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

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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.**

COAL DEVELOPMENT - 1

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**

COAL DEVELOPMENT - 2

LOWER KAROO GROUP: MID-ZAMBEZI BASIN

Matabola Formation

- Upper Madumabisa Mudstone Member ($k5^{c-f}$)
- Lower Madumabisa Mudstone Member ($k5^{a+b}$)
- Upper Wankie Sandstone Member (k4)

Hwange Formation

- Black Shale And Coal Member (k2-3)
- Lower Wankie Sandstone Member (k1)

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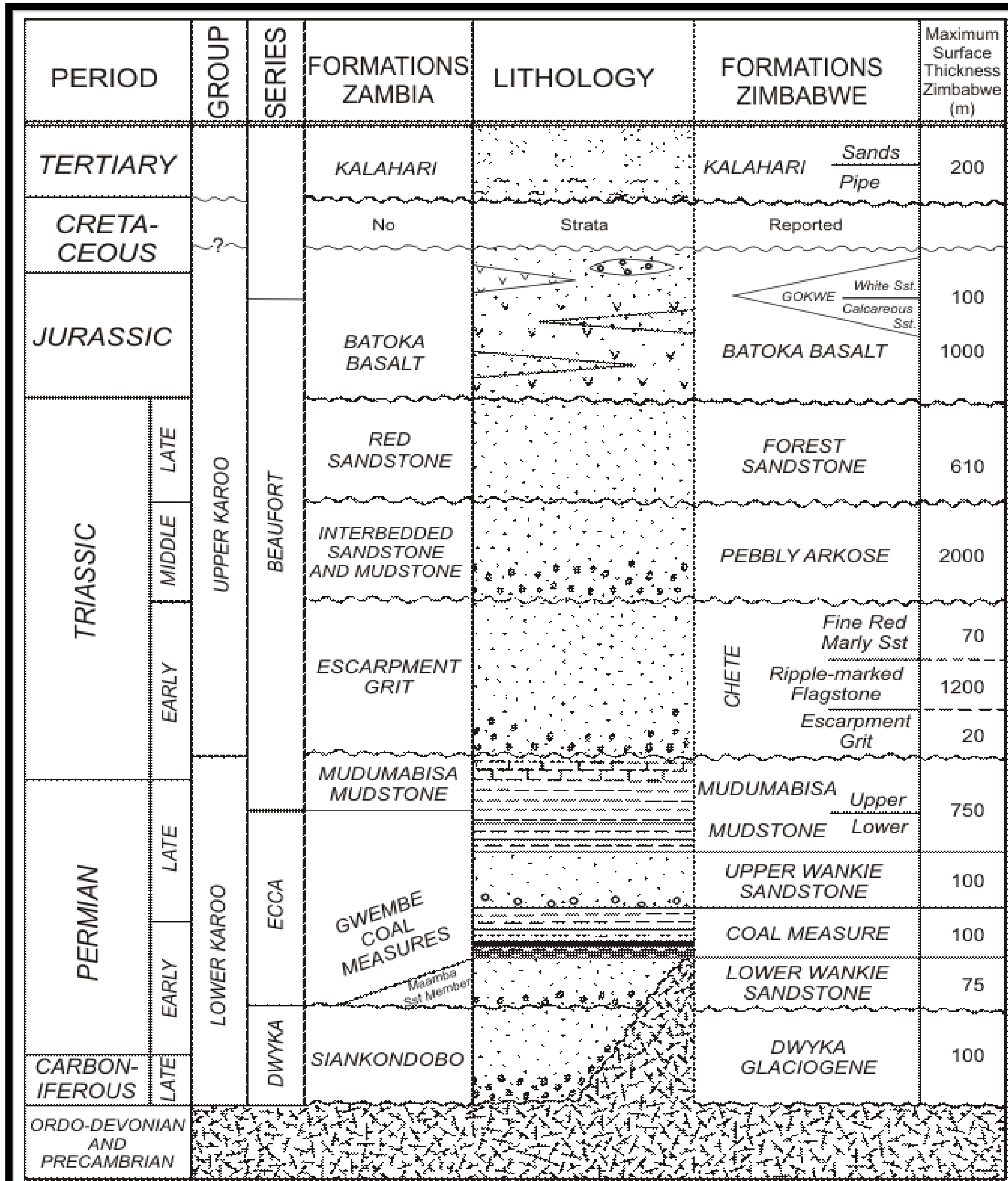
MID-ZAMBEZI BASIN



