A provisional basin analysis of the Karoo Supergroup, Springbok Flats Basin, South Africa

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MSc Geology
Contents

Introduction
Geological background
Project Overview
  – Aim and objectives
  – Methodology
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Location
Retro-arc Foreland System for the Karoo Basins

Model of the formation of a foreland system of the Karoo Basins (after Catuneanu, 2004).

(Catuneanu, 2005)
Aim and objectives

• Detailed stratigraphy
• Evolution of the basin
• Compare the basin with the Main Karoo Basin
• Used knowledge from:
  – Crustal evolution
  – Basin analysis
  – Literature study
Approach

• Literature review
• Sort data provided by Council for Geosciences
  – About 2000 boreholes
• Constructed:
  – Spatial Maps
  – Cross sections
  – Structural Contour maps
  – Isopach maps
  – Multicomponent Maps
• Acquired Geophysical Data
Boreholes

<table>
<thead>
<tr>
<th>Status</th>
<th>Number of Boreholes</th>
</tr>
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<tbody>
<tr>
<td>Un-Captured</td>
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</tr>
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</tr>
</tbody>
</table>

**Map:**
- **Legend:**
  - Captured Boreholes
  - Locunc
    - 0 - 50
    - 51 - 100
    - 101 - 200
    - 201 - 500
    - > 500
  - Uncaptured
  - Springbok Flats Basin
<table>
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Boreholes
Structural contour maps

Illustrates the depth of the selected stratigraphic horizons within the basin.
- Outlines subtle syn-depositional topography
- Indicates structure in the different strata

Assists in:
- Basin fill geometry
- Basin shape
- Basin orientation
- Sub-basins
- Depocenters
- Axes of uplift
Isophach Maps

The definition of the term isopach is a line connecting areas of equal thickness.

In areas of structural complexity, it may be impossible to draw significant information from just structure contour maps

– As post-depositional tectonic events may have occurred and altered the strata.

Isopach maps reveal the basin fill in its original, un-deformed form and reveal something about syn-depositional structure.
Isopach Map
Letaba

Structural Contour Maps
Letaba

Bottom Contact
Top Contact

[Map images with isopach and structural contour maps visible]
Multicomponent map

Ratio map of:

**Argillaceous : Arenaceous**

Useful in determining:
- The possible source area
- The possible direction of propagation of the sedimentation system

Variation of lithologies in clastic environments are caused by the hydrodynamic sorting of coarse to fine grains.
- How coarse and how fine these deposits are depends on the current strength and the grain size range of available sediments during the time of deposition.
Known Structure
Interpreted Structure
Bernie Green
Lineation Interpretation
Lineation Interpretation
SEDIMENTARY EVOLUTION
Basement Lithologies

