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Vascular plants from the Devonian to Lower Cretaceous in southern Africa

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ABSTRACT

The succession of pre-angiospermous megafloras in southern Africa from the Devonian to Lower Cretaceous is outlined. Interrelationships between continental drift, global climatic trends, and floral and faunal evolution are emphasized. Data are given on numbers of assemblages sampled; on species diversity; and on relative abundance of each genus per productive 'formation'. A total of 79 genera and about 250 species are recognized in the 150 assemblages from the 11 horizons considered. Floras are unknown from the Carboniferous and are as yet undescribed from the Jurassic. Aside from these gaps, a good idea of the floral development is obtained. Diversity lows of around 5 to 10 species per 'formation' are witnessed in the Devonian, whereas a peak of 112 species is encountered in the Upper Triassic Molteno Formation. Diversity remains around 20 to 30 species for all other 'formations'.

RÉSUMÉ

LES PLANTES VASCULAIRES DE LA PÉRIODE ALLANT DU DÉVONIEN AU CRÉTACÉ INFÉRIEUR, EN AFRIQUE DU SUD

La succession des mégaflores pré-angiospermes en Afrique du Sud du Dévonien au Crétacé inférieur est esquissée. Les relations entre la dérive des continents, les tendances climatiques globales et l'évolution de la flore et de la faune sont soulignées. Des informations sont données sur les nombres d'assemblages échantillonnés, sur la diversité des espèces, et sur l'abondance relative de chaque genre par 'formation' productive. Un total de 79 genres et environ 250 espèces sont reconnu dans les 150 assemblages des 11 horizons considérés. Les flores ne sont pas connues à partir du Carbonifère et ne sont pas encore décrites à partir du Jurassique. À part ces lacunes, une bonne idée du développement des flores est obtenue. Des normes de diversité d'environ 5 à 10 espèces par 'formation' sont observées dans le Dévonien tandis qu' un maximum de 112 espèces recontré dans la Formation Molteno du Triassique supérieur. La diversité demeure autour de 20 à 30 espèces pour toutes les autres 'formations'.

INTRODUCTION

This brief history of vascular plants, as seen particularly in South Africa, from their late Silurian origin to the rise to dominance of the angiosperms in the mid-Cretaceous, was first presented in embryo form at the AETFAT Congress in January 1982.

In order to fill out the story, which can only be partially pieced together from the current literature, we have since examined all the relevant collections housed in South Africa. It became evident also that certain formations needed to be further collected. We have organized several field trips to sample the Devonian Witteberg and Bokkeveld Groups, the Lower Triassic Burgersdorp formation, and the Lower Cretaceous Kirkwood Formation and equivalents. We have also drawn on the unpublished information of fellow palaeobotanists.

While undertaking this additional work, we decided to expand the contribution into a full Prodromus of the megaplants of South Africa from the Devonian to Lower Cretaceous. This has become a 300-page monograph, including a 150-page photographic catalogue of all taxa encountered; a taxonomic review of all forms; locality maps and discussion of the depositional environment of each formation; and biographical sketches of collectors. The Prodromus should be available soon after publication of the Congress Proceedings.

We are personally involved in a revision of the palaeoflora of the Molteno Formation, by far the richest horizon in number of localities and diversity of plants in South Africa. The first volume of that work, which includes a résumé of the whole flora, has been recently published. The Prodromus draws on this Molteno work but does not repeat the details.

The present paper is essentially a summary of the Prodromus. References are therefore excluded. Since the paper had to go to press before completion of the Prodromus, a few details will inevitably be altered in the later expanded version.

GLOBAL ENVIRONMENTAL TRENDS

First, we will consider very briefly the major global trends witnessed during the 300 million year interval with which we are concerned. This forms the backdrop to our story.

Continental drift

Over the past half billion years (500 million years) three clear phases of continental drift are discerned: the first in which a number of separate continents occur which are seen to be converging on one another; the second during which a single relatively stable supercontinent (Pangaea) exists; the third in which we witness the fragmentation of Pangaea and the drifting apart of newly delineated continents. Our 300 million year interval of plant evolution covers the latter part of phase one, the whole of the Pangaeic phase and the initial stages of fragmentation leading to phase three.

Global climatic trends

Equally dramatic climatic shifts are witnessed. Average global temperatures and precipitation have

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varied considerably. Very broadly the trend has been from medium temperatures and precipitation in the late Silurian; through to an extreme cold wet peak in the latter half of the Carboniferous with the development of extensive polar ice caps particularly in the south; followed by a long interval with the steady growth of ever warmer and drier conditions through to the Middle Cretaceous; from which time the trend was reversed till the present when polar caps once again exist.

