spore and tearing of the exine. Thickness usually variable, ranging from 2 to 5 µ thick; surface laevigate, infra-punctate to shagrate; occasionally circular shallow crater-like depressions up to 7 µ wide occur giving an irregular appearance to the exine.

Dimensions (10 specimens): Diameter: 42–65 µ.

Distinction: Pilaspora calculus is distinct from other Alete forms in possessing an unevenly thickened exine and a relatively large size.

Stratigraphic range: Occurs throughout the stratigraphic succession.

Genus: Circulisporites de Jersey, 1962 amended Norris, 1965

Type species: Circulisporites parvus de Jersey, 1962.

Diagnosis: Circular spheroidal or discoidal microfossil; wall bears circular striae extending in spiral arrangement from pole of spore to equator. Microfossil frequently splits along the equator, yielding two symmetrical halves.

Discussion: Chomotriletes Naumova, an Upper Devonian form from Russia, is said to be trilete and bears striae that are incomplete.

Circulisporites magnus sp. nova

Plate 5: figures 17, 18.

Diagnosis: Microfossil is circular to sub-circular in polar view and discoidal to flattened in equatorial views. Exine bears a circular striation from the polar point spiralling continuously outwards towards the thickened margin. No haptotypic structures are visible.

Holotype: Plate 5: figure 17.

Description: Shape: Spore is sub-circular to circular in polar view sometimes irregular, flattened to discoidal when seen equatorially with marginal over-curling and minor folding. No true dehiscent mechanism observed.

Exine: Striation extends from a central polar point in equally spaced and increasing spirals often slightly elongated due to compression. Spiral parallels outer margin of the microfossil. Striae about 1 u thick and 1 u apart and contains more than 18 spirals in the radius.

Dimensions (6 specimens): Diameter: 32-62 μ.

Discussion: Circulisporites parvus de Jersey is smaller in size, discoidal and frequently equatorially dehisced.

Distinction: Circulisporites magnus is distinct from other species by its large size, numerous spirals followed by the striation and by the discoidal nature of the spore when seen equatorially.

Stratigraphic range: Absent in Dwyka and Lower Black Shales and Coals; common in Upper Black Shales and Coals and Madumabisa Mudstones.

Genus: <u>Tetraporina</u> (Naumova) Naumova, 1950

Type species: <u>Tetraporina antiqua</u> Naumova, 1956 designated by Potonie, 1960.

Diagnosis: Quadrilateral outline, corners sometimes bear arcuate folds, exine unsculptured; no apparent haptotypic markings.

Synonyms: Sporomorph "A" Balme and Hennelly, 1956. <u>Balmeella</u> Pant and Mehra, 1963.

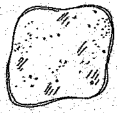
<u>Tetraporina sp.</u>

Plate 5: figure 19.

Description: Shape: Microfossil without any apparent germinal markings or dehiscence mechanism. Outline quadrilate_al, sides straight to slightly concave or convex; corners well rounded.

Exine: About 1 μ thick, laevigate to infra-punctate and occassionally folded.

Dimensions (10 specimens): Diagonal length: 35-58 μ, normal length parallel to transverse and longitudinal axes: 24-55 x 25-65 μ.



Discussion: The above specimens are very comparable to Tetraporina horologia (Staplin) Playford, 1963, Plate 95; figures 14, 15 in all respects bar arcuate folds which have never been seen in the Rhodesian forms; Balmeella tetragona Pant and Mehra is also probably synonomous. Balmeella gigantea Bose and Maheshwari is very much larger.

Distinction: Tetraporina sp. is distinct in being roundly rectangular with no haptotypic markings and fine infra-punctation.

Stratigraphic range: Rare to common in Dwyka; very rare in Black Shales and Coals; very rare to absent in Madumabisa Mudstones.

Infra-turma: GRANULONAPITI Cookson, 1947

Genus: Granulatasporites Leschik, 1956

Diagnosis: Circular to sub-circular outline; no haptotypic markings and granulate sculpture.

Granulatasporites sp.

Plate 5: figures 3, 4.

Description: *Shape:* Sub-circular to oval and rounded rectangular. No germinal markings occur, and the thin exine is often ruptured and folded.

Exine: Thin, less than 1 µ; densely covered with fine evenly spaced grani less than 0,25 µ. Exinal folds are short and randomly spaced.

Dimensions (10 specimens): Diameter: 35-55 u x 58-70 µ.

Discussion: Granulatasporites sp. although relatively rare to common in occurrence, are stratigraphically confined to the lowest Dwyka sediments. For this reason, they are described. They are closely comparable to G. pastillus but are not so covered in short narrow folds; G. indefinitus is fabiform in outline and is smaller, whilst G. irregularisplicatus bears irregular and cord-like thickenings on the exine. G. subreticulatus possesses a thick exine.

Distinction: Granulatasporites sp. is distinct in having a thin finely granulate exine with a few short narrow random folds.

Stratigraphic range: Confined to Dwyka sediments.

Genus: Verrucosphaera Glickson (unpublished Ph.D. thesis)

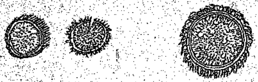
This thick-walled, densely "hairy" genus has been encountered in Australia in the Collie Basin by M. Glickson (unpublished thesis) and by Segroves (pers. comm.) in the Perth Basin. No closely comparable form has been described in Africa to the author's knowledge. Kagulubeites Bose and Maheshwari, 1968 is a spherical to avoid form with thick exine sculptured with baculli or verrucae and generally split along a weak zone. Spheripollenites (Couper) Jansonius is regarded by Hart to be synonomous with Schizosporis Cookson and Dettman, 1959 and is typically unsculptured.

The Rhodesian forms may well be an unusually sculptured Pilaspora species, but due to separate generic status, assigned by Glickson, and the abundance of this form in certain Rhodesian sediments this genus is retained; it is here divided into two varieties on the basis of size, but both are otherwise specifically identical.

Verrucosphaera colliensis Glickson

Plate 5: figures 5-12, variety 1.
figures 13-16, variety 2.

Diagnosis: Unobtainable, but from plates species are thick-walled, spherical microfossils bearing dense filamentous elements and lacking germinal distinct openings.



Description: Shape: Strongly spherical; sometimes folded or slightly compressed to give an "inverted tennis-ball" type of appearance.

Exine: Thick, 3-4 µ and often showing an apparent double wall at spore margin. Densely spaced and equally concentrated filamentous elements 0,5 µ or less in basal diameter and up to 8 µ long occur which, when compressed and sealed on microscope slides, show a directional flowing tendency similar to the tail of a meteorite.

Dimensions: Variety 1: (20 specimens): Total diameter: 18-26 µ.

Variety 2: (20 specimens): 44-55 µ.

Distinction: Verrucosphaera colliensis is distinct from all other spherical alete forms in possessing a filamentous hairy exine.

Stratigraphic range: Absent in Dwyka; rare to abundant and occasionally dominant in Upper Black Shales and Coals; rare to common in Madumabisa Shales.

5. DISCUSSION

5.1 PRESERVATION AND ABUNDANCE

No macrofossil horizons were observed during the course of sampling the Matabola Flats borehole core, but a sample taken at 1 114 ft yielded an excellent impression (and counterpart) of an insect wing. This is believed to be one of the earliest fossil specimens of a taxonomic group which typically diversifies in Mesozoic times. Dr. ~~Reicke,~~ E. C. Riek, an eminent palaeo-entomologist (Canberra, Australia) was shown this specimen by Mr. J. Anderson (with whom this specimen was collected). In correspondence with Professor Bond of the University of Rhodesia, Dr. ~~Reicke~~ Riek disclosed that this insect belongs to the group Paraplecoptera, close to Hadentomum of North America. The latter form existed in Upper Carboniferous times.

Regarding miospore content, an attempt has been made to illustrate the proportion of samples yielding three degrees of miospore abundancy and preservation. This may be seen below in Table 2. For example, in explanation of this table, 29 samples of the total 105 samples (i.e. 28 per cent) contained well-preserved miospore assemblages, in 12 of these samples the yield was high, whilst in the remaining 17 only a fair yield was obtained. Also, where 21 (20 per cent) samples showed abundant miospore content, 12 of these were in a good state of preservation and 9 only fair. 55 per cent of the samples were too poor or unproductive to warrant further study.

