PALAEONTOLOGIA AFRICANA

ANNALS OF THE
BERNARD PRICE INSTITUTE
FOR
PALAEONTOLOGICAL RESEARCH
UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

VOLUME X 1967

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REPORT OF THE HONORARY SCIENTIFIC DIRECTOR FOR THE YEAR ENDED MARCH 31, 1966

This is the first full year of the Institute's possession of its new premises and during it the full-time staff, the associated scientists and various visitors have been able to carry out their duties and undertake their research studies in congenial and satisfactory conditions, although certain facilities which should be provided by a fully-equipped Institute are still lacking. The year has also seen the resumption of the publication of *Palaeontologia Africana*, of which Volume IX appeared, dated 1965. This contained 11 contributions with 57 text figures. Research studies in the fields of Pleistocene mammalogy, Karroo fossil vertebrates, palaeobotany, micropalaeontology, and the lithology and sedimentology of Karroo sediments have been pursued steadily, field work has been continued, and a large amount of preparation undertaken. In addition, the library has been considerably augmented by the purchase of a private geological and palaeontological collection of papers, periodicals and books made possible mainly by the generosity of a mining group (The Chairman's Fund of the Anglo American Corporation of South Africa Limited).

A brief review of the more important work undertaken during the year follows.

A. Field Work

By arrangement with the Committee that has been charged by the Government to undertake scientific studies within the areas of land that will, in course of time, be permanently flooded by the waters stored under the Orange River Development Project, the services of Mr. J. W. Kitching were made available for the study and collection of fossil material within the confines of the future Hendrik Verwoerd dam. During a period of three months (August—October 1965) Mr. Kitching collected remains of 410 Karroo vertebrates and, in addition, identified some 800 mammalian remains found in excavations made by the archaeologist attached to this scientific survey. The material thus obtained will be placed in a central "pool" in the National Museum at Bloemfontein, where it will be made freely available for study by interested specialists. The Karroo fossils come from the upper part of the Lower as well as from the Middle Beaufort stages (*Cistecephalus and Lystrosavrus* zones). During the coming year, the search for Karroo fossils will be extended to the Vanderkloof Dam area, which includes lower horizons in the Beaufort series; and arrangements have been made for housing the finds from this second area in the Institute.

Various members of the Microstratigraphy Research Unit have had shorter or longer periods of field work. Mr. P. Ryan has completed his observations relative to sedimentary directional trends within the Ecca sediments around the whole of the major Karroo basin. Mr. Stratten has studied Dwyka deposits, particularly in Natal. Mr. McKinney completed, in February, a year of field work at Vierfontein colliery, aimed at elucidation of the environment of coal deposition in Lower Ecca times. Mr. Cessford (a candidate for M.Sc.) completed a year of field work in the southern Karroo, conducted as part of an investigation into the oil possibilities of this region.

B. RUBIDGE MUSEUM

The Institute has full scientific and technical control of the collection of Karroo fossils gathered together by Dr. S. H. Rubidge. The history of this collection was outlined in a note published in *Palaeontologia Africana*, vol. IX, to which is appended a list of type and described specimens contained in it. Dr. Rubidge has reconditioned the old homestead at Wellwood so that it is now a museum fitted with display cases, storage accommodation, and neon lighting. Mr. J. W. Kitching has completed both the transfer of the whole collection to this museum and a complete catalogue of the material. This catalogue is housed at the museum, and a copy transferred to the Institute. A number of specimens were temporarily sent to the Institute during the year for further preparation and study.

C. LIBRARY

The provision of additional shelving has permitted a complete rearrangement of the books, periodicals, and separates whose numbers have been greatly augmented by purchase and by exchange. A card catalogue of the holdings is being maintained. The tasks of incorporating acquisitions and of cataloguing have fallen upon the Institute's scientific personnel and have occupied a considerable amount of time that would otherwise have been devoted to research studies.

D. TEACHING

The institution by the University of an Honours course in Palaeontology within the Department of Geology has involved the Institute closely in the teaching activities of the University. A syllabus has been accepted. For this first year, one student registered within the Department for the course and, in addition, the Microstratigraphy Research Unit (financed by mining groups) consisting of two Research Assistants, one Ph.D. candidate, and three M.Sc. candidates worked in the Institute under the supervision of the Senior Research Fellow, Dr. G. F. Hart. Two Honours students of the Department of Botany received part-time instruction in palaeobotany.

Two research students from France—Miss Mendrez and Miss Sigogneau—spent part of the year working in the Institute under the control of Dr. A. S. Brink, preparing theses for their higher degrees.

At the undergraduate level, teaching has been carried out in the Departments of Geology, Botany, Anatomy, Zoology, and Archaeology.

E. Research

(1) *Palaeoanthropology*—Under the guidance of Emeritus Professor R. A. Dart, work has proceeded at the Limeworks site at Makapansgat, defining the extent (approximately 3 acres) of the hillside which represents the ancient australopithecine cavern deposit, by tracing the junction of the dolomite rear wall with the cavern breccia (pink or upper phase 1 of C. K. Brain). Secondly, the surface material has been removed, in 6½ ft. square grids, from the excavation area in a controlled manner so that from each square all stone fragments bearing on the artefact issue have been recovered. Thirdly, the contents of all surface solution pits (ranging from 6 ft. to 13 ft. in depth) have been systematically cleared with archaeological precision and their contained artefacts collected.

During the year a series of 7 papers was published in the South African Archaeological Bulletin, vol. 20, describing results obtained prior to 1965 from preliminary work on the lines outlined above. These papers were written by C. K. Brain, T. C. Partridge, B. Maguire, A. K. Boshier, and R. A. Dart.

At the instigation and under the direction of Professor Dart there has been produced a topographic map of a considerable area of country which includes the Makapansgat Valley. The map is based on photography carried out by the Aircraft Operating Company in May, 1963. Ground control was established by Messrs. Van Rensburg, Steyn and van der Hofen of Potgietersrust and contours (at 25 ft. intervals) and planimetry by Mr. G. E. Belline of the University, using a Wild A7 Stereoplotter. Drafting of the map was done by Mr. N. T. Miller of Johannesburg, while T. C. Partridge acted as liaison between the photographic, plotting and drafting aspects of the project.

Within the Sterkfontein area, near Krugersdorp, debris from earlier excavations has been examined and removed and significant material has been collected for further study. This site is under good supervision. A museum is being erected within the area and it is expected to be ready in time for the function commemorating the centenary of the birth of Dr. Robert Broom.

(2) *Vertebrate Palaeontology*—Four papers on fossil mammals and four on Karroo reptiles appeared in Volume 9 of *Palaeontologia Africana*. Miss Mendrez of France continued with her studies of the Whaitsiidae and Miss Sigogneau, also of France, with her work on the Gorgonopsia. The preparation of these two monographs has been facilitated by the co-operation of the Directors of other museums in South Africa in which specimens of these groups are housed.

Various specimens of Karroo reptilia have been adequately prepared for study and are ready for description.

The "Bibliographic list of Karroo Reptilia", published as Vol. 2 of Palaeontologia Africana in 1954, requires to be brought up-to-date. Dr. Brink has therefore taken steps to prepare, with the assistance of collaborators, a more comprehensive review which will include not only a formal bibliography but also information regarding morphological details of each of the known specimens assigned to a particular species accompanied by illustrations. His concept is to produce a loose-leaf series in which each paper will have a standard layout, each page representing a single presently-accepted species. Instead of combining the information into a single bound volume, the concept is to issue such loose leaves in batches as the information becomes available.

(3) *Palaeobotany*—Dr. E. P. Plumstead has completed an extensive monograph, illustrated by many photographs, on the Fossil flora of the Cape system. This is ready for publication, but the necessary funds to finance it have not yet been found. She has also completed a report on fossil plants from the Waterberg coalfield of the Transvaal, which has been submitted to the Geological Survey of South Africa.

(4) *Micropalaeontology*—Dr. G. F. Hart contributed a paper on "Miospore Zones in the Tanzanian Karroo Strata" to vol. 9 of *Palaeontologia Africana* and, with R. N. Pienaar and R. Caveney, one on "An Aragonite Coccolith from South Africa" to vol. 61 of the *South African Journal of Science*.

Miss M. L. de Gasparis almost completed her studies of foraminifera from the Upper Cretaceous beds of Zululand and is extending the range to include the Lower and Middle Cretaceous beds. With financial help from the Anglo-Vaal group she was able to spend six weeks in Lourenço Marques, consulting the International Catalogue of Foraminifera in order to obtain the correct Linnean nomenclature for the forms examined by her.

Mr. R. N. Pienaar worked on Cainozoic and Recent Coccolithophoridae of the Natal coastal belt and has in the press a paper on microfossils from the Cretaceous system in Zululand studied with the aid of the electron microscope.

F. Visitors

The Institute has again been visited by a number of scientists from overseas countries interested in one or other aspect of its work, and spending various periods of time in discussion or in the examination of material. The signatures of 28 of them are in the Visitors' book; but, in addition, several hundred members of the public, school children, and University students have during the year been conducted around the Institute.

G. Overseas Visits

Dr. Plumstead was overseas for some months, attending the International Botanical Congress in Britain and the International Geological Congress in India, as well as visiting and studying fossil plant collections in various institutions. In India she substituted for Dr. S. H. Haughton as President of the Sub-commission on Gondwana Stratigraphy and, on her return to South Africa, took over the duties of Secretary of this Sub-commission.

Dr. G. F. Hart attended the Executive Meeting of the International Committee for the Microflora of the Palaeozoic in Sheffield. He was also appointed as the South African representative for the "micropalaeontology of bottom sediment" section of S.C.O.R.

H. Suggestions for future running of Institute

At present the research work at the Institute is divided among four separate units which derive financial support from several different quarters. Although harmony exists among the personnel who staff these units, it seems desirable that the Board should consider methods to achieve a closer official co-ordination of their efforts and to realize the principle of making the Institute a unitary organisation instead of a federation of more or less self-dependent units consisting of scientists whose emoluments come from differing sources and who are thus individually primarily responsible to these sources. All are housed under one roof and all make use of such facilities as are available; but collaboration and co-operation in investigations depend upon personal rather than official considerations.

A second point that should be brought to the Board's attention is the burden that rests on the two permanent members of the Institute's staff—Dr. Brink and Mr. Kitching—in their responsibility for the day-to-day administrative matters such as correspondence, control of the library, maintenance and the repair of both equipment and the building fabric, and even attendance at the telephone internal exchange system. Dr. Brink is primarily ranked as Assistant Director and a Research Officer; Mr. Kitching is a Field and Technical Officer. Neither should be forced to spend a considerable amount of time on work that could be adequately performed by a person who could combine the functions of a Secretary and a Librarian together with another person ranked as a handy-man (or ordinary technician).

In the third place, the Board's attention is drawn to the lack of certain facilities that, if acquired, would assist workers in their investigations. One of these is a properly equipped dark-room for photographic purposes; another is a chemical laboratory with fume-cupboard, a desideratum particularly in request by the researchers in palaeobotany and micropalaeontology.

I commend these suggestions to the Board's consideration.

S. H. Haughton
May 20, 1966

REPORT OF THE HONORARY DIRECTOR FOR THE YEAR ENDING 31st MARCH, 1967

The year under review, ending on 31st March, 1967, has to some extent been a less happy one for the Institute and its work than those preceding it. Half-way through the year we lost the services of Dr. A. S. Brink, the Assistant Director and expert on Karroo Reptilia, who resigned in order to assume the directorship of the Museum of Man and Science in Johannesburg, an organization that is as yet in embryo and which Dr. Brink will have to nurture *ab ovo*. Dr. G. F. Hart, micropalaeontologist, who worked in the Institute as an employee of a mining house and who had studied particularly the microfauna and microflora of Karroo sediments, also left the country at the end of June in order to take up a post at the University of Louisiana. No replacement for Dr. Brink has been found as yet, although steps are being taken to that end; but in November Dr. R. J. Davey, of Nottingham and Sheffield Universities, assumed duty as a C.S.I.R. Research Fellow for work in micropalaeontology, having obtained a knowledge of the necessary techniques associated with the preparation of specimens at a concentrated course prior to his departure from England.

Buildings. The Institute is housed in the building that was formerly the Bantu Students' Hostel of the University and, with some alterations and additions, it has proved adequate for our present requirements. It has been agreed that the maintenance of the building will be undertaken by the University Maintenance Department. The former Matron's suite was for some time occupied by a Visiting Professor, with University approval; but, on his departure at the end of 1966, approval was obtained for its occupation by Mr. James Kitching and his family in his capacity as custodian of the Institute's collections of books and fossils. Plans were adopted for the conversion of certain rooms in one of the wings into an office, laboratory, and preparation room for the micropalaeontologist; but the necessary structural changes and additional furnishing were delayed for about three months. This delay is regrettable, as Dr. Davey has been forced to divide his time between work in the Institute and work in the Department of Geology of the University.

Dr. Plumstead controls the work of 4 research students in the Institute. The accommodation allocated for this purpose consists of one room, formerly used as a Board room; but it is very badly lit and requires additional plugs for lighting microscopes. Our requirements have been made known to the University Maintenance Officer who has approved of suggested alterations made to him by Mr. Kitching. To date no steps have been taken to effect these.

Research Work. In the field of fossil plants, Dr. E.P. Plumstead, who is a C.S.I.R.

Research Fellow, completed an important survey of the fossil plants of the Cape system, which will be published as a volume of *Palaeontologica Africana*. In the course of this review she studied a considerable number of specimens loaned to her by the Geological Survey of South Africa. Both this body and the C.S.I.R. have decided to contribute financially towards the cost of its publication. Dr. Plumstead has also prepared a review of recent literature on fossil plants of the Karroo system, which will be issued as a background paper for a symposium on the Gondwana system which will be held under the auspices of the International Union of Geological Sciences in Argentina in September—October 1967.

For this same symposium, reviews of literature have also been prepared by Drs. Brink and Haughton (on Karroo vertebrates) and by Mr. P. Ryan (on Ecca sedimentology), of the Institute's personnel.

In the field of micropalaeontology Miss M. A. L. de Gasparis has completed an examination of the foraminifera contained in a core from a borehole sunk through Cretaceous rocks near Lake Sibayi in Zululand and has made a statistical comparison of assemblages of various levels in the upper 525 feet of these rocks, enabling her to classify them from below upwards as belonging to the Campanian, Maastrichtian, and Upper Maastrichtian sub-divisions of the upper Cretaceous. She has submitted to the University her results in the form of a dissertation for the M.Sc. degree, consisting mainly of systematic description of foraminiferal species and morphotypes, illustrated by line drawings. Before his departure, Dr. Hart completed a report on the microfossils of parts of the Karroo system. This was handed to the mining company who financed his work. During the year he published some short notes on some aspects of Karroo sedimentation.

This subject was intensively studied in the field by Mr. T. Stratten who worked on the Dwyka series and by Mr. P. Ryan who worked on the Ecca series. Both of these post-graduate students have produced maps showing palaeocurrent directions within the main Karroo basin, based on the lithological variations in the sediments, the types and directions of cross-bedding, and the nature of ripple-marked surfaces. Mr. Ryan's studies embraced also the sedimentology within the Waterberg coal-field of the north-western Transvaal.

Certain groups of Karroo reptilia were studied during the greater part of the year by two visiting research workers from Paris—Mlles. D. Sigogneau and C. Mendrez. For their purposes, certain specimens from the Rubidge collection were brought to the Institute, where additional work on the removal of adherent matrix was carried out, enhancing considerably their scientific value. The results of the work undertaken by these two investigators have been submitted as dissertations for higher degrees at the University of Paris.

The services of Mr. J. W. Kitching were again made available to the Scientific Co-ordinating Committee of the Orange River Development Scheme, primarily for the collecting of Karroo fossils from the areas that will become flooded after the completion of the Hendrik Verwoerd and Van der Kloof dams. In all, 553 well preserved Karroo reptilian skulls have been collected from strata that appear to belong to the *Cistecephalus* zone of the Lower Beaufort stage, in addition to fossil plants and fossil wood from some 500 feet of shales belonging possibly to the Ecca series. Accurate systematic determinations of the skull material will be possible only after the specimens have been properly prepared. Arrangements have been made for part of the collection to be housed in the Institute.

Mr. Kitching also examined, on behalf of the Institute, exposures on three farms in the Bethulie district, which proved to belong to the *Lystrosaurus* zone (Middle Beaufort stage) and yielded 40 well-preserved reptilian specimens. These included four very large *Lystrosaurus* skulls, a small skull of the specialized genus *Chasmatosaurus*, and a skull and skeleton of *Ictidosuchops*. Mr. Kitching prepared, for publication in the South African Journal of Science, a paper on his investigations into the Beaufort beds at the Hendrik Verwoerd dam area.

Dr. Drysdall, of the Geological Survey of Zambia, supplied information on material obtained by him in the southern sector of the Luangwa valley.

Research on Pleistocene mammalia has continued throughout the year under the control of Dr. R. A. Dart who had conferred on him by the University the title of Honorary Research Associate of the University in recognition of his "international distinction as a physical and palaeo-anthropologist" and of his active collaboration in the research programme of the Institute. The preparation of bones from the blocks of limestone emanating from the Limeworks excavations at Makapansgat has continued throughout the year.

In addition, Mr. Garth Sampson, the archaeologist who has been excavating rock shelters in the region of the Hendrik Verwoerd dam, submitted for identification some 300 mammalian specimens collected by him from these shelters.