It is a very significant fact that polar ice caps are a rarity rather than the norm in earth history. Only during such glacial intervals (e.g. later Carboniferous and the present) are global climatic belts strongly differentiated.

Global floras

The history of vascular plants is characterized by a succession of mass extinctions and evolutionary bursts. First in the succession came the psilophytes; then appeared the lycopods, horsetails and ferns; followed shortly after by the seed ferns (pteridosperms); from which probably arose the conifers, ginkgos and cycads and the now extinct bennettitaleans; and lastly, the highly successful flowering plants.

Global faunas

The animal world follows a parallel interdependent pattern of extinctions and radiations. The early amphibians and reptiles coincide approximately with the early pteridopytes; the mammal-like reptiles with the seed-ferns; the dinosaurus with the conifers, cycads and ginkgos; and finally, the birds and mammals with the flowering plants.

PRESERVATION AND SAMPLING OF PALAEOFLORAS IN SOUTHERN AFRICA

The evolutionary history of the vascular plants is pieced together from the differently preserved dissociated plant organs. Leaves, fruit and seeds, and certain stems are usually preserved as impressions in pale fine-grained sediments, more rarely as compressions with cuticle preserved in fine carbonaceous sediments. Pollen and spores occur by the millions as resistent cuticular coatings in carbonaceous sediments. Silicified stems occur in sandy sediments.

The table, figures and text presented here are based essentially on the first category, the foliage, reproductive structures and certain stem impressions. These have been most comprehensively sampled and studied.

Although this paper discusses southern Africa (taken here as Africa south of the Sahara), in general the story is essentially told on the basis of South African material. In each successive geological period by far the most frequently preserved, best sampled and most fully studied assemblages are from South Africa. Only in the Permian are relatively good occurrences known elsewhere in southern Africa.

Since southern Africa fell entirely within the Gondwana plant realm during the 300 million year interval discussed, and since floras during each period are broadly similar throughout the realm, we feel justified in basing our story on the South African material.

The collection of fossil plants in South Africa has been underway now for around 150 years. Amateurs and professionals alike have made their contribution. The outline of developing floras and the statistics on diversity presented, can probably be taken as reasonably comprehensive. In reading the following synopsis, refer to Table 1 and Figs 1 & 2.

SILURIAN (440–400 m. yrs)

Global geography

During this period the massive southern supercontinent Gondwana lay virtually entirely S. of 30°S, with the south pole situated approximately in today's Angola. A smaller Euramerican continent lay in the equatorial belt, with a 1 500 km arm of sea isolating it from Gondwana. A few minor 'Asian' landmasses lay further afield.

No ice caps adorned the polar regions. Global climates were equable with relatively weak differentiation of climatic belts. Temperatures and precipitation were of medium proportions.

Global flora

The vascular plants made their earliest appearance in the late Silurian (close on 400 million years ago) of the Euramerican equatorial belt. They are known from Wales, Czechoslovakia, New York State and W. Russia. These earliest pioneers, referred to the Psilophyta, were small, simple, little differentiated, homosporous, vascular plants with dichotomous branching, but with no leaves and no roots.

Southern African strata

Sediments of Silurian age are unknown in Africa south of the Sahara.

Southern African flora

The Gondwana landscape was entirely barren of vascular plant life at this period.

DEVONIAN (400–360 m. yrs)

Global geography

During the Devonian Gondwana drifted northwards, steadily narrowing the seaway between its northern shores and Euramerica. The latter remained more or less static in its tropical domain. The southern pole was, towards the close of the period, situated possibly in today's South West Africa/Namibia. Global climates remained much the same as during the Silurian, with the polar regions still devoid of ice caps.

Global flora

The Devonian saw the spread and diversification of vascular plant life with all landmasses becoming colonized. In the earlier Devonian we witness a dwarf vegetation. Nothing grew over a metre or so in height and psilophytes dominated. Floras throughout the world at this time were very similar, there being little evidence of provincialism. By the close of the Devonian more diverse communities, still of a

