REVIEW OF COAL GENESIS IN ZIMBABWE AND SUMMARY OF THE MAJOR DEPOSITS

Brent Barber - Jan 2016
First Reports Coal

• David Livingstone noted coal N of Zambezi River in Zambia in 1857.
• Carl Mauch observed coal close to the Bubye River in 1868.
• Mid-Zambezi Basin in Zimbabwe coal first reported Bari Coal Locality, confluence Katswanzwa and Ume Rivers, by Armstrong, de Noon and Payne early 1890’s.
• Albert Giese pegged claims vicinity Hwange Colliery in 1894.
LOWER KAROO:

• Permo-Carboniferous deposited arctic to warm temperate climatic interval.

• Late Carboniferous – Late Permian / Early Triassic = Sag Basin: Low strain lithospheric thinning prior rifting

• Coal intercalated fluvial, deltaic, paludal and shallow water lacustrine sediments
LOWER KAROO GROUP: MID-ZAMBEZI BASIN

Matabola Formation

• Upper Madumabisa Mudstone Member (k5c-f)
• Lower Madumabisa Mudstone Member (k5a+b)
• Upper Wankie Sandstone Member (k4)

Hwange Formation

• Black Shale And Coal Member (k2-3)
• Lower Wankie Sandstone Member (k1)
<table>
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<tr>
<th>Period</th>
<th>Group</th>
<th>Series</th>
<th>Formations Zambia</th>
<th>Lithology</th>
<th>Formations Zimbabwe</th>
<th>Maximum Surface Thickness (m)</th>
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<tbody>
<tr>
<td>Tertiary</td>
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Economic seams developed diachronous Coal And Black Shale Member and equivalent strata in Zambezi and Save-Limpopo Rift Systems.

Only sub-economic developments coal recognised younger Lower Madumabisa Mudstone Member and equivalent strata.
Burnt Coal

Except river sections coal measures often poorly exposed as readily weather - burnt coal, mottled brecciated rock, sometimes define outcrop.
CONTROLs PEAT ACCUMULATION

• Facies – telmatic / limnic / paralic
• Climatic conditions incl. temperature peat
• Organic matter input – plant types
• Nutrient supply
• Rate subsidence – compaction peat
• Water-table fluctuations - oxidation
• Water pH and Eh
Karoo Basin Sub-Saharan Africa
Dissimilarity coal Hwange to banded coals Europe noted Lamplugh (1907) – suggested reflected differing conditions accumulation.

Lightfoot (1914 and 1929) argued detrital opposed *in-situ* origin coal citing:

- Lack of any seat-earths underlying seams.
- Interlamination bright and dull coal as representing alternating argillaceous and organic deposition.
- High ash content due accumulation clastic particles with organic matter.
- Largely fragmentary nature of the plant remains in the coal as supporting maceration prior to deposition.
- Reputed improvement quality coal away from interpreted basin margin.
Bond (1955) initially supported coals detrital but later, Bond (1967), concluded some *in-situ* accumulation, occurred explaining, "under the cool climatic conditions of Ecca [Permian] times, the rate of [plant] growth would be slow, and dead vegetation would be exposed to oxidation and particularly to mechanical fragmentation for a long time before burial, leading to a high percentage of ‘organic mush’ [inertinite macerals and ash] in the coal".

Watson (1958 and 1960), reasoning differences due climatic variation, flora and sedimentary settings, contended none points Lightfoot established allochthonous opposed autochthonous coal formation.
COAL FORMATION - 3

• Main Seam generally richer vitrinite coal above which contains more inertinite - indicates basal coals deposited stable anaerobic environments where peat, lowering groundwater, subject periodic oxidisation.

• Increased fusinitisation overlying peat - drier environments - reflected increase interlaminated dull & bright coal = greater inertinite content.