Mr. A. W. Keyser started, at the beginning of 1967, to work on certain Karroo reptiles as a post-graduate student of the University, on study leave from the Geological Survey.

Mr. F. Jenkins of the Yale University spent a month in the examination of cynodont post-cranial material in the Institute's collection.

Mr. J. Anderson, a B.Sc. Honours student, has worked on both mammalian material from cave deposits and on mammal-like reptiles.

GENERAL

Despite the set-backs consequent upon the departures of Drs. Brink and Hart from the effective staff, research work on the various spheres of activity covered by the Institute has progressed steadily.

Control of and easy access to individual specimens within the stored collections has necessitated the design of a simplified system of registration, a task that was undertaken by Mr. Kitching. The many additions to the library contents demand not only a pre-arrangement in the accommodation but also a more intensive card-cataloguing under subject headings; this task awaits the appointment of a competent librarian.

It is but just, at this stage, that I should record with appreciation the enthusiastic attention to the Institute's well-being displayed by Mr. J. W. Kitching who, during the past few months, has taken upon his shoulders many of the day-to-day tasks formerly borne by the Assistant Director and has performed them competently.

S. H. Haughton

A GENERAL REVIEW OF THE DEVONIAN FOSSIL PLANTS FOUND IN THE CAPE SYSTEM OF SOUTH AFRICA

by Edna P. Plumstead

CONTENTS

SECTION III DESCRIPTION OF THE FOSSIL PLANTS

SECTION IV CONTROVERSIAL ALGAL FOSSILS

SECTION V SUMMARY OF THE FOSSIL FLORA OF THE CAPE SYSTEM

SECTION I—INTRODUCTION

A. REASONS FOR REVISION

Revising the work of early scientific pioneers is an unenviable task but one which becomes a necessity when erroneous identifications outweigh the constructive value of the older work, often leading inevitably to wrong conclusions about age and relationships.

The necessity for a complete revision of the fossil plants occurring in the predominantly Devonian formation known as the Cape System has long been apparent. The more important reasons for undertaking this task at this time are summarised below:

1. The Inadequacy of Previous Records

The earliest records were not only very meagre but often inaccurate and since they have never been refuted they are still quoted. For example, as far back as 1870 specimens were sent from Grahamstown to the British Geological Survey for identification since the possibility of exploitable coal measures in the Bathurst area had been envisaged. The identifications were made by Bristow and included the following: *Sigillaria*, *Stigmaria*, *Lepidodendron*, *Lepidostrobus*, *Halonia* and *Selaginites*. *Not one of these genera is now known to occur in the Cape System.* The reasons for the wrong determinations are not now known. Specimens from another country may have been mixed up but the list was quoted by Feistmantel (1889, p. 26,) by du Toit (1926, p. 198) in his first edition of the "Geology of South Africa" and quoted by Mountain (1962) in the most recent description of the Port Alfred stratigraphy. In this way the error has been perpetuated.

No attempt at a general summary of early plant fossils has been made since the publication of papers by Seward (1903) and Schwarz (1906). A few of the plants were discussed further by Seward (1909 and 1932) but even the genera named by these authors have been subdivided and often renamed. Reliable references are rare and illustrations even more so, with the result that modern field geologists usually resort to calling any plant fossil in the Cape System "an unidentifiable stem".

2. The availability of new material

In the course of remapping portions of the Cape Province a number of new specimens have been found which the Geological Survey has kindly placed at my disposal. These added to the old museum and survey collections have made it possible to envisage a whole flora.

3. The importance of South African fossil floras in World Stratigraphy

Of growing importance in world stratigraphy is the comparison of every aspect, and at every stage of the geology, of various southern continents. In this, plant fossils must play a major role in formations which lack the usually more numerous and easily comparable marine invertebrate remains. The plant records of the upper part of the Cape System provide valuable evidence of the age of the formation and in addition furnish evidence of former land areas for palaeogeographical reconstructions.

Caster (1952) in discussing South American and South African relationships wrote "It is critical to such a correlation that the little known terrestrial flora of the Dwyka and Witteberg should be restudied". Similar views are shared by many.

4. Evolutionary Significance

From an evolutionary point of view the Devonian was a critical period for, in the course of it, the greatest experiment in the history of plant life occurred. Plants which had previously lived almost exclusively in an aquatic environment appeared in considerable numbers on land.

Plant life at this transition period had many features in common so that a closer relationship is apparent between Devonian plants throughout the world than between those of any subsequent period. In recent years interest in early land plants has increased enormously and much detailed investigation has been undertaken. A wealth and variety of Devonian plants is now known, sometimes in considerable anatomical detail, from parts of North America and of Europe and, because of the general similarity, comparisons with the Cape fossils are possible at the generic level. Nevertheless it must have been at this time that the foundations were laid for the separate development which later characterised the plant life of the northern and southern groups of land. A study of the Cape fossil plants could determine whether the subsequent changes were due to differing environmental factors acting on a common stock or to some inherent differences in the early floras themselves. This aspect will be considered further in the Summary.

5. The importance of palaeontological records in the current search for oil in South Africa

Finally the importance of all palaeontological records in the very accurate stratigraphical correlations attendant on oil investigations is obvious. The deep drilling programme currently being undertaken in the Cape Province and elsewhere in the Republic gives the present investigation an economic interest which could not have been claimed previously.

B. THE MATERIAL STUDIED

1. Difficulties of classification

Despite the great desirability of compiling an up-to-date record of the early plant life of Africa the task is a difficult one for in the predominantly arenaceous rocks of the Cape System the degree of preservation of plant matter tended to be limited in the first instance to the more resistant portions, and was further masked by the intensity of pressures during the subsequent orogenic folding of the mountain belt. The area is extensively mountainous and often extremely rough—the magnificence of the scenery being a measure of the difficulties of traversing it and I have been unable to undertake extensive field collecting.

2. Source of the fossils described and acknowledgements

The study is based on fossil plant collections at the Albany Museum in Grahamstown and at the South African Museum in Cape Town. In the latter museum are housed most of the plant fossils collected by geologists of the Geological Commission of the Cape of Good Hope before 1910, and, after Union, by members of the Geological Survey of South Africa. I am greatly indebted to the Directors of these museums for the opportunities provided to examine their collections and especially for the loan of a number of specimens for more detailed study and photography.

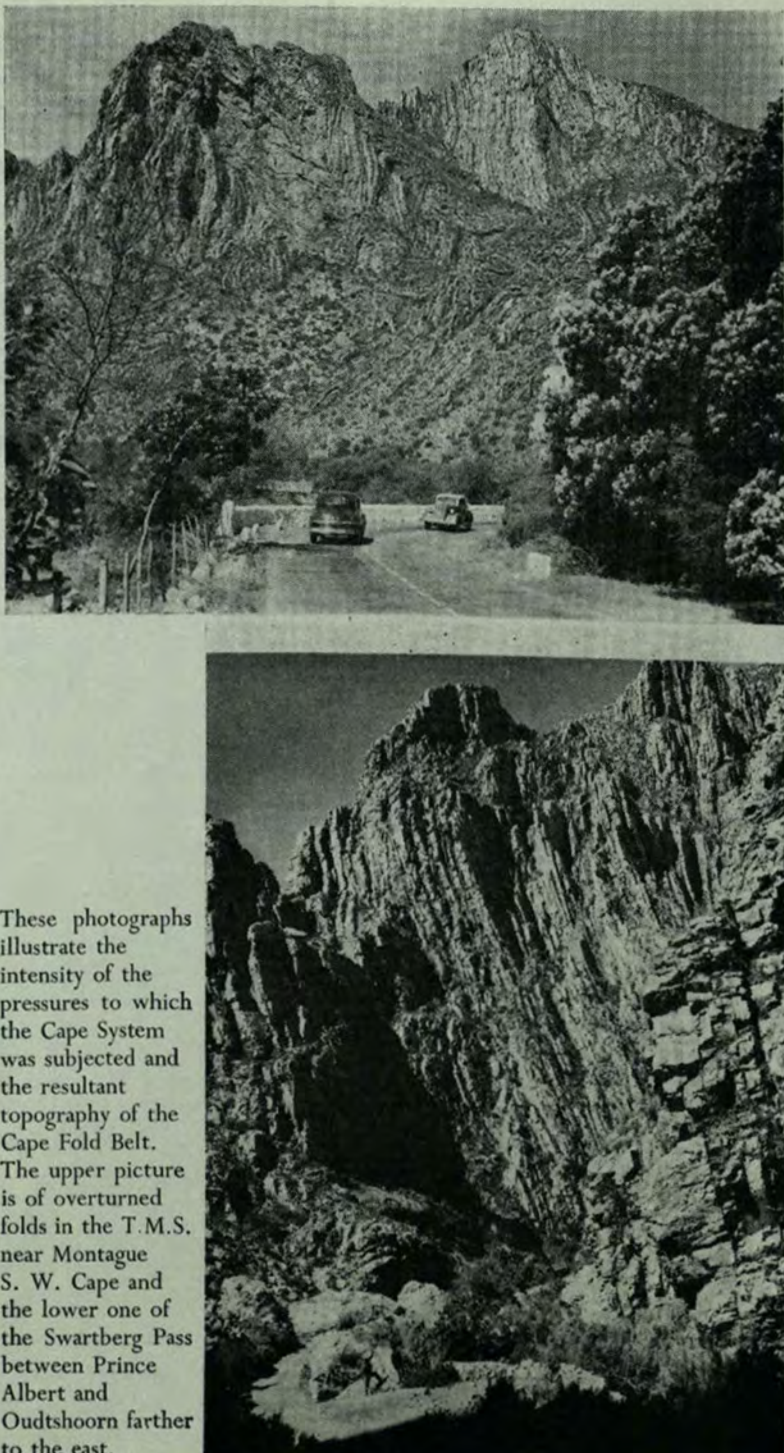
Unfortunately the exact source locality of some of these early specimens is unknown.

For later specimens I am indebted to Messrs. J. N. Theron and J. Loock who sent me the fossils they had collected in the course of studying portions of the Cape System for M.Sc. degrees at the University of Stellenbosch where the best of these specimens are now displayed in the museum of the Geology Department. J. N. Theron subsequently joined the Geological Survey and is engaged on mapping in the Cape Fold area. I am grateful to Dr. O. R. van Eeden, Director of the Geological Survey, and the Assistant Director Mr. P. J. Rossouw for sending me all the plant fossils collected recently from Cape System rocks for inclusion in this report. They will in future be housed in the Geological Survey Museum in Pretoria and some at the Bernard Price Institute for Palaeontological Research—Johannesburg, as part of the Palaeobotanical Collection of the University of the Witwatersrand.

In addition to those mentioned above who provided material for study I should like to thank the following who in various ways have contributed to the preparation of the report. I have corresponded with Devonian authorities in other parts of the world where great advances have recently been made in this field of study and in particular I am indebted to Professor Harlan Banks, of Cornell University and Dr. F Hueber of the Smithsonian Institute, Washington, U.S.A., Professor Susanne le Clercq of Liège, Dr. Chaloner of Imperial College, London, and Professor R. Kräusel of Senckenbergische Institute, Frankfurt, for valuable discussions.

To those Palaeobotanists who have sent me their papers on Devonian fossils from many parts of the world I am grateful. I wish to thank also Dr. Orlando of Argentine who procured for me some of the late Professor Frenguelli's papers which were otherwise unobtainable, and the Director of the C.S.I.R.O., Australia who kindly sent me unpublished palaeobotanical reports of areas currently being studied in that continent. I would like to thank Mr. Mark Hudson of the Geology Department, Witwatersrand University, for assisting me with the photography.

Finally I am indebted to the University of the Witwatersrand where the work has been carried out and to the C.S.I.R. of South Africa for research grants and for publication grants in which the Geological Survey has assisted also.



These photographs illustrate the intensity of the pressures to which the Cape System was subjected and the resultant topography of the Cape Fold Belt. The upper picture is of overturned folds in the T.M.S. near Montague S. W. Cape and the lower one of the Swartberg Pass between Prince Albert and Oudtshoorn farther to the east.

Fig I S. A. Railways

SECTION II—A BRIEF SURVEY OF THE GEOLOGY OF THE CAPE SYSTEM

A. THE CAPE PROVINCE FOLD BELT

1. Distribution and Folding

The main occurrence of the Cape System in South Africa is confined to the Cape Province where a threefold division is recognised, namely the Table Mountain Series, or T.M.S., the Bokkeveld Series and, at the top, the Witteberg Series. The rocks occur along the western and southern margins of the sub-continent (*see* map on p. 10) where they lie with marked unconformity on older formations with granite intrusives. In the south and southwest, the Cape System dips beneath and is overlain conformably by the tillite of the Dwyka Series which forms the base of the Karroo System, but along the western margin the tillite when followed northwards, gradually overlaps the various series of the Cape System and finally lies directly on pre-Cape rocks.

The whole system has been folded with a general N-S strike on the West and more intensely with a general E-W strike in the south with especially complex crumpling in the SW in the vicinity of Ceres and the Hex River Mountains, where the two fold axes meet. The folds in the south are frequently overturned, and are sometimes isoclinal. Usually lateral folds display a fairly steep pitch with the result that they are shortened, outcrops occur *en echelon* and a particular horizon may reappear a number of times in a traverse across the system.

Pressure has resulted in the alteration of organic matter to graphite in many cases and the complete destruction of microflora. Dr. G. F. Hart, formerly palynologist of this University, was unable to find spores in any of the Cape sediments he investigated.

At the eastern end, the highly folded Cape System rocks disappear under the Indian ocean between Port Elizabeth and Port Alfred where the straight coast-line trends NE obliquely across the folds.

Along the northern margin of the southern fold belt, the rocks of the Cape System dip northwards at fairly steep angles beneath the Karroo sedimentary basin, the lowermost members of which are equally involved in the folding.

Three divisions are recognised: The Table Mountain Series, the Bokkeveld and the Witteberg in order of age.

2. The Table Mountain Series or T.M.S.

The Table Mountain Series or T.M.S. is the dominant member of the System and is primarily arenaceous. The results of a number of detailed traverses have recently shown that it varies considerably in thickness from point to point and is often very much thicker than the 5,000 feet previously accepted as an average figure, e.g.:

Citrusdal, 12,000-12,200 feet.
Ceres, de Doorns, 9,000 feet.
Montague, 9,000 feet.
Villiersdorp, 5,800 feet.
Steenbras, 6,000 feet.
Prince Albert, 10,500 feet.
Great Winterhoek, Uitenhage, 17,500 feet.

The series is extremely resistant so that the outcrops give rise to spectacular scenery and many prominent peaks and ranges. In the upper half of the series the Upper Shale Band occurs which can normally be distinguished at the outcrop by a gentle slope of the mountain side. It consists of two minor shale horizons separated by a glacial zone, including scratched and facetted boulders, which is normally about 100 feet in thickness but in the west reaches 200-300 feet and is extraordinarly persistent throughout the province.

The tillite is of importance as a marker but especially as an indication of climatic conditions.

Fossils are rare and are confined to the upper portion. A few very poorly preserved shells and worm burrows have been recorded, and Taljaard (1962) has illustrated a remarkable occurrence of invertebrate tracks which he attributes to trilobites.

In this publication the first probable fossil plant which is believed to be of algal origin is recorded.

Since none of these fossils offers any clear evidence of the age of the series it must be based on the overlying lower Devonian sediments of the Bokkeveld Series. The Table Mountain Series is therefore variously regarded as being of lowest Devonian or more probably of upper Silurian age.

3. The Bokkeveld Series

The Bokkeveld Series is much less resistant to erosive agents than the T.M.S. so that the outcrops normally occupy valleys in the fold mountains. The series is generally recognised as being 2,500 feet in thickness and where typically developed in the west consists of five shales—each several hundred feet thick alternating with four sandstones. These numbers may, however, vary. In the Wuppertal district in the west Swart (1950) recorded six shale horizons while in the Willowmore District, Theron (1962) found only 3 shale and 2 sandstone horizons but the total thickness was 2,817 feet. The series becomes increasingly argillaceous when followed eastwards.

Both shales and sandstones are fossiliferous. The lower two-fifths is marine with a wealth of invertebrate fossils and an occasional plant fragment. In the upper three-fifths the fossils are almost wholly of plant origin. When followed eastwards the marine bands become less conspicuous and in the Port Alfred area Mountain (1962) states that no T.M.S. occurs and no marine invertebrates were found in the Bokkeveld. In this area, however, Cretaceous and younger rocks occupy the eroded fold valleys and mask sub-outcrops of the underlying Cape System rocks.

4. The Witteberg Series

The Witteberg Series is approximately 3,000 feet thick and includes a very massive and resistant quartzite known as the Main Witteberg Sandstone which forms prominent ranges in the northern portion of the Cape fold belt and in which casts and moulds of plant stems are fairly common. At the base there is a softer portion with some intercalated shales which so much resemble some of the Upper Bokkeveld Beds that the division is arbitrary and often difficult to define on either lithological or palaeontological grounds. A number of plant fossils has been recovered from this zone. Above the Main Witteberg Sandstone there is another argillaceous zone known as the Upper Witteberg Shales but for a long time this was included in the Karroo System as the Lower Dwyka Shales. It terminates at the base of the Dwyka Tillite. Some significant plant fossils have been recovered from this zone also.

The age of the Witteberg Series has been variously described as Upper Devonian or more often as Carboniferous. The bearing of the plants, described in this record, on the age of the Series will be discussed in the final chapter. The evidence definitely supports the older estimate.