TABLE 1.— South African palaeofloras, sampling, diversity and relative abundance

	Bokkeveld	L-M Witteberg	U Witteberg	L Ecca	M Ecca	U Ecca	Estcourt	Burgersdorp	Molteno	Drakensberg	Kirkwood
BRYOPHYTA											
Buthelezia	-	-	-	-	-	-	1	-	-	-	-
Muscites	-	-	-	-	-	-	-	-	2	-	-
HEPATOPHYTA											
Marchantites	-	-	-	-	-	-	-	-	2	-	1
cf. Riccia	-	-	-	-	-	-	-	-	-	-	1
PSILOPHYTA											
Palaeostigma	3	4	-	-	-	-	-	-	-	-	-
Dutoitii	5	4	-	-	-	-	-	-	-	-	-
LYCOPHYTA											
cf. Zosterophyllum	3	-	-	-	-	-	-	-	-	-	-
Haplostigma	3	5	-	-	-	-	-	-	-	-	-
Archaeosigillaria	4	3	5	-	-	-	-	-	-	-	-
Leptophloeum	-	4	-	-	-	-	-	-	-	-	-
Drepanophycus	-	2	2	-	-	-	-	-	-	-	-
cf. Haplostigma	-	-	-	4	-	-	-	-	-	-	-
cf. Leptophloeum	-	-	-	5	-	-	-	-	-	-	-
Cyclodendron	-	-	-	-	4	-	-	-	-	-	-
Lycopodiopsis	-	-	-	-	4	-	-	-	-	-	-
incertae sedis	-	-	-	-	-	-	-	1	-	-	-
SPHENOPHYTA											
Annularia	-	-	-	-	1	2	-	-	-	-	-
Sphenophyllum	-	-	-	-	2	1	3	-	-	-	-
Raniganjia	-	-	-	-	-	2	2	-	-	-	-
Paracalamites	-	-	-	-	-	-	4	-	-	-	-
Phyllotheca	-	-	-	-	-	-	3	-	2	-	-
Schizoneura	-	-	-	-	-	-	2	-	2	-	-
Neocalamites	-	-	-	-	-	-	-	5	4	-	-
Equisetites	-	-	-	-	-	-	-	-	1	✓	-
FILICOPHYTA											
Calamophyton	-	1	-	-	-	-	-	-	-	-	-
Pecopteris	-	-	-	-	2	-	-	-	-	-	-
Sphenopteris	-	-	-	-	1	1	2	-	-	-	2
Cladophlebis	-	-	-	-	-	-	-	-	2	-	3
Todites	-	-	-	-	-	-	-	-	2	-	-
Asterotheca	-	-	-	-	-	-	-	-	3	-	-
Dictyophyllum	-	-	-	-	-	-	-	-	1	-	-
incertae sedis	-	-	-	-	-	-	-	1	-	-	-
INCERTAE SEDIS											
foliage gen. A	-	-	-	-	-	-	1	-	-	-	-
" gen. B	-	-	-	-	-	-	-	-	1	-	-
" gen. C	-	-	-	-	-	-	-	-	1	-	-
Drepanozamites	-	-	-	-	-	-	-	-	1	-	-
foliage gen. D	-	-	-	-	-	-	-	-	1	-	-
Kurtziana	-	-	-	-	-	-	-	-	2	-	-
Pachypteris	-	-	-	-	-	-	-	-	1	-	-
Ginkgophytopsis	-	-	-	-	-	-	-	-	2	-	-
Chiropteris	-	-	-	-	-	-	-	-	1	-	-
Onychiopsis	-	-	-	-	-	-	-	-	-	-	4
PROGYMNOSPERMS											
Platyphyllum	-	1	-	-	-	-	-	-	-	-	-
twig gen. A	-	1	-	-	-	-	-	-	-	-	-
" gen. B	1	-	3	-	-	-	-	-	-	-	-
" gen. C	-	-	4	-	-	-	-	-	-	-	-
PTERIDOSPERMS											
Gondwanidium	-	-	-	-	3	-	-	-	-	-	-
Gangamopteris	-	-	-	-	2	-	-	-	-	-	-
Palaeovittaria	-	-	-	-	2	-	-	-	-	-	-
Glossopteris	-	-	-	-	5	5	5	-	2	-	-
Dicroidium	-	-	-	-	-	-	-	5	5	-	-
Lepidopteris	-	-	-	-	-	-	-	4	3	-	-
INCERTAE SEDIS											
Taeniopteris	-	-	-	-	2	-	1	-	3	-	2
Yabeiella	-	-	-	-	-	-	-	-	3	-	-
Dejerseya	-	-	-	-	-	-	-	-	2	-	-
Saportaea	-	-	-	-	-	-	-	-	1	-	-
Linguifolium	-	-	-	-	-	-	-	-	1	-	-
foliage gen. D	-	-	-	-	-	-	-	-	1	-	-
" gen. E	-	-	-	-	-	-	-	-	1	-	-
CONIFERALES											
Walkomiella	-	-	-	-	2	-	-	-	-	-	-
foliage shoot gen. A	-	-	-	-	2	-	-	-	-	-	-
Noeggerathiopsis	-	-	-	-	4	3	2	-	-	-	-
foliage shoot gen. B	-	-	-	-	-	-	2	-	-	-	-
Rissikia	-	-	-	-	-	-	-	-	3	-	-
Heidiphyllum	-	-	-	-	-	-	-	-	5	-	-
foliage shoot gen. C	-	-	-	-	-	-	-	-	-	✓	-
Taxites	-	-	-	-	-	-	-	-	-	-	2
Brachyphyllum	-	-	-	-	-	-	-	-	-	-	3
GINKGOALES											
Psygmophyllum	-	-	-	-	1	-	-	-	-	-	-
cf. Nephropsis	-	-	-	-	1	-	-	-	-	-	-
cf. Phoenicopsis	-	-	-	-	1	-	-	-	-	-	-
Ginkgoites	-	-	-	-	1	-	-	1	3	-	-
Baiera	-	-	-	-	-	-	-	2	4	-	-
CYCADALES											
Pseudoctenis	-	-	-	-	-	-	-	3	3	-	-
Nilssoniopteris	-	-	-	-	-	-	-	-	1	-	-
BENNETTITALES											
Otozamites	-	-	-	-	-	-	-	-	-	✓	-
Zamites	-	-	-	-	-	-	-	-	-	-	5
Pterophyllum	-	-	-	-	-	-	-	-	-	-	3
Dictyozamites	-	-	-	-	-	-	-	-	-	-	2

