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PERMIAN PALYNOMORPHS FROM THE NUMBER 5 SEAM, ECCA GROUP, WITBANK/HIGHVELD COALFIELDS, SOUTH AFRICA.

by

G. A. Aitken

Bernard Price Institute for Palaeontological Research
University of the Witwatersrand, Private Bag 3, Wits 2050, South Africa.

ABSTRACT

A palynological study of the number 5 seam in the Ecca group has yielded a wide variety of miospores, with a lateral and vertical consistency in their relative abundance, diversity and composition. Striate bisaccate pollen genera predominate, particularly *Protohaploxypinus* Samoilovich *emend.* Morbey 1975, *Striatopodocarpites* Zoricheva & Sedova *ex* Sedova *emend.* Hart 1964 and *Weylandites* Bharadwaj & Srivastava 1969. On a regional scale the number 5 seam palynomorphs correlate both quantitatively and qualitatively with Biozone F of MacRae (1988) from the Waterberg and Pafuri coal-bearing basins, and Hammanskraal plant locality. Broad palaeoenvironmental inferences drawn from both the palynology and sedimentology of this seam, support a flood plain setting, comprising shallow wide open pans and peat swamps interspersed with wide water-logged mud flats. The surrounding highlands would have been forested mostly by plants adapted to wind dispersal with colonisation of the levees and margins of small ponds by spore producers. The age of the number 5 seam is tentatively suggested as Guadalupian, which in turn is equated with the Tatarian (European Standard usage); Midian to Dzhulfian (Tethys usage).

KEY WORDS: Ecca, Karoo, Palynology, Permian, Biostratigraphy.

INTRODUCTION

The coalfields falling within the study area are part of the northern Karoo Basin and are situated approximately 100km to the east of Johannesburg (Figure 1). In this area a major depositional sequence of 120m is represented. This sedimentary package contains six bituminous coal seams and the sequence is underlain by diamictite of the Dwyka Group or pre-Karoo basement rocks. Coal seams are numbered 1-6 from the base. The No 6 seam is laterally impersistent and is rarely found in the Witbank and Highveld Coalfields.

PREVIOUS PALYNOLOGICAL INVESTIGATIONS

To date the only published palynological work on the number 5 seam in the Witbank and Highveld Coalfields has been that of Falcon *et al.* (1984), who documented the qualitative/quantitative characteristics of samples from five main seams (1-5) at Greenside Colliery. Palynological comparisons of these seams were made using a palynobiostratigraphic type sequence from Zimbabwe (Falcon 1975, 1978).

MATERIALS AND METHODS

The number 5 seam in the Witbank/Highveld Coalfields varies in thickness laterally, but generally averages about 2.5 metres. For the present study four mine sites were investigated, namely Matla, Khutala, Greenside and Rietspruit.

Twenty to thirty samples, each weighing ± 500 grams, were collected from a number of sites at each mine. Extraction of the palynomorphs from the samples was carried out using a routine process developed at the U.S Geological Survey (Dohler 1980). This process enabled the rapid maceration of a wide variety of lithotypes, and individual steps were carried out according to the characteristics of each of the samples.

Visual counts of a minimum of 250 and maximum of 500 miospore specimens were undertaken. The relative abundance of species involved absolute counts within the first 250-500 and the supra-generic analysis comprised of these initial 250-500 miospores.

GEOLOGY

The Karoo Basin of South Africa contains the subcontinent's most complete geological record of late Palaeozoic to early Mesozoic 'Gondwanan' sediments (Le Blanc Smith 1980). This asymmetrically filled basin represents a depository formed between the Cape Fold Belt to the south and the Kaapvaal Craton to the north.

In 1980 the South African Committee for Stratigraphy introduced a formal lithostratigraphic nomenclature for the Northern Karoo Sequence, which replaced the Lower, Middle and Upper subdivisions of the Ecca Group with the Pietermaritzburg Shale Formation, the Vryheid Formation, and the Volksrust Shale Formation, respectively (Figure 2).

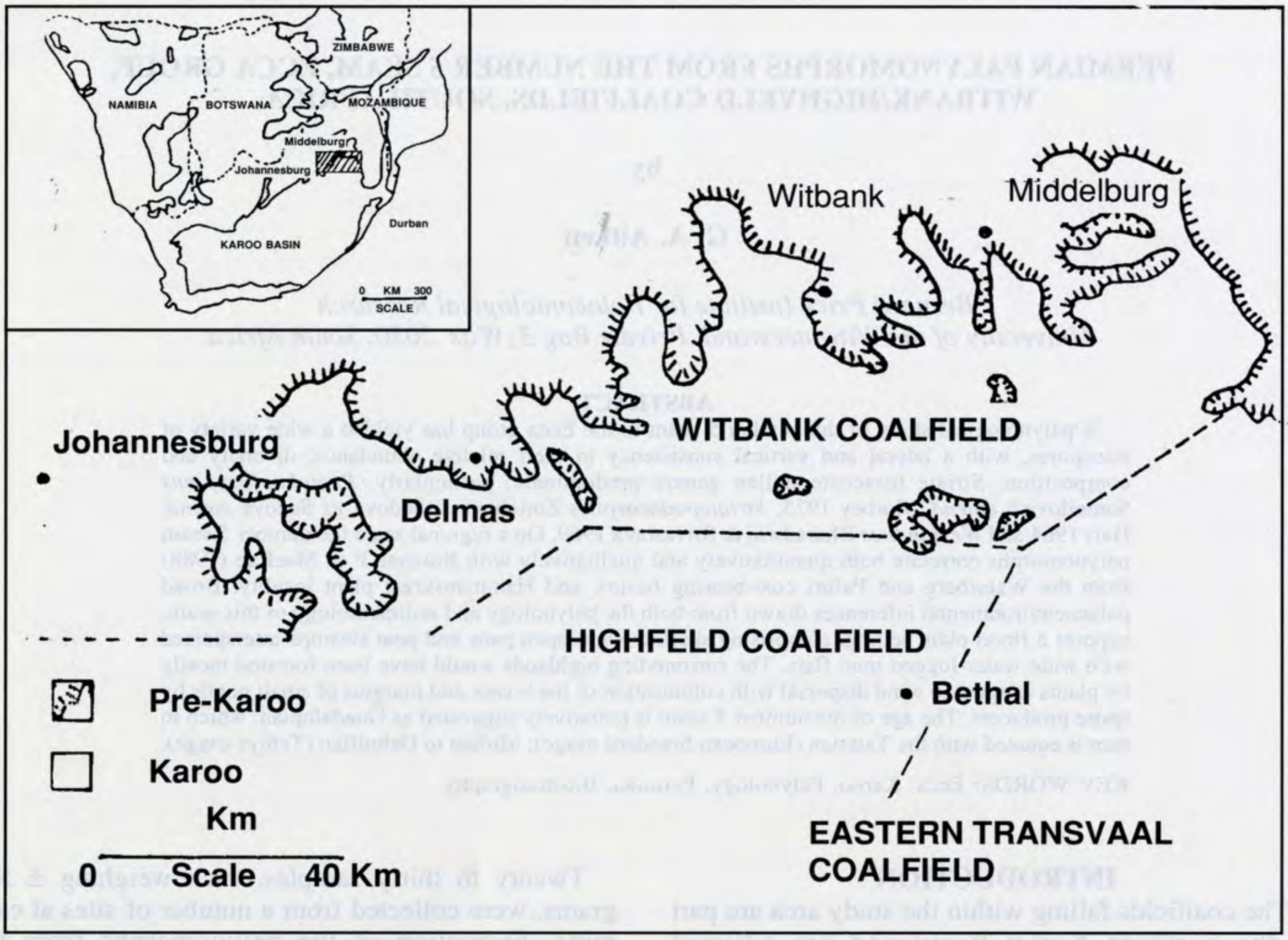


Figure 1. Geological map illustrating the location of the Witbank/Highveld Coalfields (adapted from Cairncross, 1986)