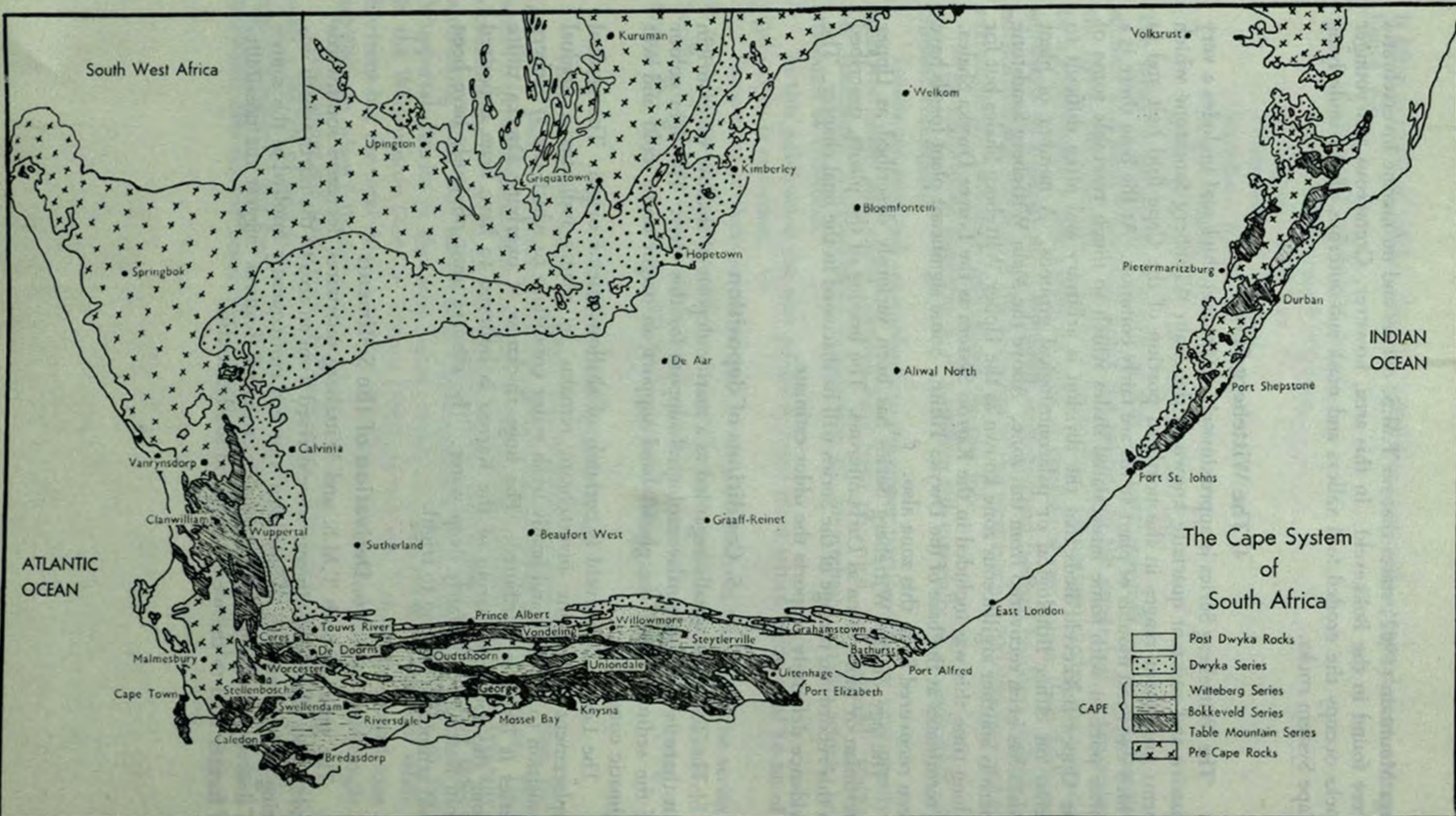
5. Conditions of deposition

The T.M.S. is usually regarded as a marine deposit of shallow water origin but there is very little palaeontological support for this view. The light colour of the sediments and the glacial band support an origin under cold and wet climatic conditions.

The Lower Bokkeveld is certainly of shallow marine origin. The gradual replacement of marine invertebrate remains by plants indicates a gradual transition to brackish and finally fresh water conditions to which the Witteberg Series is likewise attributed. The huge thickness of overlying Dwyka tillite along the southern margin of the Karroo is believed to have been deposited from floating ice in fairly deep water. The climate must obviously have been cold temperate ranging to frigid.

6. Derivation of the Sediments

The grain of both T.M.S. and Witteberg quartzites decreases southwards and implies that the sediments were derived from an area to the north which was being actively eroded. A northern source is consequently implied as the source of drifted plant fragments but certain structural features suggest the possibility of former land to the west, south and southeast also.



South West Africa
Kuruman
Volksrust
Welkom
Upington
Kimberley
Griquatown
Bloemfontein
Springbok
Hopetown
Pietermaritzburg
Durban
INDIAN
OCEAN
De Aar
Aliwal North
Port Shepstone
Calvinia
Vanrynsdorp
Port St. Johns
Clanwilliam
Wuppertal
Graaff-Reinet
Beaufort West
Sutherland
ATLANTIC
OCEAN
The Cape System
of
South Africa
East London
Prince Albert
Willowmore
Touws River
Vondeling
Steytlerville
Grahamstown
Ceres
De Doorns
Oudtshoorn
Bathurst
Malmesbury
Worcester
Uniondale
Uitenhage
Port Alfred
Cape Town
Stellenbosch
George
Port Elizabeth
Swellendam
Riversdale
Mossel Bay
Knysna
Caledon
Bredasdorp
Post Dwyka Rocks
Dwyka Series
CAPE
Witteberg Series
Bokkeveld Series
Table Mountain Series
Pre Cape Rocks

7. Map

Places mentioned in the text are marked on the map on p. 10. It has only been possible to record the main outcrops of the three series of the Cape System on a map of this scale. There are probably many small inliers and outliers in the asymmetrically folded and rugged area which have never been mapped and may yet reveal rewarding discoveries.

B. NORTHERN EXTENSION OF THE CAPE SYSTEM

1. In Natal

In the east of South Africa, extending from Port St. Johns to northern Natal, there is a thick arenaceous formation which lies unconformably on older granites and ancient sediments. It is overlain unconformably by tillite forming the base of the Karroo System. The sandstones are usually felspathic with a reddish colouration but have long been considered to be the northeastern extension of the T.M.S. No fossils have been found and no sign of any succeeding Bokkeveld or Witteberg Series.

The Natal T.M.S. forms a monocline of which the axis has been eroded so that the outcrops tend to occur in two strips with a N-S strike of which the eastern limb dips gently beneath the Indian Ocean.

2. In Malawi

Further north in Malawi there is a group of sediments known as the Nachipere Beds which lies unconformably below the tillite of the Karroo System. It is regarded as being a northern equivalent of the Cape System. Poorly preserved plant remains have been found but Dr. Schelpe of Cape Town University who examined them considered that all were indeterminable (*see* Bloomfield 1954).

3. In the Orange Free State

In the last decade gold mining operations beneath the northern half of the Karroo basin have revealed in certain shafts and deep boreholes in the Orange Free State and Southern Transvaal patches of horizontal sediments forming the base of the Karroo, and at present incorporated with that System. These rocks are associated with tillites and contain a pre-*Glossopteris* flora of Lycopods comparable with several of the fossil plants previously believed to be confined to the Cape System, but they are in a much better state of preservation than those in the Cape Fold belt. The sediments may represent a northern extension of the Witteberg Series or may be contemporaneous with some of the lower glacial sediments of the southern Dwyka. I hope to discuss this interesting plant assemblage and its relationship to Cape and Karroo Systems in a subsequent publication.

C. STRATIGRAPHICAL POSITION OF THE FOSSIL PLANTS OF THE CAPE FOLD BELT

All the plants described in this monograph are from the Cape Province and their stratigraphical position in the Cape System has been plotted as accurately as possible in the accompanying table. Unfortunately the exact horizon of many of the older specimens is not known and has had to be estimated.

All older survey reports and all other known records have been studied for references to plant fossils but only those of which the specimens are still preserved in some collection, or of which the generic determinations are regarded as reliable, have been included in the accompanying table.

The particulars about each occurrence listed will be found in the descriptive text of Section III.

TABLE 1

DISTRIBUTION OF FOSSIL PLANT SPECIES IN CAPE SYSTEM

Based on measurements by Theron 1960 in the Willowmore District

System / Series	Stratum	Horizon	*Dutoitia pulchra* Hoeg	*Dutoitia alfreda* sp. nov.	*Dutoitia maraisia* sp. nov.	Psilophytalean axes	*Palaeostigma sewardi* Krausel and Weyland	*Drepanophycus schwarzi* sp. nov.	*Drepanophycus kowiense* sp. nov.	*Protolepidodendron eximium* Frenguelli	*Protolepidodendron theroni* sp. nov.	*Archaeosigillaria caespitosum* Schw. nov. com.	*Leptophloeum australe* (McCoy) Walton	*Haplostigma irregulare* Seward	Unidentifiable lycopods	*Calamophyton capensis* sp. nov.	*Platyphyllum albanense* sp. nov.	Unidentifiable stems	Branched stems	cf. *Tontalia zollneri* Frenguelli	*Spirophyton*
Dwyka Tillite																					
CAPE SYSTEM – WITTEBERG SERIES – Upper	Sandstones and Shales	Ganoid Fish Zone								×								×			
																		×			
WITTEBERG SERIES – Middle	Main Sandstone										×	×			×						↑ × ↑
WITTEBERG SERIES – Lower	Sandstone and Shale	Howison's Poort			×								×				×		×		↕
BOKKEVELD SERIES – Upper	From 3-6 Shales alternate with sandstones	Schietkraal					×							×					×		↕
											×										↕
		Sweet Fountain					×							×		×					↕
			×																		↕
		Port Alfred		×				×	×					×							↕
															×						↕
						×															↕
BOKKEVELD SERIES – Lower	Marine in West													×							↓ ×
T. M. S.	Upper Sandstone																				
	Upper Shale Tillite Upper Shale																			×	
	Main Sandstone approx. 4,000 ft.																				
	Major unconformity																				

TABLE 2

CLASSIFIED LIST OF PLANT FOSSILS KNOWN FROM THE CAPE SYSTEM
(in order of description)

	DIVISION	SUB-DIVISION	ORDER	GENUS	SPECIES
VASCULAR PLANTS	PSILOPHYTA	PSILOPSIDA	Psilophytales	*Dutoitia* Hoeg	*Dutoitia pulchra* Hoeg
					Dutoitia alfreda sp. nov.
					Dutoitia maraisia sp. nov.
				Unclassified psilophytalean axes	
				Palaeostigma Kräusel and Dolianiti	*Palaeostigma sewardi* Kräusel and Dolianiti
	LYCOPODOPHYTA	LYCOPSIDA	Archaeolepidophytales	*Drepanophycus* Goppert	*Drepanophycus schwarzi* sp. nov.
					D. kowiense sp. nov.
			Protolepidophytales	*Protolepidodendron* Krejci	*Protolepidodendron eximium* Frenguelli
					P. theroni sp. nov.
				Archaeosigillaria Kidston	*Archaeosigillaria caespitosum* Schwarz nov. com.
				Leptophloeum Dawson	*Leptophloeum australe* (McCoy) Walton
			Uncertain classification	*Haplostigma* Seward	*Haplostigma irregulare* (Schwarz) Seward
	ARTHROPHYTA	SPHENOPSIDA	Protoarticulatales	*Calamophyton* Kräusel and Weyland	*Calamophyton capensis* sp. nov.
	Problematical Megaphyllous Devonian Plants			*Platyphyllum*	*Platyphyllum albanense* sp. nov.
	Stems of Uncertain Affinities				A. B. C. D. E.
Non Vascular Plants	THALLOPHYTA	ALGAE		*Tontalia*	cf. *Tontalia zollneri* Frenguelli
		? ALGAE		*Spirophyton*	*Spirophyton* Types A. B. C. & D.

SECTION III
DESCRIPTION OF THE FOSSIL PLANTS

A. GENERAL

1. Naming of the fossils

Because of the poverty of preservation in most instances and also the small number of representatives of any particular plant, the nominating of new genera and species has been avoided as far as possible and, wherever a reasonable similarity was evident, the South African plants have been incorporated in established taxa. This placing of most of the plant fossils in the group which they most nearly resemble may not always be regarded as botanically justifiable but in practice is of greater value to the field geologist than the adoption of some non-committal term such as 'indeterminable lycopod' for the former method may have local stratigraphical significance.

2. Order of description

The vascular plants will be described first, according to their complexity. This follows the classification adopted in most modern Palaeobotanical text-books, e.g. Andrews (1961) "Studies in Palaeobotany". It is not necessarily in their chronological nor in stratigraphical order although a general evolutionary advancement can be discerned in fossils from the older to the younger of the rocks of the Cape System. The Algae are described last, because both genera described are somewhat problematical.

3. Growth-Environment of the plants

Many of the plants described were obviously drifted to the position where they were found and little can be determined about the nature of their growth environment. A few are found in certain areas in a dense mass of stems of one species which suggests preservation where they grew.

The general climatic conditions indicated by the proximity of glacial sediments and by the pale colouration suggest a cold and wet land environment but many may have been semi-aquatic in habitat.

4. Classified list of plants fossils described (See Table 2)

B. SUB-DIVISION PSILOPSIDA

1. General

This group of very simple land vascular plants characteristic of the late Silurian and Lower to Middle Devonian plant life was at one time believed to represent the earliest form of land plants from which all other divisions arose. Increasing knowledge of areas in which the plants occur and more detailed studies of these plants, as better specimens become available, have shown that, in almost every case, among the earliest known land plants in any area there are some which can no longer be classified with psilophytes and must be regarded rather as the progenitors of other sub-divisions, and grouped as proto-lycopods, proto-articulates, proto-ferns, etc. The number of true psilophytes has thus been reduced and the plant assemblages in which they occur are considered to belong to the Psilophyte Stage of plant development which is sometimes called a "Psilophyte Complex".

Because no record of these plants has been published previously in South Africa the main features of the sub-division are described very briefly below. *Psilophyton* was first described by Sir William Dawson (1859) from Gaspe Peninsula, New Brunswick, Canada, but it was not recognised as the type of a new sub-division of the Plant Kingdom until 1917 when beautifully preserved specimens were found silicified in a band of chert of Middle Devonian Age near the small town of Rhynie in Scotland and described by Kidston and Lang (1917). Sections could be cut and every detail of the plants could be studied and they were then universally accepted as representing a vital and important stage in the history of plant life.

In all these extremely primitive plants there is an undergound stem or rhizome from which a small erect stem arises and branches several times. The stems are usually naked but may have a number of tiny hairs or spines in lieu of leaves, but no true leaves occur. The tips of several branches are enlarged and modified to form sporangia. The plants exhibit therefore the first essentials of land plants for they were anchored in the ground to obtain mineral salts and water and have a simple vascular strand to transmit this nutriment to the tips of the branches. The stems and spores have a waxy cuticular covering to protect them from the variations in humidity and temperature of an aerial, as opposed to an aquatic, environment and finally the shoots have stomata, or breathing pores which are clearly indicative of terrestrial life.

(Specimens of the Rhynie plants collected in 1964 can be seen in the Palaeobotanical Collection of the University of the Witwatersrand).

2. The Genus *DUTOITIA* Hoeg

SUB-DIVISION: Psilopsida Order: Psilophytales

Dutoitia pulchra Hoeg
Locality: Near Knysna

Horizon: Upper Bokkeveld Series
At Present: Pal. Museum, Oslo, Norway

In 1930 Hoeg described the first psilopsida known from South Africa. He found the plants in a blue clayish shale exposed on the western side of the valley of the Blaauwkrantz River on the Knysna—Port Elizabeth road. The occurrence was in Bokkeveld Beds and the affinities of the plants suggested a lower or Middle Devonian age. Hoeg named the plant *Dutoitia pulchra* (Hoeg 1930, p. 93, Fig. 1). He had been directed to this area by the specimens 2969 and 4553 in the South African museum on which some of the plants were preserved but had not been described.

In this occurrence the stems were abundant and often crowded in a small layer of shale about 1 foot thick. Only one species was preserved in the form of white impressions. The small straight stems, measuring 1-4 mm. in width, did not taper at all but often bifurcated so that one branch was longer than the other and a "kind of sympodium" was formed. Some of the stems had small spinose or hemispherical protuberances. The lower part of the plant was unknown but a most characteristic feature was the presence of large sporangia terminating many of the stems. These were described as being "bladder-like" organs, obconical in shape with a flat top and 2.5-5.5 mm in diameter. All the specimens collected by Hoeg are now in the Pal, Mus., Oslo. I have been unable to locate the two specimens in the South African Museum mentioned by Hoeg. There are several specimens in the Albany Museum which appear to be of the same genus and which I had believed to be of the same species but I was able to submit photographs of these specimens to Professor Hoeg at the Xth International Botanical Congress in Edinburgh, 1964. He agreed that they could be included in the genus *Dutoitia* but stated that they were probably of a different species. Since the specimens all came from Port Alfred I propose to name the species *Dutoitia alfreda*.

Dutoitia alfreda sp. nov.

Plate I, Figs. 1-3

Locality: Port Alfred (Kowie)
Horizon: Upper Bokkeveld Series
At Present: Albany Museum, Grahamstown.

In the Albany Museum there are several groups of specimens of black carbonaceous shale labelled 4418, 4173 or 4165, which were collected from the Station Quarry at Port Alfred.