GENERA INCLUDED

a. Foliage genera.
b. Stem impressions of plants not represented by foliage.
c. The mosses and liverworts, although not vascular plants, are included for completeness, since they occur in the same assemblages as the rest.

Fruit, seeds and silicified wood are excluded since their inclusion would amount to duplication of natural taxa. The aim here is to show diversity and relative abundance of natural taxa making up the communities of the deltas, swamps, river systems etc. of the periods in question.

GENERIC NAMES

The generic names applied here are those available in the most recent literature. Certain names will be altered, and unnamed genera formally described, in the Prodromus Volume mentioned in the Introduction. That volume will also include photographs illustrating all taxa; as well as more precise abundance and frequency data.

GEOLOGICAL HORIZONS

As included in Figs 1 & 2.

KEY

✓ present
1 very rare
2 rare
3 intermediate
4 common
5 dominant

Period	Geological formation or group	Assemblages (Mini assemblage)	(Total genera) Total species	Max. species per assemblage	Average species per assemblage
65 m. yrs.					
CRETACEOUS					
140	← Kirkwood	14(-)	(11)28	7	4
JURASSIC					
200	← Drakensberg	?	?	?	?
TRIASSIC	← Molteno	67(-)	(34)112	62	10
245	↖ Burgersdorp	13(21)	(8)18	15	4
PERMIAN	← Estcourt	24(-)	(12)22	13	5
	← U Ecca	2(-)	(6)16	9	7
	← M Ecca	10(-)	(18)32	23	12
300	↖ L Ecca	2(1)	(2) 2	2	2
CARBONIF.					
360					
DEVONIAN	← U Witteberg	9(5)	(4) 4	3	2
	← L-M Witteberg	6(8)	(9)12	4	2
400	↖ Bokkeveld	3(3)	(6) 6	2	1
SILURIAN					
440					

PRODUCTIVE HORIZONS

The geological horizons listed are all those in South Africa yielding useful and distinctive foliage (& stem impression) assemblages. Their rough positions within the geological periods are indicated.

ASSEMBLAGES

a. An assemblage is a collection of fossils from a distinct rock unit of restricted area and stratigraphical extent (lithosome).
b. An assemblage will generally represent the plants growing in the relatively near vicinity of the river channel, lake or swamp in which the fossiliferous deposit accumulated.
c. In the most productive, comprehensively sampled horizons (e.g. the Middle Ecca, Estcourt and Molteno formations) only those assemblages represented by numerous specimens have been considered.
d. In the least productive horizons (e.g. Bokkeveld, Witteberg and Burgersdorp), assemblages with down to 5 recognisable specimens are included. Mini-assemblages, with 1—4 specimens, are also taken note of to fill out the flora.
e. Assemblages have been collected from sedimentary pockets within the Drakensberg lavas. The material is housed in France and data for this table is not yet available. We hope that it will be so for the Prodromus (see Introduction).

DIVERSITY

a. Species diversity in a few instances includes infra-specific taxa.
b. We have for this work studied all relevant collections around the country. The statistics represent our own assessment of taxonomy, thus achieving a measure of internal consistency.

cosmopolitan nature, including larger trees, had evolved. Psilophytes, lycopods, ferns and progymnosperms were all in evidence.

Southern African strata.

The only known Devonian rocks in southern Africa outcrop along the southern Cape fold mountain belt and down the Natal and Transkei coastal region. Relatively narrow seaways occupied these now elevated stretches of country. A series of rivers disgorged sediments into the basins with a number of deltas forming. The Bokkeveld and Witteberg Group sediments (shales, siltstones and sandstones) of Middle and Upper Devonian age resulted.

