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MODELLING OF DISTRIBUTION AND GEOMETRY OF LITHOLOGICAL COMPLEXES OF THE ECCA GROUP (THE KAROO SUPERGROUP) IN SW BOTSWANA

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Abstract: The Ecca Group, a subdivision of the Karoo Supergroup (Upper Carboniferous – Lower Jurassic) in SW Botswana is a sequence deposited as marine deltaic bodies considered to have been supplied from a cratonic source elevated north of the basin. The Karoo strata in this region are covered unconformably by sands of the Kalahari Beds (Upper Cretaceous – Recent). Therefore the bedrock outcrops are extremely rare, limited in size and a low number of boreholes drilled in this vast area (ca. 340 × 540 km) provide the only insights into the succession of the Karoo Supergroup. Very long distances between individual boreholes make correlation, interpolation between localities and interpretations of geometry of lithological bodies that would provide clues supporting basin analysis by traditional means problematic. To achieve the first approximation of the space-time relations between lithologically complex Ecca Group lithofacies associations modelling of these sediments using Petrel software was performed. These relations in turn suggest evolutionary trends of the basin during deposition of the Ecca Group strata. The model suggests two main zones of supply indicated by two distinctly different patterns of deltaic lithofacies associations, and their evolution controlled by post-Dwyka palaeotopography and its subsequent modifications by local subsidence in the centre of the depository. Initially rapid southward progradation of relatively fine-grained delta body located in the west of the area was followed by subsidence-induced aggradation interrupted by stages of abandonment and marine transgression. Such variations, emphasised by the presence of sandy clinoforms of the delta lobes separated by basinal "fines", imply significant interplay between rates of supply and subsidence. On the other hand, the delta formed in the east contains relatively high proportion of coarse-grained sandstone facies overlying prodelta fines as laterally extensive tabular body formed most probably by lateral migration of distributary channels and delta-front mouthbars, and devoid of abandonment stages. Proximal litofacies of the "western delta" fill the subsiding depocentre and grade distally into synchronously deposited prodelta fines towards the south. By contrast, distal fine-grained prodelta facies fill basin depocentre in the eastern area and are overlain by proximal facies of the "eastern delta".

Key words: the Karoo Supergroup, the Ecca Group, deltaic sedimentation, modelling, SW Botswana

INTRODUCTION

The sedimentary succession of the Karoo Supergroup (Upper Carboniferous – Lower Jurassic) present in the western part of the Kalahari Karoo Basin in SW Botswana extends into the Gemsbok Basin to the south and is correlative to the age-equivalent suite in Namibia to the west (Fig. 1).

Considering the subdivisions of the Karoo suite occurrences in Botswana in general, the investigated area belongs to the Gemsbok Basin in the west and extends slightly eastward, into the zone called “Western Central Kalahari” by Smith (1984). The Karoo Supergroup in the region is subdivided into five groups: Dwyka, Ecca, Beaufort, Lebung and Stromberg, originally defined in South Africa. These have been correlated at a regional scale mainly on the basis of the lithostratigraphic criteria (Fig. 2). The subject of this paper, the Ecca Group in the western part of Botswana, consists of terrigenous sedimentary rocks ranging from arenites to argillites and coaly beds deposited in the marine basin in which deltas developed fed mainly by fluvial systems draining an elevated source region to the north (Smith 1984, Carney et al. 1994, Key et al. 1998, Modie & Herisse Le 2009, Wendorff et al. 2012).

The area of the Gemsbok Basin is vast (ca. 340 × 540 km) and the information on the Karoo succession limited due to the almost continuous cover of the younger sediments. The only direct observations are restricted to just a few fully cored boreholes (Fig. 3). Therefore, an attempt has been undertaken to model the lithological bodies that constitute the Ecca Group succession in SW Botswana in order to reconstruct and visualise their geometries, distribution and lateral interrelations. These aspects should help improve our understanding of evolution of this part of the Karoo depository. The exercise was performed with Petrel software designed for such modelling purposes.

GEOLOGICAL SETTING

The sedimentary succession of the Karoo Supergroup in southern Africa is divided into five main lithostratigraphic units, which reflect gradual warming of the climate from the ice age up to semi-desert conditions caused by the drift of Gondwana from polar to sub-tropical regions (Meixner & Peart 1984, Smith 1984, Carney et al. 1994, Johnson et al. 1996).

In the south (Fig. 1), the sequence of the Main Karoo Basin fills the foreland basin to the Cape Orogen, and the lower part of the succession originated in the marine environment. Further north, the deposition occurred upon the stable Kalahari Craton in mainly continental environments (Meixner & Peart 1984, Smith 1984, Catuneanu et al. 2005). Only in the southern part of the Karoo Kalahari Basin, i.e. in the discussed Gemsbok Basin of SW Botswana, the strata of the lower part of the succession were deposited in the marine environment (Smith 1984, Key et al. 1998, Isbell et al. 2008, Wendorff 2008, Diskin & Wendorff 2011).