It is possible that the Port Alfred beds represent the same horizon as the Knysna shales, but their exact position in the Bokkeveld Series is unknown. Rennie and Mountain (1942) pointed out that although the outcrop of overlying Main Witteberg Sandstone is half a mile distant from the Port Alfred Quarry, the intervening area is covered by alluvium and the Cape Beds are highly folded so that the true depth below the Witteberg cannot be assessed.

On the best of the specimens, number 4418a which is figured on Pl. I, Fig. 1 and nominated as the type, a bedding surface is covered with stems of *Dutoitia* preserved as light-coloured markings on the dark background. The preservation is apparently not as good as that of the Knysna specimens but there is no doubt, I think, of their generic identity.

The thickest stem is only 2.5 mm in width and no spines or protuberances can be seen but this could be due to the coarser matrix. The characteristic branching is, however, clearly evident and a number of large terminal sporangia are preserved. They are club-shaped with a flat top and measure 7 × 4 mm Several can be seen in section as small circles of 4 mm diameter. Pl. I, Fig. 2 is an enlargement of the right hand top corner of Pl. I, Fig. 1 showing a club-shaped sporangium 'a' and one in cross-section marked 'b' in which there is a suggestion of small spherical objects, which must be spores but of this there is no proof.

In addition to the specimens marked 4418 in the Albany Museum there are several slabs and flakes of graphitic phyllite numbered 4173 and 4165. All are from Port Alfred (The Kowie). On these a number of specimens of *Dutoitia* are preserved but they are difficult to photograph because they are graphitic and are only visible on the dark matrix by reflected light. A branched stem on a 4173 flake is shown in Pl. I fig. 3. It resembles the type of sympodial branching described by Hoeg (1930) whose paper included only one illustration which was of a branched axis on which the shapes of the sporangia do not appear to be identical with those from Port Alfred. The consistently naked axes of the latter are a further justification for the separation of the two species.

Dutoitia maraisia sp. nov.

Plate II

Locality: Howisons Poort near Grahamstown
Horizon: Near the base of the Witteberg Series
At present: Palaeobotanical Collection, University of Witwatersrand, Johannesburg

What is possibly a third species of *Dutoitia* was sent to me during 1964 by J. Marais of the Geological Survey office in Grahamstown. I had heard of the presence of psilophyte impressions in the rocks of Howisons Poort near Grahamstown, on the Port Elizabeth road. I am grateful to Mr. Marais for locating them, and have named them in his honour.

The horizon is the so-called "Shale Band" and lies near the base of the Witteberg Series. It is one which has yielded several other plant genera described later in this monograph, for the originally argillaceous sediments allowed a better preservation than that in the quartzites above and below. It is a higher horizon than the Knysna shales studied by Hoeg or the graphitic shales of the Kowie, both of which are included in the Upper part of the Bokkeveld Series. The length of the time interval between them cannot, however, be calculated accurately in the Grahamstown area because the transition from Bokkeveld to Witteberg is buried beneath a cover of much younger sediments beneath which the Cape rocks are highly folded.

The rock is a carbonaceous micaceous shale on which some of the bedding planes are covered with fragments of a small psilophyte. The shales show poor fissility and bedding planes are only well defined where a layer of plant fragments, now altered to graphite, provides an easy parting plane.

The numerous small fragments indicate that the plants were torn from their position of growth and transported although their number suggests that they could not have been carried any great distance. Their fragile nature prevented the preservation of any whole plants.

The small branching stems normally range in width from 1-0.5 mm and less, but a few fragments with a width of 3 mm and a clearly marked central vascular strand can be seen. It is not possible to determine whether the broad and narrow stems are parts of the same plant, but it is probable. Two surfaces are shown on Plate II, Figs. 1 and 3 on each of which a few broad axes and a number of smaller branched axes can be seen.

The stems are thinner and therefore more fragile than those of *Dutoitia* from the Kowie. The sporangia, where preserved, are likewise smaller but, what is more important, they appear to be of a different shape. A flat top is not visible in any instance and instead of standing erect at the end of an axis, they tend to droop and hang in a pendulous fashion (see Plate II, Figs. 2 and 3). In addition several stems, e.g. at the tops of figures 2 and 3, show projections. For these reasons the Howison's Poort plants are not included with the Kowie species and despite their poor preservation have been placed in a new species. The resemblances to *Dutoitia* are sufficient to place them provisionally in the same genus.

Comparison of *Dutoitia*

The size and shape of the sporangia of the three species of *Dutoitia* appear to be unique but the rest of the plant suggests comparison with a number of small psilophytes from other parts of the world. Hoeg compared his specimens of *Dutoitia pulchra* from Knysna with *Psilophyton*, *Rhynia* and *Hicklingia*. For the naked axes of *Dutoitia alfreda* from Port Alfred the most obvious resemblance is with *Cooksonia* from the uppermost Silurian or lowermost Devonian of Victoria, Australia (Lang and Cookson, 1935). They may be compared also with *Cooksonia* cf. *hemisphaerica* from the Upper Silurian of Pridoli (Obrhel, 1962a, Plate I, Figs. 1-3).

3. ? Psilophytalean Axes

Plate III, Figs. 1-10

Locality: De Doorns
Horizon: 3rd Bokkeveld Sandstone
At Present: Palaeobotanical Collection, University of the Witwatersrand, Johannesburg, and Geological Survey Museum, Pretoria.

Occurrence

In 1962 in the course of re-mapping the area Mr. J. N. Theron of the Geological Survey collected specimens T.D. 77-83 from the third Bokkeveld Sandstone in the De Doorns District. This horizon is marginal between the lower marine and upper fresh water phases of the Bokkeveld Series and is therefore lower than any of those in which *Dutoitia* was found.

The rock is from an outcrop and is weathered to a deep red. A great many small organic fragments are included. There is usually no colour contrast between them and the rock matrix but, when split, the fresh rock is more yellow in colour and the fossils of a dark maroon colour and therefore far more conspicuous.

The nature of these fragments is open to doubt and the possibility that some, at least, are of animal origin cannot yet be excluded. They are treated here as plants because some of them are closely comparable with primitive plant fossils (Cookson, 1935) from Victoria, Australia, whose vegetable origin was proved by organic residue.

Some of them resemble also a new group of Thallophyta described by Kräusel (1960) from the upper part of the Lower Devonian beds at Ponta Grossa in the state of Parana. Their preservation permitted chemical treatment and microscopical examination through which an algal rather than an animal origin could be implied. Since the Cape specimens are too poorly preserved to allow this type of study, only the outward form can be compared and subdivision would be unreliable. They are therefore grouped provisionally and in a very general sense under the term Psilophytalean axes but it is probable that several different genera are present and that some may be thallophytes.

The rock breaks unevenly and the stems can be seen lying in all directions and at different angles. They were probably of drift origin and deposited in water where no marked current directions existed. The stem fragments are rarely more than 2 cm in length and are often only 3 to 4 mm wide. On one surface of specimen T.D. 77B which is approximately 70 sq. cm in area, about fifty portions of different stems were counted but many other surfaces exhibited only a few. Their undulating character suggests soft herbaceous plants. Most of the stems are covered with very small round or oval "lumps", or alternatively hollow scars on negative surfaces—any elongation is longitudinal and never transverse with reference to the stem. In a few cases the scars are circular and they may therefore have formed the bases of small round spines but no projections of this type are visible on either margins or surfaces. In all cases the distribution of scars appears to be most irregular. Some of the surfaces like those in Plate III, Fig. 1 have uneven longitudinal ridges or corrugations due probably to shrinkage. It is not known whether the marked relief on these small stems represents outer or inner surfaces of the plant, but in addition to the punctate stems and interspersed with them there are a few which are of the same size but have fine longitudinal striae with only a faint suggestion of round scars (see Plate III, Fig. 4). Only one of the stems, of a much smaller size, exhibits any type of branching but the rough transportation implied by the short fragments would probably have destroyed any such evidence. No reproductive organs of any kind have been seen and no other fossils appear in the rock although the horizon is within or on the boundary of the marine invertebrate zone of the Lower Bokkeveld.

Description of Specimens

Specimen T.D. 77B

A few of the stems have been selected to illustrate different types of surfaces and of relief. Plate III, Fig. 1 is of several corrugated or crumpled stems with small round or oval and raised or ring-shaped scars. The stem on the upper left hand side is broader than most. Fig. 2 has on the left a stem, 'a', with very marked relief in which the raised scars are irregularly arranged and are ovate with the sharp end pointing downwards. On the right hand side there are several fragments of corrugated stems, 'b', without round scars and above them, at the point marked 'c', a small but distinct bifurcated stem. This is the only example of branching in this collection. It is slightly out of focus in the photograph, being on a different level, and unfortunately the tips of both branches are missing so that their possibly reproductive nature cannot be confirmed. It is not improbable that all three stem types in this figure may belong to one species of plants.

Specimen T.D. 80—Plate III, Fig. 3 illustrates the very small size and irregular distribution of the outgrowths and their longitudinal elongation. In addition there is a distinct groove which may indicate the presence of a vascular strand (cf. Cookson, 1935, Plate II, Fig. 45) and at 'b' a possible bifurcation.

Plate III, Fig. 4 is from the same slab and is of two stems with striated surfaces which possibly represent a different aspect of the same plant. A fragment of a punctate stem can be seen overlapping one of them.

Specimen T.D. 79—Plate III, Fig. 5 is of two punctate stems, presenting negative and positive surfaces, on the left and right hand side respectively. On the same surface Fig. 6 shows the variation in size and shape of the lumps and their extremely irregular distribution.

Specimen T.D. 83—Plate III, Figs. 7 and 8 show a more pronounced elongation of scars but in addition a surface indicative of cell structure. The latter is only visible in Fig. 8 where it is magnified six times. Fig. 7 must be viewed from the left to show the correct relief.

Specimen 57f and counterpart S.A.M.—Plate III, Figs. 9 and 10. The only other specimen of this type known to me is one in the South African Museum which was collected by Schwarz in 1905 from the farm Uitkomst in the district known as the Warm Bokkeveld which lies on the northern limb of the folded Hex River Mountains. Theron's specimens from De Doorns were collected from the southern limb of the same range and possibly from the same or a close horizon. Schwarz (1905, p. 276) described the area as one from which a great many well-preserved marine invertebrate fossils had been collected. This specimen appears to be the only one placed in the plant collection but its vegetable origin might have been regarded as doubtful but for the occurrence of so many fragments of comparable stems from De Doorns. Two surfaces are displayed, a convex one magnified three times in Plate III, Fig. 9 and a concave counterpart shown natural size on Plate III, Fig. 10. A probable outer surface can be seen on the top right hand side of Fig. 9. The stem is 7 mm in width and a little larger than any from De Doorns but the scars are comparable in size and shape and in irregularity of distribution cf. the left hand stem in Fig. 1.

Discussion and Comparison of the De Doorns specimens

These very poorly preserved and incomplete fossil plant fragments from the lower part of the Bokkeveld Series can be compared with primitive plants from several areas. As an assemblage they have most in common with fossil plants from Victoria; Australia, described by Cookson and Lang (1931) and especially Cookson (1935) and regarded as of Upper Silurian age. For many years these were the oldest known land plants and famous on that account. Several fossil plant sites in Victoria, Australia, have yielded primitive vascular plants. The age was fixed by finding *Monograptus* associated with some of the plants and this Graptolite is known to be "not younger than Lower Ludlow". The interrelationships between the plants of all four sites is such that their contemporaneity is assured. Recently the Silurian age was questioned but it has now been re-established.

The plants themselves were comparable with Lower Devonian types of Europe and it is possible that in Australia they may have ranged through Upper Silurian into Lower Devonian periods.

From the site near Alexandria, Victoria known as Mount Pleasant (Cookson, 1935) several stems have been described which appear to be very similar to those collected by Theron from the Third Bokkeveld Sandstone in the de Doorns district. Cookson described the plant remains as being small and fragmentary and normally preserved as encrustations of brown mineral matter on which a few carbonaceous particles may remain. In a very few cases organic material was sufficient to allow chemical treatment and thus to ascertain that the fragments were those of vascular land plants. She was able to isolate a fragment in which a few tracheids were preserved (Cookson, 1935, Plate 10, Fig. 23) which showed remains of thickening on their walls and regarded this type of structure, which had been found also in other areas, as probably characteristic of most of the plant assemblage. It is unfortunate that no such evidence is available from the highly weathered Cape specimens but every one of the specimens on Plate III can be compared to a certain extent at least with those from Australia.

Cookson (1935, Plate II, Fig. 38) can be compared with Plate III, Fig. 1 from De Doorns. The Australian stem was labelled cf. *Baragwanathia longifolia* for it resembled leafless stems of this plant preserved under better conditions in the other sites. The stems classified by Cookson (1935, p. 142 and Plate 11 Figs. 43-45) as "stems with small spirally arranged elevations" are, in size and relief, comparable with most of the De Doorns stems. The elevations were round or oval with the long axes parallel to the length of the stem (cf. Cookson, Plate 11, Fig. 43 with Cape Plate III, Figs. 7 and 8). Scars were sometimes ovate with point downwards (cf. Australian Plate II, Fig. 44 with Cape Fig. 2, Plate III). Scars were sometimes well-spaced and sometimes crowded (cf. Australian Plate 11, Fig. 45 with Cape Plate III, Fig. 3). One of the specimens showed a small central vascular strand from which the tracheids were isolated. There were, in addition, some striated stems (cf. Australian Plate 11, Fig. 37 with Cape Plate III, Fig. 4).

Although a considerable number of examples was available for investigation, Cookson regarded the nature of the elevations on the stems as obscure. As in South Africa, she found no evidence of small leaves on either margins or surface but considered that in all probability the raised scars were either small leaf bases or emergences serving a similar function.

The small branched stem on Plate III, Fig. 2 can be compared with the Australian *Hostimella* (Cookson, 1935, Plate 10, Figs. 16-18) or *Hostimella* sp. (Lang and Cookson, 1931 Plate 11, Figs. 3-9). Cookson stated that the small spiral Australian axes might be related to *Psilophyton* and with this I agree.

Fine surface markings which may represent cell structure can be seen on Plate III, Fig. 8. This can be compared with Cookson, 1935, Plate 11, Fig. 40 with similar markings which she regarded as epidermal structure. It was visible only by reflected light on a surface encrustation.

Other psilophytes have been recorded from Spiti in the N.W. Himalayas by Sahni (1953, Plate 1). They were small axes which divided into two short branches of equal length. Sahni was not completely convinced of their vegetable origin and believed them to have been of Silurian or possibly of Ordovician age.

The plants described by Kräusel and Dolianiti (1957) from the lower Devonian Beds of Picos in Brazil are the only others known and may even be specifically identical with these Cape axes.

Dawson (1862, Plate XII, Fig. 6b) illustrated as small stem with tiny scars, which he called the punctuated variety of *Acanthophyton spinosum*. The size and markings were rather similar to the specimen shown on Plate III, Fig. 3, but no enlargement was given. The stem was of Middle Devonian age. Some of the lumpy stems could be compared with *Lepidodendron gaspianum* Dawson 1862, Plate XIV, Figs. 26-28. But their arrangement is more regular.

Palaeostigma sewardi Krausel and Dolianiti

Plates IV, V, VI and VII

Localities: 1. Steytlerville
2. Near Bathurst
Horizon: 1. Upper Bokkeveld
2. Upper Bokkeveld
At Present: 1. S.A. Museum, Cape Town
2. Albany Museum, Grahamstown and No. 1806
South African Museum, Cape Town.

History of the genus

One specimen of this plant from the Steytlerville District of the Cape was originally described by Seward (1932, Plate XXIII, Figs. 1, 3 and 4 only and Plate XXIV, Fig. 8, Text Fig. 1, p. 360) who regarded it as being specifically identical with other Cape stems and included it in the species *Haplostigma irregulare* (Schwarz) Seward.

In 1954 Kräusel drew attention to the probability that at least two different plants had been united by Seward but they were only separated taxonomically by Kräusel and Dolianiti (1957, Plate I, Figs. 1 and 2) when additional specimens of the present plant were found in the Lower Devonian of Brazil. As a result these authors separated the smaller-scarred stems described by Seward from the larger-scarred ones which remained in the genus *Haplostigma*. The former were placed with the new Brazilian specimens in a new genus and species as *Palaeostigma sewardi* but they nominated the South African specimen 10744 S.A.M. (No. 836 Haughton) as the holotype of the new genus. They believed it to be a much simpler plant than *Haplostigma irregulare*, describing it as a stem probably without real leaves and with various spiny appendages which were rounded or conical and were arranged irregularly.

The type specimen and a number of new specimens are described and discussed below but the nature of the plant is still problematical and even its systematic position is somewhat uncertain. As it is closest to certain *Psilophytes* the plant has been included in this section.

Description of Specimens

Holotype 10744 S.A.M. and its counterpart 10741 S.A.M. (No. 832 of Haughton). Plate IV, Figs. 1 and 2.

This specimen was collected by Haughton (1935) from the upper part, i.e. the fresh water facies, of the Bokkeveld Series on the farm Schietkraal in the Steytlerville district of the 'Cape Fold Belt', about 80 miles northwest of Port Elizabeth. It was described and illustrated by Seward (1932, text Fig. 1, p. 360, Plate XXIII, Figs. 1, 3 and 4 and Plate XXIV, Fig. 8). In the present publication Plate IV, Fig. 2 is an enlargement of Sp. 10741, S.A.M., the counterpart of the holotypes. It illustrates clearly a comparatively smooth stem on which a number of very small, transversely elongated scars appear. Some of these are hollow and others raised and they are apparently arranged irregularly. Seward's interpretation was that the surface represented the resistant cylindrical cuticle of a stem of which all other tissue had decayed, so that the raised lumps were on the upper surface and seen from the outside, while the hollow scars belonged to the lower surface and were being viewed from the inside.