TABLE 2 - MIOSPORE YIELD AND PRESERVATION ENCOUNTERED IN ALL SAMPLES IN TERMS OF NUMBERS OF SAMPLES

		YIELD			NO. OF SAMPLES	% OF TOTAL
		POOR	FAIR	ABUNDANT		
Preservation	Poor	57	-	-	57	55%
	Fair	-	10	9	19	17%
	Good	-	17	12	29	28%
	No. of Samples	57	27	21	105	100%
	% of Total	55%	25%	20%	100%	

The distribution of the significant samples within their local stratigraphic successions may be seen in figure 1. Observation of this figure will show that:-

a) In the Dwyka Series miospores are not abundant or well-preserved in the earliest glacial phase. However, (except in the coarse tillitic fraction) the miospore content increases, diversifies and is in an excellent state of preservation within the succeeding two inter-glacial phases.

b) Lower Wankie Sandstone miospores are present but are less well preserved than the former, as may be expected in sub-aqueous well-transported sediments. Miospore genera do not exhibit any marked change in composition or relative abundance, thus indicating a continuation of the Dwyka flora.

c) <u>Black Shales and Coals</u> Samples show very fragmentary and poor miospores within the lowest 100 ft. Numbers are high in two areas but preservation sufficiently poor to make study of these samples difficult. Samples from 550 ft to 531 ft show a better preservation and yield. Subsequent study will enlarge upon the inferences gained regarding the depositional environment.

d) <u>Upper Wankie Sandstones</u> The sample taken from a grey mudstone horizon yielded a number of miospores with fair preservation. Miospore genera would appear to be in a transitional phase, with fair preservation and abundancy.

e) <u>Lower and Middle Madumabisa Mudstones</u> Samples within these horizons varied from poor to good in yield and preservation. These fluctuations are believed to vary due to the minor lithological facies changes and probably localised ecological conditions. A wide variety of miospore genera from the Mid-Madumabisa Mudstones yield a further zonal assemblage significantly different in per cent abundance of taxa from the Lower Madumabisa Mudstonee, with small variations within the 450 ft of sediments.

5.2 MICROFLORAL CONTENT

The basic characteristics of the main productive horizons throughout the Matabola Flats borehole core are summarised as follows (see figures 2, 3 and 4). It is relevant to note at this point that, as outlined under Methods of Analysis (3.3), counting has been consistent throughout, thereby giving an overall standardised picture of the major miospore components (both supra-generic and at species level). Hart (MS), in samples where the abundance of Disacciatrileti overwhelms and masks the other miospore components, gives an initial general count of 100, followed by a second count of 100 ignoring the Disacciatrileti specimens. In this way, the occurrence of the remaining minority forms are magnified and illustrated. (N.B. The counting method regarding Disaccites in this thesis involves separate counts of each infra-turma (Striatiti, Disacciatrileti and Disaccitrileti). The sum of these is termed "Total Disaccites" whilst Striatiti remains a percentage within this amount.))

For the present purposes, a "second degree" count is not considered advantageous. The highest total Disaccites percentage was 84 per cent with reasonably representative counts being totalled for the minority groups. An overall pattern of trends in the major taxa is therefore illustrated. At a later stage in basin analysis, the "second degree" count will be implemented.

Another point to note is that of "absolute absence". In samples taken from a single borehole core, the vertical range of a species depends on its occurrence in the samples; where a certain species is not actually seen during scanning, the tendency in this thesis is to regard it as absent. In basin analysis, samples taken from other sites at correlateable horizons may prove the existence of this particular species, thereby extending its range. This may be due to facies or ecological factors. For this reason the ranges of spores as shown in figures 3 and 4 must not be taken as absolute, but merely as those encountered in the Matabola Flats.

Figure 4 represents a summary of the information shown in figures 2 and 3. Four tentative zones are shown, which future palynological work on the Mid-Zambezi Basin will improve or modify.

The purpose in drawing figure 4 at this point in the research on Rhodesian miospores is:-

a) To compile a summary of the content of the Matabola Fla*s borehole core for future reference, i.e. a standard on which to base further comparisons, and
b) To attempt to correlate this both in detail and broad zonal comparison with that in other African Karroo Basins and abroad in Gondwanaland.

The microfloral content of the productive zones (encountered in the individual rock units) is as follows:-

(i) Dwyka Series - K^o

Quantitative Analysis:

SPORITES: 55-90 per cent; TOTAL DISACCITES: 1-5 per cent; STRIATITI: 0,5-3 per cent; MONOSACCITES: 20 per cent; PLICATES: 6-10 per cent; MONOLETES: - ALETES: 4 per cent.

Qualitative Analysis:

(1) Abundant (> 5 per cent):

Punctatisporites
P. gretensis
P. gretensis forma minor
Calamospora
C. plicata
Apiculatisporis
A. levis
Granulatisporites
G. tentula
Neoraistrickia
N. sp.
Cycadopites
C. cymbatus
Plicatipollenites
P. indicus
Virkkipollenites
V. obscurus
V. mehtae
V. densus
V. radialis
Elilasaccites
E. elilaensis

(ii) Rare (< 5 per cent):

Deltoidospora
- D. directa

Reticulatisporites
- R. compactus

Verrucosisporites
- V. sp. cf. V. pseudoreticulatus
- V. naumovai
- V. sp. cf. V. parmatus
- V. sp. A.
- V. sp. B.

Retusotriletes
- R. diversiformis

Zinjispora
- Z. zonalis
- Z. bullata

Alisporites
- A. gracilis
- A. tenuicorpus

Sulcatisporites
- S. ovatus

Protohaploxypinus
- P. amplus
- P. limpidus
- P. sp. A.

Illinites
- I. unicus

Limitisporites
- L. monstruousus

Potonieisporites
- P. novicus
- P. thomasi
- P. hennellyi

<u>Vestigisporites</u>

<u>V. sp.</u>

<u>Tetraporina</u>

<u>T. sp.</u>

<u>Pilaspora</u>

<u>P. plurigens</u>

<u>Granulatasporites</u>

<u>G. sp.</u>

<u>Quadrisporites</u>

<u>Q. sp. cf. horridus</u>

<u>Cycadopites</u>

<u>C. nevesi</u>

Within the three phases of glaciation woody xylem elements and small fragments of clear leaf cuticle are present in varying amounts, whilst <u>Botryococcus</u> is found in abundant quantities. Miospore preservation and yield are somewhat poor in the oldest and first inter-glacial phase, although good miospore specimens (and wood and cuticle) are present from 1 130 ft upwards. The second inter-glacial phase exhibits a clear continuation of the early miospore genera, with diversification becoming more apparent amongst genera within the Monosaccites and Disaccites. The inter-glacial sediments of the third and youngest glacial phase continues to yield the same relative abundancies and genera characteristic of the earlier phase. However, an increase in the percentage abundance of the Monosaccites group is apparent.

(ii) Lower Wankie Sandstone - K^1

Owing to the poorer condition of the organic residue in the productive horizons, true visual percentage counts were difficult to obtain. However, the qualitative analysis illustrates the continuation of older genera with minor changes. Only those genera that were sufficiently clear to recognise have been listed.

Qualitative Analysis:

(i) Abundant (> 5 per cent):

Punctatisporites
P. gretensis
P. gretensis forma minor
Calamospora
C. plicata
Granulatisporites
G. tentula
Plicatipollenites
P. indicus
Virkkipollenites
V. obscurus
V. mehtae
V. densus
Potonieisporites
P. novicus
P. thomasi
P. hennellyi
Alisporites
A. gracilis
Sulcatisporites
S. ovatus

(ii) Rare (< 5 per cent):

<u>Deltoidospora</u>

<u>D. directa</u>

<u>Verrucosisporites</u>

<u>V. naumovai</u>

<u>V. sp. cf. pseudoreticulatis</u>

<u>Neoraistrickia</u>

<u>N. sp.</u>

<u>Zinjisporа</u>

<u>Z. zonalis</u>

<u>Z. bullata</u>

<u>Cycadopites</u>

<u>C. cymbatus</u>

<u>Protohaploxypinus</u>

<u>P. amplus</u>

<u>P. limpidus</u>

<u>Limitisporites</u>

<u>L. monstruosus</u>

Humic detritus is very evident and difficult to eradicate. Thus the miospores, although in a fair state of preservation and abundance are masked or partially hidden. The most obvious and abundant genera are listed above. Apiculate Sporites, and in particular the genus <u>Granulatisporites</u>, is abundant, with increasing evidence of Disaccites. <u>Potonieisporites</u> and <u>Limitisporites</u> seem to be relatively more important. <u>Monosaccites</u> still constitutes a comparatively large proportion of the assemblage.

(iii) Black Coals and Shales - K^{2-3}

The productive horizons may be divided into three minor groups, only the uppermost one of which was suitable for true percentage counting of the major taxa. The remaining two groups are valuable in assessing the miospore generic content only, i.e. qualitative analysis.

1. 646 ft - 636 ft:-

The preservation of the microfloral assemblage is very poor to fair, although a fair yield is encountered. Miospores are (in general) very eroded, fragmented and compressed. Major taxa seem to follow the earlier pattern of high abundance of Sporites and considerably smaller proportion of Disaccites. Striatiti genera form constant members of the assemblages. Monoletes and Monocolpates (Marsupipollenites) are beginning to appear in rare cases, whilst the Monosaccites are now relatively reduced in number. Rare elements of the Zonati are seen.