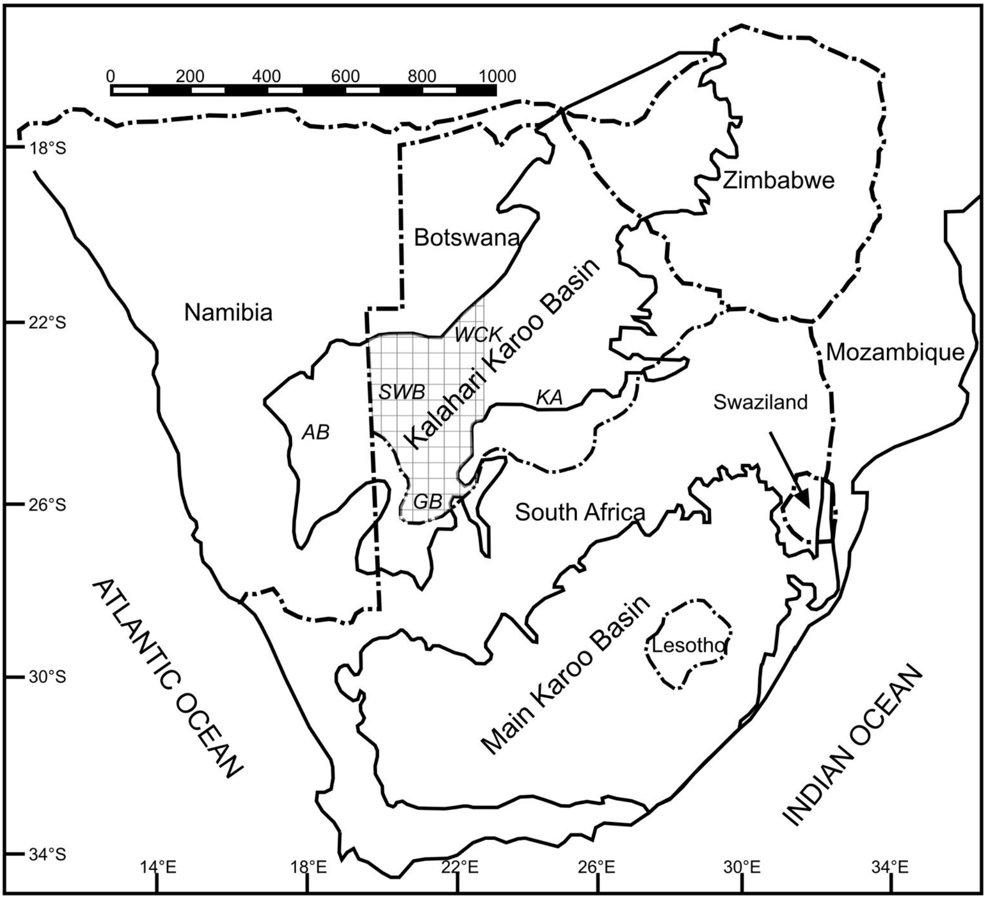


Fig. 1. The Main Karoo Basin and the Kalahari Basin of the Karoo Supergroup with the approximate area discussed in this paper marked by cross-hatching (modified from Key et. al. 1998). The areas proposed by Smith (1984) as "sub-basins": SWB – South-West Botswana, WCK – Western Central Kalahari, KA – Kweneng Area. Other abbreviations: GB – Gemsbok Basin (sub--basin), AB – Aranos Basin (sub-basin)

In the southern part of the Karoo Kalahari Basin, the glaciomarine Dwyka Group strata unconformably overlie the Precambrian basement and record Gondwana glaciation during the Late Carboniferous to Earliest Permian (Bordy et al. 2010). The succeeding Ecca Group (Early Permian) is represented by marine deltaic successions and equivalent basinal argillites, and contains interlayers of carbonaceous "fines" and coal. These are overlain by fluvial and lacustrine (?) deposits of the Beaufort Group (Late Permian to Early Triassic). The succeeding Lebung Group of aeolian and fluvial sediments lacking carbonaceous interbeds and deposited from the Late Triassic to Early Jurassic in warm, semi-desert conditions, rests unconformably, and with a hiatus, upon the older Karoo strata (Smith 1984, Bordy et al. 2010). The Stormberg basaltic lavas (Late Jurassic) and intrusions represent the youngest unit of the Karoo Supergroup (Fig. 2).