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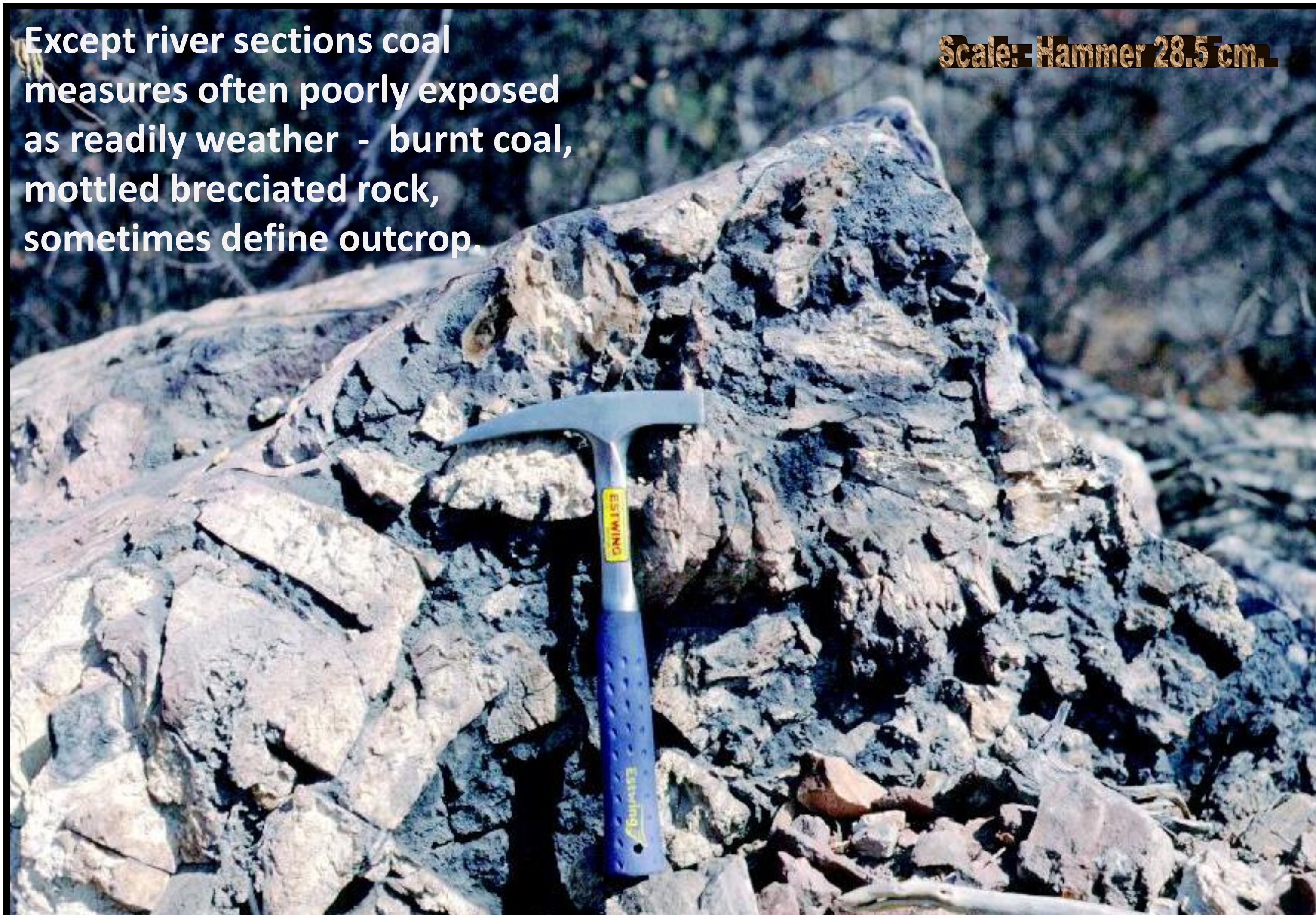
COAL DEVELOPMENT - 3

- **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.
Scale: Hammer 28.5 cm.
ESTWING
Estwing