Coal seams in the Witbank and Highveld Coalfields are situated in the Vryheid Formation which conformably overlies the glaciogenic Dwyka Group or unconformably overlies pre-Karoo rocks. The rocks of the Karoo Sequence in the study area are represented only by the Dwyka Group and the Vryheid Formation. This is due to the northern pinch out of the Pietermaritzburg Shale Formation and the removal through erosion of the Volksrust Formation. The Dwyka Group comprises diamictites, mudrocks and

LITHOSTRATIGRAPHY	GENETIC STRATIGRAPHY
VOLKSRUST FORMATION	ABSENT THROUGH EROSION
VRYHEID FORMATION	6 SEAM GENETIC SEQUENCE
	5 SEAM GENETIC SEQUENCE
	4 SEAM GENETIC SEQUENCE
	2 SEAM GENETIC SEQUENCE
PIETERMARITZBURG SHALE FORMATION	ABSENT THROUGH EROSION
DWYKA GROUP	

Figure 2. Diagram illustrating the sub-division of the Vryheid Formation into informal genetic sequences (adapted from Winter, Cairncross & Cadle, 1987).

sandstones, while the Vryheid Formation is dominated by grey mudrocks, sandstones and coal seams.

The regional stratigraphy in the northern Highveld Coalfield is essentially similar to that of the Vryheid Formation in the adjacent central Witbank Coalfield (Le Blanc Smith 1980). Cairncross and Cadle (1987) subdivided the Vryheid Formation into 6 informal Genetic Sequences which are each terminated by coal seams.

The 5 Seam Genetic Sequence comprises the interval of Karoo strata between the roof of the number 4 Upper Seam and the roof of the number 5 Seam. The number 5 Seam is laterally continuous over a large area and displays little variation in gross thickness and is characterised by negligible variations in litho-stratigraphic composition (Cairncross & Cadle 1987).

The 5 Seam Genetic Sequence is represented by a thin, laterally continuous, brown glauconitic interlaminated sandstone-siltstone, capped by a sporadically developed number 4 Local Seam and a white well-sorted, glauconitic sandstone. The number 4 Seam is overlain by an upward-coarsening succession comprising, from the base upwards, carbonaceous siltstone, lenticular-laminated siltstone, interlaminated sandstone-siltstone, flaser-laminated sandstone and cross laminated sandstone, capped by the laterally continuous, uniformly thick number 5 Seam (Winter, Cairncross & Cadle 1987).

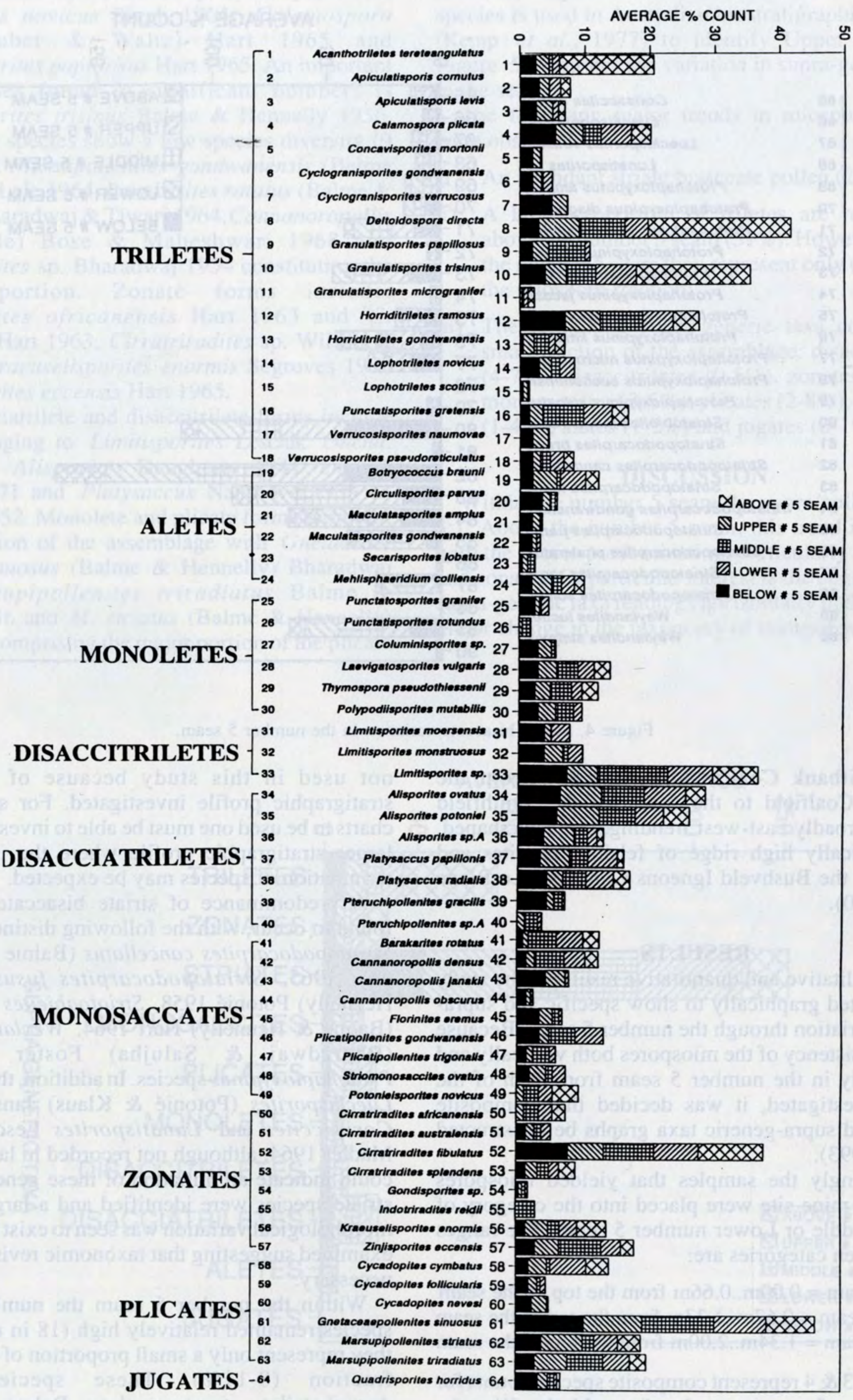


Figure 3. Species variation in the number 5 seam.