South African flora

It is the plants of the communities occupying the river banks, flood plains and marshes of the deltas that were occasionally preserved. Fossil plant localities are infrequent. Only from a handful of localities can large well preserved collections be assembled, whilst the material is more normally found as isolated specimens or fragmentary debris. A total of 12 genera and 15 species of psilophytes, lycopods, a possible fern and a few possible progymnosperms are known. The floras were clearly dominated both in diversity and abundance by the lycopods which occur as stem casts and moulds. Assemblages are invariably of very limited diversity (maximum 3 species, average 2 species.)

Silicified stems and cuticular material remain unknown. The strata, having been subjected to intense folding and metamorphism, are unsuitable for spore and pollen preservation.

CARBONIFEROUS (360–300 m. yrs)

Global geography

The Gondwana supercontinent continued to drift northwards through the Carboniferous. Collision with Euramerica occurred around the middle of the period.

This had a profound effect on world climates. The ocean currents were radically redirected, the warm waters of the west flowing equatorial current being deflected north and south to high latitudes. With abnormal levels of evaporation at high latitude and consequent precipitation in the form of snow, an extensive ice cap of proportions like Antarctica today gradually built up. The ice covered the southern third of Gondwana, including all of southern Africa, which lay beyond 60°S. Simultaneously, copious rains fell along the steamy equatorial belt. Marked climatic belts developed.

Global flora

While southern Africa lay fallow beneath the ice, tropical Euramerica experienced perhaps the longest, wettest deluge in earth history. Extensive wet forest and swamp vegetation spread. Lycopods, sphenophytes, ferns and seed ferns were now co-dominants. The major coal deposits of the USA and Europe owe their origin to this tropical biomass explosion.

Southern African strata

Sediments of Carboniferous age remain unproven in Africa south of the Sahara.

PERMIAN (300–245 m. yrs)

Global geography

By the Permian the single supercontinent Pangaea had fully welded together and straddled the globe from North to South Poles. Much of Pangaea had shifted markedly northwards such that less of Gondwana lay within the Antarctic Circle. By the close of the Permian southern Africa stretched from 30° to 60°S with South Africa at 50° to 60°S.

The northerly shift, together with relatively minor changes in continental configuration, appears to have resulted in further dramatic climatic changes. The southern ice cap waned and disappeared in the Lower Permian. The water released by the melting ice flooded all low lying landscape. However, through the remainder of the Permian with the continued inward radial drive of the tectonic plates, Pangaea buckled upwards, and was steadily drained of all its shallow seas. The vast interior of the global continent became desertified.

Global flora

During the Permian four distinctive plant realms developed: Gondwana, Euramerica, Cathaysia, Angara. The Gondwana Realm occupied the greater part of Gondwana, and stretched from 30°S to 90°S with remarkably uniform communities growing throughout. Pteridophyta, and particularly the lycopods, were dominant during the early phase of flooding after the retreat of ice. The seed fern *Glossopteris* soon took over and became the overwhelmingly dominant and most diverse genus through most of the Permian throughout the realm. It was fully contained within the realm.

With the complete draining of the shelf seas and the massive desertification late in the Permian, marine and freshwater invertebrates were decimated as were the terrestrial plants and animals.

Southern African strata

The southern Africa which emerged after the retreat of the ice was significantly different from that which we saw during the Devonian, before the onset of the ice age. Basins and rifts galore appeared throughout the sub-continent. The succession of strata which filled these features — tillites, shales and coals, red muds and silts — is everywhere remarkably similar.

Southern African flora

The Permian period is unique in a number of respects. It is the only period for which a number of good megaplant assemblages are known to the north of South Africa. It includes, also, a greater number of productive horizons than any other period. It is in the Middle Ecca and equivalents of the Lower Permian that the vast coal reserves of the region occur.

Diversity reached distinctly higher levels in the Permian than in the Devonian. The Lower Permian

a. For South African data base see Table 1 and Fig. 2.
b. We have attempted to make a comparison between the pre-angiosperm diversity trends witnessed in South Africa and those for the Euramerican Plant Realm. The best opportunity for this is provided by the work of Knoll et al. 1979 and Niklas et al. 1980 for North America. Their data for North America is plotted below.
c. Unfortunately they do not define their useage of 'flora' or 'locality', nor do they provide 'average number of species per locality' data for all of their intervals. The ubiquitous intrusion of the 'species' problem must also be kept in mind.