Quantitative Analysis:

(i) Abundant (> 5 per cent):

- Punctatisporites
  - P. gretensis
  - P. gretensis forma minor
- Apiculatisporis
  - A. levis
  - A. filiformis
- Granulatisporites
  - G. tentula
- Protohaploxypinus
  - P. amplus
  - P. limpidus
- Sulcatisporites
  - S. ovatus

(ii) Rare (< 5 per cent):

- Deltoidospora
  - D. directa
- Apiculatisporis
  - A. filiformis
  - A. cornutus
- Microbaculatispora
  - M. micronodosus
- Verrucosisporites
  - V. pseudoreticulatis
  - V. naumovai
  - V. sp. A.
- Acanthotriletes
  - A. tereteangulatis forma minor
- Neoraistria
  - N. ramosa

<u>Zinjispora</u>

<u>Z. zonalis</u>

<u>Z. bullata</u>

<u>Tetraporina</u>

<u>T. sp.</u>

<u>Pilaspora</u>

<u>P. calculus</u>

<u>Marsupipollenites</u>

<u>M. triradiates forma triradiatus</u>

<u>Plicatipollenites</u>

<u>P. indicus</u>

<u>Virkkipollenites</u>

<u>V. obscurus</u>

<u>Parasaccites</u>

<u>P. sp.</u>

<u>Potonieisporites</u>

<u>P. novicus</u>

<u>P. hennellyi</u>

<u>P. thomasi</u>

<u>Caheniasaccites</u>

<u>C. sp.</u>

<u>Striatopodocarpites</u>

<u>S. cf. S. fusus</u>

<u>Platysaccus</u>

<u>P. leschiki</u>

<u>P. radialis</u>

<u>Alisporites</u>

<u>A. cf. plicatus</u>

<u>A. gracilis</u>

<u>Limitisporites</u>

<u>L. monstruosus</u>

2. - 586 ft - 550 ft:-

Preservation is again fair to poor, and the humic fraction is such that clear distinction of species and quantitative analysis are difficult. Major genera (and species) and their apparent relative abundancies are similar to those seen in the lower group, with the exception of the rare introduction of Florinites eremus, two new species of Sulcatisporites (S. splendens and S. potoniei) and four new species of Protohaploxypinus (P. diagonalis, P. micros, P. sp. B., and P. sp. cf. P. goraiensis).

3. - 544 ft - 537 ft:-

The uppermost 10 feet of the Black Coals and Shales sequences yields abundant and predominantly well-preserved miospores. Their condition deteriorates towards the base of this minor group, where humic detritus also becomes prominent.

Quantitative Analysis: (> 5 per cent):

SPORITES: 35-65 per cent; TOTAL DISACCITES: 18-23 per cent; STRIATITI: 5-10 per cent; MONOSACCITI: 4-6 per cent; PLICATES: 2-8 per cent; MONOLETES: 1-8 per cent; ALETES: 18-35 per cent.

Qualitative Analysis:

(i) Abundant (> 5 per cent):

<u>Apiculatisporis</u>

<u>A. levis</u>

<u>A. cornutus</u>

<u>Acanthotriletes</u>

<u>A. tereteangulatus</u>

<u>A. tereteangulatus forma minor</u>

<u>Neoraistrickia</u>

<u>N. ramosa</u>

<u>Lophotriletes</u>

<u>L. sp. cf. L. rectus</u>

<u>Laevigatosporites</u>

<u>L. colliensis</u>

<u>L. sp.</u>

<u>Pilaspora</u>

<u>P. calculus</u>

<u>Verrucosphaera</u>

<u>V. colliensis Var. 1.</u>

<u>V. colliensis Var. 2.</u>

<u>Circulisporites</u>

<u>C. magnus</u>

<u>Marsupipollenites</u>

<u>M. triradiatus forma triradiatus</u>

<u>Protohaploxypinus</u>

<u>P. diagonalis</u>

<u>P. amplus</u>

<u>P. limpidus</u>

<u>P. sp. cf. P. goraiensis</u>

<u>Striatopodocarpites</u>

<u>S. sp. cf. S. fusus</u>

Platysaccus

P. lesobiki

Alisporites

A. sp. cf. A. plicatus

A. gracilis

Sulcatisporites

S. ovatus

S. splendens

S. potoniei

(ii) Rare (< 5 per cent):

Punctatisporites

P. gretensis

P. gretensis forma minor

Retusotriletes

R. diversiformis

Deltoidospora

D. directa

D. lukugaensis

Apiculatisporis

A. filiformis

Baculatisporites

B. sp. cf. B. bharadwaji

Microbaculatispora

M. micronodosus

Verrucosisporites

V. naumovai

V. sp. A.

Punctatosporites

P. granulatus

Spinosporites

S. sp.

Thymospora

T. thiesseni

T. pseudothiesseni

Cirratriradites

C. africanensis

Densosporites

D. sp.

Gondisporites

G. novus

Marsupipollenites

M. triradiatus forma striatus

M. sp.

Cycadopites

C. cymbatus

Parasaccites

P. sp.

Striomonosaccites

S. sp.

Densipollenites

D. indicus

Florinites

F. eremus

Chaenissaccites

C. sp.

Protohaploxypinus

P. sp. B.

Striatopodocarpites

S. octostriatus

S. rarus

S. communis

<u>Hamiapollenites</u>

<u>H. karrooensis</u>

<u>Platysaccus</u>

<u>P. radialis</u>

<u>Vesicaspora</u>

<u>V. sp. A.</u>

<u>Limitispora</u>

<u>L. monstruosus</u>

Of particular note at this stratigraphic level is the abundance of Aletes (inaperturate organic forms which may well be termed non-spinose acritarchs). Segroves (pers. comm.) regards their occurrence as not essentially indicative of a marine depositional environment as they occur in equal abundance in Australian marine and non-marine sediments. Spinose acritarchs are more in evidence in marine environments. However, Bond reports an unusually high saline content in underground water taken in the vic--ty of this stratigraphic horizon.

The major miospore taxa show a fairly marked increase in the number of genera and species. Plicates (Monocolpates) and Monoletes are well established, 4-8 per cent in each case, and Monosaccites maintain their minor importance with the establishment of <u>Florinites</u> and <u>Densipollenites</u>. Rare miospores of the Monosaccites genera from K^{o}-K^{1} assemblages are still encountered (<u>Parasaccites</u>).

Two genera within the taxa Zonotriletes occur only in this horizon, (2-4 per cent) which will, with further study, possibly be of some diagnostic value (e.g. Densosporites sp. and Gondisporites novus). Disaccites and Striatiti continue diversifying and increasing in relative abundance, and the advent of new species of Protohaploxypinus, Hamiapollenites and Striatopodocarpites are of zonal interest.

(iv) Upper Wankie Sandstone - K^4

Quantitative Analysis:

SPORITES: 35-45 per cent; TOTAL DISACCITES: ±35 per cent; STRIATITI: 8-15 per cent; MONOSACCITI: 5 per cent; PLICATES: 5-7 per cent; MONOLETES: 4 per cent; ALETES: 8-14 per cent.

Qualitative Analysis:

The genera and species content is similar to that listed under the Black Coals and Shales, part (3) Upper beds (544'-537'), except for an increase in the occurrence of Cirratriradites, Vittatina and Marsupipollenites. Due to the somewhat dirty nature of the slides, a reliable quantitative and qualitative analysis was not possible. However, the miospores present showed a fair degree of preservation and abundance and it is considered feasible that a more specialised treatment of this sample may reveal far more detail. From the scanning of the miospore content, no new and undescribed material was seen. It is thought that these sediments were laid down relatively quickly after the Black Coals and Shales, as the microfloral assemblage is more like that of K^{2-3} than the overlying IK^5 Madumabisa Shales.

(v) Lower Madumabisa Mudstone - IK^5

I. Lower beds, (400 ft - 420 ft):-

Quantitative Analysis:

SPORITES: 27-35 per cent; TOTAL DISACCITES: 50-58 per cent; STRIATITI: 25-30 per cent; MONOSACCITI: 3-5 per cent; PLICATES: 3-12 per cent; MONOLETES: 8-18 per cent; ALETES: 6-7 per cent.