Groups	South-West Botswana Formations	Kweneng and WesternCentral Kalahari
Stormberg Lava		
Lebung	Nakalatlou	Ntane Sandstone
	Dondong	Mosolotsane
Beaufort	Kule	Kwetla
Ecca 3	Otshe	Boritse
Ecca 2		Kweneng
Ecca 1	Kobe	Bori
Dwyka	Middlepits	Dukwi
	Khuis	
	Malagong	

Fig. 2. The Karoo Supergroup stratigraphic subdivisions in SW Botswana (Smith 1984). Correlation of the non-carbonaceous units that occur in Botswana above the Ecca Group (the Kule Fm. and Kwetla Fm.) with the Beaufort Group of South Africa is uncertain due to the lack of palaeontological evidence (Bordy et al. 2010). Thick line denotes sub-Lebung unconformity (modified from Smith 1984, Bordy et al. 2010). The Ecca Group is here subdivided into three informal sub-units (1, 2, 3) for ease of discussion

DATA PREPARATION AND METHODS

The Karoo Supergroup succession in the Gemsbok Basin is covered by young sediments of the Kalahari Beds, which results in the Karoo outcrops being extremely rare and limited in size. Therefore, the only sources of data available for the model are detailed sedimentological logs of the borehole cores (Fig. 3). Data from a total of ten cores were originally acquired (logged by Wendorff, unpubl.) and interpreted in terms of deltaic facies associations of the Ecca Group (Wendorff 2008, Diskin & Wendorff 2011, Wendorff, unpubl. data);

nine of these were used in this work, which is sufficient for a preliminary deterministic model presented in this paper. In the remaining borehole the Ecca Group succession is not sufficiently complete to be included in the model.

The observational material represented by detailed sedimentological logs had to be unified and simplified for the purpose of modelling. The applied simplification of the lithological types and their coding is summarised below.

Observed lithology	**Simplified lithological label**
sandstone fine and very fine	1 – fine sandstone
sandstone medium	2 – medium sandstone
sandstone very coarse to coarse	3 – coarse sandstone
grey siltstone and mudstone	4 – fines
black/carbonaceous mudstone and shale	5 – black/carbonaceous fines
coaly mudstone, shale and coal	6 – coal

Subsequently, the succession of the rock types recorded in each sedimentological log was discretized with the sampling rate set to 0.5 meter. The discretised logs prepared this way were imported into Petrel where they were correlated according to the lithostratigraphy proposed by Smith (1984, Fig. 2).

For the purpose of modelling and discussion the Ecca Group is split into three informal subdivisions. The slight modifications suggested here emphasize correlation between the adjacent regions (SW Botswana and Kweneng – West Central Kalahari) and are justified by the observations suggesting that, in spite of differences in lithostratigraphy, lateral facies changes between these regions are gradual (Wendorff 2008, Diskin & Wendorff 2011). The subdivision into individual "basins" (Smith 1984) was mainly for convenience at earlier stages of work on the Karroo sequence in Botswana.

The subdivisions applied here partly conform to the subdivisions of Smith (1984, Fig. 2) and their typical lithological features are summarised below in the ascending stratigraphic order:

- Ecca 1 (labelled here E1) – mostly mudstones and siltstones, with intercalations of carbonaceous "fines"; equivalent to the Kobe Fm. – Bori Fm.
- Ecca 2 (E2) – typified by sandstone, locally, in the western part of the area with mudstone-shale divisions and subordinate carbonaceous facies; equivalent to the lower and middle part of the Otshe Fm. – the Kweneng & Boritse Formations;
- Ecca 3 (E3) –mudstones and siltstones (carbonaceous and non-carbonaceous), associated with varying proportions of sandstone; equivalent to the upper part of the Otshe Fm. – Boritse Fm., and locally Kwetla Fm.