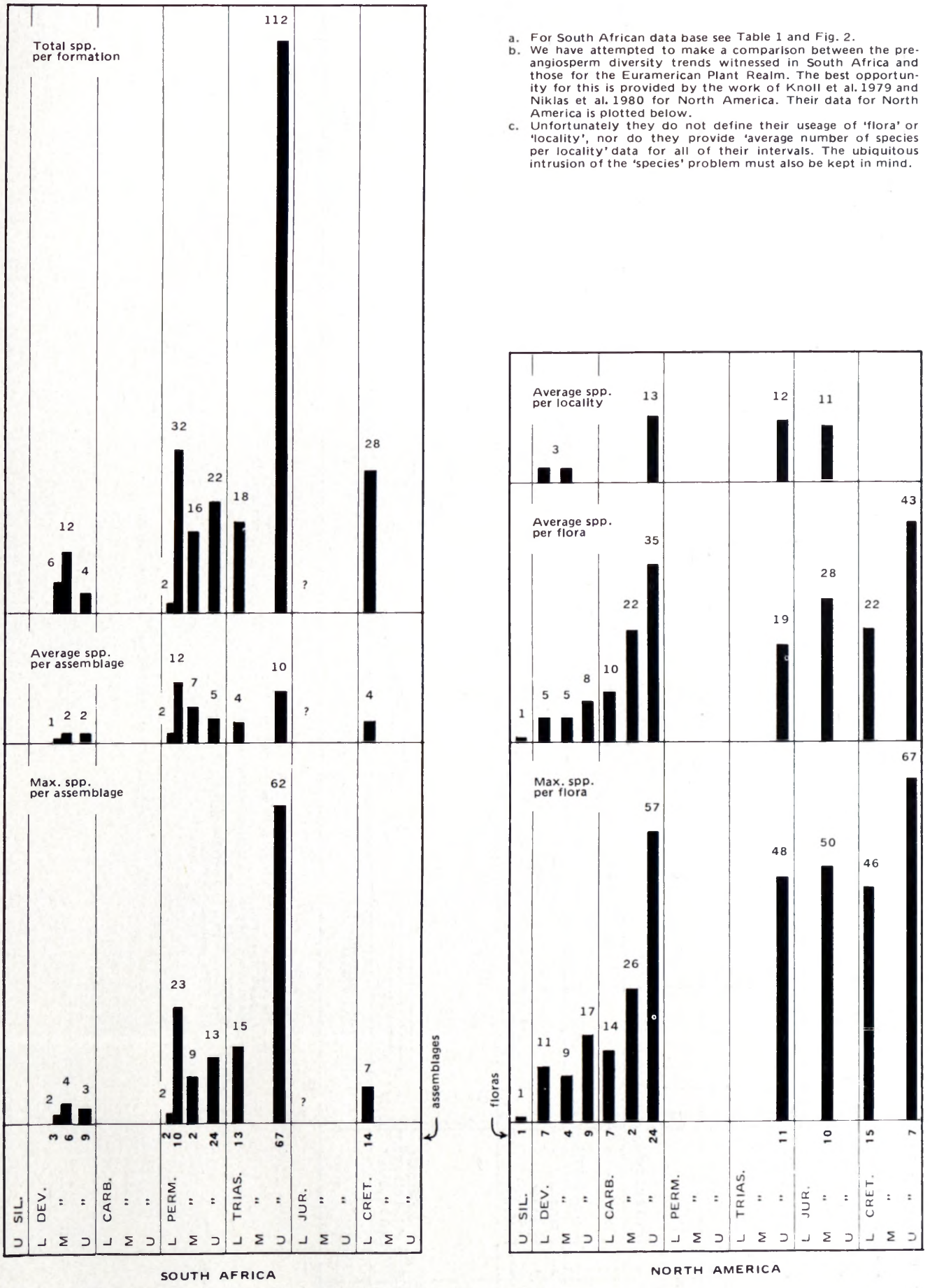

FIG. 1.—Diversity trends in pre-angiosperm fossil floras.