In support of this he illustrated two enlargements of better preserved cuticular surfaces from a South African specimen No. V. 240 in the British Natural History Museum (Seward, 1932, Plate XXIV, Figs. 9 and 12) which show the details of a few raised scars.

Kräusel and Dolianiti (1957) illustrated an enlargement of the epidermis of a Brazilian specimen (K. & D. 1957, Plate 1, Fig. 2) and this is strikingly similar to Seward's enlargement of the British Museum specimen from South Africa but their impression of a stem (K. and D., Plate 1, Fig. 1) is less like those of the South African type specimen.

Specimens 4344 *Albany Museum and* 1806 *South African Museum.* Plate IV, Fig. 3, and Plates V, VI and VII.

A number of additional specimens of *Palaeostigma* are preserved in the Albany Museum, Grahamstown, on slabs of carbonaceous shale metamorphosed almost to a graphite schist so that the surfaces are highly reflective.

The specimens which are numbered 4344 and a few 4173 were collected from Sweet Fountain (formerly Estments Farm) in the Bokkeveld Beds, 3 miles east of Bathurst Station. There is also a specimen from this area preserved in the South African Museum, Cape Town, and numbered 1806. The largest of the Albany Museum specimens is illustrated on Plate IV, Fig. 3. Unlike the type specimen the whole surface, and indeed every layer in the rock, is covered with the plants lying in all directions so that it is extremely difficult to measure individual stems but those clearly defined appear to be between 1 and 2 cm in width (see Plate V, Fig. 1).

The occurrence indicates that the plants grew in a tangled mass possibly in an aquatic environment but, if so, the thick cuticles suggest at least periodical exposure to the air.

All the stems are covered with the characteristic small, raised and hollow scars which are irregularly arranged. As in the Schietkraal specimens they may be round, but are usually oval, being elongated transversely and never vertically.

Some of the stem surfaces are wrinkled but there is neither vertical nor horizontal corrugation of the stems such as commonly develops in *Haplostigma* stems.

No appendages were seen on any of the stems and no indication of the presence of vascular tissue. In at least two small areas brownish patches of original cuticle have been preserved and a wrinkled skin-like appearance is apparent, showing that mineralisation of the plant matter had not been completed (see the area at the top of Plate VII, Fig. 2). This would provide an answer to the doubt expressed by Kräusel and Dolianiti (1957) that the fossils might conceivably have been of animal origin. An attempt to scrape and macerate material from one such surface was made but no significant residue remained.

In some areas epidermal cell structure is visible (Plate V, Fig. 2). These features appear to be identical with those illustrated by Seward (1932) of a South African specimen number V. 240, which possibly came from the same site, and also those by Kräusel and Dolianiti (1957) of a Brazilian specimen and I believe that this is an important factor in establishing their specific identity.

Specimen 1809 *Albany Museum*

On specimen 1809, Albany Museum, which was collected also from Sweet Fountain, a few fragments of *Palaeostigma* are preserved with *Calamophyton* (see left hand side of Plate XVII, Fig. 1). It is the only instance in which any other plant has been found associated with *Palaeostigma*.

Details of the scars and discussion on their origin

In view of the contradictory explanations of the projections and hollow scars, they have been rather profusely illustrated in this monograph in order to show as many aspects of the stems as possible. Seward's interpretation of the stems as overlapping surfaces of cuticle is justifiable in some of these specimens, e.g. Plate VI, Fig. 1 in which the hollows are clearly defined but the projections are either immature or masked. In places also the distance between concave and convex pairs of scars can be seen to increase with the relative position of the two surfaces but in most stems there are certain features which seem to demand another explanation.

A careful analysis of enlarged surfaces of the stems suggests that in some areas, at least, the detail is far too clear on both sunken and raised scars for them to represent upper and lower cuticular surfaces. An alternative suggestion is therefore preferred, but cannot be fully substantiated at present. It is thought that the raised scars are equivalent to small vegetative buds or bulbils which when ripe separated from the stem to form a new generation, leaving behind a saucer-like depression. (Since the term bulbil is used for similar detachable vegetative buds on some flowering plants and also on certain fungi, I consider it to be applicable in this instance.)

The development of a central scar on the raised projections may be indicative of the stage of development. It is not always present—cf. Plate V, Fig. 2 and Plate VI, Fig. 1—in which some of the 'lumps' are smooth and others display a small central dimple, the size of which apparently increased until a crater-like opening can be seen on many of them. See Plate VI, Figs. 2, 3 and 4 and VII, Fig. 4. Occasionally the opening is in the form of an elongated slit, see Plate VI, Fig. 5.

Plate VII, Fig. 1 may represent a stem on which bulbils were just beginning to form.

An examination of the surfaces on Plate V, Figs. 2 and 3 shows a certain cyclic arrangement of hollow scars but a haphazard arrangement of raised ones. Possibly such surfaces represent stems on which the bulbils were nearly ready to be detached but had not separated at the time of burial until the sliding action of the overlying stems loosened them. The pressure could have damaged some of the bulbils because in several instances, e.g. left hand side of Plate VI, Fig. 1 and the top of Plate VII, Fig. 4, remains of tissue appear to have been left in the smooth saucer-like depressions.

On Plate V, Fig. 3, which is an enlargement of Plate V, Fig. 1, I suggest that some bulbils still lie in their hollow cups; some are partly removed; others still lie near the cups; a few are missing. Many examples can be seen on the other illustrations. The isolated but well-developed bulbil on the right hand side of Plate VII, Fig. 3 may represent one which has been detached. Radiating structure is visible in many well developed bulbils and is sometimes apparent in the cups also (see Plate VII, Fig. 4 and Plate V, Fig. 3).

Fractured sections of the bulbils likewise sometimes exhibit strong radiating structure and the suggestion of a central core or column. One of these is particularly clear on Plate VI, Fig. 2.

I would therefore suggest that in the light of this new evidence a solution involving detachable vegetative reproductive buds provides a more realistic explanation of the irregularity of the observable depressions and elevations on the stems of these plants.

Comparison and Remarks

As far as I know, apart from the Brazilian specimens from a Lower Devonian horizon of Picos (Kräusel and Dolianiti, 1957) which are believed to be specifically identical, no other plants of this type have been described.

Several authors have drawn attention to projections or tubercles on certain early vascular plants and have suggested that they might have some reproductive significance, notably the hemispherical bulges on stems of *Rhynia gwynne vaughni*.

The feature is reminiscent of certain Red algae and it would seem to support the theory first advocated by Arber (1921) that Psilophytes and indeed all lower vascular plants had an algal origin. Arber actually considered Psilophyton to be a Thallophyte which probably belonged to an "obsolete race of Thallophyta, higher in the scale of complexity than any living Algae".

Plants like *Palaeostigma* could almost be regarded as transitional between Thallophyta and vascular plants.

In this connection the radiating structure to be seen in some of the small round or oval bulbils of *Palaeostigma* is reminiscent of that in *Pachytheca* and, in fact, when separated from the parent plant might, save for the smaller size, be mistaken for these small, spherical, lower Devonian plants.

Up to now *Pachytheca* has not been recorded from South Africa, but occurs in Australia as well as in many norther hemisphere formations of this age.

Further references to an algal origin and relationship will be found in the final chapter.

There is, however, an important alternative suggestion. A very interesting paper has recently been published by Pant (1962) in which he presents a strong case for regarding the stems of *Rhynia gwynne vaughni* with its much discussed hemispherical projections as the gametophyte of the other psilophytes in the Rhynie chert beds. He finds support for his views in the closely comparable vascular gametophytes of the living *Psilotum*. He demonstrated that the tissue of the hemispherical bulges of *Rhynia gwynne vaughni* was clearly demarcated from that of the parent axis by an abscission layer at the base and believes that they became detached to form a young sporeling—a new sporophyte generation. In the light of this new evidence the theory of detachable vegetative bulbils is less revolutionary. It is possible that there may be a close parallel between the Scottish and Cape plants in the manner of their reproduction although in the absence of the marvellous preservation in colloidal silica, proof may not be possible. It would explain the apparent absence of vascular tissue in *Palaeostigma* which would probably have to be regarded as an aquatic generation of *Haplostigma* or *Dutoitia* or some other primitive psilophyte associated with it. *Spongiophyton* Kräusel (1960) from South America may fall into this category also and a new vista of dual relationships between primitive land plants and associated plants formerly regarded as thallophytes is open.

C. SUBDIVISION LYCOPSIDA

General

This is the most important subdivision of fossil plants found in the Cape System, both from the point of view of numbers of genera and also numbers of occurrences. All the specimens, without exception, can be placed in genera of proto-lycopods which is highly significant, for it is indicative of Devonian age.

Like the Psilopsida, all the plant fossils described in this section are fragmental and often very imperfect. No sporangia have been found and classification has had to be based on superficial resemblances only. Nevertheless a much larger number of genera has been recognised than had been known previously from Southern Africa. Some of them provide interesting and significant comparisons with other areas.

Classification

The early lycopods have been the subject of a number of recent investigations and revisions in other countries. Unfortunately none of the reviews originated in a southern hemisphere country but once again it can be emphasized that comparisons at the level of Orders and Families are common between northern and southern hemisphere Devonian fossil plants. They are less common in Genera and only occasional in species. In later geological periods they become even more rare.

Genus *DREPANOPHYCU* Göppert

Order: Archaeolepidophytales Family: Drepanophycaceae

Plate VIII

Systematic position

The genus *Drepanophycus* Göppert now includes many specimens originally described as psilophytes. Hoeg (1942, p. 184) in discussing the origin and development of the spines and the evolutionary position of the genus emphasized the necessity of separating it from the Psilophytales. Kräusel and Weyland (1949) placed *Drepanophycus* together with *Baragwanathia*, the primitive Upper Silurian — Lower Devonian plant from Victoria, Australia, in the family Drepanophycaceae of the order Archaeolepidophytales. Pici-Sermolli (1958) included it in the class Protolepidodendridae, order Drepanophycales and family Drepanophycaceae. Banks (1960) and Grierson and Banks (1963) reviewed former classifications and, for this genus, accepted the terminology of Kräusel and Weyland (1949) which is used above.

General Distribution

Grierson and Banks (1963, p. 230) provided the following generic diagnosis —"Dichotomously branched robust axes with falcate leaves; leaf bases large. Central vascular strand with annular tracheids". The stems are among the best known of Devonian plant fossils and the genotype *D. spinaeformis* which now includes *Arthrostigma gracile* Dawson (Kräusel and Weyland 1935) is known in considerable detail. It had a creeping underground stem from which upright dichotomously forked spiny stems arose. A single sporangium was borne on the upper surface of some of the spines and it was this feature which caused the plant to be regarded as amongst the most primitive lycopods rather than as a psilophyte.

The genus is widely distributed in the Northern hemisphere but is little known from the Southern. It has been reported from Canada, U.S.A., Scotland, Wales, Norway, Germany, Bohemia, France and Portugal, and from Western Siberia and China. In the south the only reference known to me is of *Arthrostigma* from the lower Devonian of San Juan in Argentina by Frenguelli (1951) but unfortunately no figure was included in his paper.

In the vast majority of recorded occurrences, *Drepanophycus* has been found in Lower Devonian rocks but sometimes continues into the Middle Devonian. It is regarded as typical of these horizons.

Drepanophycus schwarzi sp. nov.

Plate VIII, Figs. 1-4.

Holotype Specimen 2903 S.A. Museum, Plate VIII, Figs. 1 and 2.

This specimen, on which several different stems are preserved, was collected by Schwarz from weathered pinkish grey Bokkeveld shales which outcrop in the grounds of the Mental Hospital at Port Alfred (the Kowie). All the stems were originally combined and described and figured by Seward (1909) as *Bothrodendron irregulare* Schwarz, but later (Seward, 1932) as *Haplostigma irregulare* (Schwarz) Seward. Although Seward recognised that there were "two fairly distinct forms" preserved on the surface he regarded them as specifically identical. Two stems can be seen on Plate VIII, Fig. 1 and it is evident that the nature of the projections, and the size, shape and distribution of the scars on the two forms differ radically. The larger stem has been retained in the genus *Haplostigma* (which was illustrated also by Seward (1909, Plate XXVIII, Fig. 3)) but the smaller is here transferred to the genus *Drepanophycus* Göppert. The specific name *schwarzi* has been selected in honour of Professor Schwarz who found the original specimen.

The stem is 10 cm long and 1.2 cm wide. It branches on the right hand side (see Plate VIII, Fig. 2) at an angle of 60 degrees and the curvature suggests an herbaceous but fairly rigid plant. On the surface of the stem there are closely spaced round scars arranged in definite longitudinal rows. These are controlled by the fact that although the growth of spiny projections was probably spiral, the vertical interval between them is much less than the horizontal, so that the scars which alternate in adjacent rows are almost touching in vertical alignment. The scars are round or oval in shape and are elongated vertically, being 1.5 to 2 mm in the longer diameter while the interval between them is less than 1 mm On Plate VIII, Fig. 1 an upper layer of the stem can be seen in two places and although the scars are flatter and more distinctly separate on the lower surface, the vertical arrangement remains conspicuous.

Along both margins but especially on the left hand side, a row of closely-spaced, stiff spines is preserved. They are 3 to 4 mm in length, broad at the base but taper to a sharp point and are falcate or curved upward, so that they overlap. These features are clear in Plate VIII, Fig. 2 which was photographed with different lighting and shows the branching more clearly.

The type specimen is the only one on which the spines are preserved clearly but a few other stems with similar scars are known from the Albany Museum Collection. All are from the Bokkeveld Series in the Port Alfred area but occur in carbonaceous shale which is often altered to a graphitic phyllite on which organic impressions are clearest by reflected light but details are absent. Two of these are described below.

Specimen 4165A, Plate VIII, Fig. 3.

This stem is slightly broader than the type, being 15 mm wide and 6.5 cm in length. The longitudinal rows are clear and the vertical interval between scars is less than the horizontal. Remnants of poorly preserved spines occur on both margins. There is a short length of *Haplostigma* on the same surface.

Specimen 4165*A*, *Plate VIII*, *Fig*. 3.

This has stems only 6 mm wide branching at 60 degrees as on the type specimen. The plant matter has been altered to graphite and although the longitudinal rows and close spacing are apparent, all detail has been obscured.

Discussion and Comparison

Among the many small herbaceous Devonian plants with spiny leaves, the stems described above would seem to fit best into the genus *Drepanophycus* with which they agree in having simple falcate leaves arranged on an otherwise smooth surfaced stem. In the Cape specimens neither creeping stems nor sporangia have been seen, but the rocks in which they occur are highly altered by folding and the preservation is poor. Comparison must therefore be based on the outward form of upright vegetative shoots. Among published figures of *Drepanophycus* the closest resemblance is to one of *D*. cf. *spinosus* from the Lower Givetian of Central New York State, illustrated by Banks (1960, Plate I, Fig. 3). The scars are ring-shaped and there is evidence of vertical alignment but the spines are longer and less falcate and the vertical rows far less pronounced than in the Cape specimen. The species is best known and was first described from Central Bohemia by Krejci, and reviewed by Kräusel and Weyland (1933). Obrhel (1961) cast some doubt on the inclusion of the New York specimen in the species but Grierson and Banks (1963) reaffirmed it as *D. spinosus* var. *typica*.

There is a partial resemblance also to *Drepanophycus* sp. from Spitsbergen (Hoeg, 1942, Plate XIII, Fig. 9) and to a stem from Lower Middle Devonian of Portugal (Teixeira, 1951) while the size and vertical alignment of scars is comparable with *Archaeosigillaria vanuxemi* (cf. Grierson and Banks, 1963, Plate 35, Figs. 1 and 2). I know of no fossil plant from the southern hemisphere which is comparable with *D. schwarzi*.

Drepanophycus kowiense sp. nov.

Plate VIII, Fig. 5.

There are several fragments of stems in the Albany Museum collection which in size and general appearance are similar to those of *D. schwarzi* but both scars and spines are smaller and their arrangement is so different that it seems wiser at present to place them in seperate species. All known specimens of these stems are from the Bokkeveld Beds of the Kowie. The specific name *kowiense* is suggested and Specimen 4173c of the Albany Museum is nominated as the type.

Type specimen 4173*c*. Plate VIII, Fig. 5.

The stem fragment is 5.3 cm long and 9 mm in width with scars 1 mm or less in diameter. They are arranged spirally but the horizontal distance between adjacent scars, in alternate rows, is only 1 mm and is much less than the vertical interval between those immediately below, with the result that a pattern of horizontal rows resembling whorls 3 mm apart is the dominant feature. The spines on the margin are controlled by the vertical interval and are 6 mm apart, i.e. on every alternate horizontal row. They are far smaller at the base and shorter than those of *D. schwarzi*, averaging 1.5 mm in length, and are not normally falcate. Only one showed an upward curvature but they may have been truncated: The ring-shaped scars suggest that the spines were cylindrical at the base.

Specimen 4173*A*.

A 2.5 cm length of stem of *D. kowiense* is preserved on the back of this specimen (not figured).

Fragments of others are visible on some of the slabs of carbonaceous shale from this district.

