THE AGE OF THE CARBONIFEROUS-PERMIAN *CONVERRUCOSISPORITES CONFLUENS* OPPEL BIOZONE: NEW DATA FROM THE GANIGOBIS SHALE MEMBER, DWYKA GROUP, NAMIBIA

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Abstract

The establishment of the *Converrucosisporites confluens* Oppel Zone in the Canning Basin, Australia in cored intervals from the Calytrix No. 1 Borehole was considered an advance in Gondwana Carboniferous-Permian palynostratigraphy because the zone was associated with a marine fauna that suggested a correlation with the standard Russian Lower Permian stages, and because the eponymous species has a wide occurrence in Gondwana outside Australia, e.g., Antarctica, Argentina, Brazil, India , Oman, Saudi Arabia and Uruguay. The zone was originally considered mid- to late Asselian in age, but its age was later revised to latest Asselian to early Sakmarian. *Converrucosisporites confluens* is here reported from the Ganigobis Shale Member

(Namibia) in a well-preserved, diverse assemblage alongside four of the fourteen specified accessory taxa for the *Converrucosisporites confluens* Oppel Zone. Ash layer IIb of the Ganigobis Shale Member is radiometrically-dated at 302.0 ±3.0 Ma (Pennsylvanian; Gzhelian or Kasimovian) thus the *Converrucosisporites confluens* Oppel Zone may range lower than previously thought. Preliminary study of the range top of *Converrucosisporites confluens* in Argentina and Uruguay suggests that it ranges higher there than in Western Australia with the possibility that the eponymous oppel zone may also range higher than previously thought.

Key words: *Converrucosisporites confluens* Oppel Zone; Permian; Carboniferous; glaciation; radiometric dating

INTRODUCTION

Gondwanan Carboniferous-Permian glaciogenic sediments have historically been difficult to assign to the chronostratigraphic stages of the Permian because of the lack of marine fauna and difficulty of calibration of palynological biozones (Stephenson, 2008; Stephenson et al., 2007). Thus the establishment of the *Converrucosisporites confluens* Oppel Zone in the Canning Basin, in cored intervals from the Calytrix No. 1 Borehole was an advance because the zone was associated with a marine fauna that allowed correlation with the standard Lower Permian stages of the south Urals in Russia (Foster and Waterhouse, 1988). The associated marine fauna was originally considered mid- to late Asselian in age, though subsequent revision (Archbold, 1995) suggested an extension into the Tastubian (early Sakmarian), and recent depictions of the zone indicate that its lower limit is in the latest Asselian (Text-Fig. 1; Archbold, 2001). *Converrucosisporites confluens* has been suggested as a possible pan-Gondwanan correlation species because, apart from wide occurrence in Australia, it also occurs in many other Gondwana sequences, e.g. India (Tiwari and Singh, 1981; Srivastava and Bhattacharyya, 1994); Argentina (Archangelsky and Gamerro, 1979; Césari et al., 1995; Vergel, 1993); Brazil (Souza and Callegari, 2004); Uruguay (Beri and Goso, 1996); Antarctica (Lindström, 1995); and Oman and Saudi Arabia (Stephenson and Osterloff, 2002; Stephenson, 2004; Stephenson et al., 2003, 2008). Although it generally occurs in broadly coeval sequences associated with deglaciation, for example in the Rahab shale (Oman; Stephenson and Osterloff, 2002), and the Carrandibby and Calytrix formations (Western Australia; Foster and Waterhouse, 1988), the precise constancy of its stratigraphic range across Gondwana is in doubt because of an apparently longer range in South America (Archangelsky and Vergel, 1996; S. Archangelsky personal communication, 1998). The recognition of *Converrucosisporites confluens* in a well-preserved, diverse assemblage alongside other accessory taxa of the *Converrucosisporites confluens* Oppel Zone within a radiometrically-dated sequence in Namibia has allowed a non-paleontological assessment of the age of the biozone.

GANIGOBIS SHALE MEMBER

The assemblage was recovered from the Ganigobis Shale Member of the glaciogenic Dwyka Group, the lowermost stratigraphic unit of the Karoo Supergroup in southern Namibia (Text-Fig. 2; Visser, 1997). The Dwyka Group can be subdivided into four upward-fining deglaciation sequences, each capped by relatively fine-grained glaciolacustrine or glaciomarine deposits (Text-Fig. 3). Deglaciation Sequence 2 (DS2) comprises a strongly heterolithic upward-fining unit which was formed in a predominantly marine or subaquatic environment (Bangert, 2000). The uppermost part of DS2 comprises a thick mudstone unit, known as the Ganigobis Shale Member, which contains abundant marine macro and ichnofossils as well as extrabasinally-derived ashfall tuff beds. In its type area, in the vicinity of Tses and Ganigobis, the Ganigobis Shale Member is mainly exposed in eroded river banks of the Fish River and its tributaries from the east and north (Asab, Ganigobis and Tses rivers). The Ganigobis Shale Member near Ganigobis contains 21 fine-grained ash-fall derived tuff beds which occur in 8 sets (Bangert, 2000).