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

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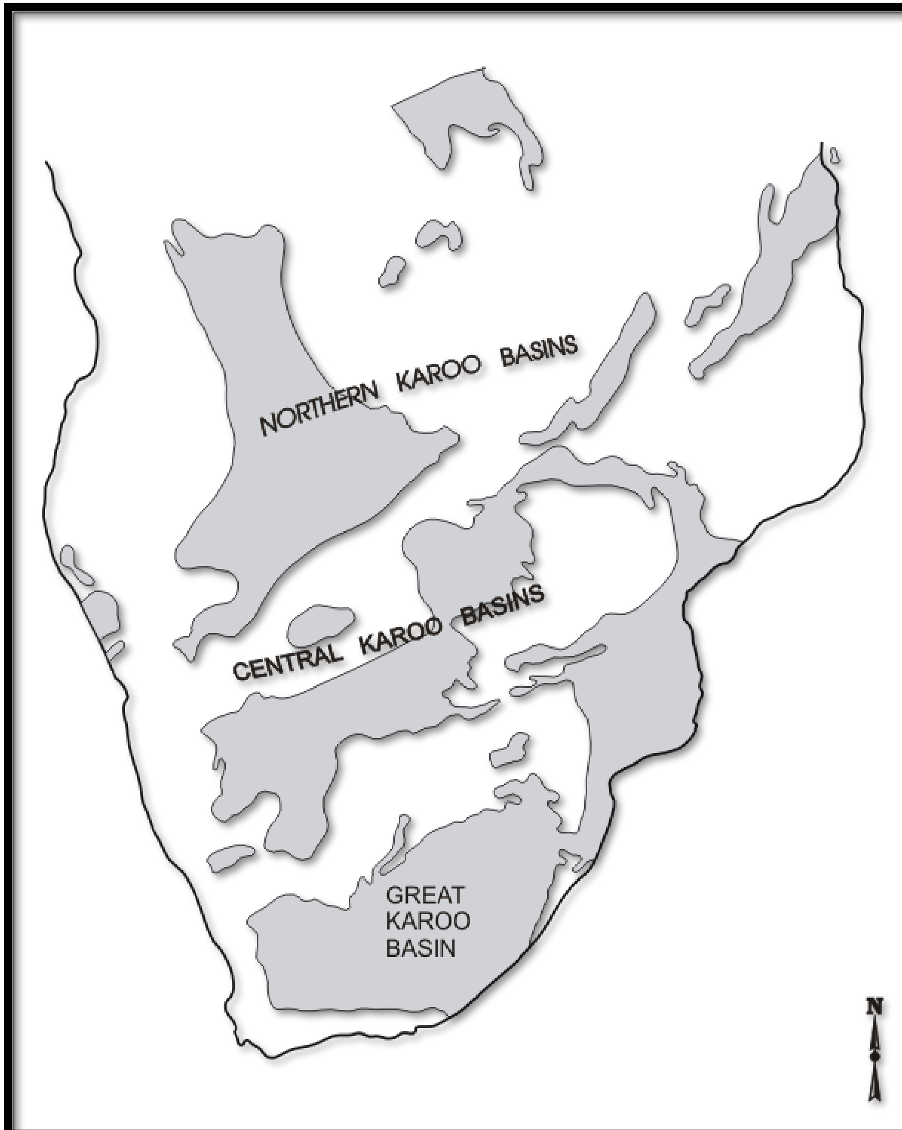
Karoo Basin Sub-Saharan Africa



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COAL FORMATION - 1

- **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.**

COAL FORMATION - 2

- 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.

COAL FORMATION - 4a

Barber (1987, 1993, 1994 & 2001) concluded:

- **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.**

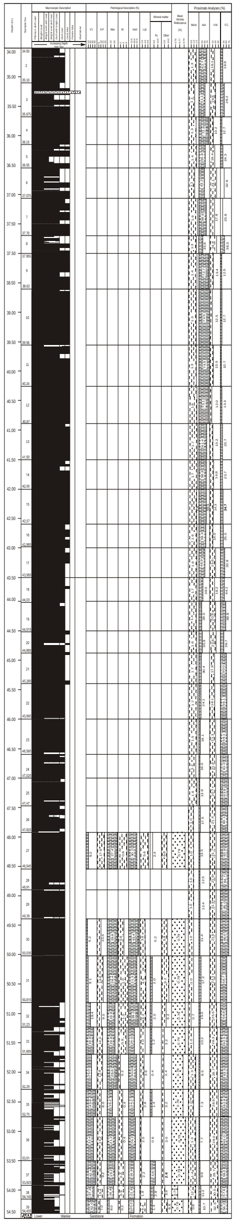
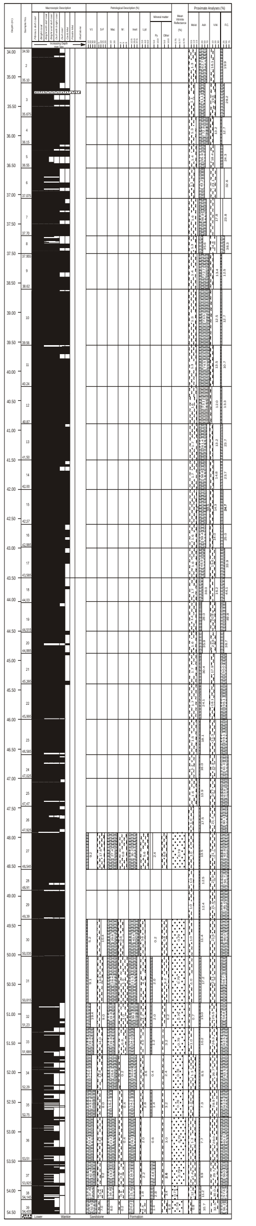


