas sandstones in unit MD 4 are of braided alluvial origin (Eriksson, 1978). At the base of MD4 is an amygdaloidal basalt unit that permits lithostratigraphic correlation across the Eureka, Saddleback, and Stolzburg Synclines (Eriksson, 1978).

The focus of this study is on the equivalent of Moodies Group Unit MD1 exposed in the belt south of the Saddleback Syncline (Fig. 1). Observations from two localities involved documentation of sediment grain size variations and sedimentary structure types in detailed measured sections and tracing of facies continuity along strike. Follow-up laboratory work included thin section observations of sediment composition, rounding and sorting, and grain size variations.

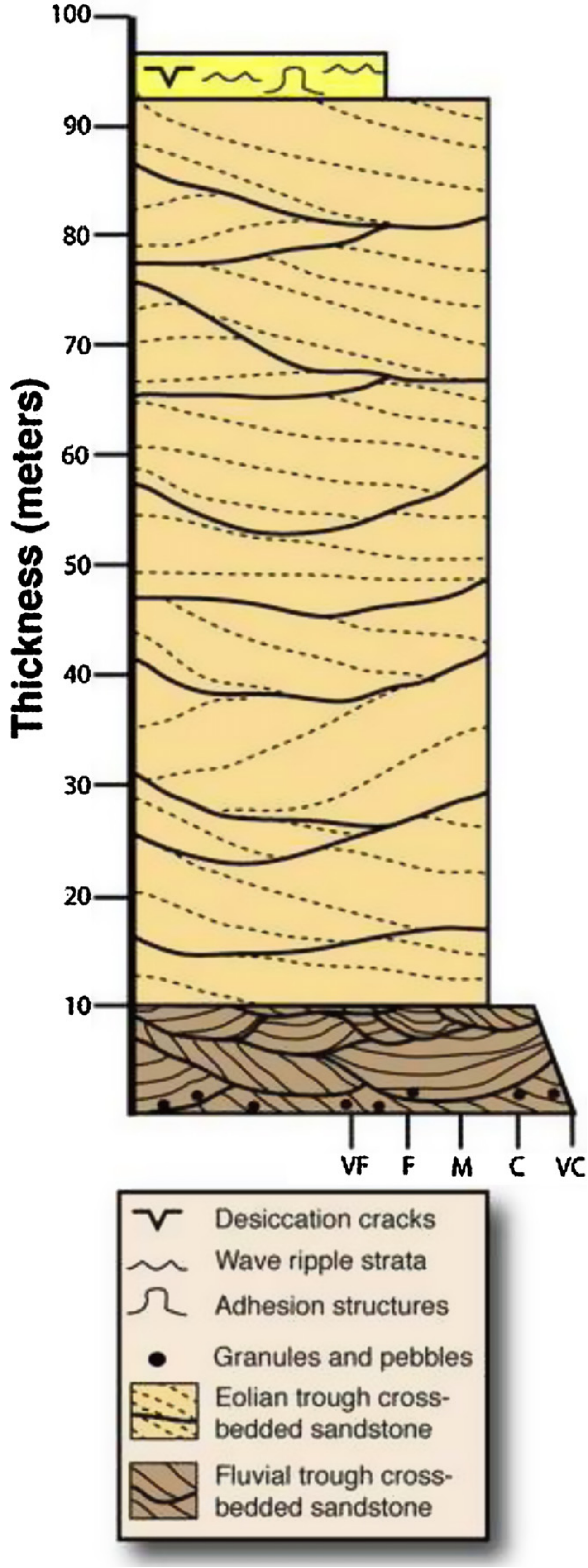

Fig. 2. Generalized stratigraphic column through fluvial and eolian facies in the Lower Moodies Group.