(Roberts 1992)
### Simplified Stratigraphy of the Springbok Flats Basin

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Log</th>
<th>Formation</th>
<th>Lithology Description</th>
<th>Average South</th>
<th>5th %ile South</th>
<th>Average North</th>
<th>5th %ile North</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Draakensberg</td>
<td>Grey to green-grey, speckled <em>barkhonda</em> breccia.</td>
<td>207</td>
<td>829</td>
<td>150</td>
<td>564</td>
</tr>
<tr>
<td>600</td>
<td></td>
<td>Olifants</td>
<td>Medium-grained white <em>sandstone</em> occurs at the top of the succession, grading into fine-grained <em>medium red sandstone</em>. The basal parts of the Olifants succession exhibit bedding and scour structures. The arenitic sandstone is cross-bedded towards the base, becoming mottled and fine-grained, well sorted and massive towards the top. Also present within these sandstones are thin mudrock or siltsite intercalations which occur sporadically.</td>
<td>127</td>
<td>234</td>
<td>166</td>
<td>166</td>
</tr>
<tr>
<td>700</td>
<td></td>
<td>Ellies</td>
<td>Alternating <em>mudstone</em>, <em>siltstone</em> and <em>sandstone</em> that are purplish-grey towards the base, becoming brick red and iron rich at the top. Planar and ripple cross-bedding is present with distinct seining and storm structures in places, as well as layers of conglomerate. Carbonate nodules throughout. Bituminisation has also been identified in some of the breccias towards the base of the succession.</td>
<td>96</td>
<td>133</td>
<td>88</td>
<td>119</td>
</tr>
<tr>
<td>820</td>
<td></td>
<td>Molteno</td>
<td>Grey <em>mudstone</em> and fine-grained <em>sandstone</em> at the base of the succession, grading to coarse-grained <em>sandstone</em> and conglomerates towards the top of the succession. Towards the central and northern regions of the basin, there is a basal unit with uppermost layers of sandstone grading into purple shale.</td>
<td>18</td>
<td>42</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>840</td>
<td></td>
<td>LCZ</td>
<td>Interbedded <em>carbonaceous shale</em> and <em>bright coal</em> layers. Carbonate and pyritic in places. Found in the central and north-central regions of the basin.</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>860</td>
<td></td>
<td>Volksrust</td>
<td>Gradational base, becomes dominated by <em>mudstone</em> and <em>siltstone</em>, with channels of fine-grained <em>sandstone</em>. The sedimentary rocks exhibit <em>carbonaceous shale</em> and <em>coal</em> concentration at the base of this succession, becoming thinner towards the top.</td>
<td>27</td>
<td>70</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>880</td>
<td></td>
<td>LCZ</td>
<td>The southern basin exhibits higher coal quality than the northern region for the LCZ, exhibiting thicker sequences of <em>bright</em> and <em>dull</em> <em>coal</em> interbedded with thin layers of <em>carbonaceous mudstone</em>. The LCZ in the northern region of the basin exhibits thicker layers of interbedded <em>carbonaceous shale</em> and <em>mudstone</em> with thinner layers of <em>bright</em> <em>coal</em>.</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>900</td>
<td></td>
<td>Dwyka</td>
<td>Basal <em>mudstone</em> that are calcareous in places, grading into medium to coarse grained <em>sandstone</em> and conglomerates with interbedded <em>shale</em>. The top of the Dwyka succession displays <em>carbonaceous siltstone</em> and <em>mudstone</em> with thin sandy laminae. Also present in the Dwyka succession is evidence of bituminisation and silt fragments. <strong>Tillite</strong> with basement granite and Waterberg Group red <em>sandstone</em> pebbles. Pebbles are angular and rounded and set in a dark grey argillaceous matrix.</td>
<td>17</td>
<td>51</td>
<td>18</td>
<td>70</td>
</tr>
</tbody>
</table>

**Note:** The stratigraphic log shows the thickness variations and properties of the formations across different regions.
Sedimentary Evolution

- SBF Sediments correspond to typical sediments expected to be found in a Forebulge basin in the Retro Arc Foreland Basin.
  - Thinner successions
  - Delay in deposition compared to the Foredeep
- Correlate to Main Karoo environments and strata
- The strata do not indicate thickening towards the northern bounding faults
  - This faulting is post deposition
- Depocentre migration is evident throughout strata
- Only major CFB uplift events are evident in the SBF
- Evidence of a major change event at the Permian-Triassic transition
  - Pr-T extinction event
  - Hinge migration
### Stratigraphy