Comparison

It is not unusual for Devonian stems of both hemispheres to exhibit a pseudo-whorled leaf scar arrangement due to a very tight spiral. *Colpodexylon deatsii* from North America (Banks 1944, Figs. 1 and 13) can be cited and several other Cape stems described in this publication exhibit portions in which a transverse line of scars simulates a whorl. The short-spined specimens described above are perhaps closest to *Drepanophycus gaspianus*, a species which includes the original *Lepidodendron gaspianum* Dawson from Gaspe Peninsula in Canada (Dawson, 1862, Plate XIV, Figs. 26-28). The species was renamed *Drepanophycus gaspianus* by Kräusel and Weyland (1948) who found it in the Lower Devonian beds of New York State. It has been refigured recently by Grierson and Banks (1963, Plate 33 of which Fig. 4 shows horizontal pseudo-whorls near the base). The leaves of *D. gaspianus* are dorsi-ventrally flattened beyond the base which does not appear to be true of the Cape specimens in which the leaves are stiffer and rounder, while the leaf scars are ring-shaped.

Genus *PROTOLEPIDODENDRON* Krejci

Order: protolepidophytales Family: Protolepidodendraceae

The term *Protolepidondendron* has been used by different authors for various plants which were considered to be primitive lycopods. However, in 1932 Kräusel and Weyland redefined the genus to apply only to a group of herbaceous lycopods, characteristically of Lower and Middle Devonian age but which has occasionally been found also in Upper Devonian beds. They bore spirally arranged leaves which had enlarged bases and were bifurcated near the tip. The genis is of wide occurrence in the Northern Hemisphere in Bohemia, Germany, New York State, probably Quebec and China. The type species *P. scharianum* is particularly widespread and is known in great detail. See Kräusel and Weyland (1932c). The genus has been recorded from a few places in the Southern Hemisphere, viz. Brazil, Argentina, New South Wales and Queensland in beds ranging from Lower to Upper Devonian. It has not been recorded previously from Africa.

Protolepidodendron eximium Frenguelli

Plate IX, Figs. 1-4.

Specimens J.T. 3, Plate IX, Fig. 1 and J.T. 22, Plate IX, Fig. 2, were collected from the Upper Witteberg shales in the vicinity of Vondeling, approximately 360 feet below the tillite, by J. Theron and will be stored in the Geological Survey Museum in Pretoria.

In a matrix of black carbonaceous and ferruginous sandstone which exhibits no bedding planes, there are numerous small stems stained yellowish-brown by iron oxides. They ramify through the rock in all directions, even vertically, and were possibly buried in a position of growth.

The surfaces of the stems are extremely undulating and many are curved, suggesting a soft herbaceous plant (see the right hand stem on Plate IX, Fig. 1). The nature of the matrix is not conducive to perfect preservation. The stems are from 4-7 mm in width and the longest unbranched portion preserved is 6 cm One of the stems on each of the rock specimens bifurcates at angles of 25 to 35 degrees. They bore numerous spiny leaves of which the longest measured was 3.5 mm, and 1 mm broad at the base but tapered sharply to a point. Most of the spines curve outwards and upwards but some are perpendicular to the stem and quite straight while a few curve downwards. A careful search of the many spiny leaves revealed only three which appear to divide at a wide angle near the tip. One of these can be seen on the right hand side of Plate IX, Fig. 3. Spines are preserved only on the margins while the surfaces of the stem bear

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the leaf cushions and scars which are sometimes most irregularly arranged but in other places exhibit a marked horizontal, or sometimes vertical alignment causing corrugation after shrinkage. The uneven surface can be emphasized by oblique lighting. Four or five rows of scars are usually visible on a stem. Some of the raised leaf cushions have a small hole which probably indicates the passage of a vascular bundle into the leafy spine, and, on a few of the stems, longitudinal central strands indicate vascular tissue.

On the right hand side of the branch on specimen J.T. 22 (Fig. 4) there is a small spherical object approximately 0.5 mm in diameter. It lies at the end of a leaf but not attached to it. This may be a detached sporangium but no other indication of fertile leaves was seen.

Comparison

Frenguelli (1954, Plates I-III) described and illustrated a number of stems, from the uppermost middle Devonian beds of Quebrada de la Charnela in the province of San Juan in Argentina, as *Protolepidodendron eximium*. They resemble the Cape stems so closely that there is little doubt of specific identity. Most of the Argentinian stems are a little narrower but some are of the same size. Frenguelli found a few bifurcating leaves but thought they were accidental.

In discussing this Argentinian plant Kräusel and Dolianiti (1957, p. 13) suggested that it should not be included in *Protolepidodendron* since the genus is founded on the bifid nature of its leaves. With this opinion Grierson and Banks (1963, p. 248) concur. I believe that since in both the Argentinian and the Cape plants a few bifid leaves have been found the retention of the classification proposed by Frenguelli is justified. It is possible that the paucity of evidence is due to the separate tips lying in different planes. This, however, raises the question of its possible inclusion in *P. scharyanum* Krejci, for Frenguelli considered that apart from bifid leaves the species were identical. With this opinion I cannot agree for the specimens of *P. eximium* from both Argentina and the Cape have leaves with very wide bases and borne at an acute angle. In this they differ considerably from the slender and pronouncedly bifid leaves of *P. scharyanum*.*

The closest Northern Hemisphere comparison known is with *Eleutherophyllum drepanophyciforme* Remy and Remy (1960, Plate I, especially Figs. 1 and 5) from the Namurian A horizon of Niederschlesien in which the general appearance of the stems is very similar, but the leaves of the Northern plant are longer and more delicate.

* Since this was written Menendez (1965b.) has reclassified Frenguelli's specimens as *Drepanophycus eximius* nov. comb. Since the S. American and S. African specimens are regarded as specifically identical, the South African specimen should also be renamed *D. eximius* (Frenguelli) Menendez, but in the light of the argument above this may not be wise until more specimens from each country are available and the argument of the existence or otherwise of bifurcating leaves can be settled.

Protolepidodendron theroni sp. nov.

Plate X, Figs. 1-5.

Two specimens, J.T. 31 and J.T. 24 which are from lower horizons than *P. eximium* differ sufficiently to be placed in a new species. They were collected by J. Theron, in whose honour the species is named, in the vicinity of the railway station of Vondeling between Prince Albert and Willowmore. J.T. 24 will be stored in the Geological Survey Museum, Pretoria but J.T. 31 has been donated to the Geological Museum of the University of Stellenbosch.

Specimen J.T. 31

The best preserved specimen is J.T. 31, Plate X, Figs. 1-4 and was recovered from the main Witteberg sandstone at approximately 1,900 feet below the tillite. It is a small stem preserved in weathered but still dense quartzite. At the base there is a bifurcating mould which branches at 40 degrees. An uncompressed limonite cast of the stem still occupies the right hand branch (Plate X, Figs. 1, 3 and 4). The stem is 1 cm wide above the point of bifurcation and bears spirally arranged, vertically elongated diamond-shaped leaf bases which measure 5 mm in length and 1 mm in breadth. The outlines of these can be seen only faintly on the top of the stem but they are clear on the left hand side where moulds of several leaves can be seen projecting into the quartzite. They were apparently 2-3 mm long and 1 mm wide. Most of them are truncated but the thick base tapers downwards into the stem at a steep angle. One of the leaves ends in a sharp point but the moulds of two others are preserved near the area where a quartz vein cuts the stem, and are clearly bifid in the last 1 mm (Plate X, Fig. 4). A transverse section of the stem shows the projecting leaf bases (Plate X, Fig. 3). Two slides numbered X4725 were cut and are in the palaeobotanical collection of the Witwatersrand University. It was hoped that even in this opaque medium it might be possible to determine the outline of the triangular xylem strand which is characteristic of the genus *Protolepidodendron* but unfortunately no structure was visible.

Specimen J.T. 24, Plate X, Fig. 5 is from the 2nd sandstone of the Bokkeveld Series in the Vondeling area. It is a negative impression in weathered quartzite of a bifurcating stem which is 2 cm wide just below the branching In certain areas the hollow moulds of diamond-shaped leaf cushions are clearly preserved, separated by a network of ridges. Near the base of the stem these are elongated to emphasise a vertical alignment. The size of stem and the size and shape of the leaf bases are comparable and the angle of bifurcation is the same as in J.T. 31, but no leaves are visible.

Discussion and Comparison

The specific differences between the specimens described above and *Protolepidodendron eximium* are obvious but it seems justifiable to place them provisionally in the same genus.

The size of the stems and angle of bifurcation as well as the size and diamond-shaped distribution of the leaf bases are similar but in particular the bifid nature of several spines of both species warrant this decision. Nevertheless, the slender nature of the evidence provided by only two specimens of *P. theroni* is apparent and it is possible that more material and better preservation may disprove even the generic affinity suggested here.

Comparisons with other southern hemisphere species of *Protolepidodendron* and with some other genera are given below.

From Spitzbergen, Hoeg (1942) described *Protolepidodendron pulchra* of Upper Middle Devonian age. The specimens illustrated by him on Plate LIV, Figs. 1 and 2, and Plate LV, Fig. 2, are especially comparable in the size of the stems and in the size, shape and arrangement of the leaf bases with specimen *P. theroni* J.T. 24.

Walkom (1928, Plate XXIV, Figs. 1, 2 and 4) described two species of *Protolepidodendron* from Devonian rocks of Yalwal, New South Wales. The exact horizon was uncertain but was given as Upper Devonian. He named them *P. lineare*, in which the cushions are similar in size to the Cape specimens but the vertical arrangement is far more pronounced with a vertical groove separating adjacent columns, and *P. yalwalense*, in which the arrangement of cushions is comparable but they are larger and also less elongated. Well raised leaf scars were preserved which are not visible in the African stems. No projections were visible in the Australian specimens.

Kräusel and Weyland (1949) transferred these Yalwal specimens to the genus *Lepidodendropsis* but more recently Grierson and Banks (1963, p. 247) have supported Walkom's original comparison with the "Naples Tree" and regard them as possible *Lepidosigillaria whitei*. Only two other examples of southern hemisphere species of *Protolepidodendron* have been recorded. Kräusel and Dolianiti (1957) Plate 3, described *Protolepidodendron kegeli* from Lower Devonian beds of Picos, Piaui, Brazil, but this species differs from the Cape stems in having very long curved leaves.

Dawson (1881, p. 306 and Plate XIII, Figs. 15 and 16) described *Dicranophyllum australicum* from the Fanning River, Burdekin, Queensland. The rock was of Devonian age and occurred below the Star and Mount Wyatt beds. The plant has long and delicate bifurcating leaves and is therefore not comparable with the Cape specimen and Kräusel and Weyland (1933) combined it with the northern hemisphere *Protolepidodendron scharyanum* Krejci.

Genus *ARCHAEOSIGILLARIA* Kidston

Order: Protolepidophytales Family: Archaeosigillariaceae

Plate XI, Figs. 1-8.

The type species of this genus *Archaeosigillaria vanuxemi* was first described by Vanuxem in 1842 as a species of *Lepidodendron* and only received the present designation from Kidston in 1901. Recently Grierson and Banks (1963) have redescribed the Type specimen and provided a detailed history of the genus which need not therefore be repeated here.

It is a genus of mainly Middle Devonian protolepidophytes in which there is a general resemblance to the longitudinal arrangement of scars on Carboniferous *Sigillaria* trunks. The scars may look round, rhombic or hexagonal according to the preservation but are always prominent and are closely packed. Their shape is due, according to Grierson and Banks (1963), to a "subepidermal net-like layer of resistant cells through which passed the leaf trace surrounded by parenchymatous cells like those of the cortex". Consequently the degree of decortication of the stem determines the shape of the scars.

In 1937 Arnold described stems from the type area under the name of *Gilboaphyton goldringiae*. They bore sharply pointed tapering thornlike leaves. The stem surface, where leaves were absent, was smooth between fairly well-spaced separate and almost round scars. In 1949 Kräusel and Weyland after examining the original specimens and related ones from the Devonian type area of New York State came to the conclusion that *Archaeosigillaria* and *Gilboaphyton* represented two aspects of the same plant and united them under the former name. They provided a number of illustrations of transitional stages between decorticated and outer surfaces. Grierson and Banks (1963, Plates 34-37) have given further proof of the relationship.

Leafless decorticated stems with small hexagonal or rhombic scars occur in South Africa and resemble some of the illustrations of *A. vanuxemi* fairly closely. They are described below. Because of minor differences and the fact that no leaves of any kind are preserved and having regard to the great distances from the type area, the specimens have been placed in a separate species for which the name given to the original South African specimen has been retained.

Archaeosigillaria caespitosa (Schwarz) nov. comb.

Plate XI, Figs. 1-8.

The only previous record of a stem of this type from South Africa was one described by Schwarz (1906, p. 357, Plate VI, Figs. 5 and 5a) as *Bothrodendron caespitosum*. I do not know whether Schwarz originally intended to call it *Bothrodendron* or *Cyclostigma*. He used the former term as a heading but on p. 358 referred to the specimen as *C. caespitosum* and all his comparisons were with specimens of *Cyclostigma*. In the text he nominated Specimen 142, Albany Museum, as the type of his species but in the description of the plates, specimen 145 is quoted. The drawings although not very clear are definitely of Specimen 142 which is therefore accepted as the type. A re-examination of this specimen suggests that it is far closer to the genus *Archaeosigillaria* than to either of the genera mentioned by Schwarz. It is redescribed and refigured below.

Holotype Specimen 142 A.M. Plate XI, Figs. 1 and 2.

This specimen was collected by Bain and is stated to have come from the Witteberg Beds of the so-called cold Bokkeveld area of the Ceres District, Western Cape. The exact horizon, however, is unknown.

It is an almost cylindrical cast of a stem 5 cm long and 1.5 cm in diameter, the centre of which is now filled with sediment. The scars are round or oval and about 1 mm in diameter or elongated longitudinally to 1.5 mm and are arranged in vertical rows in which the scars alternate in adjacent rows. They take the form of small raised areas or bosses which in a few cases are truncated and appear ring-shaped. There is no distinctive marking on any of them. On the right hand side of the stem in Plate XI, Fig. 2 an area can be seen where the projecting bosses have been flattened, leaving hexagonal scars crowded together. On Plate XI, Fig. 1 scars can be seen on the inside of the upper part of the cast showing that the stem had apparently branched at a very steep angle but the left hand branch is now missing.

Specimen J.T. 30, Plate XI, Figs. 3-4 will be kept in the museum of the Geology Department of Stellenbosch University.

This well-preserved small stem was collected by J. N. Theron (1962) of the Geological Survey from the main Witteberg Sandstone approximately 2,000 feet below the top of the Cape System in the vicinity of Vondeling in the district of Willowmore and was sent to me for determination. It is a limonite cast of a stem which bifurcates at a very acute angle like that of the type specimen. At the base only the mould is preserved. The matrix is of deeply weathered ferruginous sandstone. The left hand branch of the stem, after dividing, is 8 mm wide and exhibits 8 closely spaced rows of leaf bases which alternate in adjacent longitudinal rows. They form a closely interlocked rhombic and sometimes hexagonal pattern suggesting spiral growth. Some of the projections have a small hole and others a longitudinal slit on the top. The marks are not consistent but since similar marking can be seen on some of the American specimens (Kräusel and Weyland 1949, Fig. 6) it is possible that both are related to the emergence of a vascular bundle.

On the mould at the base of the stem the hollow scars are more hexagonal in shape and some still contain a round, ferruginous remnant of a leaf trace. No leaf or spine-like outgrowths now remain even along the margins and the specimen is almost certainly a decorticated one.

A slide, No. X4726, was cut to determine whether any broad pattern might have been preserved although there was no possibility of detailed structure in the opaque mineral replacement. None could be seen.

This specimen is regarded as being specifically identical with the Schwarz Specimen 142 A.M. from Ceres.

A few other stems from the Albany Collection have been included provisionally in the genus. They exhibit rhombic scars and far less relief but may represent other surfaces on the same plant.

Specimen 10739 S.A.M. (824 Haughton) Plate XI, Fig. 8 is a fragment of a similar stem. It was figured by Seward (1932, Plate XXIII, Fig. 5) as *Planta* *incertae sedis* but he compared it with *Archaeosigillaria vanuxemi*. The specimen came from the Witteberg shales of Nourse Poort near Steytlerville.

Specimens 4172*b and* 4172*c*, A.M. Plate XI, Figs. 5 and 6.

Figs. 5 and 6 are counterparts on each of which two surfaces of a small stem are preserved, viz. a convex and possibly decorticated surface of the cast and a concave inner surface. I do not think that the latter represents the mould of an outer surface.

The matrix is of dark carbonaceous micaceous sandstone and the cast is a lighter coloured, bleached clay. The size of stem and of the rhombic leaf bases are similar to J.T. 31 but the latter do not project to the same extent.

The locality of the specimens is unknown.

Specimen 4140 *A.M.*, Plate XI, Fig. 7

In micaceous sandstone there is a 9 cm long and 9 mm wide hollow mould of a stem which is possibly of the same species. The small rhombic leaf bases are clear but no further detail is apparent.

All the specimens described above are of the decorticated *Archaeosigillaria* type. Stems with more openly spaced small protruberances or with thorny leaves which might be compared with the outer surface of the *Gilboaphyton* type are fairly common but since no transitional forms have been found they have not been included here but are described under headings of *Drepanophycus* and *Haplostigma*.