The largest outcrop of the lower part of the Ganigobis Shale Member is situated on the banks of the Fish River north of Ganigobis. Cliffs, which reach a maximum height of 18 m with an average of 3-10 m, stretch along the Fish River creating continuous outcrops over a length of 2.5 km. The lowermost part of the Ganigobis Shale Member is characterised by a rapid transition from dropstone-bearing mudstones (diamictites) to mainly dropstone-free mudstones with interbedded phosphatic-siliceous concretions enclosing remains of paleoniscoid fishes (Bangert et al., 1999). Sixteen of the twenty-one tuff beds are present in this part. The palynological samples for this study were collected by Dr D. Condon about 2.5 km north of Ganigobis on the banks of the Fish River at two nearby locations (25°48.621' S, 18°00.340' E and 25°48.743' S, 18°00.477' E) within a sequence with a diamictite at the base and dark mudstone with concretions above (Text-Fig. 4). The second locality is pictured in Text-Fig. 5. Bangert et al. (1999) identified three sets of ash layers (termed I, II and III) in this area and the first two sets which consist of a triplet and doublet respectively are present in the locations where palynological samples were taken (Fig. 3). The upper ash layer of Set II (Ash Layer IIb at 25°53'35"S, 18°00’51”E, south of Ganigobis; Fig. 4) gave SHRIMP-based age determinations from juvenile magmatic zircons of 302.0 ±3.0 Ma (Bangert, 2000). This range (299 - 305 Ma) places Ash Layer IIb entirely within the Pennsylvanian, Gzhelian or Kasimovian (Gradstein et al., 2004; Ramezani et al., 2007).

PALYNOLOGY

Seven samples (A to E, G, H) were processed for palynology. A and B contain the most diverse and best-preserved assemblages, while those above contain progressively poorer-yielding assemblages. The most common taxa occurring in the seven samples are *Alisporites indarraensis*, *Converrucosisporites grandegranulatus*, *Cristatisporites* spp., *Horriditriletes uruguaiensis*, *Lundladispora braziliensis*, *Lundbladispora* spp., *Microbaculispora tentula*, *Vittatina* spp., and indeterminate bisaccate and monosaccate pollen (full author citations given in Appendix 1; Plates 1 and 2). Also present in small numbers in samples A and B is *Converrucosisporites confluens* along with *Cannanoropollis* spp., *Caheniasaccites ovatus*, *Cycadopites cymbatus*, *Horriditriletes ramosus*, *Plicatipollenites* spp., and *Striatoabieites multistriatus*. The *Converrucosisporites confluens* Oppel Zone is defined by the presence of at least four of fourteen specified accessory taxa along with the eponymous taxon, and those listed above are amongst the specified accessory taxa (see Foster and Waterhouse, 1988). Thus assemblages A and B can be assigned to the *Converrucosisporites confluens* Oppel Zone. The latest Asselian to Tastubian age attributed to the biozone by Archbold (2001) corresponds to an approximate age range of 295 Ma to 290 Ma (M. Schmitz, personal communication, 2007; Gradstein et al., 2004) which is younger than the age suggested by radiometric dating.

DISCUSSION

There are three explanations for the conflicting ages suggested for the *Converrucosporites confluens* Oppel Zone: (1) the age range suggested in Australia is incorrect; (2) the age range varies across Gondwana; and (3) the radiometric age of the Ganigobis Member is incorrect.

Age range suggested from Australian studies

Ages for palynological biozones in the Early Permian of Australia rely most heavily on ammonoids and brachiopods within palyniferous sequences of Western Australia (Foster and Archbold, 2001). Ammonoids provide the key control points with Russian (south Urals) standard sequences, particularly of the Sakmarian and Artinskian stages, despite being patchy in their stratigraphic and geographic distribution. Brachiopods are abundant at some levels but show a high degree of endemism (Foster and Archbold, 2001) so that only brachiopods of the Family Spiriferidae can allow correlation with the Urals (Foster and Archbold, 2001). However no Asselian ammonoids occur in Western Australia (Leonova, 1998; Foster and Archbold, 2001), and there are no independent dates for the lowest Carboniferous-Permian brachiopod biozone of Western Australia, the *Lyonia lyoni* Biozone, which is based on taxa endemic to Gondwana. The approximately coeval *Lyonia bourkei* Biozone of eastern Australia also lacks evidence for age (Briggs, 1998).