Qualitative Analysis:

Abundant (> 5 per cent):

Apiculatisporis
- A. levis
- A. filiformis
- A. cornutus

Microbaculatispora
- M. micronodosus

Acanthotriletes
- A. tereteangulatus
- A. tereteangulatus forma minor

Laevigatosporites
- L. colliensis

Thymospora
- T. thiesseni
- T. pseudothiesseni

Cirratriradites
- C. africanensis

Gondisporites
- G. sp. cf. G. vrystaatensis

Zinjisporа
- Z. ecconsis

Marsupipollenites
- M. triradiatus forma triradiatus
- M. triradiatus forma striatus

Protohaploxypinus
- P. diagonalis
- P. amplus
- P. limpidus
- P. sp. cf. P. goraiensis

Striatopodocarpites
- S. octostriatus
- S. sp. cf. fusus

Platysaccus
- P. leschiki

Sulcatisporites
- S. ovatus
- S. splendens
- S. potoniei

Rare (< 5 per cent):

Retusotriletes

R. diversiformis

Deltoidospora

D. directa

D. lukugaensis

Apiculatisporis

A. minutus

Granulatisporites

G. tentula

Verrucosisporites

V. naumovai

Reinschospora

R. sp.

Punctatosporites

P. granulatus

Spinosporites

S. sp.

Pilaspora

P. calculus

Verrucosphaera

V. colliensis Var. 1

V. colliensis Var. 2.

Circulisporites

C. magnus

Marsupipollenites

M. sp.

Striomonosaccites

S. sp.

Florinites

F. eremus

<u>Protohaploxypinus</u>
- <u>P. globus</u>
- <u>P. microa</u>

<u>Striatopodocarpites</u>
- <u>S. cancellatus</u>
- <u>S. rarus</u>
- <u>S. communis</u>
- <u>S. sp. A.</u>

<u>Striatoabietites</u>
- <u>S. multistriatus</u>

<u>Lueckisporites</u>
- <u>L. nyakapendensis</u>

<u>Hamiapollenites</u>
- <u>H. karrooensis</u>

<u>Vittatina</u>
- <u>V. africana</u>
- <u>V. minima</u>

<u>Platysaccus</u>
- <u>P. radialis</u>

<u>Alisporites</u>
- <u>A. cf. plicatus</u>
- <u>A. gracilis</u>

<u>Vesicaspora</u>
- <u>V. sp. A.</u>
- <u>V. sp. B.</u>

<u>Jugasporites</u>
- <u>J. sp.</u>

<u>Limitisporites</u>
- <u>L. monstruosus</u>

Of particular note in these stratigraphic horizons is the large increase in Disaccites and Striatiti. Sporites represent about a quarter, and Disaccites just more than half of the total assemblage. Striatiti now comprise half of the total Disaccites - a noticeable increase in relative proportion from Upper K^{2-3} percentages.

Diversification of the Striatiti genera is once more apparent, illustrated by the introduction of several new species of the ever-abundant Protohaploxypinus, (P. globus and P. micros) and new species of Striatopodocarpites (S. cancellatus and S. sp. A.). Striatoabietites, Vittatina and Hamiapollenites appear in minor quantities, and Lueckisporites in rare instances.

In the Disacciatrileti taxon Sulcatisporites (i.e. S. ovatus, S. potoniei and S. splendens) remains most abundant and conspicuous.

Monocolpates and Monoletes increase slightly in abundance, and are seemingly inversely proportionate to one another. Alete genera continue but represent only 6-7 per cent of the assemblage.

Zonotriletes account for 1-5 per cent of the general content, and include a number of the Cavati/Cingulati genera similar to those found in older sediments with the introduction of the Zonati form Cirratriradites. Very rare specimens of Reinschospora occur.

2. Upper beds, (240 ft - 335 ft):-

Quantitative Analysis:

SPORITES: 15-25 per cent; TOTAL DISACCITES: 61 per cent; STRIATITI: 30-40 per cent; MONOSACCITES: 6-8 per cent; PLICATES: 11-14 per cent; MONOLETES: 3-5 per cent; ALETES: 2 per cent.

These sequences are quantitatively and qualitatively very similar to the lower beds within this lithozone. Yield and preservation within the productive horizons are good. The minor differences noted between the beds are basically quantitative, with a slight increase in percentage abundance of Disaccites and Striatiti. Marsupipollenites (Monocolpates) exists in greater abundance than previously (11-14 per cent), and an increase in Cirratriradites (Zonotriletes) is evident.

(vi) Mid-Madumabisa Mudstone - MK^5

Quantitative Analysis:

SPORITES: 15-20 per cent; TOTAL DISACCITES: 70-85 per cent; STRIATITI: 45-60 per cent; MONOSACCITES: 2-3 per cent; PLICATES: 3-4 per cent; MONOLETES: 2-4 per cent; ALETES: 0-2 per cent.

Qualitative Analysis:

(1) Abundant (> 5 per cent):

<u>Protohaploxypinus</u>

<u>P. globus</u>

<u>P. micros</u>

<u>P. diagonalis</u>

<u>P. limpidus</u>

<u>Striatopodocarpites</u>

<u>S. octostriatus</u>

<u>S. rarus</u>

<u>S. sp. cf. fusus</u>

<u>S. communis</u>

<u>S. cancellatus</u>

<u>Vittatina</u>

<u>V. africana</u>

<u>V. minima</u>

<u>Lueckisporites</u>

<u>L. nyakapendensis</u>

<u>Guttulapollenites</u>

<u>G. hannonicus</u>

<u>Platysaccus</u>

<u>P. leschiki</u>

<u>Sulcatisporites</u>

<u>S. ovatus</u>

<u>S. splendens</u>

<u>S. potoniei</u>

<u>Alisporites</u>

<u>A. gracilis</u>

<u>A. sp. cf. plicatus</u>

(ii) Rare (<5 per cent):

<u>Retusotriletes</u>

<u>R. diversiformis</u>

<u>Deltoidospora</u>

<u>D. directa</u>

<u>D. lukugaensis</u>

<u>Apiculatisporis</u>

<u>A. minutus</u>

<u>Acanthotriletes</u>

<u>A. tereteangulatus</u>

<u>Laevigatosporites</u>

<u>L. colliensis</u>

<u>Thymospora</u>

<u>T. thiesseni</u>

<u>T. pseudothiesseni</u>

<u>Pilaspora</u>

<u>P. calculus</u>

<u>Marsupipollenites</u>

<u>M. triradiatus forma triradiatus</u>

<u>M. triradiatus forma striatus</u>

<u>Densipollenites</u>

<u>D. indicus</u>

<u>Florinites</u>

<u>F. eremus</u>

<u>Protohaploxypinus</u>

<u>P. amplus</u>

<u>P. sp. cf. P. goraiensis</u>

<u>Striatopodocarpites</u>

<u>S. cancellatus</u>

<u>S. sp. A</u>

<u>Striatoabieites</u>

<u>S. multistriatus</u>

Quantitative results show once more a marked increase in total Disaccites and Striatiti. The latter taxon now represents up to three quarters of the parent taxon (Disaccites). In qualitative terms, all the genera of the LK^5 assemblages are present to varying degrees in these sequences. The genera Vittatina and Lueckisporites are well established and abundant, and two new miospore genera appear, Taeniaesporites and Guttulapollenites. Striatopodocarpites has now increased and become an abundant member of the Striatiti elements.

5.3 STRATIGRAPHIC CORRELATION

A. Problems in Correlation:

In attempting to correlate the palynology of the Matabola Flats borehole core with assemblages in other parts of Africa and Gondwanaland certain limitations must be borne in mind:-

1. The fact that the assemblages described in this thesis are obtained from only one borehole core, albeit that several samples per horizon are used in compiling the averages depicted in the histograms.
2. Due to the involvement of only one locality, local topographic and ecological conditions must be considered as possible factors affecting the local flora, although one distinct advantage of palynology is the inclusion in the assemblages of most microfloral elements found within the vicinity of the locality of sampling.

3. The possibility of erroneous existing correlations which have to date been based on lithology, climate, and macroplants.
4. Localised tectonic movements resulting in varied topographic and depositional environments, thereby affecting the local flora. This would also result in apparent gaps in the floral succession where erosion or depositional environments not conducive to fossilisation must have periodically existed.
5. The existence of distinct latitudinal and climatic belts in Africa varying from the Congo to South Africa. This is a recognised condition which is associated with the proposed South Rotational polar wanderings of these times (Mc Elhinny and Opdyke, 1968, Frakes and Crowell, 1970, Stratten, 1970, Bond, 1970). Due to this fact, diachronous floral assemblages may have existed non-contemporaneously, but under similar climatic, geographical and ecological conditions. One may therefore expect, for example, a very cold Dwyka arctic flora to have existed in South Africa during say Upper Carboniferous times which had previously flourished in the Congo in, say, Lower Carboniferous times (when the south pole was further north). A problem such as this may well affect the relative dating of stratigraphic units which are otherwise correlated on the basis of similar plant remains. This, however, remains an interesting study for the future.

6. Another factor to be considered is that of plant evolution which would be reflected in miospore diversity. This is especially noticeable where florae differ in pre-glacial, glacial and post-glacial times. Macroplants during Devonian and early Carboniferous times include the lower vascular orders as typified in Plumstead's Lycopod Zone (1) (1967). This is followed in Southern Africa by the Pre-Glossopterid type of plants (and an early moss) which very probably represent the early evolutionary steps towards the typical and abundant Glossopteridae and lesser Gymnospermae of the Permian (Plumstead, 1966). In conjunction with this evolutionary pattern the early Pteropsida (ferns) which are relatively rare in Southern Africa during late Palaeozoic times (as opposed to the Northern Hemisphere coal age) evolve into the Pteridosperms typical of Upper Karroo times.

Likewise, amongst the microflora, a tremendous evolution of forms occurs during Late Palaeozoic times. Early in the Devonian and Lower Carboniferous the Sporites (Triletes, Zonales, etc.) are predominant, and only during Upper Carboniferous times do Pollenites (Disaccites, Monosaccites, Plicates, etc.) become significant and gradually dominant in the assemblages of Permian times.