Comparison and Age

In the Northern Hemisphere the likeness of these Cape stems to *Archaeosigillaria vanuxemi* has been mentioned already. The hexagonal and rounded scars of specimens 142 and J.T. 31 can be compared with the type specimen as illustrated by Dawson (1862, Plante XII, Fig. 7) and by Grierson and Banks (1963, Plate 34, Figs. 1 and 3 and Plate 36, Figs. 3 and 5). The rhombic scars of Specimens 4140 and 4172 are more like those shown by Banks 1960, Plate I, Fig. 2) and by Grierson and Banks (1963, Plate 35, Fig. 37) but they may also be compared in size and shape with a small specimen illustrated by Dawson as *Lepidodendron gaspianum* (1862, Plate XVII, Fig. 58) and others from Bear Island illustrated by Heer (1872, Plate LIV, Figs. 1 and 1b) as *Lepidodendron veltheimianum*.

Southern Hemisphere records of the genus are very limited but offer interesting comparisons. There is a very close resemblance which may amount to specific identity between type specimen 142 and J.T. 30 and *Cyclostigma con-*

fertum (Frenguelli 1954, Plate 4, Figs. 1 and 2) from the Middle Devonian beds of San Juan, Argentina, Both Kräusel and Dolianiti (1957, p. 14) and Banks (1960, p. 68 and 72) have expressed the belief that the San Juan plant is really *Archaeosigillaria* and that there is a strong resemblance to *A. vanuxemi* and Grierson and Banks (1963, p. 246) in a table of distribution doubtfully assigned the plant to this species.* In 1951 Frenguelli (Plate I, Fig. 11) illustrated a fragment of a stem with small rhombic markings. It was from the Middle Devonian beds of San Juan and he called it *Asteroxylon* sp. but it may well be *Archaeosigillaria*.

Specimens 4172 and 4140 can best be compared with *Archaeosigillaria picosensis* Kräusel and Dolianiti (1957, Plate IV, Figs. 1 and ?). This specimen was from the Lower Devonian of Picos in the State of Piaui, Bolivia. It is a small piece of stem broken at a point just below branching which is indicative of a steep angle. The scars in the upper half are almost oval but those in the lower half are distinctly rhombic and are elongated transversely.

Grierson and Banks (1963, p. 245-246) have expressed doubt about the inclusion of this species in the genus but there are some transitional features between *A. picosensis* and Frenguelli's specimen and those from the Cape. Kräusel and Dolianiti had suggested in 1957, the uniting of the two South American specimens but since the hollow mould of J.T. 30 also exhibits similar features, it is believed that all the specimens could be included in one species. If the San Juan and the South African plants should prove to be identical, and for this more specimens from each area are desirable, Schwarz' specific name would have priority.

A possible comparison may be made with an Australian specimen from Devonian rocks of Yalwal, New South Wales (exact horizon unknown) (Walkom, 1928, Plate XXIV, Fig. 3) which was described as ? *Lepidodendron clarkei*. Walkom compared his specimen with the rhombic scars of *L. australe*, but found that those of *L. clarkei* were considerably smaller. Most of them are more hexagonal than rhombic and although they are a little larger than those of the Cape specimens and the area of the stem illustrated is much larger than of any yet found in Africa, it agrees very well with the other southern hemisphere stems.

Corsin (1934) described *A. vanuxemi* of Dinantian Age from French African equatorial regions but I have not seen this paper.

According to Banks (1960) *Archaeosigillaria* is known to range from the Lower Devonian to the Upper Carboniferous. This is, however, misleading because the only Lower Devonian specimen is from Brazil (Kräusel and Dolianiti, 1957) and the only Upper Carboniferous one from Saxony, Germany. The vast majority of known specimens are from Middle Devonian while from the Upper Devonian the type specimen is the only one known. There are several occurrences in the Lower Carboniferous of Europe.

* Since this was written Menendez (1965a.) has re-described Frenguelli's species as *Archaeosigillaria conferta*. He was apparently unaware of Schwarz' type specimen described in 1906.

Genus *LEPTOPHLOEUM* Dawson

Order: Protolepidophytales Family: Leptophloeacea

N. Hemisphere: *Leptophloeum rhombicum* Dawson, 1862

S. Hemisphere:
- *Lepidodendron nothum* Carruthers 1872 (non Unger)
- *Lepidodendron australe* McCoy 1874
- *Lepidodendron nothum* | Feistmantel 1890
- *Lepidodendron australe* | Feistmantel 1890
- *Lepidodendron albanense* Schwarz 1906
- *Leptophloeum australe* (McCoy) Walton 1926

General

The genus *Leptophloeum* is believed not to extend beyond the upper part of the Devonian and it is therefore of considerable value as a zone fossil. It is widely distributed in rocks of this age in both hemispheres and is essentially a type of lycopod stem in which a very pronounced pattern of regular rhombic and slightly convex or raised leaf cushions are separated from one another by comparatively wide margins. In many of the stems, but by no means in all, a small circular scar of the leaf trace occurs near the centre of the cushion or, more often, in the upper corner. In addition fertile specimens have a zone of closely spaced T-shaped sporophylls (see Walton, 1926) but these are seldom preserved.

Leptophloeum rhombicum Dawson

This name was applied first by Dawson to stems from the Upper Devonian of Perry, Maine, U.S.A. and his illustrations have often been reproduced (Dawson, 1862, Plate XII, Fig. 6 and Plate XVII, Fig. 52, also Dawson, 1863, Plate XVIII, Fig. 19). His reconstruction of the plant in 1863 which showed a terminal tuft of long, linear, single-veined leaves is no longer accepted but the nature of the stems is well supported.

Leptophloeum australe (McCoy) Walton, its history, occurrence and age in Australia

The naming of southern hemisphere representatives of the genus *Leptophloeum* has suffered considerable confusion. The first record was by Carruthers (1872) who described stems from Queensland, Australia, as *Lepidodendron nothum* Unger. He believed that these were specifically identical with Dawson's *Leptophloeum rhombicum* but also with Unger's specimens from Thuringia (1856) which had priority of naming. In this he was mistaken because the Thuringia specimens are now known to be unrelated, but the error was perpetuated for many years. Two years later McCoy (1874) described similar stems from Victoria, Australia, as *Lepidodendron australe*. Later Feistmantel reproduced McCoy's drawings of *L. australe* which were at that time believed to be of Lower

Carboniferous age, and illustrated also very similar specimens from New South Wales and from Queensland (Feistmantel, 1890, Plate I, Figs. 1-4, and Plate II, Figs. 1-6) for which he retained the name *L. nothum* because they were of Upper Devonian age. Modern stratigraphers have shown that the Australian plants from all these states are of Upper Devonian age so that separation on the basis of age is not valid. In addition, a number of authors in this century have agreed with Carruthers that the Australian plants were generically and possibly specifically identical with Dawson's *Leptophloeum rhombicum*. In particular, it was Walton (1926) who in redescribing the original Australian specimens advocated that all the Australian specimens in question should be combined with Dawson's *Leptophloeum* but that the small doubt of specific identification should be accepted because of the great distance which separated them. The Australian specimens should henceforth be known as *Leptophloeum australe*. Although a few other authors and notably Sze (1952) who found similar specimens in the Upper Devonian of China have concurred with Walton's views, the name *Lepidodendron australe* had become entrenched in Australian literature and is still used by a number of geologists but must be regarded as synonymous with *Leptophloeum australe*.

Through the courtesy of the Director of the Bureau of Mineral Resources, Canberra, I have received within the last few years a number of current but unpublished reports by Mrs. Mary White of plant fossils from many parts of Australia. These included photographs of *L. australe* in different stages of preservation which confirmed my belief that the Cape stems can be included in the same species.

In a recent composite description of the Devonian of Queensland, Bush et al (1960) described the thick sediments which accumulated in the Tasman geosyncline. They occur now in a number of basins in which the ages of plant horizons and of known marine invertebrate horizons can be compared. *L. australe* occurs in the Yarrol Basin, the Hodgkinson Beds, the Gilberton Formation and the Lower Burdekin Valley where it is found in both the Dotswood Beds and in the overlying Star Beds in association with *Cyclostigma* cf *kiltorkense*. It has been found also in the extreme north of the Drummond basin.

In New South Wales a recent revision of the Devonian sediments has been undertaken by Crook (1961). In the Parry Mudstone (formerly the Barraba Mudstone) Crook reported that *L. australe* is found throughout its thickness of 1150′ but especially at the base. Near the top, it is associated with an Upper Devonian plant known otherwise only from New York. In the overlying Kiah Limestone a very high Devonian goniatite is found. Crook places the Upper Devonian to Carboniferous, or Tournaisian to Visean boundary, in the Kiah Limestone and considers that *L. australe* is completely confined to Upper Devonian beds. He states that it has never been found associated with Carboniferous marine fossils in Australia. In addition, White (1957/53) has described the plant from Laurel Downs in Western Australia.

Leptophloeum australe in Africa

Plate XII, Figs. 1-6

General

In South Africa, apart from indecisive early records, such as Jones (1872) who mentioned that *Lepidodendron* had been found at Riversdale and also 50 miles to the south in the Swellendam district, by Dr. Atherstone, Thomas Bain and others, and Feistmantel (1889) who recorded a number of separate lycopods from Cape System rocks but did not describe them, the first description of the plant was by Schwarz (1906, Pl. VI, fig. 1). Under the name of *Lepidodendron albanense*, a specimen from the Witteberg Beds at Howisons Poort was described and figured. Schwarz compared this and other specimens with the Australian species and found a close likeness but was uncertain that they were identical since the Cape specimens usually lacked the characteristic vascular scar. Other authors e.g. Rogers, Seward (1907) have drawn attention also to the similarity. There are many references to such stems in the Witteberg Series implying that they are comparatively common but only a few specimens have been preserved in Museum collection. The best of these are described below. The lack of detail in most of them can be ascribed to the fact that all were preserved in coarse quartzites of the Witteberg Series so that they retain no organic residue and only broad features are evident, but one of the specimens, No. 4088 A.M., shows the small vascular scars quite clearly and I believe that there is no longer any justification for keeping them separate. The Cape specimens are therefore included as *Leptophloeum australe*.

Description of specimens

Specimen 150 *A.M.* (Schwarz 1906, Pl. VI. fig. 1) Pl. XII, fig. 1

This specimen from a quarry in Witteberg Series, south of Grahamstown, was formerly the type of *Lepidodendron albanense* (Schwarz 1906). It is the impression of a large stem on which the rhombic scars can be seen to decrease in transverse diameter from 15 mm to 8 mm within the preserved length of stem. No leaf trace scar is visible but Carruthers (1872) had pointed out that they were rarely preserved on large stems.

(*Specimen* 152 *A.M.* not figured here but quoted by Schwarz as a decorticated form of *L. albanense* does not appear to belong to the species.) Schwarz (1872) had mentioned other specimens in which there is "a slight protuberance near the upper corner of some of the leaf bases" and another with "larger rounded protuberances fixed centrally in the scar area".

Specimen 4088 *A.M.* Pl. XII, fig. 2

This hollow mould of a stem is also from the Witteberg Series and from Howison's Poort but is preserved in dense, recrystallised quartzite. On at least six of the rhombic scars a small round protuberance is evident near the apex of the rhomb. It provides confirmation of the specific determination of *L. australe*.

In the Grahamstown Area Rennie and Mountain (1942) have stated that the rhombic scarred stems appear to be confined to the Witteberg quartzites.

Specimen 11403 *S.A.M.* Pl. XII figs. 3-6

This is the most interesting of the specimens and is from the Western Province. It is a cast of *L. australe* from Touws River 2 miles east of Nourse Poort, near the base of the Witteberg in which the external pattern of raised rhombic cushions is preserved in yellowish limonite. There are no signs of vascular scars on the outside but a number of thin limonite strands project into the sandstone filling of the cast. Each of these may be regarded as a vascular strand which terminated in a small hook. The longest of them is 2.5 cm, and since the radius of the stem is 2.7 cm, the pith must have been very small, as in most lycopods. Pl. XII, figs. 5 and 6 illustrate the two ends of the stem. Several of the strands can be traced to the upper corners of the rhombic scars but others have been misplaced for this resistant tissue obviously survived after the decay of the rest of the internal structure of the stem.

On Pl. XII, fig. 4, photographed perpendicular to the stem, the wide double-edged margins between the cushions can be seen clearly on the lower right hand side. These are common in a number of Australian specimens and provide further confirmation of identity.

Comparison with similar stems in other areas

In addition to the type area of Australia, *L. australe* has been recorded from several parts of S. America.

Frenguelli (1952) recorded a conformable succession of Lower Gondwana Beds on the eastern slopes of the Pre-Cordillera of San Juan, Argentina, in which *L. australe* has been found in the Cortadera Beds. These beds are overlain by the Tupe Beds in which abundant *Rhacopteris ovata* occurs. The latter fossil is essentially of Lower Carboniferous age and an Upper Devonian age can therefore be assigned to the Cortadera. No figure was included in this paper. The only illustration I have been able to find of a South American *Leptophloeum* was included in Frenguelli (1946) but was very poor and not altogether convincing.

From a Devonian horizon in Bolivia, I have been sent by Dr. Guy A. Chamot a number of small specimens which I believe to be *L. australe*. They occur in beds which lie conformably above a lower Devonian marine horizon with invertebrate fossils related to those of the Lower Bokkeveld.

From the northern hemisphere, apart from the specimens of *Leptophloeum* from New York State already discussed, a number of fossils with similar characteristics have been recorded from Devonian rocks of Europe and from China where Sze in a series of papers (1952-1956) on Devonian plant fossils in China has described *L. rhombicum*—from Upper Devonian beds in a number of provinces. Two groups of rhombic scarred Devonian stems, originally believed to be

Leptophloeum have now been separated into other genera and special mention must be made of them. The first group, from the Devonian of Spitzbergen was described by Nathorst (1894) and later by Hoeg (1942b, p. 128) who summed up the evidence and decided against including the Spitzbergen specimens in the genus *Leptophloeum* mainly on the grounds that the small fertile peltate leaves described by Dawson for *L. rhombicum* and by Carruthers and Walton for *L. australe* had not been found in Spitzbergen. He named them *Bergeria mimerensis*. His figures (Hoeg 1942, Pl. L figs. 1-3) can be compared in size with *Leptophloeum* but the strong vertical keel present on some of the rhombic scars has not been seen on any South African specimen. Recently Schweitzer (1965) has been able to confirm Hoeg's decision to keep *Bergeria* from Spitzbergen as a separate genus.

The second comparison is with Devonian stems from Russia which were originally described by Krystofovitch (1927) from the Middle Devonian of the Minusinsk Region of Central Siberia as *Leptophloeum sibiricum* but later transferred to the genus *Blaseria* by Zalessky (1934).

In almost every publication on Devonian floras from the earliest records, an association of rhombic scarred stems with round scarred stems has been reported. Some authors believed that they represented different aspects of the same plant. This will be discussed in more detail at the end of the next section in which the round scarred stems from the Cape System are described.

The controversial **Genus** *HAPLOSTIGMA* Seward

The confusion in early descriptions

Stems with spirally arranged round or oval scars are undoubtedly the most common Devonian plant fossils found in the Cape System. They occur in rocks of both Bokkeveld and Witteberg Series although the preservation differs in these respectively predominantly argillaceous and arenaceous formations. The history of their description has been one of considerable confusion and they have been regarded by various authors as decorticated or "knorria" forms of lycopod stems and alternatively as outer surfaces of psilophytes with round projections. Early authors compared them to both *Bothrodendron kiltorkense* Haughton and to *Cyclostigma australe* Feistmantel. The chief reason for confusion can be attributed to the fact that on three different occasions two separate genera were united under one name.

In South Africa, stems described here as *Palaeostigma* and *Drepanophycus* were formerly included in *Haplostigma* and in South America *Palaeostigma* and *Spongiophyton* have been separated from it by Kräusel. The pruning in both countries has left a plant which is constant in many features and probably a true genus but in the upper part of the Cape System some doubtful specimens preserved in quartzite are still included, and more collecting is necessary before the upper stratigraphical limits of the plant can be defined and the diagnosis emended to describe a single true genus.

In an attempt to produce some order out of the present chaos it has been necessary to photograph a number of early specimens, of which previously only drawings have been available, together with others discovered more recently and to undertake a general review of earlier literature on the South African examples in order to compare them with similar stems in other continents. The specimens named below represent the stages towards the creation of a separate genus by Seward. They will be described and discussed chronologically and summarised at the end of this section.

Haplostigma irregulare (Schwarz) Seward

Plates XIII-XVI

Bothrodendron leslii (Seward 1903 Pl. XI fig. 4)
Lepidodendroid stem (Seward 1903 Text fig. 8, p. 89)
Bothrodendron irregulare (Schwarz 1906, Pl. VI, fig. 4)
Bothrodendron irregulare (Seward 1909 Pl. XXVIII, figs. 1-4)
Haplostigma irregulare (Seward 1932 Pl. XXIII, figs. 2, 5, 6 and 7 —Pl. XXIV, figs. 11 and 13)

Description of Specimens—Old and New

Paratype of *Haplostigma irregulare*—Spec. B, S.A. Mus. Pl. XIII fig. 2
Bothrodendron leslii (Seward 1903, Pl. XI, fig. 4)
Paratype of *Bothrodendron irregulare* (Schwarz 1906, p. 356)

The earliest illustration of this type of stem from the Cape System was a drawing published by Seward (1903, Pl. XI, fig. 4) of a stem which he called *Bothrodendron leslii* under the mistaken impression that it was part of a collection of younger stems from Vereeniging to which it bore a superficial resemblance and which were described in the same paper. The latter are now known as *Cyclodendron leslii* (Seward) Kräusel and are unrelated but the scars of Spec. B. were smaller and it was the only bifurcating stem in the collection. Even at that time Seward drew attention to this feature and stated that Specimen B could be matched almost exactly with *Bothrodendron kiltorkense* from Bear Island (Nathorst 1902, Plate XI, figs. 1, 2, 5, 6, 10 and 11).