The upper age limit of the *Converrucosporites confluens* Oppel Zone was assessed by Archbold (1995) as Tastubian on the basis of ammonoids, and is therefore probably correct since ammonoids are well known and used in Russian Permian stratotype biostratigraphy. Archbold (1995) did not specify the lower limit of the age of the biozone, referring only to it '…ranging down into the Asselian'. In his more recent publications, however, the base of the biozone is shown in the uppermost Asselian where it correlates with the base of the brachiopod *Lyonia lyoni* Biozone (Archbold, 2001). The endemism of the *Lyonia lyoni* Biozone brachiopods and the absence of ammonoids, fusulinids and conodonts prevents any independent date, thus the age of the base of the *Converrucosporites confluens* Oppel Zone is unknown but could extend lower than the latest Asselian age originally suggested, and be as low as the latest Carboniferous (Gzhelian). Thus the lower limit of the age of the *Converrucosporites confluens* Oppel Zone in Western Australia could be consistent with that suggested by radiometric dates from the Ganigobis Shale Member.

Age range across Gondwana

There is very little direct independent evidence for the age of the *Converrucosporites confluens* Oppel Zone outside Australia. In Oman the zone has a range top well below the Haushi limestone which contains Sterlitamakian (late Sakmarian) fusulinids (Angiolini et al., 2006), but its lower limit cannot be assessed independently because of the lack of paleontological or other radiometric evidence at this level.

Converrucosporites confluens was first described from Argentina by Archangelsky and Gamerro (1979) and since then has been recorded widely in South America. A number of studies show its range as extending the length of the *Cristatisporites* Zone and into the *Striatites* Zone in Argentina (e.g. Playford and Dino, 2002). There appear to be no independent dates for the *Cristatisporites* Zone (see Playford and Dino, 2002), but radioisotopic dating of the Argentinian *Striatites* Biozone (Melchor, 2000) gives 266.3 ± 0.8 Ma (Wordian, Middle Permian according to Gradstein et al., 2004). A similar range for *Converrucosporites confluens* through the *Cristatisporites* Zone and *Striatites* Zone is also indicated in Uruguay (Archangelsky and Vergel, 1996). In the Brazilian Paraná Basin *Converrucosporites confluens* first occurs at the base of the *Vittatina costabilis* Interval Zone (Souza and Callegari, 2004). Radiometric dates for the middle part of the Rio Bonito Formation which broadly corresponds to the *Vittatina costabilis* Interval Zone include 296.9 ±1.4 Ma and 299.1 ±2.6 Ma (Guerra-Sommer et al., 2005; see also Césari, 2007) and 298.5±2.6 Ma (Rocha-Campos et al., 2006). Though it is not possible to estimate the time interval between the dated horizons and the base of the Rio Bonito Formation, it is clear that this base and the level of the base of the *Vittatina costabilis* Interval Zone is older and may approximate to the level of the Carboniferous-Permian boundary (i.e. 298.9 +0.31/–0.15 Ma; Ramezani et al., 2007) as suggested by Césari (2007). Thus the age of the first occurrence of *Converrucosporites confluens* may approximate to the Carboniferous-Permian boundary in the Paraná Basin. Since the presence of *Converrucosporites confluens* is a prerequisite for the eponymous oppel zone, it is possible that the age of the zone itself is closer to the age suggested by the Ganigobis Shale Member than to the original lower limit of the range in Western Australia.

Radiometric age of the Ganigobis Shale Member

As well as the 302.0 ±3.0 Ma age of Ash Layer IIb north of Ganigobis, Bangert et al. (1999) also gave an age for other ash layers within the Ganigobis Shale Member of 299.2 ±3.2 Ma from a road cut locality east of Ganigobis, near Tses. Both these ages are still substantially older than the age corresponding to the lower limit of the range of the *Converrucosporites confluens* Oppel Zone in Western Australia (approximately 295 Ma).

Stollhofen et al. (2008) indicated that the AS3 zircon standard (Duluth Complex gabbroic anorthosite) was used as the standard for U/Pb calibration for the Ganigobis dating. The SL13 Australian National University zircon standard was used only for determination of U and Th concentrations relative to those measured in the standard. Thus the doubts expressed as to the veracity of the SL13 standard (e.g. Black et al. 2003; Foster and Archbold, 2001) do not apply.

If the margins for error of 3.0 Ma and 3.2 Ma were taken as ranges entirely younger than the quoted means, then the resulting figures, 299 Ma and 296 Ma respectively, would suggest that the discrepancy between the original Western Australian lower age limit for the *Converrucosporites confluens* Oppel Zone and the radiometric age of the Ganigobis Shale Member is much smaller.

In conclusion, it seems likely that the upper limit of the range of *Converrucosporites confluens* is quite variable in Gondwana, being Tastubian in Australia and probably in Oman, but possibly younger in South America. The purely paleontological evidence for the lower limit of the *Converrucosporites confluens* Oppel Zone in Western Australia is rather weak and the radiometric ages from the Paraná Basin and Ganigobis Shale Member indicate a range base of at least latest Carboniferous, Kasimovian/Gzhelian, or earliest Asselian, which may also apply in Western Australia.

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Figure Captions

Text-Fig. 1 Chronostratigraphy of the Pennsylvanian to Cisuralian, after Gradstein et al. (2004) and Ramezani et al. (2007).