• Megascopic logging & petrological studies indicate:
  ▪ Relatively shallow groundwater, denoted intercalated bright and dull coal logged 50.815 – 54.405m (3.095m).
  ▪ Predominantly high ash coals deposited 42.985 – 50.815m (7.830m), supported rise ash content upwards, indicate increase groundwater level.
  ▪ Further increase denoted carbonaceous mudstones, containing intercalations dull coal, logged 37.955 – 42.985m (5.030m).
  ▪ Rises groundwater levels, indicated carbonaceous mudstone interbedded bright and dull coal intersected 34.500 – 37.955m (3.455m).
  ▪ Additional increase water depth signified mudstone 34.500m upwards.

- The Carbo-Permian coals Lower Karoo Group formed largely deciduous *Gangamopteris* – *Glossopteris* flora - flourished cold to temperate climatic interval following Dwyka glaciation.
- Palaeo-surface postulated exhibited subdued topographic relief.
COAL FORMATION - 4b

- Major seams hyp- and autochthonous - exotic constituents comprise greater proportion coals overlying basal seams.
- Slower rates accumulation peat cold to cool temperate climate in interior continent, combined mineral content Gondwana flora, predom. factors relatively high ash Karoo coals. However, possible derived aerially as wind-blown loess / volcanic ash.
- Inorganic matter coals finely disseminated rendering beneficiation difficult.
COAL DEPOSITIONAL FACIES

Two end models proposed:

- Limnic
- Telmatic
Duguid (1981) proposed that in the Mid-Zambezi Basin peat deposition, wedging-out within 35 km down-dip, occurred diachronously along gently shelving palaeo-shoreline areally extensive lake.
OVERFILLED LACUSTRINE BASIN
TELmatic dePositional FacieS

Nyambe (1999) observed abundance inertinite indicated episodes aerobic decomposition - proposed coals deposited alluvial floodplain environments – analogous Niger delta where peat accumulates linear back-swamps:

- Lower Wankie and equivalent Maamba Sandstones alluvial channel deposits. Coal measures paludal floodplain accumulation.

- Peat accumulation large areas governed subsidence, with fluvial channels, confined levees higher floodplain, maintaining high water table. Detrital matter (ash) content semi-dependent proximity rivers and palaeo-topography.
PEAT FORMATION ALLUVIAL PLAIN FACIES

BASEMENT

TERRACE

LEVEE

SHALLOW SWAMP

BRAIDED RIVER

MEANDERING RIVER

CREVASSE CHANNEL AND SPLAY

FLOOD PLAIN

Braided River Sands

Meandering River Sands

Levee Sands and Silts

Flood Plain and Overbank Muds and Silts Rich In Carbonaceous Matter

Peat and Muds Rich In Carbonaceous Matter

Crevasse Channel and Splay Sands
Concepts re-introduced Oesterlen & Lepper (2005) who over-interpreting available data hypothesised:

- Supposed coal “swamp zone” adjacent palaeo-limnic shoreline stretching arc E – Hwange, via Lubimbi, Lusulu, Lubu and Busi Coal Localities to Sengwa.
- All coal S lake accumulated alluvial plain.
HYPOTHESISED LIMNIC / TELMATIC FACIES

Oesterlen and Lepper (2005)
COAL EXPLORATION

- Coal exploration was until relatively recently routinely conducted under tenure Exclusive Prospecting Orders [EPOs].
- Reports detailing work undertaken submitted ZGS.
- On expiry reports archived in ZGS library for public access.
- Summaries work completed EPOs 1 – 900 contained ZGS publications:
    - Bulletin 72 - EPOs 1 to 250.
    - Bulletin 74 - EPOs 251 to 400.
    - Bulletin 82 - EPOs 401 to 500.
  - Oesterlan (1998):
    - Bulletin 102 (EPOs 501 – 600).
  - Nachsel-Weschke (2002):
    - Bulletin 106 (EPOs 651 – 900).
COAL RANK

• Rank coal Mid-Zambezi Basin increases WNW direction - *Lignitic* at Bari in Matabola Sub-basin to *Bituminous Medium to High Volatile* at Hwange in Mlibizi Sub-basin.