FIGURE: 4 PROFILE WANKIE MAIN SEAM COMPARING THE INFLUENCE OF VARIATIONSIN WATER TABLE DURING DEPOSITION ON PROXIMATE ANALYSES AND THE MACERAL COMPOSITION OF THE COAL

-B.H. W.C.C 42,61 Wankie Coalfield : Grid Ref. MK 40226510
Elevation 767,84m Coal 234,50-54,05 (19.905m)

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.**



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COAL DEPOSITIONAL FACIES

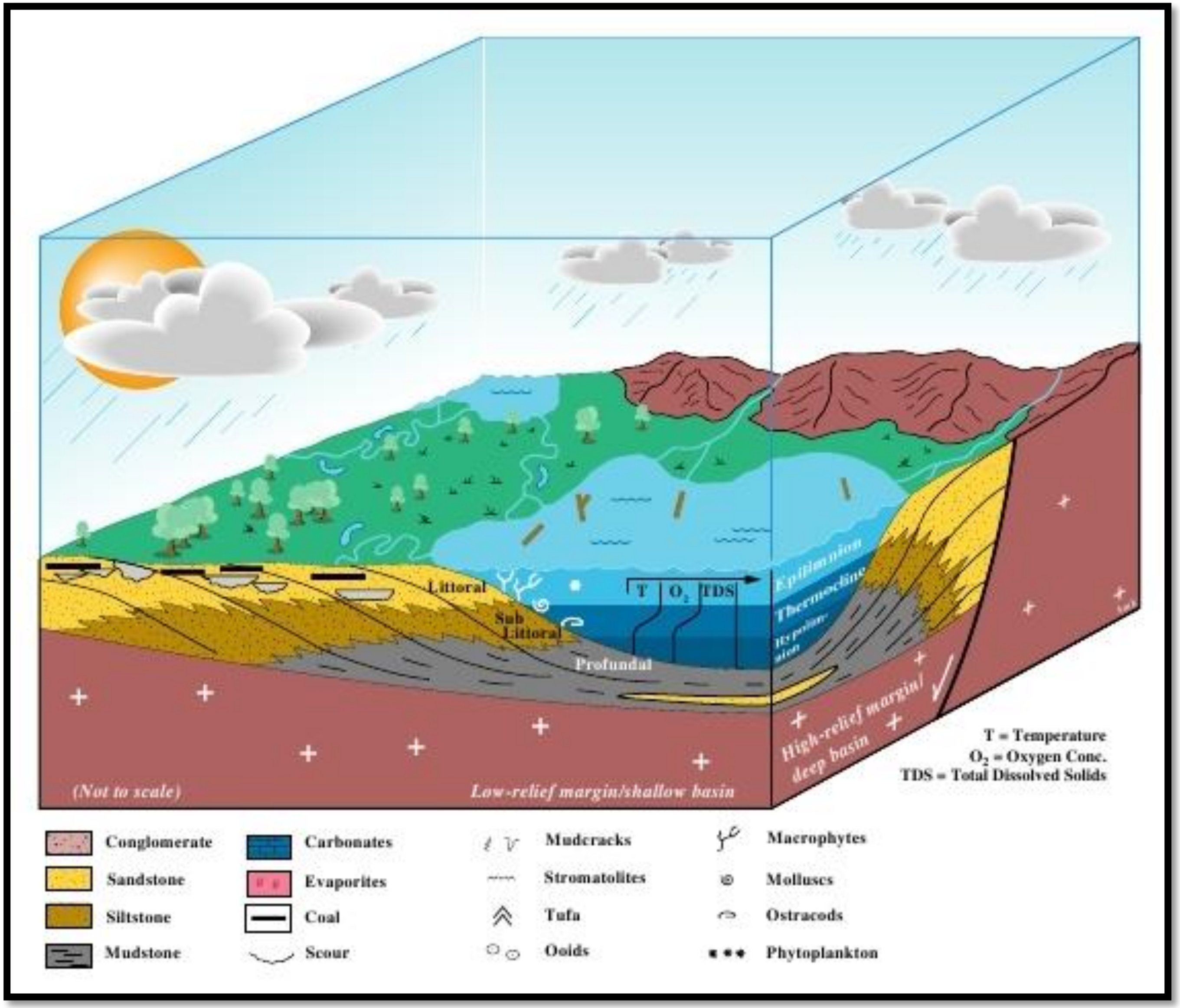
Two end models proposed:

- **Limnic**
- **Telmatic**

LIMNIC DEPOSITIONAL FACIES

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

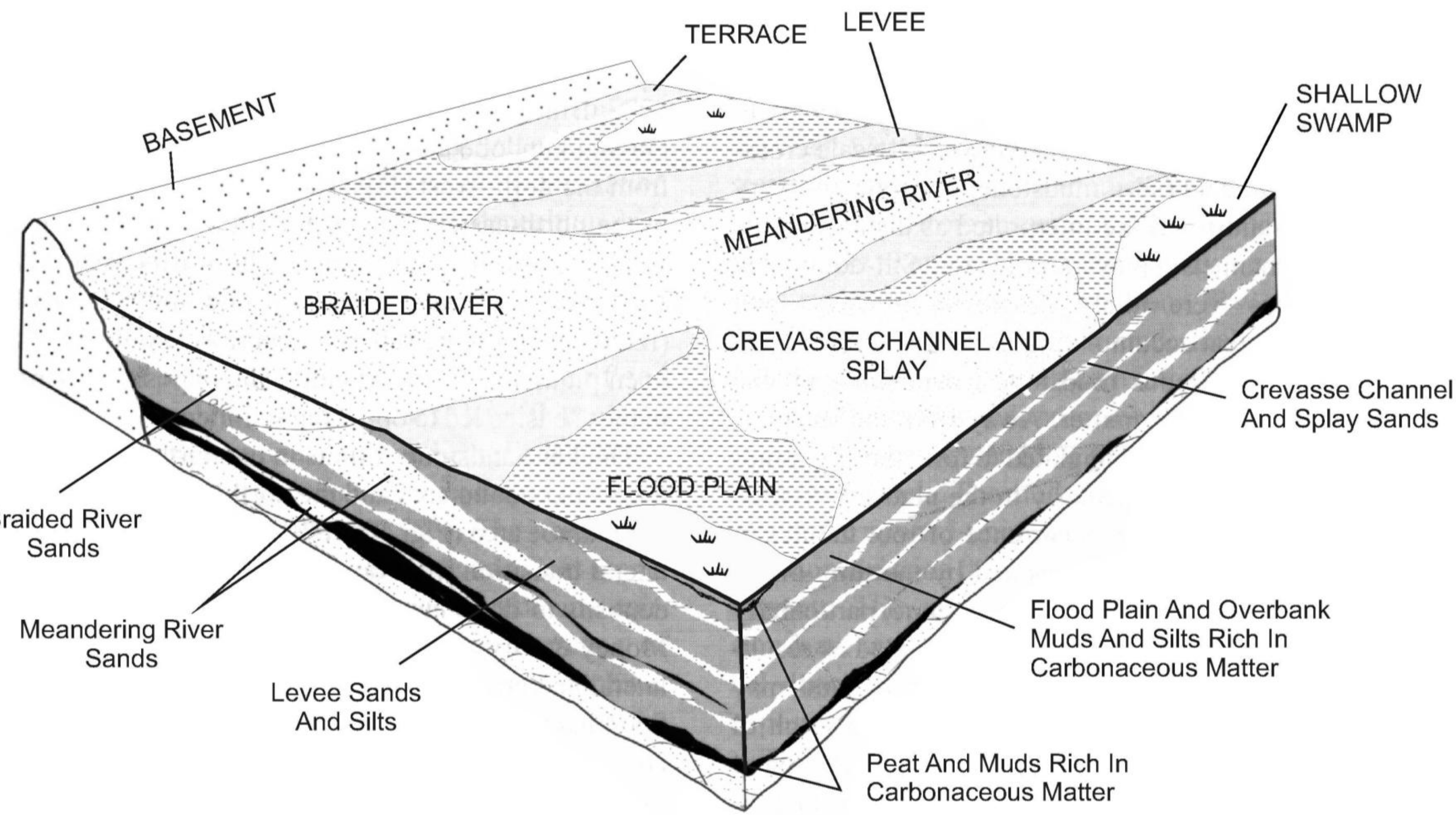


TELMATIC DEPOSITIONAL FACIES

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 flood-plain, maintaining high water table. Detrital matter (ash) content semi-dependent proximity rivers and palaeo-topography.