Text-Fig. 2 Location of Ganigobis.

Text-Fig. 3 Deglaciation sequences (DS) of the Dwyka Group, after Stollhofen et al. (2000).

Text-Fig. 4 Sketches of sections north of Ganigobis at two locations 25°48.621’ S, 18°00.340’ E and 25°48.743’ S, 18°00.477’ E, and a composite section showing positions of samples. Asterisk shows ash layer dated at 302.0 ±3.0 Ma.

Text-Fig. 5A Section at 25°48.743’ S, 18°00.477’ E. Cliff is approximately 9 m high. Inset B shows prominent light coloured Set II ash layers of Bangert (2000), approximately 20 cm apart. The upper ash layer, IIb, gave a SHRIMP-based age of 302.0 ±3.0 Ma.

PLATE 1

The locations of specimens are given first by England Finder reference and then by slide code; dimensions of the longest axis of each specimen are also given individually. Slides are stored in the Micropaleontology Collection of Petroleum Development Oman, PO Box 81, Muscat 113, Sultanate of Oman.

1. *Converrucosisporites confluens*, F44, A, 54 µm, proximal focus.
2. *Converrucosisporites confluens*, F44, A, 54 µm, distal focus.
3. *Converrucosisporites confluens*, Q60/2, 50 µm, distal focus.
4. *Brevitriletes cornutus*, S45/1, A, 35 µm.
5. *Converrucosisporites confluens*, J39/4, A, 55 µm, distal focus.
6. *Converrucosisporites confluens*, J39/4, A, 55 µm, proximal focus.
7. *Deusilites tentus*, M44/3, A, 80 µm.
8. *Converrucosisporites confluens*, M42/3, A, 36 µm, proximal focus.

9. *Alisporites indarraensis*, M55, A, 60 µm.

10. *Alisporites indarraensis*, T36/1, A, 50 µm.

11. *Microbaculispora tentula*, X50/1, A, 35 µm.

12. *Alisporites indarraensis*, T36/2, A, 50 µm.

13. *Protohaploxypinus limpidus*, F57/3, A, 68 µm.

14. *Cycadopites cymbatus*, R35/1, A, 63 µm.

15. *Lophotriletes sparsus*, F32, A, 38 µm.

PLATE 2

1. *Vittatina* sp., H52/2, A, 50 µm.

2. *Horriditriletes ramosus*, K40/2, A, 30 µm.

3. *Horriditriletes uruguaiensis*, R34/1, 35 µm.

4. *Microbaculispora tentula*, W48/1, A, 35 µm.

5. *Deusilites tentus*, W47/1, A, 85 µm.

6. *Horriditriletes tereteangulatus*, N33, A, 35 µm.

7. *Cristatisporites* spp., F44, B, 44 µm, distal focus.

8. *Cristatisporites* spp., F44, B, 44 µm, proximal focus.

9. *Leiotriletes directus*, N47, B, 50 µm.

10. *Alisporites indarraensis*, M55, A, 60 µm.

11. *Striasulcites tectus*, J61, F, 38 µm.

12. *Alisporites indarraensis*, L50/4, B, 50 µm.

13. *Alisporites indarraensis*, Z46/3, B, 47 µm

14. *Vallatisporites arcuatus*, D38/2, 53 µm, distal focus.

15. *Vallatisporites arcuatus*, D38/2, 53 µm, proximal focus.

APPENDIX 1 Species author citations

Alisporites indarraensis Segroves 1969

Brevitriletes cornutus (Balme & Hennelly 1956) Backhouse 1991

Caheniasaccites ovatus Bose & Kar 1966

Converrucosisporites confluens (Archangelsky & Gamerro 1979) Playford & Dino 2002

Converrucosisporites grandegranulatus (Anderson 1977) Lindström 1995

Cycadopites cymbatus (Balme & Hennelly 1956) Segroves 1970

Deusilites tentus Hemer & Nygreen 1967

Horriditriletes ramosus (Balme & Hennelly 1956) Bharadwaj & Salujah 1964

Horriditriletes tereteangulatus (Balme & Hennelly 1956) Backhouse 1991

Horriditriletes uruguaiensis (Marques-Toigo 1974) Archangelsky & Gamerro 1979

Leiotriletes directus Balme & Hennelly 1956

Lophotriletes sparsus Singh 1964

Lundbladispora braziliensis (Pant & Srivastava 1965) Marques-Toigo & Pons 1976

Microbaculispora tentula Tiwari 1965

Protohaploxypinus limpidus (Balme & Hennelly 1955) Balme & Playford 1967

Striasulcites tectus Venkatachala & Kar 1968

Striatoabieites multistriatus (Balme & Hennelly 1955) Hart 1964

Vallatisporites arcuatus (Marques-Toigo 1974) Archangelsky & Gamerro 1979

Biopic:

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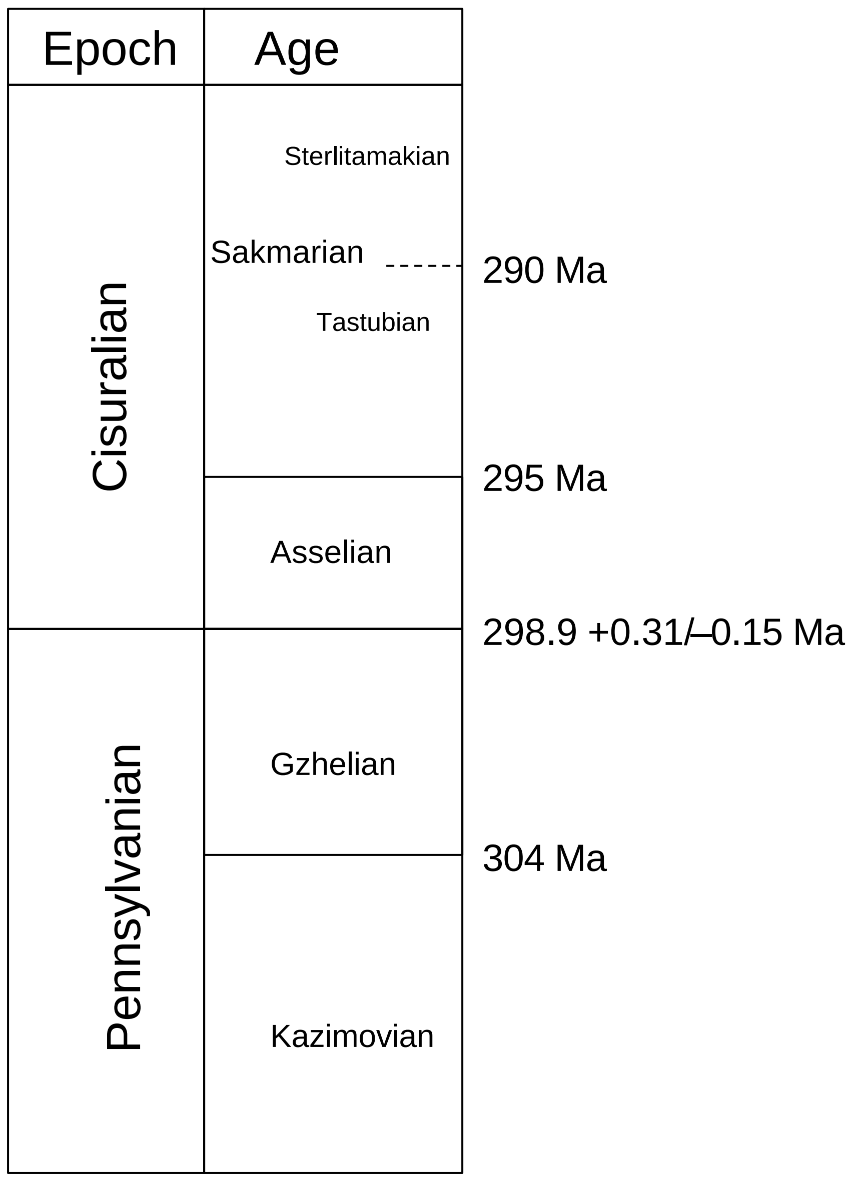
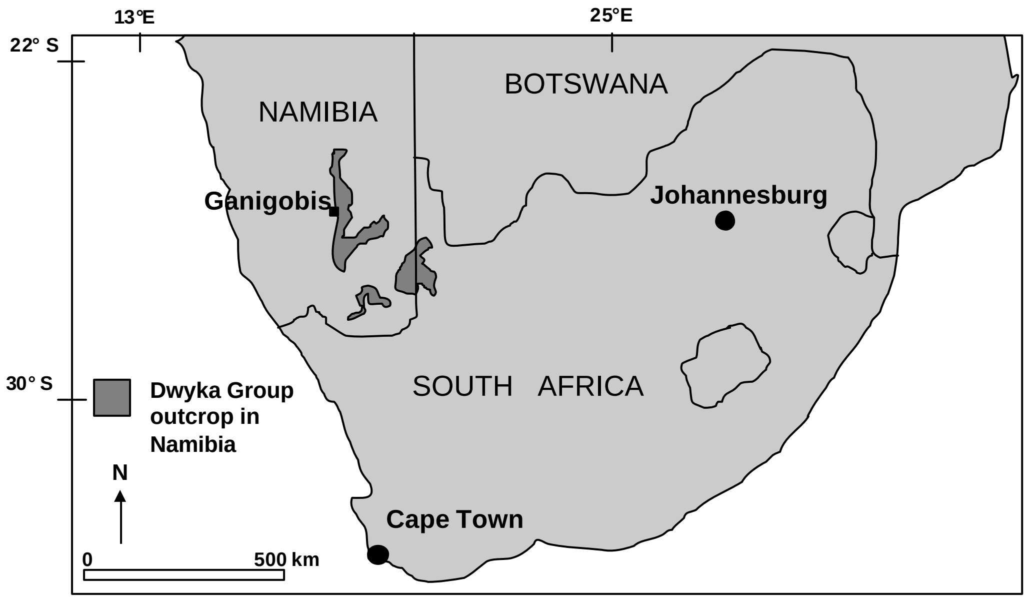
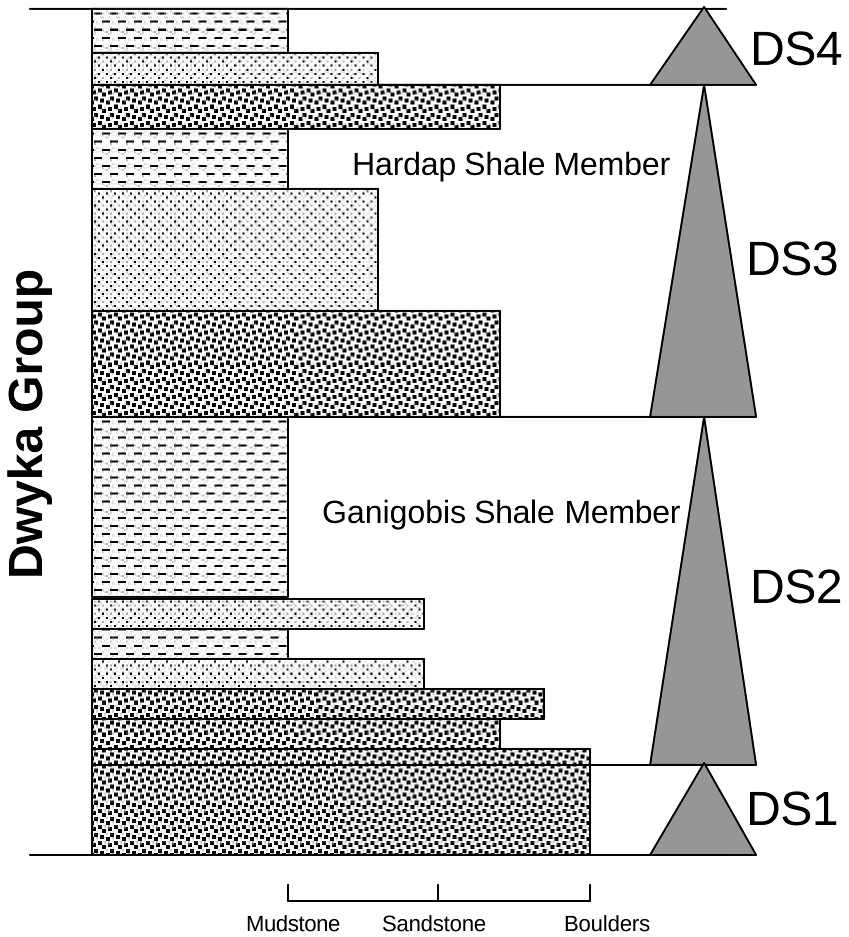
Arabia, and he has published a number of papers on this region as well as working extensively as a consultant for oil companies in the area. Mike is also involved in computing applications in stratigraphy, and the paleoecology, palynostratigraphy, and sedimentology of the Paleozoic of Africa, Australia, and northwest Europe. He has also published on the Paleozoic of Ireland, Scotland, and southern Africa. Mike is a member of AASP and the Petroleum Exploration Society of Great Britain (PESGB), was Secretary-General of the Commission Internationale de Microflore du Paléozoique (CIMP) between 2002 and 2008, and is presently Editor-in-Chief for paleopalynology of the *Review of Palaeobotany and Palynology*.