• Variations rank of diachronous coals Mid-Zambezi Basin largely attributable differing depths burial and geothermal gradient:

W portion of the Mid-Zambezi Basin coalification enhanced increased temperatures areas buried beneath Batoka Basalt Formation - Nyblade *et al.* (1990) reported relatively high heat flow of 120 mW/m² in a drillhole sunk in the Hwange.

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Mid-Zambezi Basin

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PRIOR ASSESSMENTS COAL DEPOSITS

• Assessments coal resources Zimbabwe undertaken behalf GSZ by Barber (2001), Harrison (1980), Macgregor (1947) and Maufe (1924) and Montan Consulting GmbH (1983).


Insufficient public domain data available at the ZGS ~ 1990’s to Present ~ to facilitate the re-evaluation resources any coal deposit in Zimbabwe.
1. Describe coals accordance method developed Diessel (1982) macroscopic characterisation highly variable, laminated and thinly banded Gondwana coals which, containing organic constituents intermediate banded bituminous Carboniferous age and younger N hemisphere coals, often problematic categorise using definitions International Committee For Coal Petrology (1963 and 1971) based on lithotypes proposed by Stopes (1919 and 1935).


3. Estimate coal *Resources* and *Reserves* in accordance Australian Guidelines Estimation and Classification Coal Resources (2014).
COAL LITHOTYPES

**Bright Coal (Vitrain):** Vitreous to sub-vitreous lustre - ≤5% dull bands ≤5mm. Represents gelified woody material.

**Banded Bright Coal (Clarain):** Bright, thinly bedded coal, with shiny, black satin lustre – 5 to 40% bands dull coal ≤5mm.

**Banded Coal (Duroclarain):** Approx. equal proportions, 40 – 60%, bright and dull coal bands ≤5mm thick.

**Banded Dull Coal (Clarodurain):** Predom. dull coal with uneven fracture containing 5 – 40% bands of bright coal ≤5mm thick.

**Dull Coal (Durain):** Tough, dull coal, with matt lustre and uneven fracture, containing ≤5% bands bright coal ≤5mm thick. Product oxidised organic matter.

**Fibrous Coal (Fusain):** Dull, dirty, friable coal with satin lustre - ≤5% bands other lithotypes ≤5mm. Represents material subjected oxidation or fire.
<table>
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<tr>
<th>RELATIONSHIP BETWEEN JORC INVENTORY COAL, COAL RESOURCES AND COAL RESERVES</th>
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<td><strong>NON - JORC</strong></td>
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<td><strong>INVENTORY COAL</strong></td>
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<td>Mining / Processing / Metallurgical / Legal / Marketing / Environmental / Govt / Social</td>
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<td>Increase Geological Confidence</td>
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Mid-Zambezi Basin
LARGER COAL DEPOSITS - ZIMBABWE

○ MID-ZAMBEZI RIFT SYSTEM:
  ▪ Entuba
  ▪ Hwange
  ▪ Lubu
  ▪ Lusulu
  ▪ Western Areas
  ▪ Sengwa N & S

○ SAVE-LIMPOPO RIFT SYSTEM:
  ▪ Bubye

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BUBYE COAL LOCALITY

• Four of six seams, Bubye Bottom, Bubye No: 2, Bubye Main and Bubye Top, assessed possess economic coal potential.

• Due widespread igneous activity no average coal seam quality data reported.

• Rank high ash coal based proximate analyses ranges *Bituminous Medium Volatile to Anthracite*. Coal possesses coking characteristics.

• Tonnage in-situ *Inventory* coal, *Inferred* standing, in Bubye E and W estimated total 438mmt. Greater proportion delineated Bubye Main and Bubye Bottom. Majority only exploitable u/g mining.
ENTUBA COAL LOCALITY

• Palloks (1984), despite inconsistent sampling and analytical procedures Hwange Colliery, established ±10m Main Seam decreased quality upwards.

• Basal 1.5m Main Seam straight coking coal and overlying 1.5m blend. Bulk upper portion thermal. Possibility increase av. thickness coking coal ±3 metres only slight decrease quality.

• Vitrinite reflectance 0.7 - 1.28 RoV (mean) but readings 0.7 and 1.13 RoV (mean), bhs only 270m apart area, devoid known igneous activity, contentious. Disregarding results assessed Bituminous High Volatile rank.

