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Two member subdivision of the Bima Sandstone, Upper Benue Trough, Nigeria: Based on sedimentological data

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ABSTRACT

The Early Cretaceous Bima Sandstone is a continental succession in the Upper Benue Trough, Nigeria formally divided into the Lower, Middle and Upper Bima Members. Sedimentological data presented here indicates a two member model (Lower and Upper Members) is more appropriate for the formation. The boundary separating the two proposed members is exposed at the Bollere River, Bima Hill, Wuyo II, and Kaltungo Fault sections. The lithological differences between the two members are perhaps to a large extent a reflection of the sediments sources. The Lower Bima Sandstone Member was deposited in aggradational braided alluvial systems and contains well preserved overbank fines, avulsive and crevasse splay sandstones, and channel deposits. Pedogenic carbonates are also common features of these alluvial deposits in the Bima Hill. The Kaltungo Fault section exposes sediments of brief lacustrine setting within the Lower Bima Sandstone Member. The Upper Bima Sandstone Member was deposited in fully matured braided river with well-developed accommodation space in both shallow and deep fluvial channels. Sedimentation in this braided river was mostly on braid bars and with scarce channels. Preliminary δ^{13}CTOC data along the Bollere River lithosection shows lack of any significant carbon isotope excursion suggesting climate, especially changes in aridity was not a major contributor in differences between the two members of the Bima Sandstone.

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1. Introduction

The Early Cretaceous Bima Sandstone is the basal unit of the sedimentary succession in the Upper Benue Trough (Fig. 1). It was named by Falconer (1911) and described by Carter et al. (1963), whose work was the basis for subsequent reviews e.g., Guiraud (1990), Zaborski et al. (1997), Zaborski (1998, 2003), Braide (1992a,b). Cant and Walker (1978) and Miall (1978) regarded braided rivers as devoid of overbank deposits. However, works by Bentham et al. (1993), Bristow et al. (1999), Sabaou et al. (2005) and Hajek and Wolinsky (2012) have questioned these early braided river's models which were based purely on non-aggrading systems. The aim of this work is to critically look at the sedimentology of the Bima Sandstone in light of the more recent literature on fluvial deposits and also to provide preliminary stable carbon isotope data in order to test for possible excursion or otherwise.

2. Geological setting

The Bima Sandstone unconformably overlies the crystalline Basement Complex throughout the Upper Benue Trough (Fig. 1). In most places it represents by far the greatest proportion of the lithostratigraphic succession present in the Upper Benue Trough (Zaborski, 1998). The type section of the formation is to the south in the Lamurde anticline (Zaborski et al., 1997). The Bima Sandstone was named by Falconer (1911). Carter et al. (1963) studied the formation and established the type section at the Bollori (correct name "Bollere") section and its type locality at the Bima Hill. Carter et al. (1963) divided the Bima Sandstone into three members principally based on physical sedimentary structures, mainly the paucity and/or abundance of cross-beddings. The Lower Bima Sandstone Member, the base of which is not exposed in the type section (Carter et al., 1963), consists of coarse-grained, feldspathic sandstones with occasional pebble horizons alternating with purple and reddish clays and shales. Calcareous sandstone, well-bedded, medium grained sandstone and thin siltstone also occur within this sequence. The Middle Bima Sandstone Member consists of very coarse-grained, feldspathic sandstones, thin clays, shales, calcareous sandstone and impure limestone with numerous

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bivalves. The Upper Bima Sandstone Member, consists almost wholly of whitish, cream, white-grey to buff coloured, medium- to coarse- and very coarse-grained feldspathic sandstone. The sandstones are commonly cross-bedded and frequently contain scattered pebbles and occasionally layers of rounded quartz pebbles. Allix (1983) and Guiraud (1990) also recognized three subdivisions from the Bollere section and the Zambuk Ridge respectively. Allix (1983) referred to these subdivisions as formations, whereas Guiraud (1990) called them members. However, the thicknesses of the subdivisions reported by all the workers differ (Table 1). Guiraud (1990) reviewed the sedimentology of the Bima Sandstone, mostly from the Zambuk Ridge and reported that the Bima 1 is lithologically variable reaching up to 1500 m thick and with a basin-wide angular unconformity at its upper boundary.

The Bima 2, 50–200 m thick was described as gravels to coarse-grained sandstones dominated by large scale trough cross-bedding. Bima 3 is homogeneous, medium- to fine-grained sandstone with oblique tabular cross-bedding.

Table 1
Thickness of the members of the Bima Sandstone as presented by the previous authors and the present work.

Member	Author Carter 1963	Allix 1983	Guiraud 1990*	Zaborski 2003*	Present work
Upper Bima	1,737m (5,700ft)	1,200m	600m	500m	1050m
Middle Bima	823m (2,700ft)	700m	50–200m	500m	N
Lower Bima	396m (1,300ft)	365m	1,500m	>1,500m	62m[1], >250m[2]
Total	2956m	2265m	2300m	2500m	1112m

* Readings not tied to any section of the formation, N: not seen.
1,2 Measured at the Bollere River and Bima Hill respectively.

3. Methods

The type section of the Bima Sandstone (i.e., the Bollere River section) and several other sections in the Upper Benue Trough (Fig. 1) were logged in the present study from exposures in gullies along rivers, road cuts, and hills. Lithological profiles (Fig. 2) were constructed using CorelDraw X5 software, and described. Sedimentological attributes measured in the field include bed thickness, textures, structures, paleocurrent direction, colour, and their field relationships.