Epoch
Age
Sterlitamakian
Sakmarian
290 Ma
Tastubian
Cisuralian
295 Ma
Asselian
298.9 +0.31/–0.15 Ma
Gzhelian
Pennsylvanian
304 Ma
Kazimovian

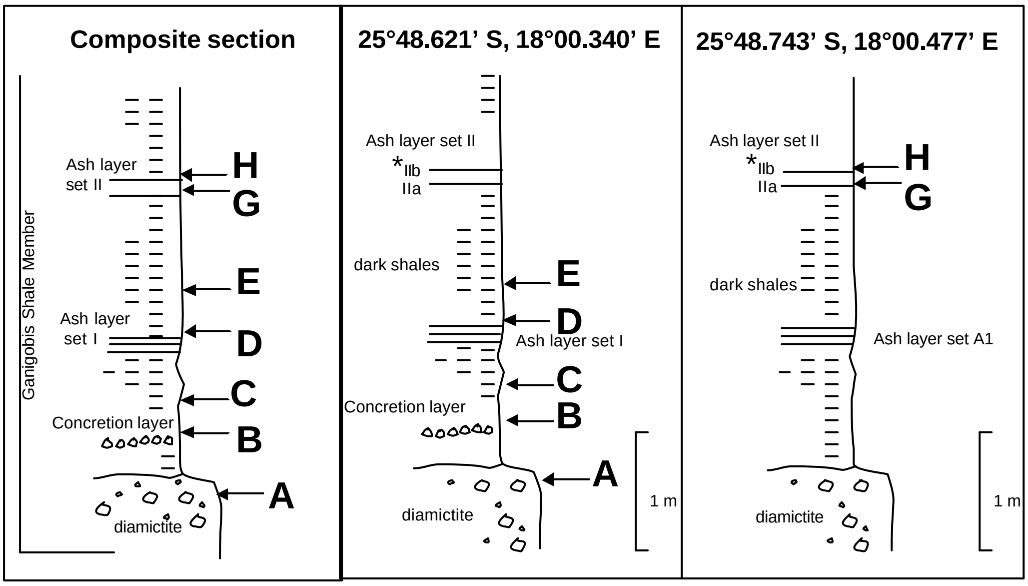
Text-Fig 1


13°E
25°E
22° S
30° S
NAMIBIA
BOTSWANA
Ganigobis
Johannesburg
SOUTH AFRICA
Dwyka Group outcrop in Namibia
N
Cape Town
0
500 km

Text Fig 2


DS4
Hardap Shale Member
DS3
Dwyka Group
Ganigobis Shale Member
DS2
DS1
Mudstone
Sandstone
Boulders

Text fig 3


Composite section
25°48.621' S, 18°00.340' E
25°48.743' S, 18°00.477' E
Ganigobis Shale Member
Ash layer set II
H
G
E
Ash layer set I
D
C
Concretion layer
B
A
diamictite
Ash layer set II
*IIb
IIa
dark shales
E
D
Ash layer set I
C
Concretion layer
B
A
1 m
diamictite
Ash layer set II
*IIb
IIa
H
G
dark shales
Ash layer set A1
diamictite
1 m