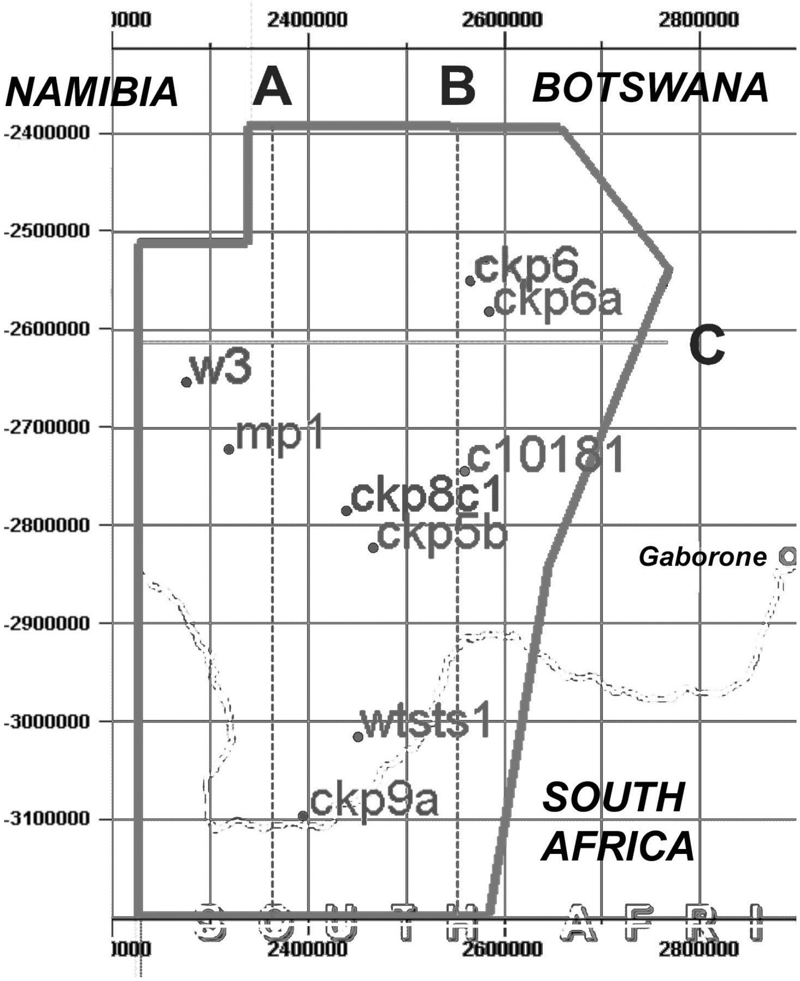


Fig. 3. The discussed area along with borehole and cross-section locations (A, B and C). Units denote meters. The coordinate system used is the WGS 1984 Web Mercator Auxillary Sphere

THE MODEL

The model was built based on the indicator kriging algorithm implemented in Petrel. The algorithm itself is deterministic. Due to the preliminary nature of this research and the scarcity of the data, the main goal was creating a simple 3D visualization of the Ecca Group, which could then be inspected specifically in terms of evolving geometry of the Gemsbok Karoo Basin and the spatial relationships between the Ecca Group subdivisions. Indicator kriging, being a deterministic algorithm, produces a clear image with no random noise, satisfactory for visual inspection with repeatable results, as opposed to stochastic algorithms, which tend to generate random solutions applicable rather for detailed prospecting model regarding uncertainty assessment.

Scarce and unevenly spatially distributed boreholes, which provided the input data allow creating a rough preliminary facies distribution models for each distinguished stratigraphic sequence, which comprise each of identified facies group. To achieve that goal, simple modelling was performed using Indicator Kriging algorithm (Dubrule 1998). The estimation procedure was based on regional variograms with very large search radius fitting the size of the investigated basin. Variograms were calculated for facies and sequences separately. They reflect North-South variability trends quite well.

The final result of this modelling exercise is a generalized 3D digital model of the Ecca Group in South-West Botswana shown in Figure 4. Three cross-sections in Figure 5 present facies relations revealed by the model, which are discussed below. Discussing these relations on the basis of cross-sections is more informative than on the basis of the 3D diagram, which is shown below mainly to present to the reader the source upon which the cross-sections are based (Fig. 4).