Thus, bearing these factors in mind, the varying floral patterns seen in the Dwyka and Lower Ecca sequences in Southern Africa may be better understood. However, much more palynological research is necessary in order to clarify this very complex era. This is envisaged as a most fruitful subject for further study. From this, the sequence of floral evolution in relation to the movements and relative ages of the Dwyka ice caps and flows may also be clarified.

It is considered beyond the scope of this thesis to correlate, describe and postulate in any great detail the sequence of floral events within the Central/Southern African region during the lowest Karroo depositional phases. A straight comparison with existing florae is all that can be safely attempted at present.

B. Analysis of Rhodesian Microfloral trends

The characteristic trends of the Matabola Flats miospore assemblages is discussed under two headings:-

1) Quantitative analysis, and
2) Qualitative analysis.

1) Quantitative Analysis

The quantitative analysis is primarily concerned with the relative average percentage abundance of the microfloral taxonomic units. This method is favoured in short distance correlation (Hart, 1963) and allows the general trends of these major units to be studied locally within a basin and possibly interegionally. Generally speaking, however, Lower Gondwana trends are easily defineable and may be seen from the oldest sediments upwards in the Mid-Zambezi Basin (as seen in the Matabola Flats borehole core), i.e.

i) Decreasing Monosaccites
ii) Decreasing Triletes
iii) Increasing Disaccites and in particular Striatiti, and
iv) Decreasing ratio of Striatiti to Disaccites.

The distribution of the miospores throughout the productive horizons in the borehole core is summarised in figures 2, 3 and 4.

Figure 2 shows the distribution of the major supra-generic miospore taxa. Four major microfloral assemblages are indicated, as broadly delineated by the quantitative trends of the major taxa, and the qualitative components (i.e. genera and species).

(1) The earliest assemblage in Dwyka (K^o) and the overlying Lower Wankie Sandstone beds are characterised by a dominant Trilete element ($\pm$72 per cent) with fairly abundant Monosaccites (20 per cent), Disaccites represent

3 per cent and Striatiti are present but are relatively rare (1-5 per cent). Plicates are up to 8 per cent and Zonales comprise ±4 per cent of the assemblage.

(2) The Black Coals and Shales (K^{2-3}) assemblages can only be reliably analysed, in terms of percentage abundance, in the upper beds, and here the dominant taxon is still the Triletes (±45 per cent), with Disaccites representing 20 per cent and Striatiti 7-5 per cent - a Striate: Disaccate ratio of 3 : 1 is seen here. Monosaccates only form 5 per cent of the assemblage. Aletes are a very important constituent accounting for an average of up to 25 per cent.

(3) The Lower Madumabisa Mudstones (LK^5) exhibit an increasing dominance of Disaccites (57 per cent), and Striatiti (32 per cent) the ratio of Striatiti: Disaccites is now 2 : 1. Triletes represent 36 per cent, more or less in equal proportions to Striatiti.

(4) Middle Madumabisa Mudstones (MK^5) exhibit an overwhelming dominance of Disaccites (75 per cent) and increasing abundance of Striatiti (52 per cent); a ratio of Striatiti: Disaccites is 3 : 2. Triletes are much reduced (20 per cent).

Three transitional phases are noted. The oldest is seen in the lower horizons of the Black Shales and Coals where the Monoletes are first noted in the assemblage, and the Disaccites (a minority group) begin to diversify. The second transitional phase is seen in Upper Wankie Sandstones where the numerous Cingulati and Trilete forms begin to reduce in abundance in favour of the Disaccites and Striatiti. The third transitional phase is taken as occurring during the deposition of the Lower Mid-Madumabisa Shales when the abundant Zonati and Trilete elements of the Lower Madumabisa beds begin to wane and the Striatiti forms diversify to become a major component of the microflora.

The four microfloral assemblages are considered to be manifestations of climatic change, which from previous evidence (see Climate, 2-3) was thought to fluctuate between frigid and sub-arctic (Dwyka) to warm-temperate (Madumabisa Mudstones) (see 5.4).

2) Qualitative Analysis

Figure 3 summarises the genera and species analyses and their ranges. Examples of those genera and species found throughout the succession are: Sulcatisporites ovatus, Retusotriletes diversiformis, Apiculatisporis levis and Pilaspora calculus. These are termed "general" and of no stratigraphic use.

Others may be confined to the microfloral assemblage "zone" such as Zinjispora zonalis, Z. bullata and Reticulatisporites compactus (Dwyka); Densosporites sp., Gondisporites novus, and Neoraistrickia ramosa (Black Shales and Coals); Cirratriradites africanensis and Gondisporites sp. cf. G. vrystaatensis (Lower Madumabisa Shales); and Striatopodocarpites cancellatus, Taeniaesporites noviaulensis, and Guttulapollenites hannonicus (Upper Madumabisa Shales). These forms are of stratigraphic importance. Other species begin in one floral assemblage and transgress to one or two more e.g. Vittatina africana, Protohaploxypinus diagonalis, and Hamiapollenites karrooensis (Black Shales and Coals to Madumabisa Mudstones).

3) Summary of Microfloral Assemblages

Summarising figures 2 and 3, figure 4 shows the tentative Rhodesian miospore zones in diagrammatic form, with the mean percentage abundance of the major miospore groups (taken as an arithmetic mean from sample analyses within the relative horizons), and representative genera and species with apparently finite stratigraphic ranges. The miospore assemblages are thus summarised (only significant components are included):-

<u>Dwyka and Lower Wankie Sandstone</u>: Of the major taxa, Triletes (±70 per cent) dominate the assemblage with Monosaccites relatively important (±20 per cent) Disaccites (3.5 per cent) and Striatiti (1.5 per cent) are present but rare. Abundant species include <u>Punctatisporites gretensis</u>, <u>Apiculatisporis levis</u>, <u>Granulatisporites tentula</u>, <u>Cycadopites cymbatus</u>, <u>Plicatipollenites indicus</u>, <u>Virkkipollenites obscurus</u> and <u>V. mehtae</u>. Significant minor components are <u>Zinjispora zonalis</u>, <u>Z. bullata</u>, <u>Reticulatisporites compactus</u>, <u>Verrucosisporites naumovai</u> and <u>V. parmatus</u>, <u>Protohaploxypinus amplus</u>, <u>P. limpidus</u>, <u>Potonieisporites novicus</u>, <u>P. thomasi</u> and <u>P. hennellyi</u>, and <u>Quadrisporites cf. horridus</u>.

<u>Black Shales and Coals</u>: Triletes are still dominant (45 per cent) but Aletes (±25 per cent) and Disaccites (±20 per cent) are now important constituents. Monosaccites are much reduced (5 per cent). Monoletes represent 4 per cent. Abundant species include <u>Apiculatisporis levis</u>, <u>Acanthotriletes tereteangulatus</u>, <u>Neoraistrickia ramosa</u>, <u>Laevigatosporites colliensis</u>, <u>Marsupipollenites triradiatus forma triradiatus</u>, <u>Protohaploxypinus limpidus</u>, <u>P. diagonalis</u>,

Striatopodocarpites fusus, Pilaspora calculus, Verrucosphaera colliensis, Circulisporites magnus. Significant minor components are Microbaculatispora micronodosus, Thymospora thiesseni, T. pseudothiesseni, Cirratriradites africanensis, Striomonosaccites sp., Densipollenites indicus, Florinites eremus, Striatopodocarpites octostriatus, S. rarus, Vesicaspora sp. A., Sulcatisporites splendens, S. potoniei.

Lower Madumabisa Mudstones are typified by dominance of Disaccites (±57 per cent), followed by similar proportions of Striatiti (32 per cent) to Triletes (36 per cent). Monoletes are relatively important (±13 per cent). Abundant species include: Apiculatisporis cornutus, Thymospora thiesseni, T. pseudothiesseni, Cirratriradites africanensis, Gondisporites cf. vrystaatensis, Marsupipollenites triradiatus forma striatus, Protohaploxypinus diagonalis, P. limpidus, P. amplus. Significant minor components are:- Striatoabietites multistriatus, Lueckisporites nyakapendensis, Hamiapollenites karrooensis, Vittatina africana, V. minima, Protohaploxypinus globus, P. micros, Striatopodocarpites cancellatus, Sulcatisporites splendens, S. potoniei.

Mid-Madumabisa Mudstones: Disaccites are dominant in the assemblage (±75 per cent) with Striatiti comprising 52 per cent of this major taxon. Triletes are a minor component of the assemblage (20 per cent). Significant species include

Protohaploxypinus globus, P. micros, P. diagonalis, P. limpidus, Striatopodocarpites cancellatus, S. octostriatus, S. rarus, Vittatina africana, Lueckisporites nyakapendensis, and Guttulapollenites hannonicus.

C. Stratigraphic Comparison

The microfloral assemblages typical of the Rhodesian stratigraphic units are discussed in relation to other zones and stratigraphic units (i) in Africa, and (ii) in Gondwanaland. (See figures 6 and 7.)

Dwyka and Lower Wankie Sandstone:

(i) Africa:

In terms of percentage abundance of the major miospore taxa, Zone 1 as seen in the Matabola Flats core is comparable to Hart's Cavati Zone in South Africa. Both zones possess dominant Trilete miospores with abundant (±20 per cent) Monosaccites. Striatiti are present but are rare. (See figure 7.)