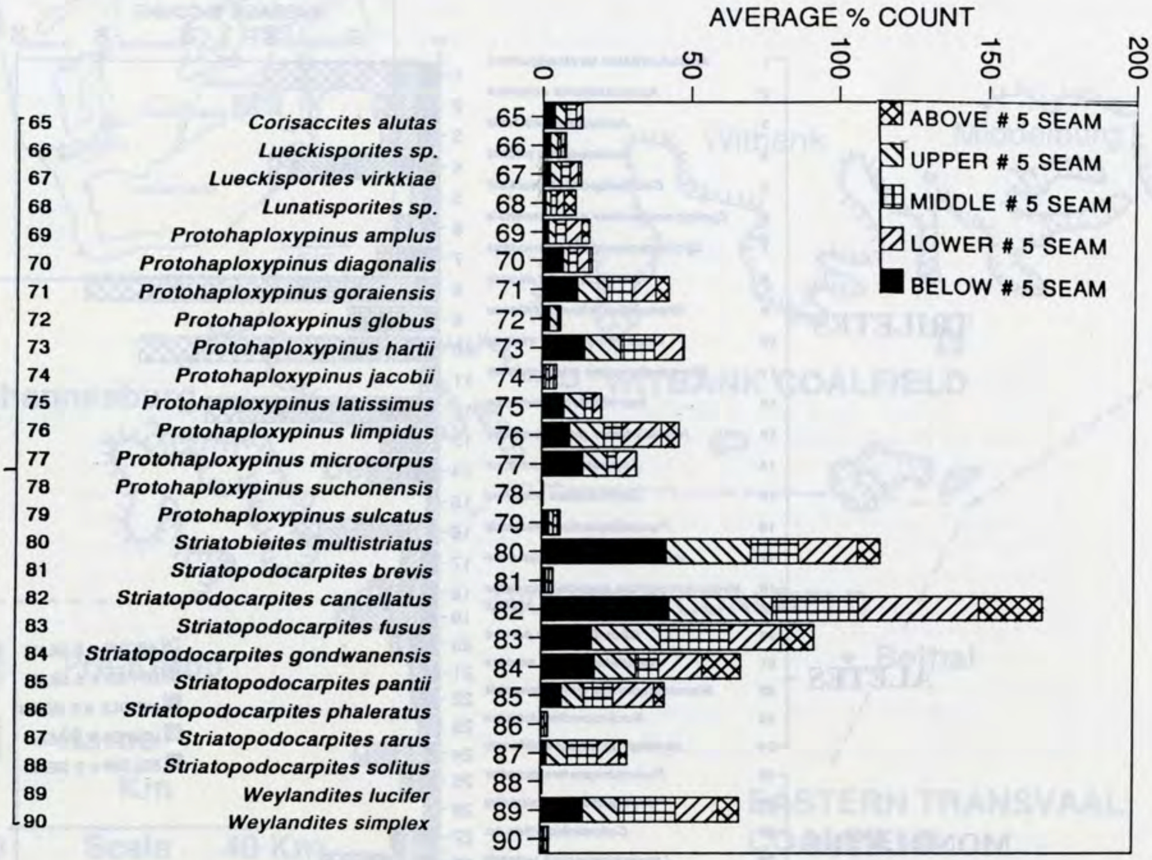


Figure 4. Striate bisaccate variation in the number 5 seam.

The Witbank Coalfield is separated from the Highveld Coalfield to the south by the Smithfield Ridge, a broadly east-west trending, crescent-shaped, topographically high ridge of felsites, granites and diabase of the Bushveld Igneous Complex (Le Blanc Smith 1980).

RESULTS

The qualitative and quantitative results of the study are presented graphically to show specific and supra-generic variation through the number 5 seam. Because of the consistency of the miospores both vertically and horizontally in the number 5 seam from each of the mines investigated, it was decided that composite species and supra-generic taxa graphs be constructed (Aitken 1993).

Accordingly the samples that yielded miospores from each mine site were placed into the category of Upper, Middle or Lower number 5 seam. The ranges for the given categories are:

Upper 5 seam = 0.00m..0.66m from the top of the seam
Middle 5 seam = 0.67m..1.33m from the top of the seam
Lower 5 seam = 1.34m..2.00m from the top of the seam

Figures 3 & 4 represent composite species counts for the number 5 seam samples from Matla, Khutala, Greenside and Rietspruit. Species range charts were not used in this study because of the limited stratigraphic profile investigated. For species range charts to be used one must be able to investigate a much larger stratigraphic profile where the initiation and termination of species may be expected.

A predominance of striate bisaccate pollen was found to occur, with the following distinctive species: *Striatopodocarpites cancellatus* (Balme & Hennelly) Hart 1965, *Striatopodocarpites fusus* (Balme & Hennelly) Potonié 1958, *Striatoabieites multistriatus* (Balme & Hennelly) Hart 1964, *Weylandites lucifer* (Bharadwaj & Salujha) Foster 1975 and *Protohaploxypinus* species. In addition, the presence of *Lueckisporites* (Potonié & Klaus) Jansonius 1962, *Corisaccites* and *Lunatisporites* Leschik *emend.* Madler 1964, although not recorded in large numbers, could indicate an initiation of these genera. In all, 26 striate species were identified and a large amount of morphological variation was seen to exist in the species examined suggesting that taxonomic revision might be necessary.

Within the number 5 seam the number of trilete species remained relatively high (18 in all), although they represent only a small proportion of the miospore fraction (8-11%). These species include: *Acanthotriletes tereteangulatus* Balme & Hennelly 1956, *Deltoidospora directa* (Balme & Hennelly) Norris 1965, *Apiculatisporis cornutus* (Balme &

Hennelly) Hoeg & Bose 1960, *Horriditriletes ramosus* (Balme & Hennelly) Bharadwaj & Salujha 1964, *Lophotriletes novicus* Singh 1964, *Calamospora plicata* (Luber & Waltz) Hart 1965 and *Granulatisporites papillosus* Hart 1965. An important trilete species found in significant numbers is *Granulatisporites trisinus* Balme & Hennelly 1956. Monosaccate species show a low species diversity (9 species) with *Plicatipollenites gondwanensis* (Balme & Hennelly) Lele 1964, *Barakarites rotatus* (Balme & Hennelly) Bharadwaj & Tiwari 1964, *Cannanoropollis densus* (Lele) Bose & Maheshwari 1968 and *Potonieisporites* sp. Bharadwaj 1954 constituting the major proportion. Zonate forms include: *Cirratriradites africanensis* Hart 1963 and *C. australensis* Hart 1963, *Cirratriradites* sp. Wilson & Coe 1940, *Kraeuselisporites enormis* Segroves 1970 and *Zinjisporites eccensis* Hart 1965.