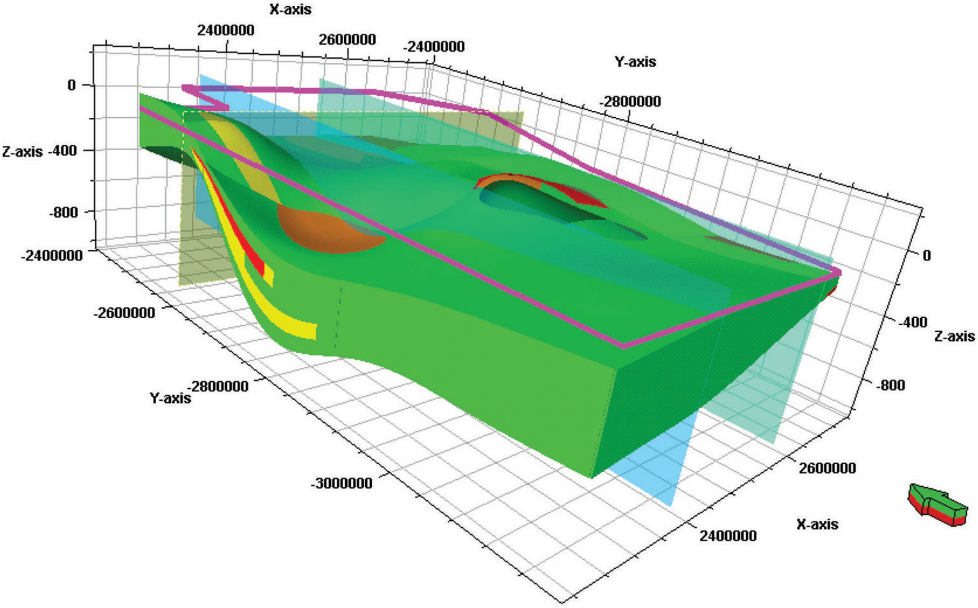
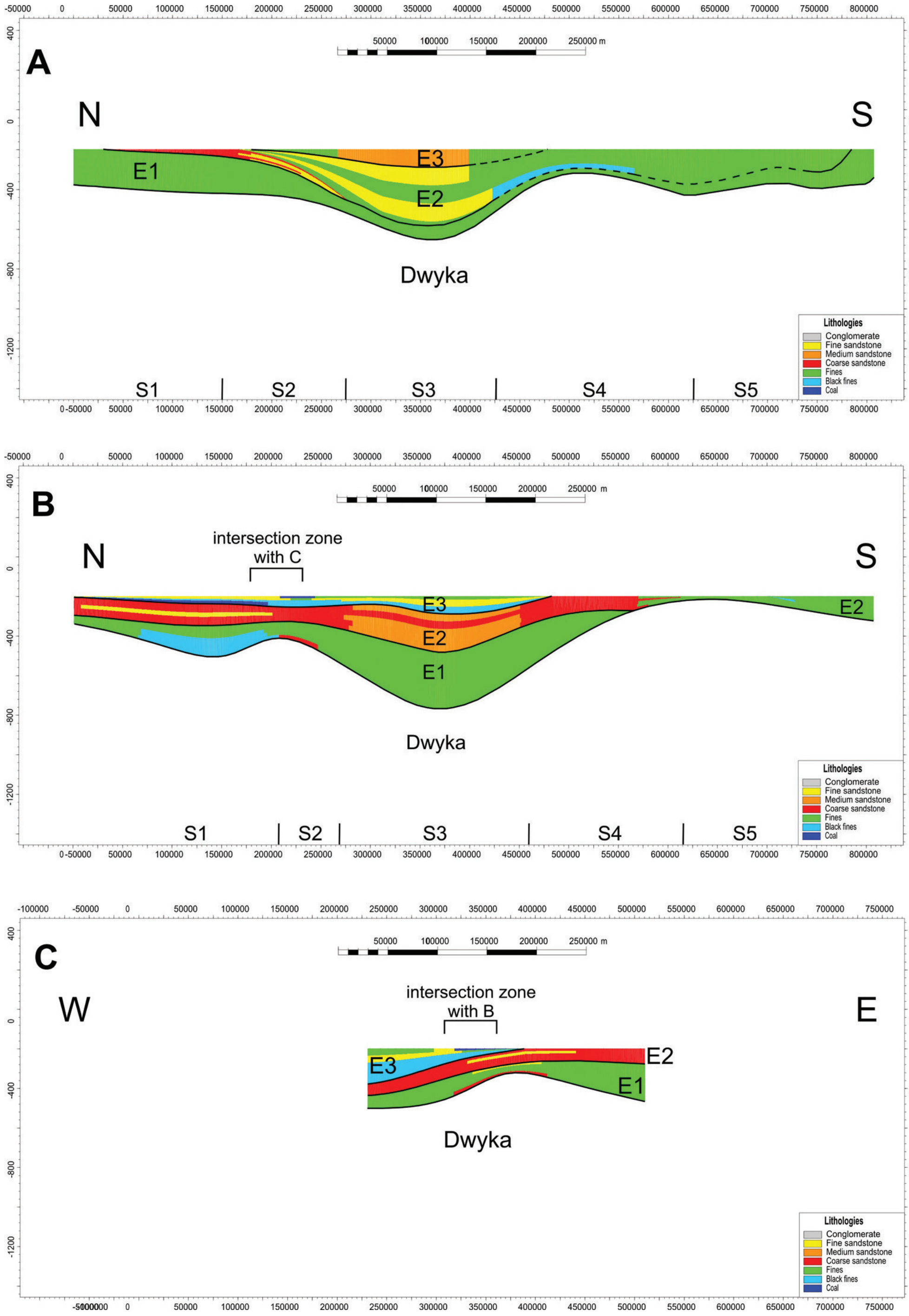


Fig. 4. A 3D model of the Ecca Group in SW Botswana. Arrow indicates north direction and vertical planes show position of cross sections in Figure 5. See Figure 2 for location of the area and Figure 5 for legend


A
N
S
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E2
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50000 100000 150000 200000 250000 m
400
0
-400
-800
-1200
Lithologies
Conglomerate
Fine sandstone
Medium sandstone
Coarse sandstone
Fines
Black fines
Coal

MODELLING RESULTS AND INTERPRETATIONS

Lithological associations along cross section A-A'

The cross section A-A' runs N-S in the western part of the analysed region (Figs 2, 3, 5A). In order to facilitate the discussion of the modelling results, the whole length of the section was subdivided into sectors S1–S5, boundaries of which are defined by major lateral changes of the facies associations. The top of the section, and the datum, are defined by contact with the Beaufort Group strata in the north and by the sub-Kalahari Beds unconformity in the south (sectors S4–S5). The lithofacies relations are discussed separately for each of the subdivisions E1–E3 of the Ecca Group.