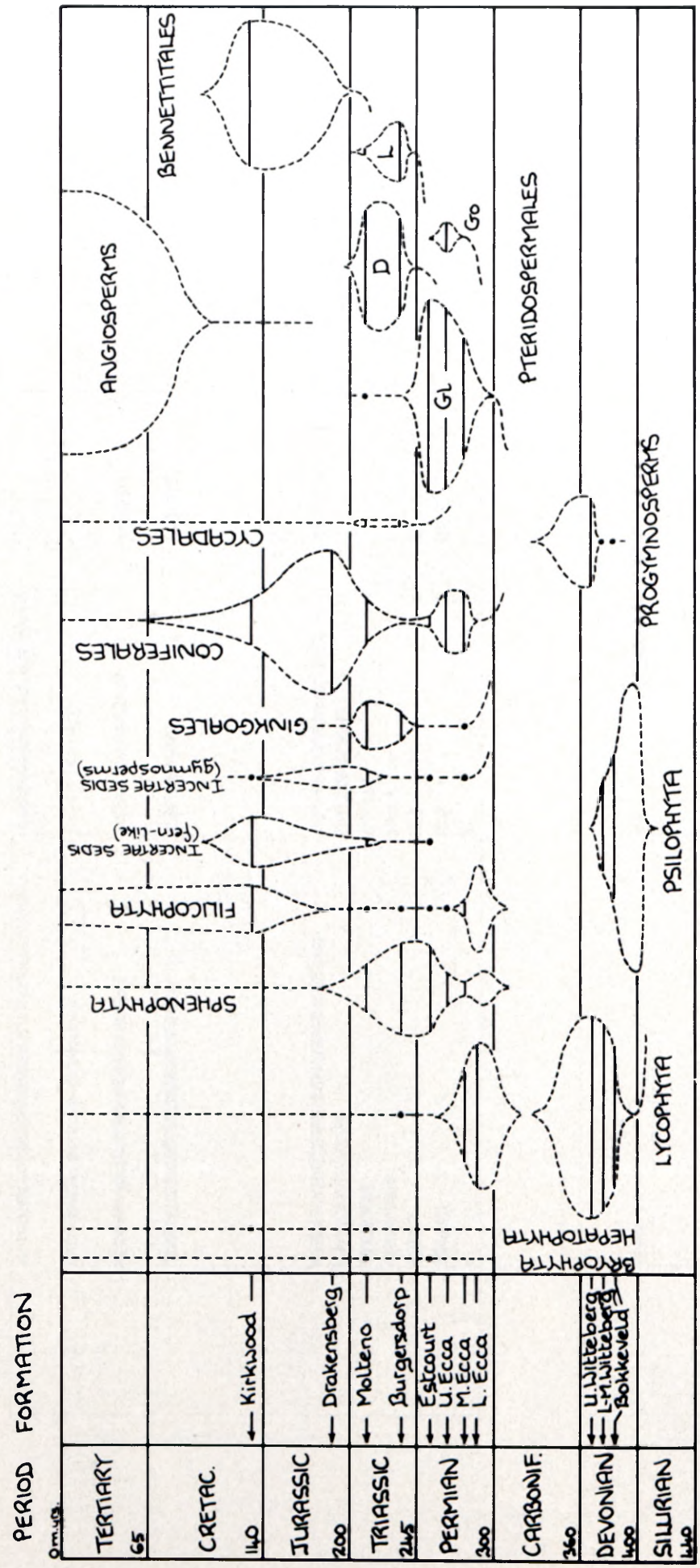

FIG. 2.—Evolution of vascular plants in South Africa.

coal measure flora consists of 18 genera and 32 species. After the initial short ascendent spell enjoyed by the lycopods, *Glossopteris* rose to dominance and maintained that role for a clear 30 million years. The sphenophyta steadily increased in significance throughout the Permian.

Good spore and pollen assemblages have been studied through a fairly complete Permian sequence both in South Africa and further north. These support and elaborate on the megaflora evidence in piecing together the patterns of floral history.

TRIASSIC (245–200 m. yrs)

Global geography

Pangaea appears much the same in shape and latitudinal position as it did during the Permian. The Permian/Triassic (Palaeozoic/Mesozoic) transition marked the turning point in the cycle of continental drift. From this time on the tectonic plates ceased their inward radial drive. There followed rebound and outward drift through till the present. Pangaea subsided in the Lower Triassic and all low-lying country was once again flooded.

The vast interior remained desertified. In the absence of polar ice caps latitudinal climatic belts were little differentiated.

Global flora

After the decimation of plant and animal life at the close of the Permian, a major shift in prominence of plant classes occurred. The pteridophytes were displaced by the gymnosperms. Ginkgos, conifers, cycads, bennettitaleans and new orders of seed fern became pre-eminent. During the early Triassic global flooding of low country, extensive low diversity lycopod groves spread (much as witnessed during the flooding in the early Permian). This was the swansong of the lycopods. With the general trend towards warmer drier climates through the Triassic, and indeed through the whole Mesozoic, the more diverse gymnosperm communities took hold.

Southern African strata

In southern Africa deposition occurred in rejuvenated Permian basins and rifts. Lacustrine, riverine and floodplain deposits accumulated intermittently through the Triassic. We visualize the highly fossiliferous Molteno Formation as being deposited in a situation not unlike the Okavango Swamps in Botswana: with rivers flowing inland and terminating in an extensive swampy depression bordering the desertic Gondwana interior.

Southern African flora

Although scattered megaplant occurrences are known elsewhere in southern Africa, by far the most productive deposits are confined to the Karoo Basin of South Africa. The Upper Triassic Molteno ranks as easily the most productive megaplant yielding formation of any age in South Africa. In total diversity (112 species), its flora is three to four times richer than the next most lucrative formation — the Middle Ecca with 32 species. The Molteno Formation is relatively carbonaceous in character (with minor coal deposits) and, as such, also yields excellent spore and pollen assemblages.