Text Fig 4

Fig 5

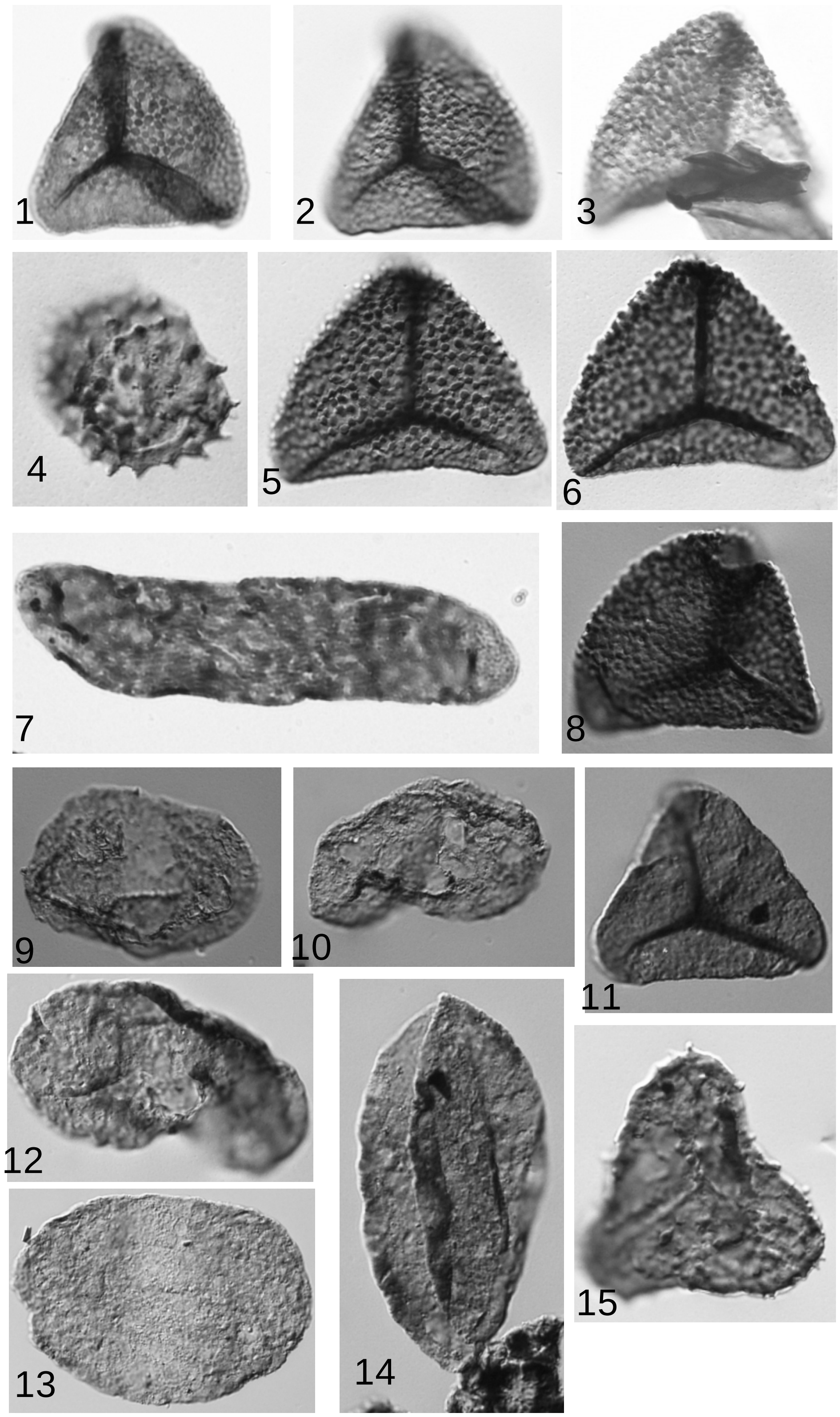


Plate 1

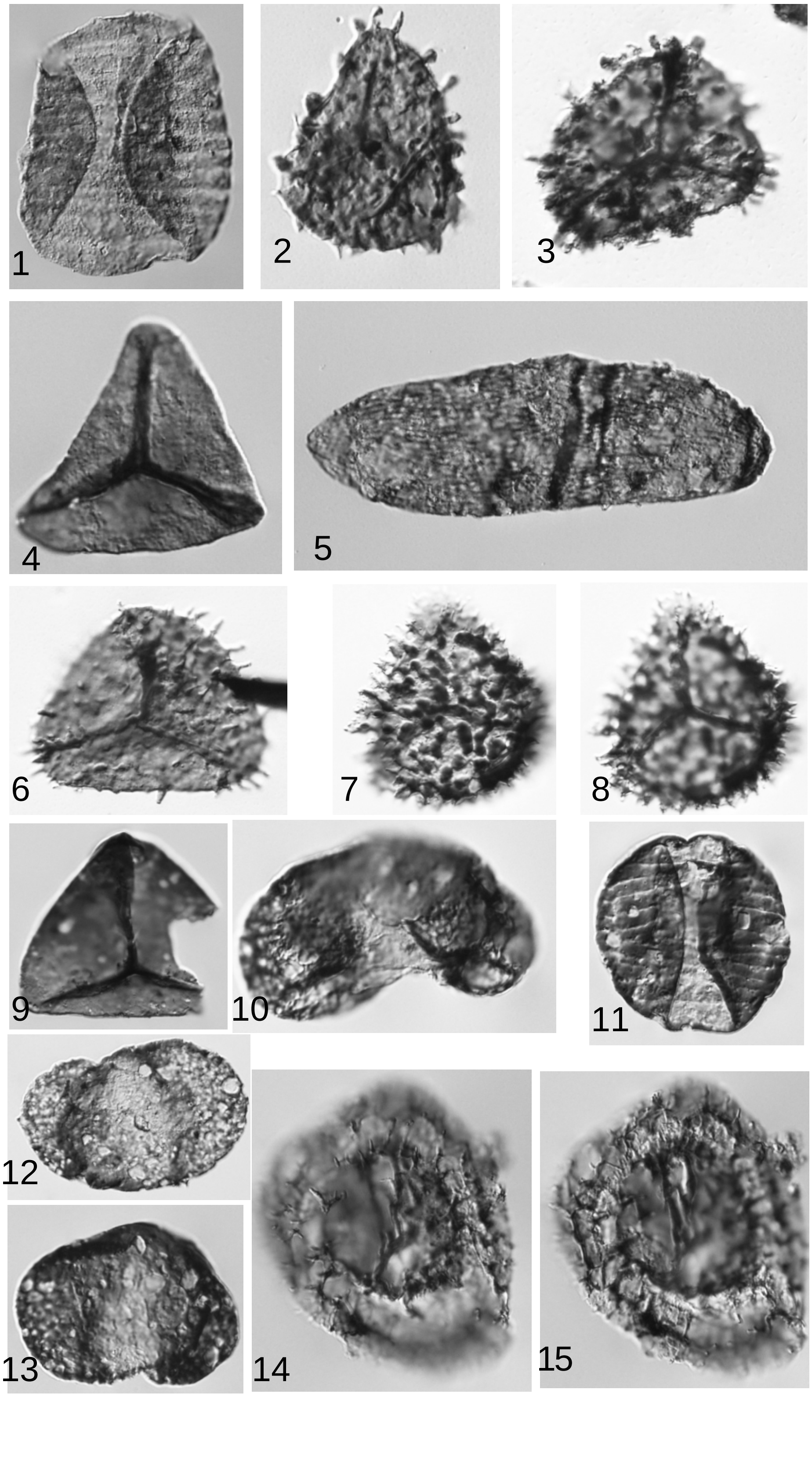


Plate 2