Proposed stratigraphy for Springbok Flats Basin.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stormberg Series</strong></td>
<td>Bushveld Amygdaloid</td>
<td>Letaba Formation</td>
<td>Letaba Formation</td>
<td>Letaba Formation</td>
<td>Letaba Formation</td>
</tr>
<tr>
<td></td>
<td>Bushveld Sandstone</td>
<td>Clarens Sandstone Formation</td>
<td>Clarens Sandstone Formation</td>
<td>Clarens Formation</td>
<td>Clarens Formation</td>
</tr>
<tr>
<td></td>
<td>Bushveld Mudstone</td>
<td>Irrigasie Formation</td>
<td>Elliot Formation</td>
<td>Irrigasie Formation</td>
<td>Elliot Formation</td>
</tr>
<tr>
<td><strong>Ecca Series</strong></td>
<td>Upper Ecca Shale Stage</td>
<td>Beaufort Group</td>
<td>Vryheid Formation</td>
<td>Vryheid Formation</td>
<td>Volkrust Formation</td>
</tr>
<tr>
<td></td>
<td>Middle Ecca Coal Measures Stage</td>
<td>Ecca Group</td>
<td>Vryheid Formation</td>
<td>Hammanskraal Formation</td>
<td>Beaufort Group</td>
</tr>
<tr>
<td></td>
<td>Lower Ecca Shale Stage</td>
<td>Pietermaritzburg Shale Formation</td>
<td>Ecca Group</td>
<td>Ecca Group</td>
<td></td>
</tr>
<tr>
<td><strong>Dwyka Series</strong></td>
<td>Not Named</td>
<td>Dwyka Group</td>
<td>Dwyka Group</td>
<td>Dwyka Group</td>
<td>Dwyka Group</td>
</tr>
</tbody>
</table>
TECTONIC EVOLUTION
Depocentre Migration
Basin Extent
Faulting Ages
Basin Preservation

Eruption of the Letaba Basalts

Erosion leading to today’s preserved basin
Basin Evolution

- The onset of the Karoo Stratigraphy in the SBF was due to uplift resulting from the mid-carboniferous assembly of Pangea
- Lower Karoo deposition, lithospheric subsidence was facilitated by crustal-scale faults, resulting in the deposition of the glacial Dwyka and Lower Ecca
- Later Ecca succession was characterized by large subsidence with little accompanying brittle deformation
- The lower Beaufort was deltaic basin and was terminated towards the end of the Permian period, identified with a significant fauna and flora change
Basin Evolution

- An uplift event in the foredeep resulted in the compression of the forebulge. This marked in the structural inversion during the Beaufort Group and Early Molteno Formation.
- Elliot formed during this unloading of structural relief and relation of basin-forming stresses.
- An extensional basin formed by reactivation of older structures such as the TML as a result of displacement on the principle shear zones. This resulted in the preservation of the SBF strata by the Letaba Basalts in the basin today.
Summary

• The Karoo sediments in the SBF Basin clearly represent the broad spectrum of the same set of palaeo environments that are recognized in the Main Karoo Basin rocks.

• These reflect the progressive infilling of the Karoo Basins, the changing tectonic framework as well as the migration of Gondwana from polar to tropical latitudes.

• However, due to the development of the SBF basin on the forebulge, the compression of the CFB had the opposite effect, where it resulted in uplift of the fore-bulge and subsidence of the foredeep.

• This subsequently resulted in the SBF correlated Karoo sedimentary successions to be markedly thinner than those of the Main Karoo Basin, and in some cases, certain strata are completely absent.
Recommendations

This study is a baseline and preliminary investigation into the Springbok Flats Basin, and may act as a canvas to which more in-depth investigations may be added. Possible fields of investigation include:

• Source and distribution of the Uranium occurrences in the coal zones and mudstones;
• CBM potential of the SBF Coals;
• CGS potential of the SBF Coals;
• Palaeontological investigation to determine the correlative ages of the SBF strata and the Main Karoo Basin strata;
• QAQC of the borehole database with core samples;
• A study into the basement lithology of the Springbok Flats Basin;
• Possible extension of the Nylstroom Basin, Waterberg Group, beneath the SBF;
• P-Tr extinction event evidence in the SBF.
340 Ma

Pre-Karoo

Letaba
Clarens
Elliot
Molteno
Irrigasie
Ecca
Dwyka
280 Ma
260 Ma

Ecca - Irrigasie
220 Ma

- Letaba
- Clarens
- Elliot
- Molteno
- Irrigasie
- Eccca
- Dwyka
170 Ma

- Letaba
- Clarens
- Elliot
- Molteno
- Irrigasie
- Ecca
- Dwyka
150 Ma
65 Ma
Pleistocene
Present

Thank you!
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University of Pretoria
Honours students
Shango Solutions
SRK Consulting
References


[http://geology.gsapubs.org/content/28/12/1083/F3.expansion.html](http://geology.gsapubs.org/content/28/12/1083/F3.expansion.html)