The Lower-Middle Triassic Burgersdorp Formation, the only other productive horizon of the period in South Africa, is altogether different. It is characterized by purple, green and buff coloured sediments and is primarily tetrapod (bone) bearing. Foliage and stem impressions occur only in the silty sandstones.

The Gondwana Triassic plant realm, including South Africa, follows the global pattern in that a wide range of gymnospermous plants, ginkgos, cycads, conifers and seed ferns, are prominent. As with *Glossopteris* in the Permian, *Dicroidium* (also a seed fern) was by far the most abundant, ubiquitous, diverse plant through most of the Triassic (some 30 m. yrs) throughout the realm. Also, like *Glossopteris,* it was confined to the realm.

JURASSIC (200–140 m. yrs)

Global geography

Pangaea appears outwardly much as it did during the Permian and Triassic. But during the Jurassic we see the first incipient signs, particularly evident in southern Africa, of its fragmentation.

Global flora

Coniferous forests clothed the landscape of the Jurassic. Ginkgos, cycads, bennettitaleans and ferns were common.

Southern African strata

During the earlier part of the Jurassic desert sands accumulated in the desertic Gondwana interior. Then another of those devastating events which coloured earth's history began. Out of the crustal fissures marking the start of fragmentation, poured lava flow upon lava flow. This apparently continued unabated for some 50 million years, but with shifting focus as new rifts opened up around southern Africa. On a geological map of southern Africa, we see only scattered remnants of these lavas. There would originally have been a more or less continuous blanket over the whole region south of the Zambezi. Similar volcanic activity was widespread throughout the extent of the Gondwana Realm.

Southern African flora

The potential for unearthing plant remains in desert sands and sheet lavas is not great. A few foliage and silicified wood assemblages are known in Lesotho in oases in the upper desert sandstones (Cave Sandstones or Clarens Formation) and lower lavas (Drakensberg Lavas). Several localities in Lesotho have been sampled by French palaeobotanists, but the data is as yet unavailable. The collections are apparently dominated by conifers, with sphenophytes and bennettitaleans also present. The silicified wood also suggests conifers.

LOWER HALF OF CRETACEOUS (140–100 m. yrs)

Global geography

During the Cretaceous, continental drift is clearly seen to be in motion. Ever widening rifts have opened up between the southern continents.

Southern African strata

Seas flooded into the rifts demarcating southern Africa. Marine sediments are seen to occur on the continental shelf surrounding the whole region. This offshore sedimentation continued more or less uninterrupted throughout the Cretaceous.

Outside of the massive Congo Basin, with its riverine and lacustrine sediments, continental deposits were rare. In the earliest Cretaceous, onshore deposits (the Kirkwood Formation and equivalents) occur in the Algoa Basin behind Port Elizabeth; in scattered smaller basins situated in the valleys of the Cape fold belt; and down the eastern coastal plains of Natal and the Transkei.

Global flora

In the first half of the Cretaceous the character of plant life remained much like that of the Jurassic, with conifers still dominant and the cycads, ginkgos, bennettitaleans and ferns common. Quite suddenly (in geological terms), around the middle of the Cretaceous, something dramatic once again occurred. The gymnospermous plants were ousted by the angiosperms (flowering plants).

Southern African flora

The assemblages from the Kirkwood Formation and equivalents comprise a more or less typical Lower Cretaceous flora. In this case, the bennettitaleans make up the greater part of the collections, with conifers and a variety of ferns and fern-like plants being common. The total species tally is 28; around the same order found in the Permian Middle Ecca.

Well preserved spore and pollen assemblages occur throughout the sequence of offshore and onshore Cretaceous deposits.

POST LOWER CRETACEOUS (100 m. yrs to present)

Global geography

From the Middle Cretaceous onwards the southern continental plates have drifted steadily apart and generally northward; North America and Eurasia have likewise drifted apart; certain north-/south collisions, between Africa and Europe, and between India and Asia, have occurred.

Global flora

The angiosperms have become ever-more dominant and diverse globally, till now we have some 200 000 species of vascular plants on earth with some 20 000 species in South Africa.

Southern African strata

Exposed continental sediments representing this last 100 million year interval of earth history are seldom encountered in southern Africa. The sub-continent has experienced general uplift with the products of erosion being carried away by rivers to be deposited offshore on the continental shelf.

Southern African flora

The best megafloras are preserved in the open vents of Kimberlite pipes of various ages. The full development of the flora will be most successfully traced by the study of the innumerable spores and pollen grains preserved in the continuous pile of sediments on the continental shelf. Samples are readily available from the borehole cores resulting from the drilling activities of the oil companies.