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Sedimentology of the Upper Triassic–Lower Jurassic (?) Mosolotsane Formation (Karoo Supergroup), Kalahari Karoo Basin, Botswana

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ABSTRACT

The Mosolotsane Formation (Lebung Group, Karoo Supergroup) in the Kalahari Karoo Basin of Botswana is a scantly exposed, terrestrial red bed succession which is lithologically correlated with the Late Triassic to Early Jurassic Molteno and Elliot Formations (Karoo Supergroup) in South Africa. New evidence derived from field observations and borehole data via sedimentary facies analysis allowed the assessment of the facies characteristics, distribution and thickness variation as well as palaeo-current directions and sediment composition, and resulted in the palaeo-environmental reconstruction of this poorly known unit. Our results show that the Mosolotsane Formation was deposited in a relatively low-sinuosity meandering river system that drained in a possibly semi-arid environment. Sandstone petrography revealed mainly quartz-rich arenites that were derived from a continental block provenance dominated by metamorphic and/or igneous rocks. Palaeo-flow measurements indicate reasonably strong, unidirectional current patterns with mean flow directions from southeast and east–southeast to northwest and west–northwest. Regional thickness and facies distributions as well as palaeo-drainage indicators suggest that the main depocenter of the Mosolotsane Formation was in the central part of the Kalahari Karoo Basin. Separated from this main depocenter by a west–northwest – east–southeast trending elevated area, an additional depocenter was situated in the north–northeast part of the basin and probably formed part of the Mid-Zambezi Karoo Basin. In addition, data also suggests that further northeast–southwest trending uplands probably existed in the northwest and east, the latter separating the main Kalahari Karoo depocenter from the Tuli Basin.

1. Introduction

Southern Africa is characterized by several distinctive Late Paleozoic-Early Mesozoic basins (Fig. 1) which are filled by the Karoo Supergroup, resulting in successions with similar lithological characteristics and fossil assemblages (Rust, 1975; Johnson et al., 1996). The main Karoo Basin of South Africa, which formed part of a foreland system along the palaeo-Pacific margin of southwestern Gondwana, is the largest basin and contains the most complete and best-studied Karoo succession (Johnson et al., 1996; Catuneanu et al., 1998, 2005). The second largest Karoo basin in the region, the Great Kalahari Basin, stretches from Namibia (Aranos Basin) through Botswana (Kalahari Karoo Basin) into Zimbabwe (Mid-Zambezi Basin). In-depth studies dedicated to the development of the Great Kalahari Basin are lacking, and hence current theories on its tectonic setting and syn-Karoo tectonic history are rather cursory (e.g., Daly et al., 1991; Johnson et al., 1996; Stollhofen et al., 2000; Catuneanu et al., 2005).

Covering ~70% of Botswana, the Kalahari Karoo Basin is filled by the Late Carboniferous – Early Jurassic Karoo Supergroup (Table 1), a predominantly clastic succession sub-divided into local formations in the various sub-regions delineated mainly by basement topography and sedimentary facies changes (Smith, 1984). Except for a few poor exposures on the eastern and northeastern basin margins, the basin fill is covered by sediments of the Cenozoic Kalahari Group. In comparison with the main Karoo Basin, therefore, the stratigraphy of the Kalahari Karoo Basin remains largely unknown and sedimentological studies, especially of the upper part of the succession, are virtually non-existent in the published record. With the intention of closing this gap, we present here the results of a facies analysis study undertaken in the eastern and northeastern parts of the Kalahari Karoo Basin to provide insight into the palaeo-depositional setting, stratigraphic thickness and facies distribution trends of the Mosolotsane Formation.

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Fig. 1. Karoo Supergroup (light yellow) distribution in Botswana and neighbouring countries (after Johnson et al., 1996). Note that after the main Karoo Basin, the second largest basin in the region, the Great Kalahari Basin (not marked) comprises the Aranos Basin in Namibia, the Kalahari Karoo Basin in Botswana and the Mid-Zambezi Basin in Zimbabwe.

2. Geological background

Characterized by variable thickness and an overall south–south-west thickening succession (from ~1000 m in the north to ~1500 m in the south–west), the Karoo Supergroup in the Kalahari Karoo Basin was deposited in relatively shallow depressions that resulted from the pre-existing relief of the rigid cratonic basement and postulated syn-Karoo faulting (Green et al., 1980; Meixner and Peart, 1984; Smith, 1984; Williamson, 1996).