The disacciatrilete and disaccitrilete forms include species belonging to *Limitisporites* Leschik *emend.* Klaus 1963, *Alisporites* Daugherty 1941 *emend.* Jansonius 1971 and *Platysaccus* Naumova 1939 ex Ishchenko 1952. Monolete and plicate forms represent a small fraction of the assemblage with *Gnetaceaepollenites sinuosus* (Balme & Hennelly) Bharadwaj 1962, *Marsupipollenites triradiatus* Balme & Hennelly 1956 and *M. striatus* (Balme & Hennelly) Foster 1975 comprising the major portion of the plicate fraction. *Gnetaceaepollenites sinuosus* is found in relatively large numbers in the number 5 seam. This species is used in Australian biostratigraphic schemes (Kemp *et al.*, 1977) to identify Upper Stage 4a. Figure 5 illustrates the variation in supra-generic taxa in the seam.

The following major trends in miospore content were observed:

i) An abundant striate bisaccate pollen (26-61%);

ii) A large proportion of triletes are represented above the number 5 seam (51%). However, within the number 5 seam they represent only (8-12%) of the miospore fraction;

iii) The remaining supra-generic taxa constitute a small fraction of the assemblage, disacciatriletes (4-7%), disaccitriletes (0-5%), zonates (3-13%), monosaccates (2-6%), plicates (2-8%), monoletes (1-4%), aletes (1-2%) and jugates (0-1%).

DISCUSSION

Within the number 5 seam the spore/pollen ratio is 3:1. Above the number 5 seam, this trend is reversed with the spores predominating, particularly the triletes and zonates. Of particular interest is the consistency of supra-generic taxa readings horizontally in the seam. A major change in the taxonomy of miospores is evident

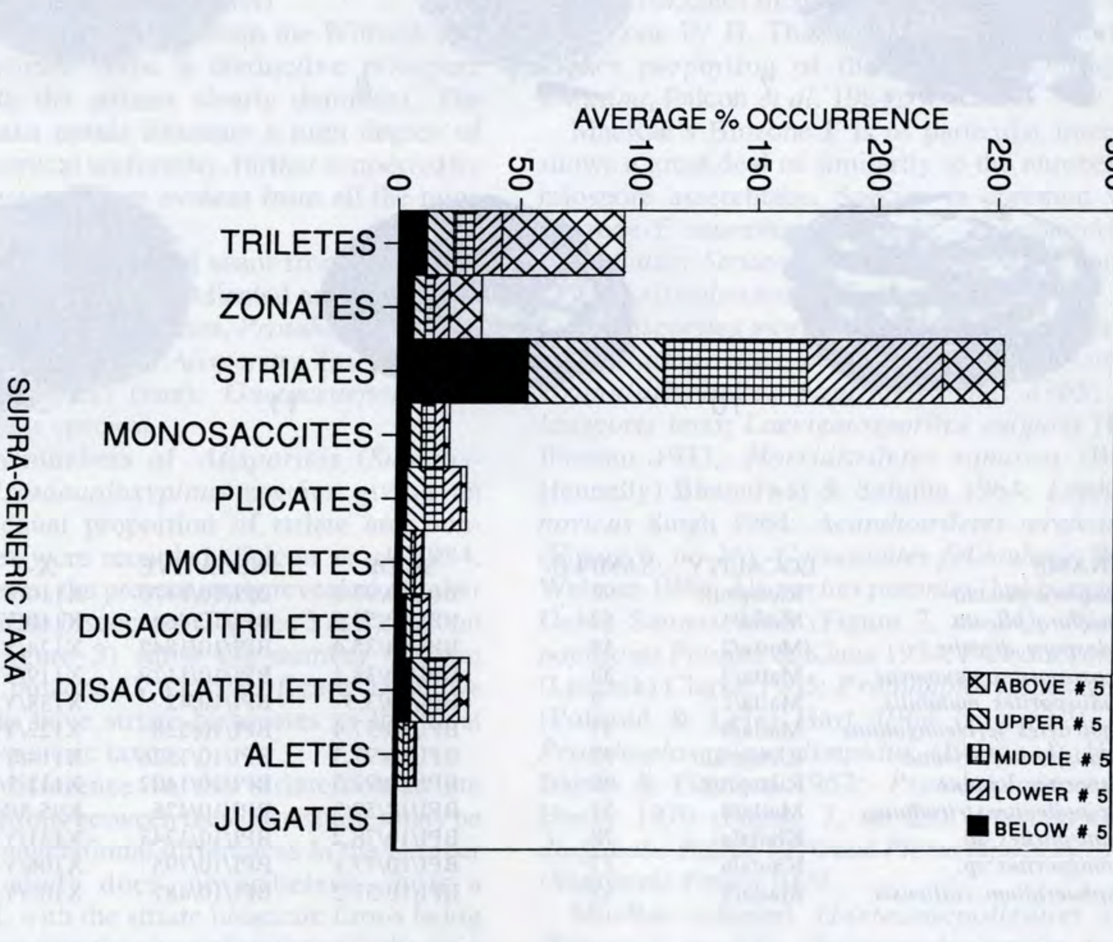
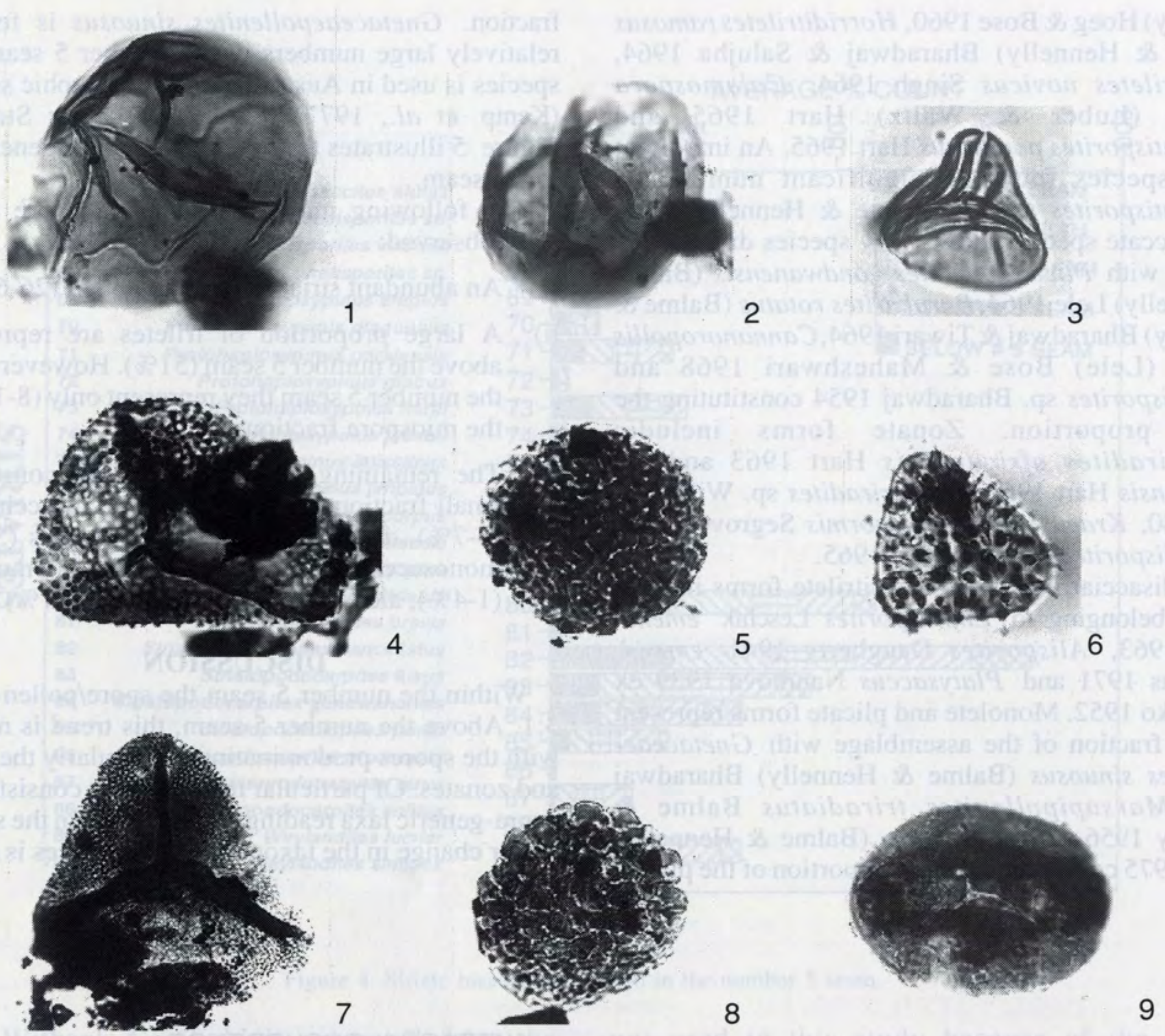