Fig. 5 – DIAGRAM SHOWING THAT RHODESIAN ZONES BASED ON PALYNOLOGY ARE CLOSELY COMPARABLE WITH BOND'S (1952, 1955 AND 1967) LITHOLOGICAL AND PALAEONTOLOGICAL ZONES

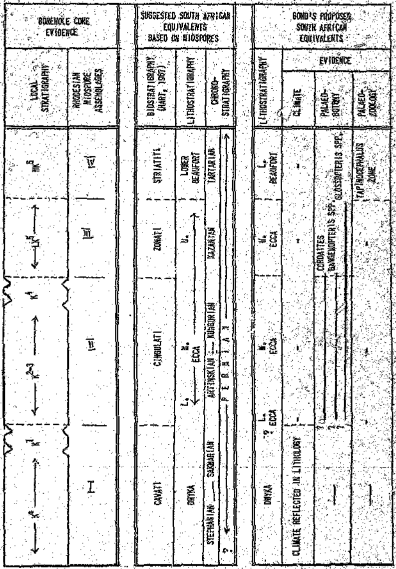


Fig. 6 - INTERNATIONAL COMPARISON OF PALYNOLOGICAL FLORIZONES.

SOUTH AFRICA	RHODESIA		TANZANIA	MALAGASSY		CONGO			AUSTRALIA					INDIA	ANTARCTICA
	MID-ZAMBEZI VALLEY		MCHUCHUMA-COALFIELD ETC.	SAKOA-SAKAMENA BASIN		a.	b.	c.	WESTERN AUSTRALIA				EASTERN AUSTRALIA		BEAVER LAKE, PRINCE CHARLES MTS
HART 1967 a, b.	ZONES according to this thesis		HART 1960, 1965a, 1965b.	RAKOTOARIVELO 1970		PIERART 1959	HOEG AND BOSE 1960 KAR AND BOSE 1967	BOSE AND MAHESHWARI 1965		BALME 1964	SEGROVES 1970 (ZONES)		EVANS 1961	BHARADWAJ et al.	BALME AND PLAYFORD 1967
STRIATITI	m^5	ZONE IV							STRIATITES MICROFLORA	DULHUNTYISPORA COMPLEX	5	DULHUNTYISPORA ASSEMBLAGE	STAGE 5	RANIGANJ	UPPER AMERY FORMATION
ZONATI	Lt^5	ZONE III							STRIATITES MICROFLORA	DULHUNTYISPORA COMPLEX	5	DULHUNTYISPORA ASSEMBLAGE	STAGE 5	(IRONSTONE OR BARREN MEASURES)	?
CINGULATI	x^4, x^{2-3}	ZONE II	$K2e_2$	II	COUCHES À HOUILLE	ASSISE À COUCHES DE HOUILLE	ASSISE À COUCHES DE HOUILLE; ASSISE DES SCHISTES NOIRS DE LUKUGA	COAL MEASURES	STRIATITES MICROFLORA	VITTATINA COMPLEX	4	HAPLOCYSTIA ASSEMB.	STAGE 4	BARAKAR	
	x^1	ZONE II	$K2e_1$	I	COUCHES À HOUILLE	ASSISE À COUCHES DE HOUILLE	ASSISE DES SCHISTES NOIRS DE LUKUGA	COAL MEASURES	STRIATITES MICROFLORA	VITTATINA COMPLEX	3	ACANTHOTRILETES ASSEMB.	STAGE 3	KARHARBARI	
CAVATI	x^0	ZONE I	$K2^d$, $K2^c$				ASSISE DES SCHISTES NOIRS DE WALIKALE		STRIATITES MICROFLORA	NUSKOI-SPORITES COMPLEX	2	QUADRISPORITES ASSEMB.	STAGE 2	TALCHIR	
							ASSISE GLACIAIRES ET PERI-GLACIAIRES		STRIATITES MICROFLORA	NUSKOI-SPORITES COMPLEX	1	MICROBACULISPORA ASSEMB.	STAGE 1		

Fig. 7 - COMPARISON OF HART'S SOUTH AFRICAN FLORIZONES (S.A.) WITH THE MATABOLA FLATS (M.F.) MICROFLORAL ASSEMBLAGES

S.A.	M.F.	S.A.	M.F.	S.A.	% M.F.	S.A.	% M.F.	S.A.	% M.F.	S.A.	% M.F.	S.A.	% M.F.	S.A.	% M.F.	S.A.	% M.F.	SOUTH AFRICAN DIAGNOSTIC GENERA • GENERA COMMON TO S.A. & RHODESIA.	MATABOLA FLATS WITH ADDITIONAL COMMENTS
STRIATITI LOWER BEAUFORT	NK^5	1:2	1:5	30	15-20	64	75	58	±52 (45-60)	1	2.5 (2-3)	1	±3.5 (3-4)	3.7	±3 (2-4)	1.3	±1 (0-2)	• VITTATINA } ABUNDANT • LUECKISPORITES) DULHUNTYISPORA } • THYMASPORA } PRESENT SCHOPFIPOLLENITES) LHORDASPORA } RARE • TAENIAESPORITES) • VITTATINA AFRICANA • GUTTULAPOLLENITES HANNONICUS STRIATOPODOCARPITES PHALERATUS • PLATYSACCUS FUCOUS ANAPICULATISPORITES DENTATUS	N.B. INTRODUCTION OF:- TAENIAESPORITES - RARE GUTTULAPOLLENITES - RARE TO COMMON
ZONATI UPPER ECCA	LK^5	1:1	1:4	58	(15-25) (±25) (27-35)	62	61 ±50 (50-58)	36	(30-40) ±33 (25-30)	2.6	(6-3) ±5 (3-5)	2.5	(11-14) ±8 (3-12)	1.3	(3-5) ±10 (8-10)	0.0	2 ±4.5 (5-7)	• VITTATINA } ABUNDANT • LUECKISPORITES) DULHUNTYISPORA } • THYMASPORA } SCHOPFIPOLLENITES) PRESENT ? KARROOIA } • CIRRATRIRADITES } • STRIATOABIETITES } • APICULATISPORIS CORNUTUS • VITTATINA AFRICANA	N.B. INTRODUCTION OF:- VITTATINA LUECKISPORITES RHEINSCHOSPORA CIRRATRIRADITES INCREASE IN: MARSUPIPOLLENITES STRIATOABIETITES N.B. ALETES CONTINUE IN LESS ABUNDANCE
CINGULATI LOWER TO MIDDLE ECCA	(a) K^{2-3} (b) K^1	2:1	1:1	69	35-65 (~50)	52	(18-23) ~20	19	±13 (5-20)	5.5	±5 (4-6)	2.9	±5 (2-8)	1.7	±4 (3-8)	1.3	±26 (18-35)	? ZINJISPORA • LYCOSPORA • DENSOSPORITES • CYCLOBACULISPORITES • DELTOIDOSPORA • CIRRATRIRADITES • GRANDISPORA REINSCHOSPORA • FLORINITES LYCOPODIUMSPORITES ? VITTATINA • GRANULATISPORITES • MARSUPIPOLLENITES • STRIATOPODOCARPITES • THYMOSPORA (=TUBERCULATOSPORITES) • PILASPORA	a) ABUNDANT ALETES: CIRCULISPORITES (=CHOMOTRILETES) PILASPORA CF. VERENCOSPHAERA SCHIZOSPORIS INTRODUCTION OF:- DENSIPOLLENITES TUBERCULATOSPORITES (?=THYMOSPORA) PLATYSACCUS STRIATOABIETITES b) INTRODUCTION OF:- FLORINITES LAEVIGATOSPORITES STRIATOPODOCARPITES SPP. PROTOHAPLOXYPINUS SPP.
CAVATI DWYKA	K^1	3:1	3:1	71	55-80 (~70)	15	(5-15)	3.0	(0.5-3) ~2	19.2	(5-35) ~20	0.8	(6-10) 8	1.7	-	0.5	(0-8) ~4	• GRANDISPORA • CONVERRUCOSISPORITES • APICULATISPORITES • GRANULATISPORITES RHEINSCHOSPORA MARSUPIPOLLENITES • GONDISPORA FLORINITES • LYCOSPORA • DELTOIDOSPORA • ZINJISPORA • VIRKKIPOLLENITES RHABDOSPORITES PARKAPITES • CYCADOPITES • PILASPORA	PRESENT: PUNCTATISPORITES CALAMOSPORA QUADRISPORITES SULCATISPORITES (=VESICASPORA) ALISPORITES PROTOHAPLOXYPINUS POTONIEISPORITES
FLORIZONES LITHOSTRATIGRAPHY	LITHOSTRATIGRAPHY	RATIO OF SPORITES: POLLENITES		TOTAL SPORITES		TOTAL DISACCITES		STRIATITI		MONOSACCITES		PLICATES (MONOCOLPATES)		MONOLETES		ALETES			

N.B: THE QUANTITATIVE COMPARISON IS BASED ON HART (1967) TABLE 3, (VALUES OF ARITHMETIC MEANS) AND THE AUTHOR'S PERCENTAGES OF TOTAL BIOSPORE POPULATION.