PEAT FORMATION ALLUVIAL PLAIN FACIES

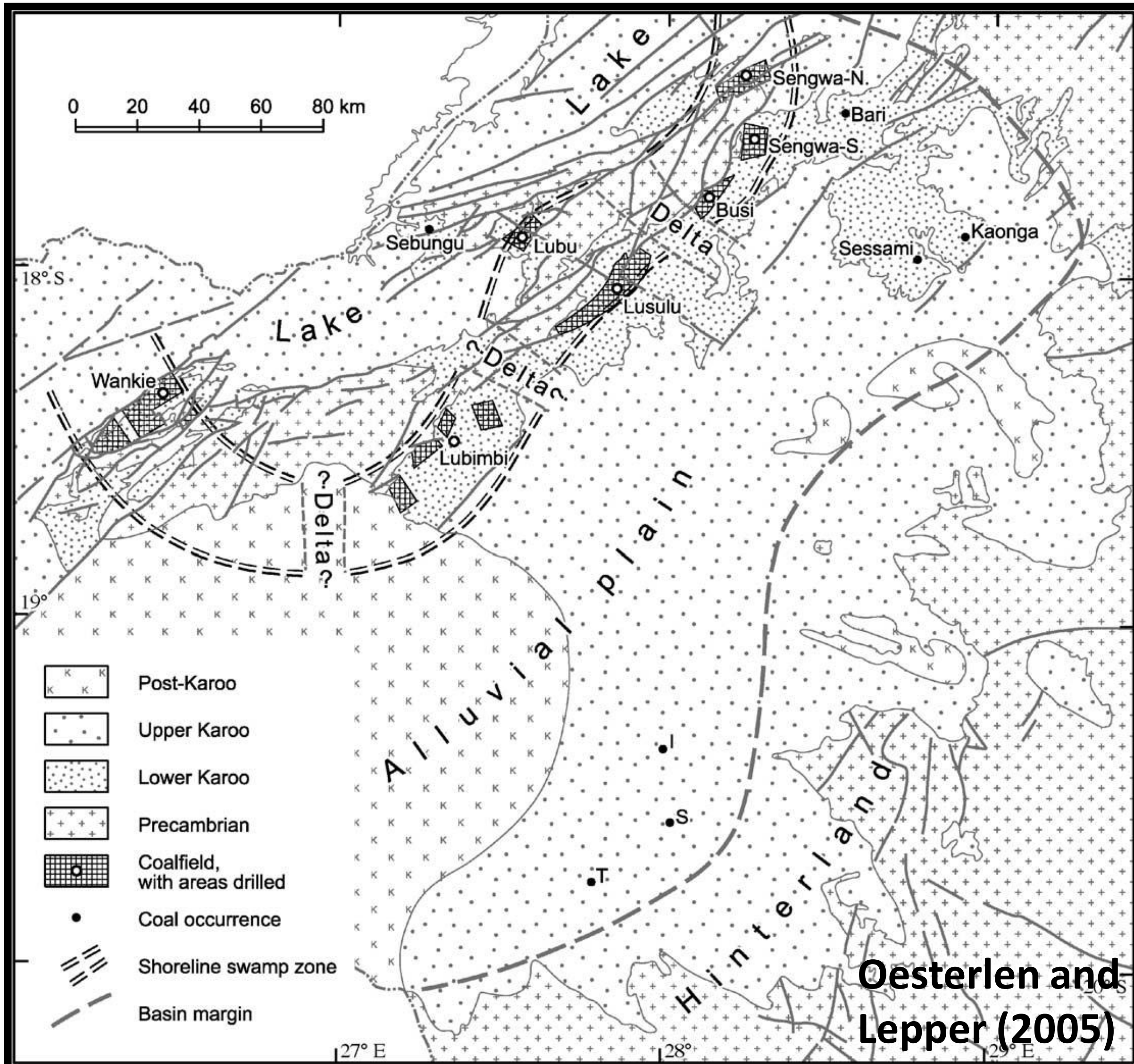


LIMNIC & TELMATIC FACIES

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

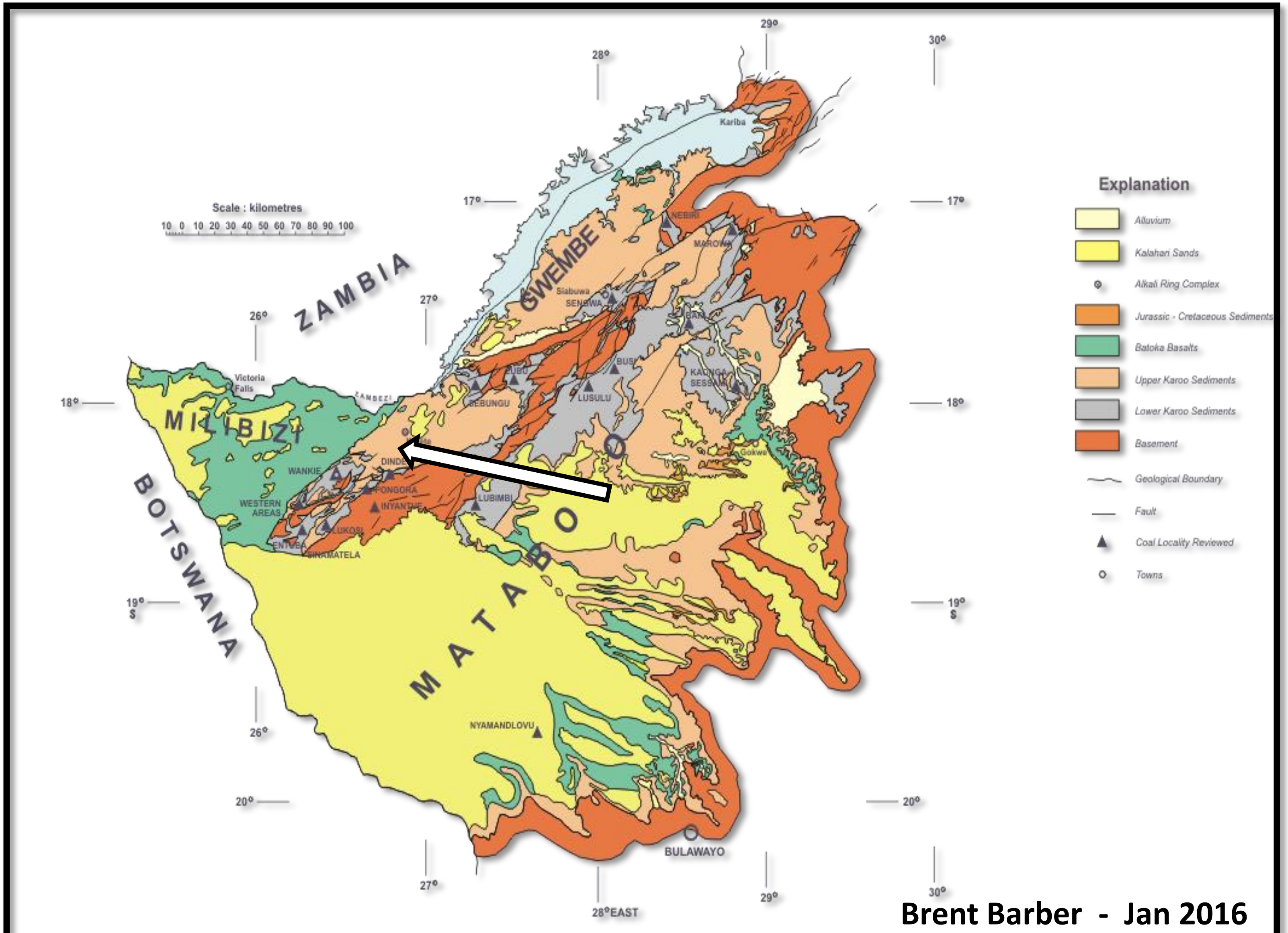
- Coal exploration was until relatively recently routinely conducted under tenure Exclusive Prospecting Orders [EPOs].
- Reports detailing work undertaken submitted ZGS.
- On expiry reports archived in ZGS library for public access.
- Summaries work completed EPOs 1 – 900 contained ZGS publications:
  - Morrison (1974, 1975 and 1978):
    - 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/m^2 in a drillhole sunk in the Hwange.

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).

- Additionally, using information archived ZGS and held companies, detailed evaluations individual deposits completed Barber (1986, 1987[b+ c], 1988 and *In Press*) and Palloks (1984 and 1987).

Note: That available on Lubimbi, which as reported by Thompson (1981) documents investigations Industrial Development Corporation directed establishing material suitable production synthetic fuel, judged inadequate by Palloks (1984) for Coal *Resource* estimation.

RE-ASSESSMENT COAL DEPOSITS

Insufficent <u>public domain</u> data available at the ZGS ~ 1990's to Present ~ to facilitate the re-evaluation resources any coal deposit in Zimbabwe.

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COAL RESOURCES & RESERVES

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).**
2. **Report coal rank accordance standards adopted American Society Testing and Materials (1958 and 1991).**
3. **Estimate coal *Resources* and *Reserves* in accordance *Australian Guidelines Estimation and Classification Coal Resources* (2014).**

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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.