Figure 5. Quantitative variation of supra-generic taxa in the number 5 seam.



SPECIES NAME	LOCALITY	SAMPLE	SLIDE	NEGATIVE	X-Y	SIZE μm
1. *Calamospora plicata*	Rietspruit	97	BPI/10/97.1	BPI/10/1470	X110/Y19	48
2. *Calamospora plicata*	Matla/4	57	BPI/10/57.2	BPI/10/464	X110/Y9	35
3. *Deltoidospora directa*	Matla/2	35	BPI/10/35.4	BPI/10/1847	X124/Y22	33
4. *Verrucosisporites naumovae*	Matla/3	38	BPI/10/38.1	BPI/10/1129	X119/Y4	59
5. *Polypodiisporites mutabilis*	Matla/1	3	BPI/10/3.3	BPI/10/42	X138/Y14	29
6. *Acanthotriletes tereteangulatus*	Matla/4	57	BPI/10/57.4	BPI/10/538	X122/Y6	31
7. *Granulatisporites trisinus*	Rietspruit	97	BPI/10/97.3	BPI/10/1526	X114/Y19	64
8. *Secarisporites lobatus*	Rietspruit	97	BPI/10/97.3	BPI/10/1402	X112.5/Y3	43
9. *Marsupipollenites triradiatus*	Matla/4	57	BPI/10/57.2	BPI/10/476	X95.5/Y8	50
10. *Columinisporites sp.*	Khutala	78	BPI/10/78.2	BPI/10/1243	X131/Y21	48
11. *Columinisporites sp.*	Khutala	77	BPI/10/77.1	BPI/10/795	X106/Y18.5	45
12. *Mehlisphaeridium colliensis*	Matla/4	57	BPI/10/57.2	BPI/10/487	X105/Y10	41

Figure 6. Selected tribete, monolete and alete palynomorphs from number 5 seam.

above the number 5 seam. This can be attributed to a change in the palaeodepositional environment. The vertical consistency of supra-generic taxa in the number 5 seam shows that no major floral changes occurred in the accumulation of this peat swamp and the plant forms were well established in this environment. The horizontal consistency of supra-generic taxa at all of the mine sites also reflects a stable flora and confirms that the same seam was sampled.

The spore colour index technique has been used in the past to determine the degree of thermal maturation of carbonaceous sediments by differences observed in the colour of organic matter (Batten 1981; Burne & Kantsler 1977; Correia 1971; Dow 1977 & Staplin 1969, 1977). The technique involves an expression of the colour range of organic matter from transparent light yellow, with a value of 1 to opaque black with a value of 5. This particular method has also been more commonly termed thermal alteration index (T.A.I.).

The palynological material from the number 5 seam samples is a dark orange to brown colour. The organic material would therefore be assigned a T.A.I. of between 3,0 and 3,5 with the equivalent vitrinite reflectance (% RoV) of 0,7 to 1,25.

This compares favourably with a figure of 0,7% RoV quoted for the number 5 seam at Greenside mine (Boshoff *et al.,* 1993).

REGIONAL CORRELATION (SOUTH AFRICA)

The number 5 seam samples from the Witbank and Highveld Coalfields show a distinctive miospore assemblage with the striates clearly dominant. The supra-generic taxa trends illustrate a high degree of horizontal and vertical uniformity, further supported by a consistent species pattern evident from all the mine sites.

Previous studies of this coal seam from Greenside mine by Falcon *et al.* (1984) indicated an assemblage consisting of *Striatopodocarpites*, *Protohaploxypinus*, *Weylandites* (as *Vittatina*), *Alisporites* (as *Sulcatisporites*), *Lueckisporites* (rare), *Gnetaceaepollenites* and *Cirratriradites* species.

Equally high numbers of *Alisporites* (*Sulcatisporites*) and *Protohaploxypinus* species giving an approximately equal proportion of striate and non-striate bisaccates were recorded (Falcon *et al.* 1984, Figure 3). However, the present study revealed a higher proportion of striate bisaccates (Figures 3 & 5). Falcon *et al*., (1984 Figure 3) show the number 5 seam correlated with biozone IV G; their figure 4a shows biozone IV G to have striate bisaccates as the most abundant supra-generic taxon.

A possible difference in the striate/non-striate bisaccate proportions between these two studies may be due to regional vegetational differences in the number 5 seam. This study does, nevertheless, show a consistent trend, with the striate bisaccate forms being far more abundant than the non-striate forms in the ratio of 3:1.