E1 Description

E1 division is present throughout the area. The lower boundary is defined at the top of the glaciogenic Dwyka Group below. The upper boundary is marked by facies change from mudstone-siltstone to sandstone in the north and center (S1–S3) and is unknown in the south only the lowermost part of the Ecca succession is preserved beneath the basal unconformity of the Kalahari Beds resulting from pre-mid-Cretaceous erosion.

The maximum thickness of 180 m is attained in the north (S1) and decreases southward to a minimum of 40 m in S4. A wedge of carbonaceous shale (rich in coalified plant detritus) appears within the grey mudstone, pinches out southward and is locally underlain by a lens of coarse-grained sandstone. Another wedge of carbonaceous shale appears in south, in S4.

E1 Interpretation

The thickness variations of E1 strata above the top of the Dwyka Group imply a depocentre in the north (S1), probably related to the post-glacial topography. The sandstone lens represents the Ncojane Sandstone Member, a series of normally-graded turbidite beds. They could have been generated by earthquakes triggered by post-glacial relaxation and possibly initiated at the front of the Ecca delta positioned at that time well beyond the N margin of the cross section. The black shale above represents an anoxic episode in the N part of the basin, which may be related to local rapid subsidence or acceleration of post-glacial marine transgression.

Fig. 5. Results of modelling shown in three cross-sections: A) N-S section in the western part of the Gemsbok Basin runs parallel to the regional palaeotransport direction from the north in this part of the basin; B) N-S section in the easternmost part of the Gemsbok Basin in Botswana and a zone transitional to the western part of the Western-Central Kalahari Sub-basin (divisions after Smith 1984) is perpendicular to the palaeotransport direction, which appears to have been from the east in this part of the basin (compare with C); C) W-E section located in the north-eastern part of the area. This section is running parallel to the palaeotransport from the east and shows longitudinal relations of facies in sector S1–S2 for comparison with section B, which is interpreted as perpendicular to the palaeotransport

Another occurrence of the carbonaceous “fines”, further to the south in sector S4, may reflect deposition upon distal basin plain. The mudstone-siltstone predominant here represents a prodelta facies.

E2 Description

A coarse-grained sandstone lithosome in the north evolves southward into a complex 290 metres thick of three wedges (from the oldest labelled E2.1, through E2.2, to the youngest E2.3) in S2 and S3. The wedges are composed of fine-grained sands, pinching out southward and are separated by two mudstone-siltstone intervals wedging out in the opposite direction.

Towards the south (in S4–S5), these sandstones clinoforms evolve into fine-grained facies. In E2.2 these are represented by carbonaceous “fines” rich in coalified plant detritus (in S4), evolving further south into non-carbonaceous mudstone.

E2 Interpretation

The E2 association is interpreted in terms of deltaic depositional system, from the proximal facies of fluvial channel system defining delta top in the north of the area (S1) to the distal facies to the south. The three sandstone wedges represent three stages of advancement of delta lobes, separated by two periods of delta abandonment, marine transgression and deposition of basinal “fines”. The lateral extent of the second, major lobe (E2.2 in sectors S2–S3), by comparison with the first/oldest, minor lobe (E2.1 in S2) indicates a stage of delta progradation, whereas deposition of the next delta lobe E2.3 records aggradation.

The direct geometrical link between the supply system (coarse grained facies) in the N and the lobes complimented by the lobe pinchout direction southwards suggest that the cross section is running along the delta system axis.

E3 description

E3 division (max. thickness 90 m) occurs only in the central part of the area and consists of a medium-grained sandstone lens in the centre, flanked by mudstone-siltstone complexes.

E3 Interpretation

Two alternative interpretations may be advanced in this case. The increase of the grain size between the fine-grained sandstone of E2.3 lobe and the medium-grained sandstone of E3 may reflect further progradation of the delta between E2 and E3, formation of sandbar and deposition of “fines” in both low energy embayment to the north and on prodelta to the south.

On the other hand, this sandstone body, which must be related to the delta-top distributary system, is flanked by mudstone-siltstone facies. This may suggest that the evolving supply system migrated laterally and the cross section shows the effect of supply of a delta front mouth bar oblique with relation to the section orientation.