According to Smith (1984), the lithostratigraphy of the Kalahari Karoo Basin is informally sub-divided into lower Karoo (Dwyka, Ecca and Beaufort Groups) and upper Karoo (Lebung and Stormberg Groups) units by a regional unconformity (Table 1). The Permo-Carboniferous lower part of the Karoo Supergroup generally commences with the glacial deposits of the Dwyka Group (diamictite, varvite and sandstone) followed by the marine to fluvio-deltaic rocks of the Ecca Group (coal-bearing and carbonaceous mudstone and white, poorly cemented arkosic sandstone). The succeeding Permo-Triassic succession is entirely non-marine, non-carbonaceous fluvio-lacustrine in nature (Beaufort Group equivalent, Tlhabala and Kwetla Formations: varicoloured to pale grey, non-carbonaceous mudstone, thin limestone and rare claystone; Table 1). The Late Triassic–Early Jurassic upper Karoo contains the fluvial and aeolian strata of the Lebung Group (red mudstones, sandstones and medium- and coarse-grained, orange to white sandstones) and igneous units of the Stormberg Lava Group (continental flood basalts and associated subvolcanic complexes). Based on $^{40}Ar/^{39}Ar$ geochronology, the volcanics range in age from 178.6 ± 0.5 Ma in southern to 180.5 ± 2.2 Ma in northern Botswana (Jourdan et al., 2007).

2.1. The Lebung Group and the Mosolotsane Formation

The Lebung Group (Table 1) consists of a maximum ~190 m thick succession of red mudstones, siltstones and fine- to coarse-grained, red, orange and white, massive and cross-stratified sandstones (Green, 1966; Smith, 1984; Carney et al., 1994). The succession is underlain by a well-documented regional unconformity (Smith, 1984, p. 56, 160), and is mostly conformably overlain by igneous rocks of the Stormberg Lava Group. Over most of the Kalahari Karoo Basin, the Lebung Group is sub-divided into two

Table 1
Lithostratigraphy of the ~500 m thick Karoo Supergroup in Kalahari Karoo Basin of Botswana (redrawn based on Smith, 1984).

		CENTRAL KALAHARI BASIN					
GROUPS	SOUTH WEST BOTSWANA	WESTERN CENTRAL KALAHARI & KWENENG	MMAMABULA	SE CENTRAL KALAHARI & MORUPULE	NORTHERN BELT CENTRAL KALAHARI & NE BOTSWANA	NORTH WEST BOTSWANA	TULI BASIN
STORMBERG LAVA	STORMBERG LAVA GROUP (Undivided)						Bobonong Lava Formation
LEBUNG	Nakalatlou Sandstone	Ntane Sandstone Formation				Bodibeng Sandstone Formation	Tsheung Sandstone Formation
							Thune Formation
	Dondong Fm.	Mosolotsane Formation			Ngwasha Fm.	Savuti Formation	Korebo Formation
					Pandamatenga Fm.		
*	Kule Fm.	Kwetla Fm.	Tlhabala Formation			?	Seswe Formation
ECCA	Otshe Fm.	Boritse Fm.	Korotlo Fm.	Serowe Fm.	Tlapana Fm.	Marakwena Formation	
			Mmamabula Fm.	Morupule Fm		Tale Formation	
		Kweneng Fm.	Mosomane Fm.	Kamotaka Fm.	Mea Arkose Fm.	?	
	Kobe Fm.	Bori Fm.	Bori Fm.	Makoro Fm.	Tswane Fm.	?	Mofdiamogolo Formation
DWYKA	Middlepits Fm.	Dukwi Formation				?	?
	Khuis Fm.						
	Mmalogong Fm.						

* This non-carbonaceous sequence lacks firm palaeontogical and lithological evidence and thus its correlation with the Beaufort Group of the main Karoo Basin is uncertain (see Smith, 1984 – p. 3). Thick black line shows the regional unconformity at the base of the Lebung Group which divides the Karoo Supergroup into the informal lower and upper Karoo (Smith, 1984, p. 56, 160).