The comparison based on genera and species content is not as close. Hart (1967) selects sixteen representative genera, to illustrate the Cavati Zone of which eleven are represented in the Matabola Flats Zone 1 sediments. Three of these are very rare and have not been included in the present microfloral lists (5.2): viz. Grandispora, Gondispora and Lycospora. Of particular interest is the fact that three elements exist in the South African Cavati Zone: (Hart, 1963); (i) the Pre-Permian forms:- Grandispora, Lycospora, Endosporites, Reinechospora and Reticulatisporites. Of these only Reticulatisporites (R. compactus) has been described and is very rare in Rhodesia. (ii) The Permian element, containing Marsupipollenites, Plicatipollenites (Cordaitina) and Striatiti genera; the latter two are present in Zone 1. (iii) Forms restricted to Lower Permian times; of the eleven forms present in the South african Cavati Zone, six occur in the Rhodesian Zone 1. viz. Zinjispora, Verrucosisporites, Vestigisporites, Apiculatisporis, Punctatisporites and Cordaitina.

Zone 1, (Rhodesia) also possesses four species characteristic of Hart's Cingulati Zone (Hard, 1969c) viz. Cordaitina balmei, Vestigisporites thomasi, Cycadopites nevesi and Reticulatisporites sp.

In terms of correlation, the South African Dwyka microfloral assemblage is regarded as somewhat heterogeneous and in need of revision, and therefore it cannot represent an absolute standard of reference. The problem of age and wrong stratigraphic bases is a related problem. The sediments from which Hart (1963) extracted his Cavati assemblage may be regarded as Lower Ecca and not Dwyka (J. Anderson, Ph.D. thesis in prep.) For the present purpose, the Rhodesian Zone 1 assemblage is regarded as possibly Upper Cavati Zone, on the basis of little Pre-Permian miospore elements, abundant Lower Permian elements and the presence of Striatiti (although rare) from the base of the productive horizons.

The Rhodesian Zone 1 would appear to be very similar to the lowest beds of the Lower Coal Measures in Tanzania (K2c) due to the common occurrence of Punctatisporites, Zinjisporа, Vesicaspora, and Cordaitina. In the Congo, (Pierart, Hoeg and Bose, 1960, Bose and Kar, 1966 et al) the generic content of the Assise de Schistes noirs de la Lukuga and Assise de Schistes noirs Walikale are both similar to the Rhodesian Zone 1 assemblage due to the presence of

Virkkipollenites, Plicatipollenites, Illlasaccites, Stroterasporites (Protohaploxypinus), Punctatisporites, Apiculatisporis, Ginkgocycadophytus (Cycadopites). On the basis of diversity of species, the Congo assemblages are far more varied and have many forms not yet encountered further south. The Assise Periglaciaires et Glaciaires is represented by a very dominant Monosaccate assemblage unlike anything encountered elsewhere in Africa so far, the Assise Schiste noirs de Walikale has an equally high proportion of Disaccites, Monosaccites and Triletes, whilst the Assise de Schistes noirs de Lukuga assemblage is predominantly Trilete. The Rhodesian Zone 1 is tentatively correlated on the basis of the above common abundant genera, and low per cent of Striatiti with the Assise des Schistes de Walikale and Assise des Schistes de Lukuga.

(ii) Gondwanaland:

No parallel assemblages have as yet been described from Madagascar; in India, the Talchir Flora (Potonie and Lele (1961) possess a very comparable Monosaccate-dominated flora (Nuskoisporites and Potonieisporites). Other genera are Leiotriletes, Punctatisporites, Granulatisporites, Lophotriletes, Apiculatisporis, Quadrisporites, Lunatisporites (Protohaploxypinus), Pityosporites and Ginkgocycadophytus (Cycadopites).

The presence of Quadrisporites in minor quantities, abundant Botryococcus and Microbaculispora (M. tentula) equate this miospore assemblage to Zones Upper - 1 and 2 of Segroves, Western Australia (1970) and Stage 2 of Evans, Eastern Australia (1967). Also to Balme's (1964) lower Nuskoisporites - Complex. K^1 would appear to be equivalent to the upper part of this assemblage. These assemblages are characteristic of glacigene deposits and post-glacial shales in Australia, and are represented by the Nangetty Formation-Holmwood Shale-Fossil Cliff Formation (K^1) of the Perth Basin (Segroves, 1970) and the Lochinvar-Allandale strata of the Sydney Basin (Evans, 1967).

Correlation on the basis of biostratigraphy (i.e. microfloral assemblages and percentage abundance patterns) is evident, but the age relationship or chronostratigraphic tally is somewhat problematic. The base of the Permian in Australia is taken as being the introduction of the Glossopteris-Gangamopteris flora and striatitid disaccate pollen, (Balme, 1964; Evans, 1967). In Western Australia, Balme assigns the lowermost glacials (containing striatitid pollen) as the base of the Permian, whilst Evans, in Eastern Australia, regards the glacials as starting earlier, but still regards the occurrence of *Glossopteris-Gangamopteris* and striate pollen as the introduction of the Permian.

Plumstead, however, is of the opinion that the mixed *Glossopteris-Gangamopteris* macroflora in Southern Africa began in Upper Carboniferous times (Plumstead, 1967), and that this flora, her Zone III, was introduced prior to the end of the glaciation in Africa. This implies a fair discrepancy in age, based on the absolute time-scale.

As a point of comparison, earlier microfloral assemblages are found and defined in Australia in Evans' Stage 1 (Seaham and Kuttung Series, Sydney Basin) and the lowest part of Segroves' Zone 1 (lower part of the Nangetty Formation, Perth Basin).

In these assemblages, Disaccites are rare, no striatiti are found, and a few Monosaccites appear in the uppermost beds. A large abundance of Sporites occurs. This microfloral content may be equivalent to the early Proto-Glossopterideae and Lycopod Assemblages of Plumstead (Zone II, macrofloral), for which she gives a Middle Carboniferous age in Southern Africa.

These floral assemblages are not considered present in the Matabola Flats sediments as Striatiti Disaccites are represented from the base. Also Monosaccites are fairly abundant and diverse, and Plicates are present in significant numbers. This miospore content is thought to indicate a flora equivalent to Plumstead's early Zone III. It is relevant to note here, that palaeomagnetism has inferred a Lower to Middle Carboniferous age for the Dwyka Series in Rhodesia. In the light of microfloral evidence taken from the Matabola Flats glacigene sediments, this dating would seem to be somewhat early.

If the South African Cavati florizone (in Dwyka sediments) is of Stephanian - Sakmarian age (Hart, 1967) then the age of the Rhodesian Dwyka, based on comparable miospore assemblages may be very similar. This agrees with Bond's proposals (1952, 1966, 1967) based on climatic and lithological evidence, i.e. the occurrence of glacial tillites and conglomerates and varved sediments due to climatic conditions. (See figure 5.)

Black Coals and Shales - K^{2-3}

Lower K^{2-3}:

(i) Africa:

This portion of the Black Coals and Shales series seems equivalent to the $K2e_1$ beds in the Mohuchuma-Ketewaka stratigraphy on the grounds of quantitative and qualitative content. The introduction of Monoletes occurs at the top of both these beds together with the gradual introduction of the Plicate infra-turma group Monocolpates (Marsupipollenites) from the base. There is a comparable decrease in Sporites, a rapid increase in Disaccites (to a higher percentage in Tanzania), gradually increasing striatiti and reduction in Monosaccites.

Generic content is essentially similar, with reduction in Zinjispora, and Punctatisporites, and the introduction of Acanthotriletes (A. tereteangulatus), Laevigatosporites, Marsupipollenites, Striatopodocarpites and new species of Protohaploxypinus (= Striatopinites).

On comparison with the miospore flori-zones of South Africa, Hart places his $K2e_1$ (and therefore the Rhodesian lower K^{2-3} beds) on the border of the Cavati and Cingulati Zones. This, on South African standards, is in the Lower Ecca. Bond (pers. comm.) assigns these beds, together with K^1 (Lower Wankie Sandstone) to Lower Ecca on the grounds of Glossopteris/ Gangamopteris occurrences.

(ii) Gondwanaland:
On detailed comparison with Australian microfloral assemblages, this microflora would appear to be comparable to Balme's (1963) upper Nuskoisporites Complex, Segroves lower Acanthotriletes Assemblage (= High Cliff Sandstone, Northern Perth Basin), and Evans' (1967) lower stage 3 (= Rutherford and Farley sequences, Sydney Basin).