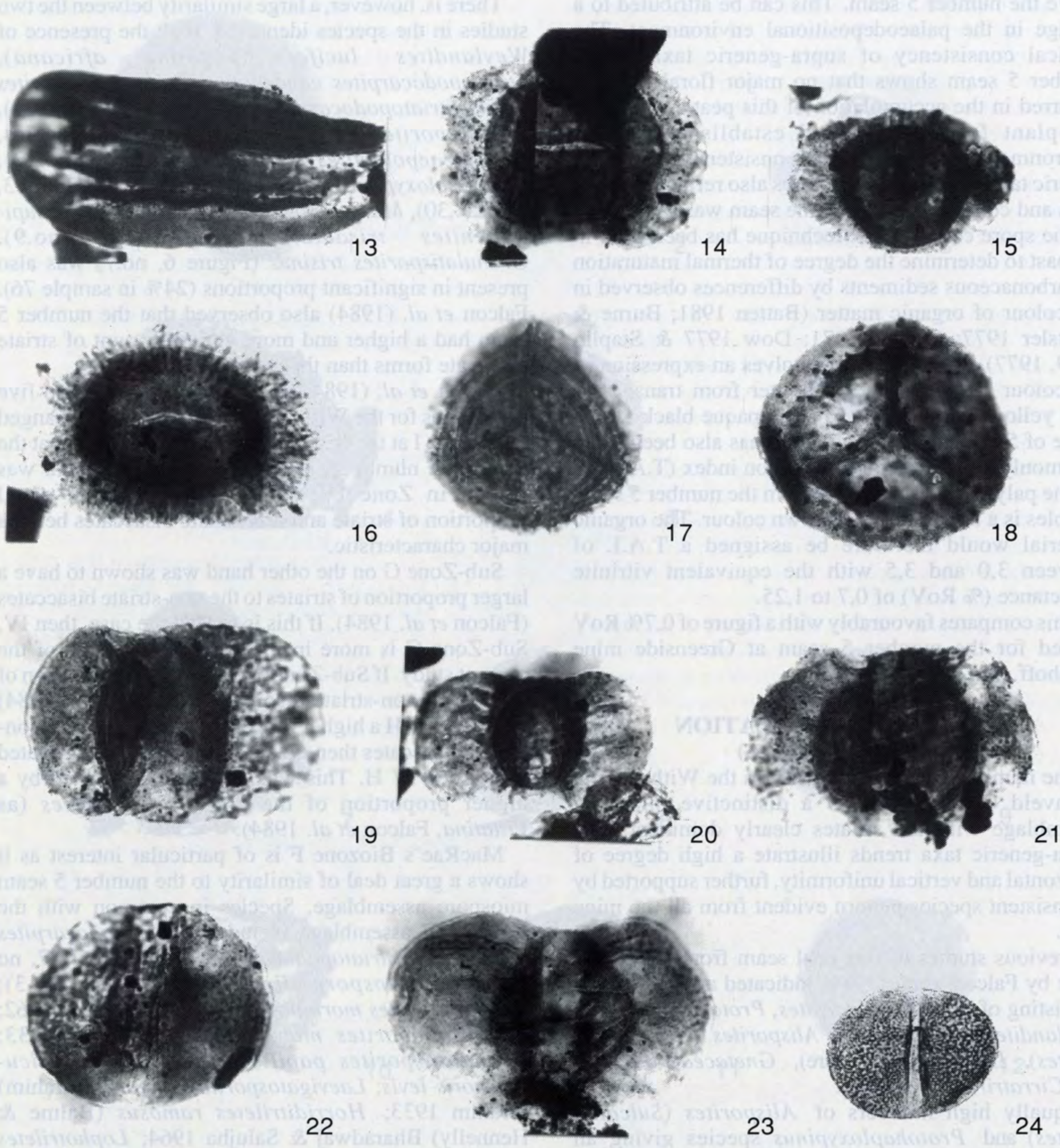
There is, however, a large similarity between the two studies in the species identified, with the presence of *Weylandites lucifer* (*Vittatina africana*), *Striatopodocarpites cancellatus*, *Striatopodocarpites fusus*, *Striatopodocarpites rarus* (Figure 7, no.21), *Lueckisporites virkkiae*, *Lueckisporites* species, *Gnetaceaepollenites sinuosus* (Figure 7, no.13), *Protohaploxypinus* species (Figure 7, no's 14,23; pl.3, no's 27,30), *Marsupipollenites striatus*, and *Marsupipollenites triradiatus* (Figure 6, no.9). *Granulatisporites trisinus* (Figure 6, no.7) was also present in significant proportions (24% in sample 76). Falcon *et al.* (1984) also observed that the number 5 seam had a higher and more varied amount of striate bisaccate forms than the number 4 seam.

Falcon *et al.* (1984) proposed four Zones and five Sub-Zones for the Witbank Basin. These Zones ranged from Zone I at the base of the coal sequence to IV at the top of the number 5 seam. The number 5 seam was placed in Zone IV, Sub-Zone G with an equal proportion of striate and non-striate bisaccates being a major characteristic.

Sub-Zone G on the other hand was shown to have a larger proportion of striates to the non-striate bisaccates (Falcon *et al.* 1984). If this is indeed the case, then IV, Sub-Zone G is more in line with the findings of the present study. If Sub-Zone G has an equal proportion of striate and non-striate disaccates (Falcon *et al.* 1984) and Zone IV H a higher proportion of striates than non-striate disaccates then the number 5 seam is correlated with Zone IV H. This would also be supported by a higher proportion of the genus *Weylandites* (as *Vittatina*, Falcon *et al.* 1984).

MacRae's Biozone F is of particular interest as it shows a great deal of similarity to the number 5 seam miospore assemblage. Species in common with the Biozone F assemblage include: *Striatopodocarpites cancellatus; Striatopodocarpites rarus* (Figure 7, no 21); *Deltoidospora directa* (Figure 6, no 3); *Concavisporites mortonii* (de Jersey) de Jersey 1962; *Granulatisporites micrognifer* Ibrahim 1933; *Granulatisporites papillosus* Hart 1965; *Apiculatisporis levis*; *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933; *Horriditriletes ramosus* (Balme & Hennelly) Bharadwaj & Salujha 1964; *Lophotriletes novicus* Singh 1964; *Acanthotriletes tereteangulatus* (Figure 6, no 26); *Cycadopites follicularis* Wilson & Webster 1946; *Alisporites potoniei* (Lakhanpal, Sah & Dube) Somers 1968 (Figure 7, no 24); *Platysaccus papilionis* Potonié & Klaus 1954; *Platysaccus radialis* (Leschik) Clarke 1965; *Protohaploxypinus goraiensis* (Potonié & Lele) Hart 1964 (Figure 9, no 30); *Protohaploxypinus limpidus* (Balme & Hennelly) Balme & Playford 1967; *Protohaploxypinus hartii* Foster 1979 (Figure 7, no 23); *Protohaploxypinus diagonalis* Balme 1970 and *Pteruchipollenites gracilis* (Segroves) Foster 1979.

MacRae selected *Gnetaceaepollenites sinuosus* (Figure 7, no 13); *Striatopodocarpites fusus* and *Weylandites lucifer* as being distinctive species of



SPECIES NAME	LOCALITY	SAMPLE	SLIDE	NEGATIVE	X-Y	SIZE µm
13. *Gnetaceaepollenites sinuosus*	Khutala	77	BPI/10/77.1	BPI/10/772	X133/Y15	90
14. *Protohaploxypinus globus*	Rietspruit	97	BPI/10/97.2	BPI/10/1493	X133/Y18	63
15. *Limitisporites monstruosus*	Khutala	72	BPI/10/72.2	BPI/10/753	X115/Y14	98
16. *Limitisporites sp.*	Rietspruit	97	BPI/10/97.2	BPI/10/1543	X109/Y21	92
17. *Gondisporites sp.*	Matla/4	57	BPI/10/57.2	BPI/10/496	X102.5/Y14	55
18. *Indotriradites reidii*	Khutala	82	BPI/10/82.1	BPI/10/1014	X136/Y9	60
19. *Platysaccus radialis*	Rietspruit	97	BPI/10/97.2	BPI/10/1528	X132/Y19	85
20. *Striatopodocarpites solitus*	Rietspruit	97	BPI/10/97.1	BPI/10/1419	X107.5/Y16	67
21 *Striatopodocarpites rarus*	Rietspruit	97	BPI/10/97.3	BPI/10/1382	X121/Y7	79
22. *Alisporites potoniei*	Rietspruit	97	BPI/10/97.2	BPI/10/1521	X122/Y5	73
23. *Protohaploxypinus hartii*	Rietspruit	97	BPI/10/97.3	BPI/10/1440	X123.5/Y16	68
24. *Alisporites potoniei*	Matla/1	3	BPI/10/3.1	BPI/10/1714	X122.5/Y19	62

Figure 7. Selected plicate, zonate and bisaccate palynomorphs from the number 5 seam.