Lithological associations along cross-sections B-B’

The cross-section B-B’ runs from N to S in the eastern part of the area where the modelled geometries and relations of the lithosomes are determined by the sequences intersected in boreholes located in the easternmost part of the Gemsbok Sub-basin transitional to the western part of the West-Central Kalahari Sub-basin, as defined by Smith (1984).

E1 Description

E1 division is present in sectors S1–S4 and attains the greatest thickness of 280 m in S3. Further to the south, E1 wedges out and the division E2 rests directly upon the Dwyka glaciogenic unit. The lower boundary of E1 is defined at the top of the glaciogenic Dwyka Group below. The upper boundary is marked by facies change from mudstone-siltstone to sandstone (in S1–S4) and is unknown in the south where only the lowermost part of the Ecca succession is preserved beneath the basal unconformity of the Kalahari Beds that resulted from pre-mid-Cretaceous erosion. The maximum thickness of 280 m is attained in the centre (S3) and decreases quickly southward to 0 m in S4/S5 where the mudstone-siltstone facies pinches out between the Dwyka Group below and the Ecca Group division E2 above.

E1 Interpretation

The facies association is of the same type as observed in A-A’ section and represents prodelta deposits, locally containing basinal black mudstone. The zone of the maximum thickness (280 m) defines a basinal depression controlled mainly by the Dwyka-top palaeotopography, probably enhanced by subsidence in S3 sector.

E2 Description

In the Ecca division E2 sandstone fine- to coarse-grained facies predominate. The lithosome thickness is relatively uniform throughout (ca. 195 m) and each of the constituent sub-complexes is characterised by an individual predominant grain size. To the south, at the boundary between S4 and S5, homogeneous coarse-grained sandstone unit passes quickly into mudstone-siltstone facies in S5. Two wedges of coarse-grained sandstone that pinch-out southward within the mudstone-siltstone strata, which demonstrates that these two contrasting facies associations are time-equivalent and E2 rests directly on the Dwyka glaciogenic strata in sector S5. An interlayer of fine-grained arenite occurs within the coarse sandstone in the north (sector S1). In the centre (S3) medium-grained sandstone prevails and contains an interlayer of coarse arenite. Sandstone facies passes into laterally adjacent mudstone-siltstone complex deposited in low-energy environment beyond the proximal distributary system.

E2 Interpretation

Almost uniform thickness of the E2 sandstone complex, with only gentle undulations of the upper and lower boundaries suggest that the area represented by sectors S1–S4 underwent subsidence that was almost uniform, and only slightly more intense in the centre (S3) than in the north (S1). The geometry of whole E2 lithosome, coupled with shape and space relations of the constituting sandstone bodies suggest that section B-B' is perpendicular with regards to the sediment supply/palaeotransport direction. The regional trends and gradients of the Ecca sedimentary facies (Wendorff 2008, 2012), including the presence of a conglomerate section to the east of the discussed area (Wendorff, unpubl. data), all point to the source of the detrital material supplying this part of the basin from the east. The presence of coarse-grained facies throughout suggests lateral migration of proximal channelled distributary system and formation of laterally coalescing delta front mouth bars composed of medium-grained sands (Emery & Myers 1996). Vertical sequences in which facies complexes of different grain-size occur in vertical order are here interpreted as resulting from progradation and retrogradation events. Hence, the lens of fine-grained sandstone in sector S1 marks an event during which the margin of the coarse-grained delta front retrograded at first, but then prograded overstepping fine-grained clinoform/lobe sediments. The latter are represented by a lens of fine-grained sandstone within coarse-grained facies. On the other hand, a short-lived progradation event is recorded in the central part of the section (S3) by an interbed of coarse sandstone within medium-grained facies of delta-front mouth bars.

The mudstone-siltstone complex adjacent to the sandstone body of delta front was deposited in low-energy environment beyond the proximal distributary system.

E3 Description

E3 is a relatively thin (max. 90 m) association of fine-grained and thin facies complexes: mudstone-siltstone, fine-grained sandstone, carbonaceous mudstone and coal.

E3 Interpretation

The lithological character and stratigraphic position above the delta-front sands (E2) suggest a delta top palaeogeographical position of the E3 association.

DISCUSSION & CONCLUSIONS

The Ecca Group modelling in A-A' section

Except for the position of the source, the remaining aspects of facies relations and their tectonic implications are new results that stem from this modelling exercise. It must be stressed, that the effects of modelling cannot be extrapolated to reflect the field situations with precision. They rather approximate and suggest such trends and facies relations that one may expect to find in the field. However, as modelling is partly controlled by the applied algorithms, the results are presented as a likely possibility rather than accurate representations of the existing subsurface conditions.