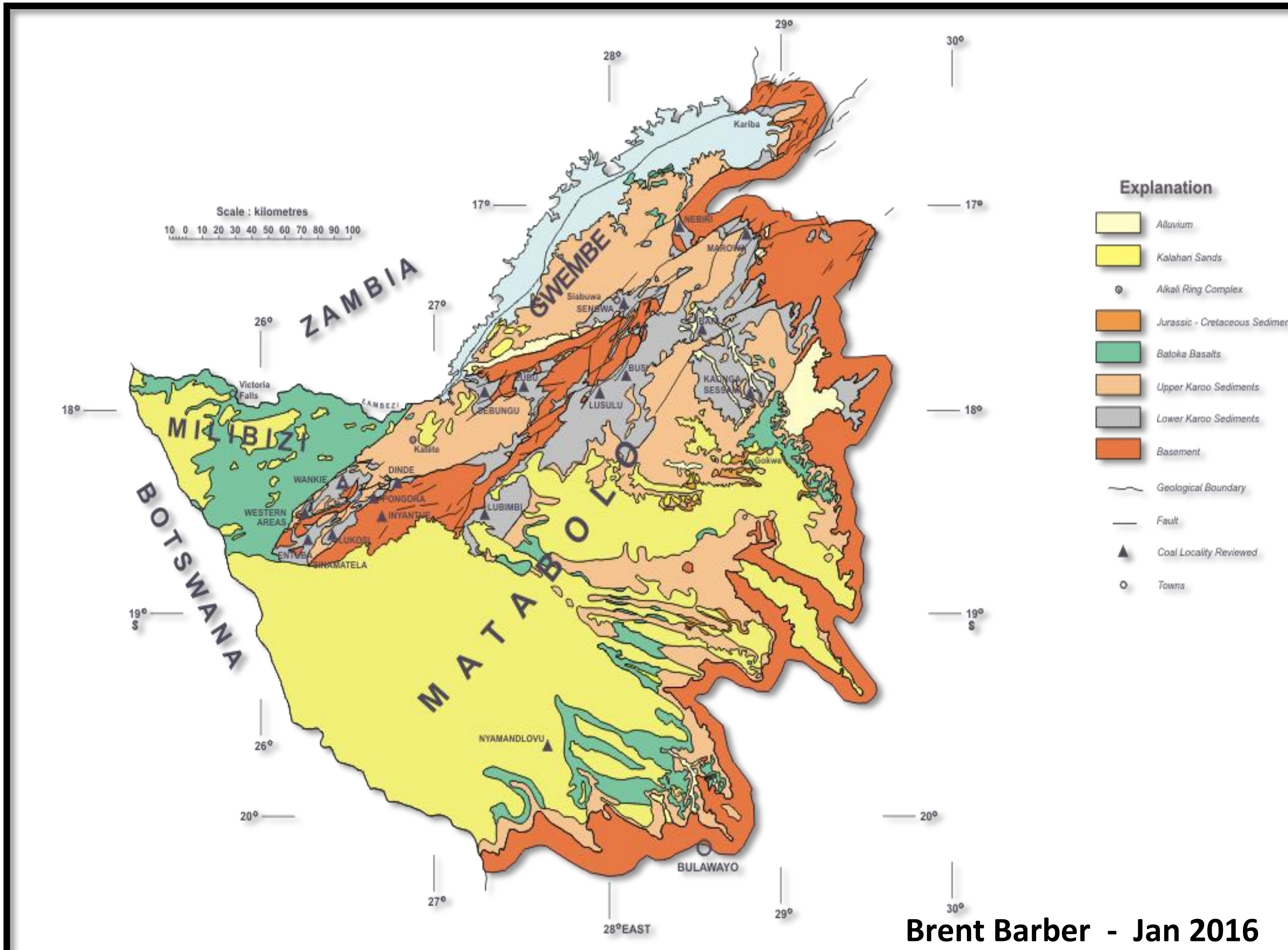
DULL COAL (DURAIN): Tough, dull coal, with matt lustre and uneven fracture, containing ≤5% bands bright coal ≤5mm thick. Product oxidised organic matter.

FIBROUS COAL (FUSAIN): Dull, dirty, friable coal with satin lustre - ≤5% bands other lithotypes ≤5mm. Represents material subjected oxidation or fire.

RELATIONSHIP BETWEEN JORC INVETORY COAL, COAL RESOURCES AND COAL RESERVES

	NON - JORC (Govt & Internal Reports)	JORC (Public Reports)		
	INVENTORY COAL	**COAL RESOURCES** (Reasonable Prospects Economic Extraction)	**COAL RESERVES** (Application Predicted Yield And Moisture Factors)	
↓ Increase Geological Confidence ↓	**Inferred** ↓ **Indicated** ↓ **Measured**	**Inferred** ↓ **Indicated** ↓ **Measured**	**Probable** ↓ **Proven**	**Probable Marketable** ↓ **Proven Marketable**
	No Modifying Factors		**Consideraton *Modifying Factors:*** **Mining / Processing / Metallurgical/ Legal / Marketing / Environmental / Govt / Social**	

Mid-Zambezi Basin



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LARGER COAL DEPOSITS - ZIMBABWE

- **MID-ZAMBEZI RIFT SYSTEM:**
  - Entuba
  - Hwange
  - Lubu ??? Lubimbi ???
  - 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.
- I*n-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 .
- I*n-situ* u/g ***Inventory*** coal, ***Indicated*** standing, with 19% coking and blend coking quality, totals 106mmt.

HWANGE 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.**

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.
- I*n-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.

SPONTANEOUS COMBUSTION - SENGWA

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WESTERN AREAS COAL LOCALITY

- **Ash content and frequency mudstone partings increases up dip towards outcrop.**
- **Quality coal deteriorates upwards.**
- **Up to ⅓ 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.**