Biozone F. All of these are found to be present in significant numbers in the number 5 seam. *Thymospora pseudothiessenii* (Kosanke) Wilson & Venkatchala 1963 which terminates just below Biozone F (MacRae 1988) is present in the number 5 seam and there are a number of species in the number 5 seam which are not listed as being present in Biozone F. These are *Corisaccites alutas* (rare), *Lueckisporites virkkiae* (Figure 9, no 28) (rare), *Lueckisporites* species (Figure 9, no 29) (rare), *Granulatisporites trisinus* (Figure 6, no 7) (abundant), *Lunatisporites* species (Figure 9, no 32) (very rare), *Limitisporites* species (Figure 7, no's 15, 16) and *Columinisporites* sp. (Figure 6, no's 10,11).

Comparison of the relative proportions of supra-generic taxa and the species profile would indicate a very close similarity between Biozone F and the number 5 seam. MacRae (1988) reports an increasing trend of striates and a decreasing trend of non striate forms towards the top of his Biozone F (striates 60-80%, disacciatriletes/disaccitriletes 10-20%).

It is suggested that the number 5 seam may be correlated with Biozone F (Figure 8). Alternatively, a new Biozone is indicated, based on the presence of *Corisaccites alutas*, *Lueckisporites virkkiae*, *Lueckisporites* species, *Granulatisporites trisinus* and *Lunatisporites* species.

The number 5 seam miospore assemblage is equated with the more broadly defined *Striatiti* florizone from South Africa of Hart (1967). Species in common include: *Weylandites lucifer* (as *Vittatina africana*), *Striatopodocarpites cancellatus, Striatopodocarpites fusus* (as *S. paralicus*) and *Gnetaceaepollenites sinuosus* (as *Schopfipollenites sinuosus).*

A broad similarity exists between the miospore content of the number 5 seam and Zone 5 described from the northern Karoo Basin, South Africa (Anderson 1977). A high proportion of striates are present in Zone 5 and many species are common. These include *Protohaploxypinus goraiensis* (as *Pitysporites goraiensis*), *Striatopodocarpites cancellatus* (as *Protohaploxypinus cancellatus*), *Protohaploxypinus amplus* (as *Pityosporites amplus*), *Protohaploxypinus micros* (as *Pityosporites micros*) and various *Lueckisporites* species.

CHRONOSTRATIGRAPHIC UNITS *VIDE* HARLAND *ET AL.* 1982			WATERBERG & PAFURI BASINS SOUTH AFRICA	ZIMBABWE	WITBANK HIGHVELD COALFIELDS SOUTH AFRICA
PERIOD	EPOCH	AGE	MACRAE 1988	FALCON 1978	PRESENT STUDY
PERMIAN	UPPER PERMIAN	TATARIAN	F	H'	**No. 5 SEAM**
		KAZANIAN		**H**	
		UFIMIAN	**E**	**G**	

Figure 8. Correlation chart of Biozones in the present study with international chronostratigraphic units (adapted from MacRae, 1988)

PALAEOENVIRONMENTAL SETTING

A great deal of literature exists on the interpretation of the palaeodepositional and palaeoenvironmental setting of the coal seams in the Witbank and Highveld Coalfields (Cadle *et al.* 1993; Cairncross 1980, 1986, 1989, Cairncross & Cadle 1988a, 1988b; Falcon 1980, 1986, 1989; Falcon *et al.* 1984; Le Blanc Smith & Erikkson 1979; Le Blanc Smith & Falcon 1982; Plumstead 1957, 1966).

Climatic amelioration during the Late Carboniferous and Early Permian was accompanied by glacial thawing and retreat to the north and northeast of the present day Karoo Basin (Crowell & Frakes 1975; Stratten 1968). The retreat of these glaciers has been proposed as being pulsatory rather than continuous (Falcon 1986). In the early stages of the Vryheid Formation glaciogenic conditions still prevailed causing infilling of palaeo-valleys by glaciofluvial braided alluvium (Cairncross 1989). Epicontinental coal-forming environments follow conformably above these paraglacial sediments and are related to major sedimentation across the entire northeastern stable shelf area of the Karoo basin.