A horizontal transition between the proximal delta facies in the north through intermediate to distal in the south indicates the position of the source area north of the cross section, which remains in agreement with the original interpretation published by Smith (1984).

The delta top is represented by distributary facies at stage E2.1 that grade into a minor sandy lobe E2.1. This transition occurs underneath the apical part of the lobe E2.2. Such relation suggests that progradation of the delta lobe was associated with retreat of the delta platform front/shoreline, and therefore marine transgression, at stages E2.2, which could have been caused by:

- ongoing subsidence of the basin bottom in sectors S2–S3, or
- compaction of the predominantly fine-grained sediments of E1, or
- ongoing post-glacial sea-level rise.

Either one, or two, or all three of the above factors could have contributed to this stratigraphic relationship.

The delta-top facies evolve southward into three lobes implying that the cross section runs approximately along the axis of the delta system at E2 stage, and the regional palaeotransport direction was from N to S. However, a change of this pattern occurs at E3 stage. Namely, the medium-grained sandstone (E3) rests above fine-grained E2.3 and is flanked by the basinal "fines". This implies an oblique supply direction at E3 stage. Therefore at the last stage, the delta distributary system (channel active in this part of the basin) must have:

- prograded, which is shown by coarsening-upwards trend between E2.3 and E3, and simultaneously;
- shifted laterally, either westward or eastward and bent in the opposite direction because what we now observe in the cross-section is an oblique intersection of the delta lobe surrounded by the basinal fines.

The observed pattern of facies progradation followed by aggradation, as well as thickness variations of E1 and E2 suggest subsidence as the main driving mechanism of facies emplacement and migration. Delta progradation between E2.1 and E2.2 was induced by subsidence, which created the accommodation space filled by these two lobes (in sectors S2–S3). Subsequently, at stages E2.2 and E2.3 the subsidence axis must have remained stationary and subsidence rate balanced with rate of supply, which is implied by the aggradation trend.

By comparison with E2 facies associations and overall progradational trends, it is suggested that the fine-grained E1 strata in sectors S1–S2 represent prodelta and basin plain facies, i.e. distal equivalents of the delta front located further to the north and beyond the cross-section, over which coarse sandstone facies of delta top prograded rapidly southward at the initial stage of formation of E2.

The Ecca Group modelling in B-B' section and comparison with A-A' section

There is a marked difference in the patterns of the Ecca Group facies (controlled by palaeogeography) between the western and eastern area (Fig. 5A, B) The main depocentre was located in S3, extended in the W-E direction and its development was controlled by local subsidence superimposed upon the initial postglacial palaeotopography on the Dwyka Group top.

A comparison of both cross sections (Fig. 5A, B) suggests that simultaneous deposition of two delta bodies took place in what is now the region of SW Botswana. The detrital material in the western area was supplied from the north ("northern delta", whereas the eastern area was fed by a separate fluvial system from the east and resulted in a depositional body of "eastern delta".

The front of the "western delta" quickly prograded southward at first, but then the general position of the delta body remained mostly stationary filling up the subsiding depocentre. However, fine sandstone clinoforms of distal delta front facies retreated (abandonment stages) three times. Such oscillations suggest significant variations in intensity of supply and rate of subsidence.

The "eastern delta" was fed by detritus coarser and more abundant than the "western delta", which is evidenced by much higher proportion of coarse- and medium-grained sandstone facies in the succession of the former (Fig. 5A, B). The basin depocentre (E1 in S3; Fig. 5B) was filled with prodelta and basinal "fines", unlike the case of the western region where the depocentre is filled by delta body (E2 in S3; Fig. 5A).

The "eastern delta" front prograded over thick prodelta and basinal "fines" (E1), then remained essentially stationary, aggrading over a considerable period, which is suggested by a substantial thickness of E2 sandstone lithosome. The delta front facies formed as laterally extensive, continuous and thick sandy tabular body composed of laterally migrating distributary channels (coarse sands), delta-front mouthbars (medium-grained sands), and only one clinoform of fine-grained sand (Fig. 5B, C). The vertical facies variations suggest progradation and retrogradation stages, but all the time within the range of the same facies association of delta front and without an abandonment event.

The present authors believe that these results of the Ecca Group modelling, which represent a new approach to the analysis of the Karoo Basin in NW Botswana, provide framework for further studies and more detailed work at basin-scale that should be undertaken as soon as more data becomes available – especially additional high-resolution seismic and borehole data. A much larger database of borehole data would be helpful for future precise testing, verification and refining of the interpretations presented in this paper.

Further revisions of the presented model and experiments with additional modelling algorithms, such as the Multi-Point Facies Truncated Gaussian or Truncated Pluri Gaussian method (Caers 2005, Doyen 2007) are now being conducted by the present authors and are expected to yield additional results in the future.

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