Upper K^{2-3}

(i) Africa:
The palynological content of this sequence is closely comparable to $K2e_2$ in the Tanzanian stratigraphy, more on the basis of generic content (qualitative) than quantitative content. In the Rhodesian material a noticeable increase (up to 35 per cent) in Alete forms tends to mar the closer tally between the Disaccites and Striatiti percentage abundances of the two regions. However, despite their reduction in abundance, both major miospore taxa continue to increase in the Matabola Flats samples, with Striatiti comprising roughly one third of the total Disaccites content. Monosaccites drop to 10 per cent or less in both regions, Monocolpates and Monoletes increase up to 8 per cent and 10 per cent and Sporites vary with samples, but are generally reduced.

Genera coincide markedly with the common abundance of Acanthotriletes (A. tereteangulatus), Laevigatosporites, Marsupipollenites, Protohaploxypinus species, Striatopodocarpites, Sulcatisporites and Platysaccus. Circulisporites (= Chomotriletes) and Verrucosphaera are amongst the diagnostic abundant Aletes. The introduction of Striatoabietites, Vittatina, Florinites, Densipollenites and Cirratriradites is apparent, but these genera are relatively rare in occurrence.

On the basis of the overall microfloral similarity to Hart's $K2e_2$ strata in Tanzania, this series is placed within the Cingulati Zone, implying a South African Lithostratigraphic equivalence of Middle Ecca. This confirms Bond's (pers. comm.) chrono-stratigraphic assignment of these beds on macrofloral and lithological (concretions) grounds.

(ii) Gondwanaland:

Australian comparisons illustrate differences due to marine incursions. However, basic quantitative and qualitative analyses of major taxa and genera are possible. K^{2-3} (upper sequences) and K^4, appear to be equivalent to Balme's <u>Vittatina</u> Complex, Segroves' Upper <u>Acanthotriletes</u> Assemblage and <u>Haplocystia</u> Assemblage (Irwin Coals - Caryngina Sequences, Perth Basin) and Evans' (1967) Upper Stage 3 and Lower Stage 4 (Greta Coal Measures, and Branxton Formation, Sydney Basin).

On the quantitative and qualitative information supplied by Rakotoarivelo (1970), the two zones of the Couches à Houille of the Sakoa-Sakamena Basin in Madagascar fit in very closely to the lower and upper K^{2-3} beds and their characteristic assemblages. The Barakar microfloral assemblages in India (Tiwari (1965)), and the Assise à Couches de Houille of the Congo (Hoeg and Bose, 1960; Pierart, 1959) and Coal Measures South of Albertville near Lake Tanganyika, Congo (Bose and Maheshwari, 1968) are all considered equivalent to the Cingulati Zone.

<u>Lower Madumabisa Shales - lK^5</u>

(i) Africa:

The comparison between the miospore content of the lower lK^5 beds in the Matabola Flats borehole core and Hart's Tanzanian microflora in $K2e_2$

indicates a continued similarity. Relative percentages tally fairly closely (Hart, 1967), as does the major generic content. The presence of Alete forms (6-7 per cent) may account for the minor variations. However, comparison of progressively younger beds within this series show the quantitative figures of Disaccites and Striatiti more in keeping with those of Hart's South African Zonati Zone. The greater decrease in Sporites and greater increase in Monocolpates is thought to be an ecological factor.

Generic content does indicate a close resemblance to the Zonati Zone, from lowermost IK^5 beds upwards. Common genera to both assemblages in significant quantities are: Vittatina, Striatoabietites, new species of Striatopodocarpites, Florinites, Densipollenites and Cirratriradites. Apiculatisporis and Marsupipollenites are found in greater abundance. Minor variations within the Matabola Flats assemblage are the rare occurrences of Hamiapollenites, Ineckisporites and Reinschospora.

Hart places the Zonati florizone in South African Upper Ecca litho-stratigraphy (Kazanian in age). Bond (pers. comm.) once again agrees with this on the basis of macrofloral evidence. Gangamopteris has now all but disappeared in the Mid-Zambezi Valley, whilst Glossopteris species continue. Plumstead's Zone IV (*Transition Zone*), with an *abundance* of Glossopteris and lack of Gangamopteris and abundance of swamp lovers (Phyllotheca and Schizoneura), is apparently equivalent, and to this she assigns an Upper Ecca, Middle to Upper Permian dating.

(ii) Gondwanaland:

The comparative Australian florizones would be the lower Dulhuntyispora Complex of Balme (1963), the lower Dulhuntyispora Assemblage of Segroves' (1970) (lower Wagina Sandstone, Perth Basin) and lower stage 5 of Evans' (Muree Formation). The main features common to all these zones is the high percentage of Disaccites and Striatiti, and Marsupipollenites. A fair number of genera are common to the Rhodesian and South African microflora, but possibly marine incursions and ecological and climatic factors would have been the cause of a break away and development of different microfloral elements.

Mid-Madumabisa Shales - MK[5]

(1) Africa

a) The microfloral content of this sub-series appears to be very closely allied to Hart's (1967) South African Striatiti Zone. The percentage relative abundance of Sporites, total Disaccites, Striatiti, Monosaccites, Monocolpates and Monoletes are all closely comparable.

Generically, Guttulapollenites and Taeniaesporites are minor but significant introductions into the Matabola Flats MK[5] assemblage, while Vittatina, Lueckisporites, Thymospora and new species of Striatopodocarpites and Platysaccus - all of which are common to the Striatiti Zone - are in more substantial evidence.

On the basis of greatest abundance of Disaccites and Striatiti and the above significant genera, this zone apparently fits the Striatiti Zone very closely. Hart (op cit.) assigns this to the Lower Beaufort in South Africa, whilst Bond (pers. comm.) proposes a Lower Beaufort correlation on the presence of Tapinocephalus Zone reptiles and other vertebrate and invertebrate macrofaunal fossils.

(ii) Gondwana:

The MK[5] assemblages, via Hart's Striatiti Zone is considered equivalent to the Raniganj Stage in India, and the Dulhuntyispora Assemblages in Australia (Wagina Sandstone, Perth Basin, and Newcastle - Tomago - Mulbring Formations, Sydney Basin). Hart (1967) suggests the inclusion here of the dominantly striatitid assemblage reported by Balme and Playford (1968) from Beaver Lake, Prince Charles Mountains, Antarctica.

The Middle Madumabisa Shales like the Lower Madumabisa Shales, are placed by Plumstead (1967) in her Zone IV, with a Middle to Upper Permian dating. The Glossopteris woodlands and equisetalians on the mudflats would seem to be even more pronounced in this zone (higher percentage of Striatiti) than the lower one, probably creating an excellent environment f - the fairly abundant reptilia and amphibia reported by Bond.

5.4 CLIMATIC IMPLICATIONS

The climatic changes as envisaged during the deposition of the Matabola Flats have been briefly discussed above (2.3). Three climatic changes are considered to have occurred which are manifested by the changes in microfloral assemblages. Certain basic factors must be borne in mind when interpreting climate from miospore content:-

1. Broad changes in microfloral assemblages may be expected to occur when the climate changes. Evolutionary changes in a microfloral assemblage are slower and not so widespread as to effect all members within the "suite".

2. Due to the different patterns in the reproductive cycle exhibited by the various plant orders, only certain reproductive elements are found widely dispersed. In the lower orders (cryptogams, and the like) the asexual method of reproduction with abundant spore production is dominant; the sexual method is dependent on water. In the higher orders (Gymnosperae, etc.) the sexual method is dominant, with wind or insect dispersal of the male gemetophyte or pollen for transport to the female gametophyte, and is therefore more highly evolved in structure.

Arising from this two factors may be used in climatic determination:

1) The dominance of a lower order plants indicates an environment with abundant water (necessary for sexual reproduction), whilst an abundance of pollens indicates a macroflora of higher or[illegible]) not dependent on water, but rather wind or insects for their dispersal.

2) Seasonal abundance of pollens, as is suspected in the coals and carbonaceous shale horizons, illustrates seasonal climatic changes of sufficient magnitude to cause the plants to evolve this system of reproduction.

In the determination of the macrofloral assemblage in the vicinity of sampling several other factors must be noted:-

1) Lower plant orders produce an abundance of spores for dispersal whilst those higher plant orders produce far less pollen, but with a more efficient structure to aid in specific dissemination to the female counterparts. This differential spore/pollen reproduction may cause the masking of the true percentage abundance of the macrofloral elements where the spore count is particularly high.

2) From inferences gained by close association, large miospore groups have been allied to broad plant orders (Bharadwaj, 1970) thereby allowing a certain modest degree of speculation or plants existing in the vicinity of the sample during deposition. These are as follows:-

Triletes (Varitriletes, Zonates laevigati Apiculati)	- vascular cryptogams
Radial monosaccates	- Gangamopterids
Striate saccates	- Glossopterids
Monocolpates	- Cycado-ginkgopsids
Alete non-saccates	- Proto-conifers.

It is of interest to note that Plumstead (1958) macerated male pollen organs from a <u>Glossopteris</u> - associated fructification and obtained small ($\pm 10\ \mu$) circular unsculptured spores. The affinity is obvious, but as yet no other such dispersed miospores have been described.

1. The oldest climate encountered in the borehole core is that in the Dwyka and Lower Wankie Sandstones. Here the abundance of Triletes and Monosaccites indicate a prevailing macroflora of lower order vascular