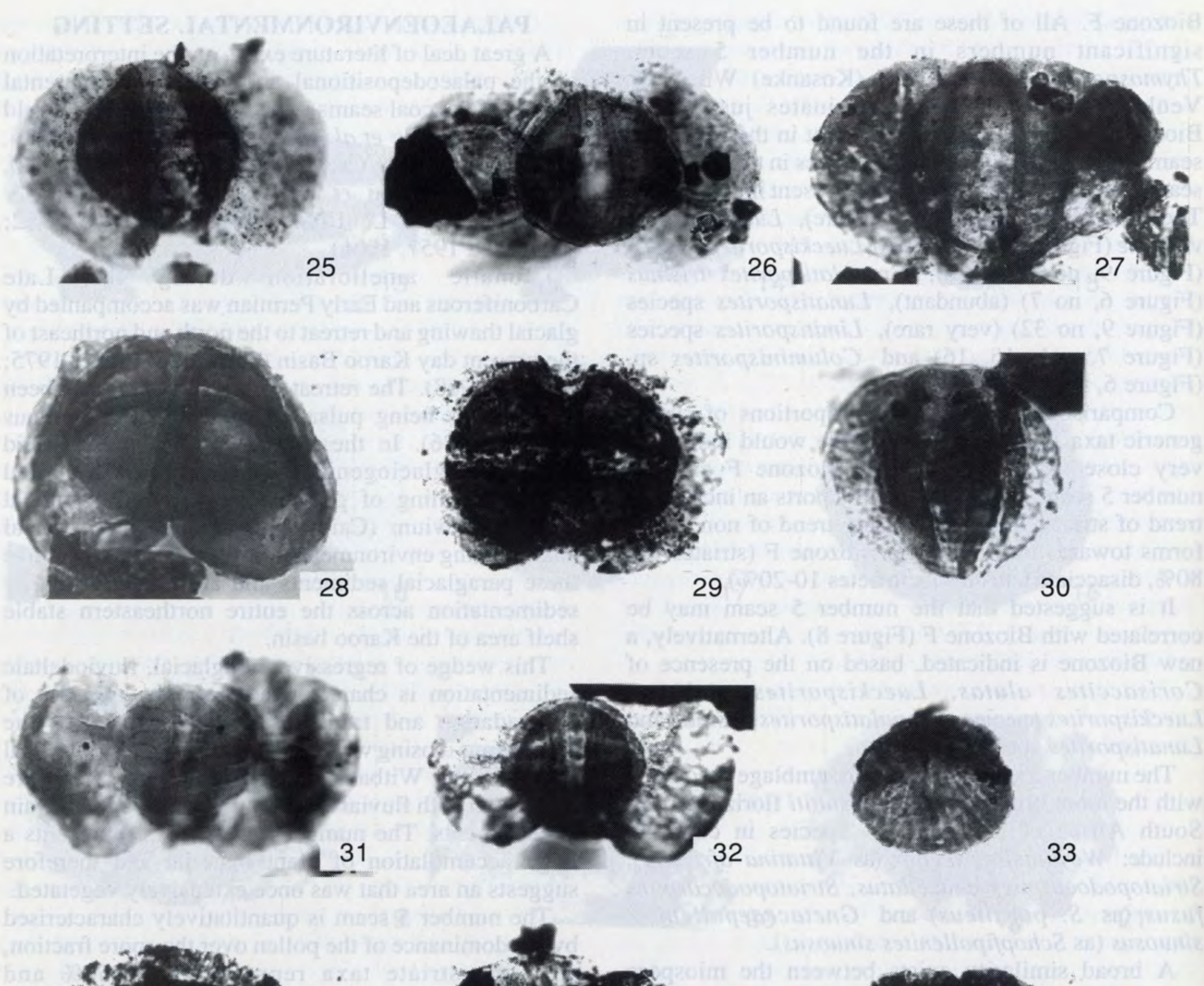
This wedge of regressive, nonglacial, fluviodeltaic sedimentation is characterised by eight episodes of progradation and transgression with many of the regressions closing with a peat bed (Falcon 1989). Coal seams in the Witbank and Highveld Coalfields are associated with fluvial and delta dominated flood plain environments. The number 5 coal seam represents a large accumulation of plant material and therefore suggests an area that was once extensively vegetated.

The number 5 seam is quantitatively characterised by the dominance of the pollen over the spore fraction, with the striate taxa representing ± 60% and disacciatriletes/disaccitriletes ± 15% of the miospore fraction. These two dominant supra-generic taxa represent grains which are adapted to wind dispersal (MacRae 1988). Combining this evidence with data from previous sedimentological studies a flood plain setting is proposed, comprising of shallow, wide open pans and peat swamps interspersed with wide, water-logged mudflats.

The levees and margins of these mudflats were possibly colonised by the lower order spore producers. Cryptogam spore producers are also most likely to have occurred as part of the understorey on the lake/pond margins and as the primary colonisers of the emerged portions of the shallow depository.

The abundance of striates in the samples might indicate that well away from the margin of these mudflats a fairly stable forest vegetation of high order pollen producing plants was situated. Long distance wind blown transport of this higher order pollen could account for dominance of the striates in the number 5 seam.

The dramatic increase in the striates and the decrease in all other taxa could conceivably indicate a vegetational response to a change in climate. This possibly occurred because of the drifting of the sub-



SPECIES NAME	LOCALITY	SAMPLE	SLIDE	NEGATIVE	X-Y	SIZE µm
25. *Striatopodocarpites pantii*	Khutala	72	BPI/10/72.1	BPI/10/702	X123/18	70
26. *Striatopodocarpites pantii*	Khutala	72	BPI/10/92.2	BPI/10/754	X115.5/Y15.5	60
27. *Protohaploxypinus amplus*	Rietspruit	97	BPI/10/97.2	BPI/10/1387	X102.5/Y12.5	91
28. *Lueckisporites virkkiae*	Rietspruit	97	BPI/10/97.3	BPI/10/1533	X103/Y8.5	73
29. *Lueckisporites sp.*	Rietspruit	97	BPI/10/97.2	BPI/10/1358	X94.5/Y15	81
30. *Protohaploxypinus goraiensis*	Rietspruit	97	BPI/10/97.2	BPI/10/1557	X114.5/Y2.5	87
31. *Striatopodocarpites pantii*	Rietspruit	97	BPI/10/97.2	BPI/10/1463	X112/Y17	103
32. *Lunatisporites sp.*	Rietspruit	97	BPI/10/97.2	BPI/10/1432	X116/Y4	71
33. *Weylandites simplex*	Rietspruit	97	BPI/10/97.1	BPI/10/1412	X117/Y12	33
34. *Cannanoropollis densus*	Rietspruit	97	BPI/10/97.1	BPI/10/1167	X125/Y7	115
35. *Cannanoropollis* sp.	Khutala	78	BPI/10/78.3	BPI/10/1242	X124.5/Y5.5	85
36. *Cannanoropollis densus*	Matla/1	5	BPI/10/5.2	BPI/10/1168	X102.5/Y13.5	98

Figure 9. Selected striate bisaccate and monosaccate polynomorphs from the number 5 seam.

continent into lower latitudes, and signals the first stages of the warmer temperate climates of Beaufort Permo-Triassic times.

AGE

Palaeobotanical age determination for Permian sediments remains a controversial subject. Two approaches have been described. The first, direct correlation, is based on a bio- and chrono-stratigraphic correlation comparing fossil plant assemblages found in spatially separated areas and the second, indirect correlation where the age of the flora is determined by comparison with marine faunas (Kovács Endrödy, 1991).

These different approaches result in age determinations that frequently differ. Kovács Endrödy (1991) discusses the validity of these two approaches. It is considered beyond the scope of this paper to critically analyze these two approaches; ages referred to in the preceding section are subject to revision when more palynological information becomes available.

The number 5 seam was correlated with the upper portion of Biozone F of MacRae (1988). MacRae (1988) dated his Biozone E as extending from the Ufimian to the lower part of the Kazanian Age and Biozone F was tentatively suggested as having extended over the remainder of the Kazanian, including part of the Tatarian. The number 5 seam was also correlated with the *Striatiti* Florizone for which Hart (1967) showed a Tatarian Age.

CONCLUDING REMARKS

An important palynological trend in Upper Permian sediments both in South Africa and its Gondwana counterparts is the emergence of abundant striate bisaccate forms, in particular genera such as *Striatopodocarpites, Protohaploxypinus, Weylandites, Lueckisporites, Lunatisporites, Corisaccites* and *Guttulapollenites* Goubin 1965. In the stratigraphy, the number 5 seam is situated towards the top of the Vryheid Formation. This has led to this seam being placed in the Upper/Lower to Lower/Middle Permian Epoch and hence of Aktastinian to Baigendzinian age. However, this study and previous work by Falcon (1984) and MacRae (*pers comm.*) place this seam in the Lower Upper Permian Epoch, which in turn supports a Kazanian to Tatarian age. An investigation of material stratigraphically higher and lower in the South African succession than the number 5 seam is needed to help resolve the age discrepancies.

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