Samples were collected from the type section for stable carbon isotope analysis. The type section is the longest section of the formation and exposes both the Lower and the Upper Bima Members (as proposed here, Section 5). Whole rock samples (mudstone and sandstone) were oven dried (30 °C, 24 h), crushed using a granite pestle and mortar, and de-carbonated following Domingo et al. (2009) using excess hydrochloric acid (10% v/v) until any visible sign of reaction had ceased. This was followed by repeated washing with deionised water until a neutral solution was obtained, then oven drying (30 °C, 24 h). Stable carbon isotope analyses were conducted at the Natural Environmental Research Council (NERC) Isotope Geosciences Laboratory, Keyworth – Nottingham, United Kingdom. Total organic carbon content was measured using a Carlo Erba 1500 elemental analyser with acetanilide used as the calibration standard. Replicate analyses indicated a precision of ±0.1% in well-mixed samples (1 Standard Deviation, SD). For $\delta^{13}C$ analysis a Carlo Erba 1500 EA online to a VG Triple Trap was used. This setup also included a secondary cryogenic trap in the mass spectrometer for samples with very low carbon content. The mean standard deviation on replicate

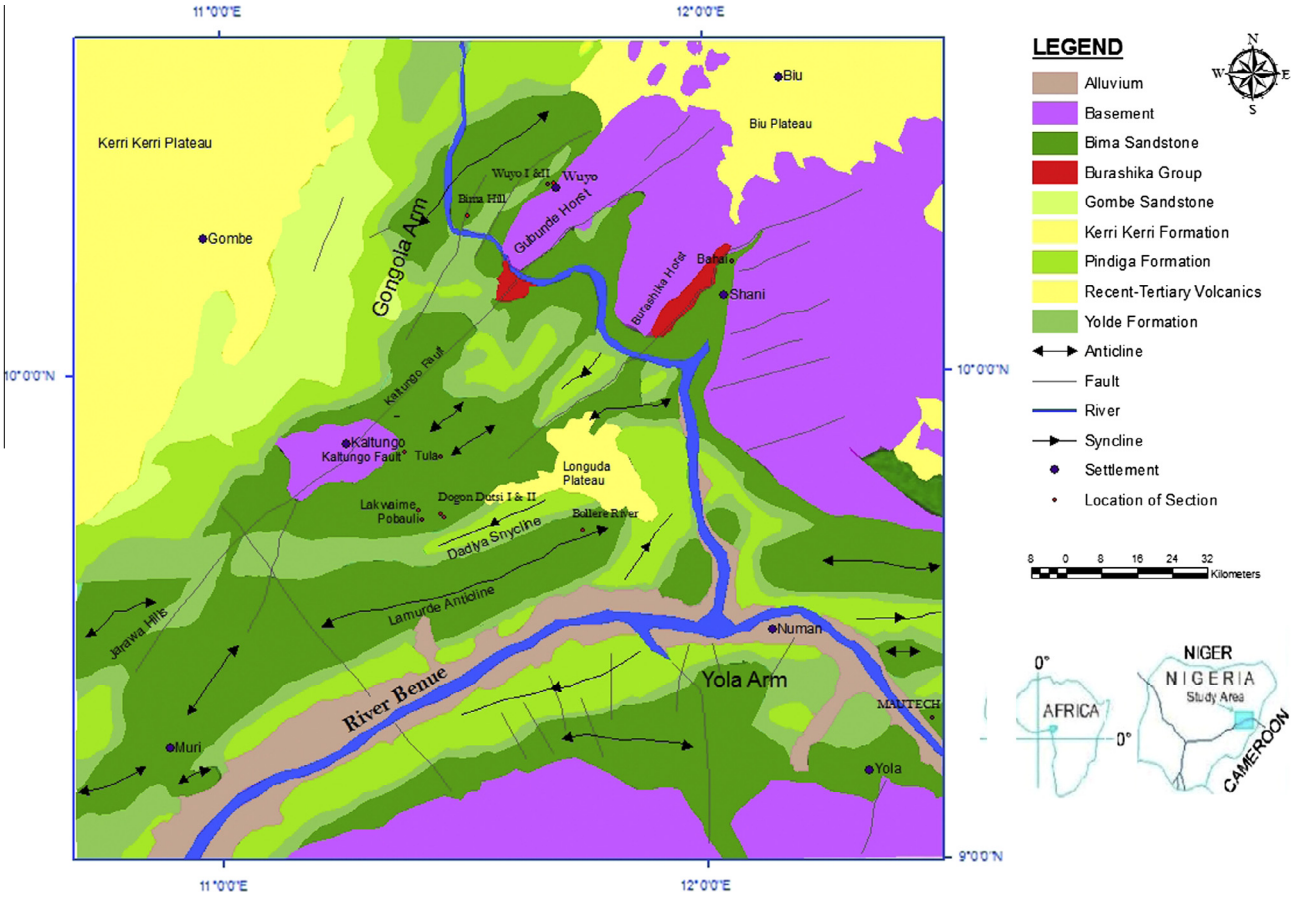

Fig. 1. Geologic map of the Upper Benue Trough with location of the studied sections. (Modified after Benkhelil (1986).)

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