• In-situ Inventory coal, Indicated standing, o/c cumulative strip ratio cut-off ≤3.5m ob/t coal, estimated total 77.3mmt. Approx. 25% coking and blend coking coal.

• In-situ u/g Inventory coal, Indicated standing, with 19% coking and blend coking quality, totals 106mmt.
HWANGA COLLIERY

• Main Seam, decreases quality upwards - composed sub-seams variable thickness and non-established continuity.
• Bright coal developed base Main Seam formed Sub-seams 1 and parts 2 and/or 3.
• *Inventory Bituminous to High Volatile Bituminous* rank coal, *Measured* standing, estimated 1,506mmt *in-situ.*
• Portion o/c, cumulative strip ratio cut-off 3.5m o/b per tonne coal, totals 225.7mmt.
• Coking coal totals 472mmt with 66mmt o/c.
• Coal remaining, following depletion mining, requires assessment.

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LUBU COAL LOCALITY

• Main seam, relatively high ash *Bituminous High Volatile* coal, av. 12.5m thick.
• Best quality coal, with top and bottom portions inferior, towards centre Main Seam.
• Portions low S coking coal potential.
• *In-situ o/c Inventory* coal of *Indicated* standing estimated total 334mmt – mineable relatively low strip ratio of 2.9.
• If A–Seam mined tonnage increased ±30%.
• Additional large *Inferred* tonnage noted to S.
LUSULU COAL LOCALITY

- Rank high ash Main Seam *Sub-bituminous to Bituminous Medium Volatile*.
- Best coal, ash content increases upwards, occurs lower portion Main Seam. Quality coal decreases to SE and SW.
- Portions Main Seam possess some coking potential.
- Coal possess high moisture retaining capacity - on drying prone spontaneous combustion.
- S content raw coal reduceable 0.6% washing S.G. 1.6.
- Coals overlying A-Seam inferior quality.
- *In-situ o/c Inventory* tonnage coal, cumulative strip ratio 3.5m o/b per tonne coal, estimated 402.6mmt and u/g 1,492.2mmt. Both *Indicated* standing.
SENGWA COAL LOCALITIES

- *Sub-bituminous* - *Bituminous High Volatile* rank non-coking coal Main Seam.

- Thickness Main Seam, wedges-out E in Sengwa S and S in Sengwa N, av 14.1m and 12.5m respectively.

- Central portion Sengwa S raw ash content footwall averages ±20%. Then decreases <10% before increasing, ±2m above footwall, to >20% near top.

- Sulphur Sengwa S low, av 0.24% as opposed 0.75% Sengwa N.

- Phosphorus av 0.095% Sengwa S and 0.168% Sengwa N.

- High moisture content, >3.5% Air Dried, prohibatative caking.

- Drying coal and coaly shale prone spontaneous combustion.

- **In-situ Inventory** coal, estimated *Indicated* standing:
  - **Sengwa N**: 205mmt o/c at cumulative strip ratio cut-off 3.5m o/b per tonne coal.
  - **Sengwa South**: 302mmt coal extractable u/g.
WESTERN AREAS COAL LOCALITY

• Ash content and frequency mudstone partings increases up dip towards outcrop.
• Quality coal deteriorates upwards.
• Up to $\frac{1}{3}$ basal portion Main Seam, av ±8m, coking potential.
• S content raw coal averages 1.5.
• Possible, accepting lower part Main Seam absent, that Main and No. 1 Seams coalesce o/c, with poorer coal base upper portion Main Seam and overlying coal No. 1 Seam.
• *Medium to High Volatile Bituminous Inventory* coal present Main and No. 1 Seams assessed *Indicate* standing.
• Main Seam estimated 77.1mmt o/c and 874.8mmt u/g *in-situ* coal. In addition, in-situ coal No. 1 Seam estimated 28.0mmt o/c, cumulative strip ratio cut-off 3.5m o/b per tonne coal, and 143.2mmt u/g.

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