The mistaken identity was noted in a foreword to volume 4 of the Annals of the S.A. Museum (1903) and also by Schwarz (1906) who had collected the original specimen from Bokkeveld Shales near Triangle Station (now Matroosberg) in the Hex River Pass, Worcester Division, of the Western Cape. It can be seen in the S.A. Museum where I found a missing portion in the collection and have glued it into place. The present illustration Pl. XIII, fig. 2, is therefore larger on the left hand side than the drawing in Seward (1903). Signs of vascular strands are apparent in the left hand branch and a form of horizontal ribbing is developing at the top of the right hand branch.

This specimen was later nominated by Schwarz (1906) as a paratype of *Bothrodendron irregulare*.

Paratype of *H. irregulare* Spec. V. 236 Nat. Hist. Mus. Lond. Pl. XIII, fig. 4

This specimen came from the Atherstone quarry, Kowie (Port Alfred) from beds now regarded as Bokkeveld Series (Rennie and Mountain 1942). It was figured by Seward (1903, Text fig. 8, p. 89) as a "lepidodendroid stem". I am indebted to Dr. Chaloner of Imperial College for the photograph of this specimen reproduced on Pl. XIII, fig. 4, particularly since the stem is the best preserved of any yet found.

There are what Seward called "curved linear appendages, presumably leaves", attached along each margin almost at right angles to the stem. The preservation suggests that at the base they were inclined upwards and were thick, strong and rigid but tapered to a thin flexible apex. The stem, which is a flattened cast shows only a spiral arrangement of rounded scars and no suggestion of longitudinal or transverse ridges. Seward in a later publication (1909, p. 483) suggested that it might be regarded as specifically identical with the type specimen of *Bothrodendron irregulare* (Schwarz) which is described below. Although the stem is 2.5 cm wide and therefore considerably broader than the type, the spacing and arrangement of the scars is similar.

Type Specimen H. irregulare (Schwarz) Seward. Specimen 165 Albany Museum Pl. XIII, figs. 1 and 3. *Bothrodendron irregulare* Schwarz (1906, p. 3560357, Pl. VI, fig. 4)

Specimen 165 Albany Museum was nominated by Schwarz (1906) as the type of *Bothrodendron irregulare* and later (Seward 1932) became the type of *Haplostigma irregulare*. The illustrations on Pl. XIII figs. 1 and 3 are the first published photographs of the slab of graphitic phyllite from Bokkeveld beds on the farm Sweet Waters, near Bathurst. The specimen measures 18 cm x 10 cm and is covered with a mass of small stems, two of which must have been selected by Schwarz for his drawing which, however, did not express all the features adequately, and so may have been responsible for some of the later confusion. He stated that the species was common in the quartzites of the Witteberg Series at Port Alfred, i.e. in beds now accepted as Bokkeveld Series.

The stems are all approximately 1 cm in diameter and are covered with small spherical scars which are either convex or concave according to positive or negative preservation or to some degree of decortication. They are normally equidistant both transversely and longitudinally and exhibit a spiral arrangement but through later distortion or from drying of the stems, the scars may be arranged in either longitudinal or transverse rows and are sometimes contracted into ridges. The latter can be emphasized by the direction of the oblique lighting. The curvature of the stems shows that they were pliable and the wrinkling of some of the cuticular surfaces suggests that they were soft herbaceous plants.

No leaflike projections or spines are preserved on any of the stems but a circular hole on each raised scar suggests that a round spine has been truncated. Pl. XIII fig. 3 is an enlargement of the lower part of fig. 1 and shows a stem bifurcating at an acute angle.

Schwarz was so impressed with the similarity of these stems to *Cyclostigma australe* Feistmantel that he stated he would have included them in the Australian species had not Seward already placed Spec. B in the genus *Bothrodendron*. He thus perpetuated Seward's original error. His choice of *irregulare* as a specific name was scarcely suitable because a regular arrangement of scars is far more common.

It is a little difficult to understand why every stem on this type specimen No. 165 is so uniform in size. Can it be regarded as an entanglement of young plants all at the same stage of development or does it represent a smaller species of the same genus? At present not enough is known to justify the separation of the two forms.

Haplostigma irregulare from Port Alfred.

Spec. 2903-2905 S.A. Museum, Pl. XIV, figs. 1-5

Bothrodendron irregulare (Seward 1909 Pl. XXVIII figs. 184)

These specimens in pinkish grey talcose phyllite are from Bokkeveld Beds which outcrop in the grounds of the Mental Hospital at Port Alfred. Some of them were sent to Seward who described and figured a few (Seward 1909, Pl. XXVIII figs. 1, 2, 3 and 4) and considered that all could be included in *Bothrodendron irregulare* Schwarz (now *Haplostigma*). The stems present a number of different aspects of preservation and several show bifurcation but there is no doubt of their inclusion in Seward's later genus *Haplostigma* with the exception of the stem illustrated by Seward as fig. 3 which in the present paper is described as *Drepanophycus schwarzi*. The illustrations given here supplement those of Seward (1909) or emphasize some new aspect.

Specimen 2903 is illustrated on Pl. XIV fig. 1. Two of the stems have a flat surface with concave scars and represent negative impressions, but the central stem, the left-hand one in the figure, is part of a compressed cast and exhibits a columnar thickening which tapers downwards below each scar. This suggests the presence of strong fibrous, and probably vascular, tissue leading upwards into each projection.

The scars vary in form from prominent round swellings with a truncated top, giving the impression of two concentric circles, to circular depressions or crescent-shaped scars in which the deep groove marks the upper side of former projections.

Specimen 2909 *A*.1, Pl. XIV, fig. 2 includes a stem on which the marginal protuberances, which were so well shown on Spec. V236, Pl. XIII fig. 4, are preserved. This specimen is of particular interest because it is partly decorticated and in the lower half of the stem a central vascular strand 2 mm wide, can be seen, while in the upper part similar strands of tissue curve upwards and outwards from the centre and run along the lower side of each projecting spine.

The lighting used for the photograph emphasizes the lateral fibres but unfortunately the median one at the base is scarcely visible. If, as seems probable, this is vascular tissue, and not merely strengthening fibre, the appendages can be regarded as primitive leaves and not mere outgrowths of surface tissue. It would mean that the plants were lycopods rather than psilophytes but without better preservation no confirmation is possible.

Specimen 2905, Pl. XIV fig. 3. The preservation of this stem is intermediate between that on Plate XIII fig. 4 and Pl. XIV fig. 2. No vascular strands are visible and the outgrowths, three of which can be seen clearly on the upper margin with a row of them faintly visible on the lower margin, are rather short and falcate, resembling spines rather than the long round outgrowths to be seen in other figures. They may have dried and the thin terminal portions withered. The outer surface of the stem, with raised scars, is preserved on the left and right-hand sides leaving a decorticated surface with sunken scars in the middle portion.

On *specimen* 2909 A_2 Pl. XIV fig. 4 there are portions of a large and a narrow stem. On both the scars are crescent-shaped, and I believe represent somewhat deeply decorticated surfaces. The smaller stem is 11 mm wide and the arrangement of scars is particularly regular giving rise to a rhombic pattern which can be emphasized by oblique lighting. A few of the scars at the top of the stem are round. Although this unusual aspect is the only one preserved, Seward believed it probable that the stem could be included in the same species but the small outgrowths on the left hand side make this somewhat doubtful.

Pl. XIV fig. 5 is another stem on Spec. 2905 showing an outer and inner surface and the development of ribbing.

Specimen 3750 *Albany Museum* Pl. XIV fig. 6

A completely different aspect of *Haplostigma* is illustrated on Spec. 3750, A.M., Pl. XIV, fig. 6. A piece of dark carbonised cuticle is preserved on micaceous sandstone. Faint cell structure is visible and the position of the leaf spines is indicated by round holes. The preservation implies a thick tough cuticle and indicates that most of the stems with projecting lumps represent outer surfaces with truncated spines and are not decorticated or "knorris" types of preservation as both Schwarz and Seward at various times suggested. Unfortunately the source locality of this specimen is uncertain.

Haplostigma irregulare from Schietkraal nr. Steytlerville

Specs. 10742-10746 S.A. Museum Pl. XIV, figs. 7 and 8

A group of specimens preserved in a hard fine-grained ferruginous quartzite was collected by Haughton in the course of mapping in the Steytlerville district (Haughton 1935) and sent to Seward who described them in 1932 (Pl. XXIII and XXIV).

Only two of the specimens are re-illustrated here in order to give a complete representation of S.A. specimens from different areas and preserved in different kinds of rock.

Most of the specimens were collected on the farm Schietkraal in the Steytlerville district about 80 miles northwest of Port Elizabeth and from the upper part of the Bokkeveld Series. The farm lies just off the west margin of Geol. Sheet 150 (Sundays River) and Haughton (1935) stated that the same plant fossils could be found also in the Witteberg Series in that area. One specimen (Seward 1932, Pl. XXIII, fig. 7) was from the Uitenhage district, east of Bezuidenhouts River and from the second Bokkeveld shales "well down in the marine beds". It has not been refigured here but represents the lowest horizon in which the plant has been found.

The Schietkraal specimens are preserved in a fine-grained, highly ferruginous bed which is dark grey when fresh but weathers to a hard yellowish brown surface on which the casts and moulds of stems stand out in marked relief. All the specimens are preserved in the South African Museum, Cape Town. For convenience both the present museum numbers and those of Haughton quoted by Seward have been given for the Schietkraal specimens described below.

Specimen 10742, *S.A. Museum* (Haughton 833). On Pl. XIV, fig. 7 there are two stems of different sizes and different degrees of decortication. A portion of this specimen was illustrated by Seward (1932, Pl. XXIII, fig. 6). The larger stem exhibits ribbing, truncated leaf spines and a surface texture which may well represent the outer cuticular surface. The smaller stem displays an inner surface, on the left hand side of which the scars are distinct and crescentic while on the right hand side a raised rhombic pattern can be seen separating the depressions. It may form a link with the smaller stem shown in fig. 4.

Specimen 10746 *S.A. Museum* (Haughton 838) Pl. XIV fig. 8, is another stem figured previously by Seward (1932 Pl. XXIV, fig. 11).

It is a stem with very small flat scars and a pronounced transverse ribbing. Seward considered that the scars were of the same size as those shown in the larger stem of the present Pl. XIV fig. 7 but he also compared the surface with that of the stem which is described here as *Palaeostigma sewardi* and illustrated on Pl. IV, fig. 1. I believe that the latter comparison is more reliable. Seward regarded all the specimens from Schietkraal, Steytlerville, including that of

Palaeostigma as specifically identical with those from Port Alfred which he had previously (1909) described as *Bothrodendron irregulare* Schwarz. He decided, however, to erect a new genus based on the combined specimens which he renamed *Haplostigma irregulare* retaining Schwarz' specimen 165 as the type. It is doubtful, however, whether Seward ever had access to this type specimen. His diagnosis was naturally influenced by the inclusion of the *Palaeostigma* (Seward 1932, Pl. XXIII, figs. 1, 3 and 4 and Pl. XXIV, figs. 8, 9 and 12) on which he had based his description of the cuticle and also probably his emphasis on the classification of *Haplostigma* which he regarded as intermediate between psilopsida and lycopsida. He described it as a simple stem in which the scars of the appendages showed no scars of leaf traces, parichnos strands or ligules. (At that time it was not recognised that southern hemisphere Palaeozoic lycopods lacked parichnos and ligular scars.) It thus served to separate the plants from *Cyclostigma* and *Bothrodendron*, the northern genera with which they had so often been compared. There were furthermore no long foliage leaves like those of *Cyclostigma*. The fructification of *Haplostigma* is still unknown.

Round scarred stems preserved in sandstone Pl. XV

All the previous specimens were preserved in fine-grained sediments and all were from the Bokkeveld Series and therefore probably of Middle Devonian Age. There are, however, many stems preserved in sandstone and in some areas in dense quartzite, according to the degree of folding, in which only the main features survive. Many of these are comparable in size and arrangement with *Haplostigma* stems. Most of the quartzite and sandstone impressions are in rocks of the Witteberg Series and therefore a little younger but some are from Bokkeveld Sandstones. They are included here in the belief that some of them represent the same plant and because the absence of detail does not justify their separation. Others are included because this is the most convenient section for indeterminable lycopods. No organic matter survives in this matrix. The fossils are usually in the form of hollow moulds or sandstone casts and often not greatly compressed. The stems must therefore have been sufficiently rigid to withstand pressure until the rock had hardened around them. They include a few of the Albany Museum specimens to which Schwarz (1906) gave a number of different generic and specific names but which Seward (1909) on the evidence available considered should all be lumped together in *Bothrodendron*, and also a number of stems collected since 1932. They have been selected so as to represent as wide a range as possible.

*Specimen T.X.*18, Pl. XV fig. 1 was collected by J. N. Theron of the Geological Survey from Witteberg quartzite on the farm Elandsvlei in the De Doorns district. Two stems 1.4 cm in diameter are preserved as moulds in dense quartzite but only one has been figured. In this the original projecting spines have left deep circular depressions while at the base of the stem mould a portion of a quartzite cast is preserved, which in turn has a cylindrical hollow centre 2-3 mm in diameter which probably represents the diameter of the more resistant vascular tissue. This is the commonest type of fossil and may well represent *Haplostigma irregulare.*

Specimen 161 *A. Museum.* Pl. XV fig. 2

This hollow mould from the quartzites of Grootriver Heights in the Steytlerville district was described by Schwarz (1906, pl. VI, fig. 2) as *Didymophyllum expansum* but is now included in *Haplostigma*. Some of the cavities contain casts of the spiny projections.

Specimen 143, *A. Mus.* Pl. XV fig. 3

This was described by Schwarz (1906, Pl. VI, fig. 2) as the holotype of *Lepidodendron kowiense*. It was collected in the "Cold Bokkeveld" of the Ceres District but the exact horizon, although probably Witteberg, is unknown. Schwarz believed it to be specifically identical with the British Museum stem spec. B 260, described earlier. The fossil is a sandstone cast with evenly distributed protuberances each of which is truncated to leave a circular hole. The arrangement of the scars shows both horizontal and vertical alignment giving a faint checker board effect which was not visible on any of the specimens described previously.

Schwarz thought that the regular arrangement justified separation from *Bothrodendron irregulare* but it has been pointed out that the regular arrangement in the latter is more common and would be more likely to survive on casts than on flattened cylinders of the outer tissue.

Both Seward (1932) and Rennie and Mountain (1942) considered that the *L. Kowiense* type of stem should probably be combined with *Haplostigma irregulare.*

Indeterminable Lycopods Pl. XVI

Large cast of Lycopod stem. Pl. XVI, fig. 1 (scale in inches)

This is the largest known lycopod stem to have been found in the Cape System. It was recovered by J. N. Theron from the main Witteberg quartzite and is now in the museum of the Geology Department of Stellenbosch University where I have examined it. The markings are regular but unfortunately too indecisive for even generic determination. I am indebted to Mr. Theron for the photograph produced here.

Specimen J.T. 26, Pl. XVI fig. 2 was collected in 1960 by J. N. Theron from the 2nd Bokkeveld sandstone ? near Vondeling. It shows the typical preservation of these stems in the form of a flattened sandstone cast and both sides of the mould.

Specimen J.T. 25 Pl, XVI fig. 1 is from the 2nd Bokkeveld Sandstone near Vondeling. The hollow mould of a narrow branched stem exhibits pits and faint ribbing but details are obscure.

Specimen Pl, XVI, figs 4 and 5

This specimen was collected by Dr. A. J. Bruwer from the highly folded Witteberg quartzite on his farm Mijmering in the Ladismith District of the Cape, and presented to the Witwatersrand University B.P.I. (Pal.) Collection.

The narrow tapering mould exhibits clean cut oval scars (the strong lighting makes some appear crescentic). These can be compared with Pl. XV fig. 5 and to a certain extent, with Pl. XIII fig. 1, but their size and relief differ from those of the Port Alfred and Steytlerville *Haplostigma*.

Comparison of *HAPLOSTIGMA* with fossil plants from other areas in the Southern Hemisphere

Throughout the Southern Hemisphere stems of *Haplostigma* type constitute, in a number of cases, the only or the most important Devonian records. Some of them are listed below.

From the Falkland Islands where the Upper Palaeozoic succession of the Lafonian System bears so close a relationship to the rocks of the Cape and Karroo Systems, a number of Devonian stems has been found. Halle (1912, Pl. 6 figs. 1-3) illustrated three, among which his figure 3, where both cast and mould are preserved, appear to be identical with those from the Cape. Halle called them "lepidendroid fragments" and was apparently unaware of similar stems in Africa.

Seward and Walton (1923, Pl. XIX, figs. 1 and 2) illustrated two more stems from the same area and in a lengthy discussion concluded that they were more closely related to *Bothrodendron irregulare* Schwarz from the Cape than to any other known plant.

From South America a few closely related, if not identical stems have been recorded. White (1908) figured a specimen from Brazil which Seward (1909 and 1932) considered to be identical with those from South Africa. Darrah (1941 Pl. I, fig. 3) illustrated a closely comparable specimen from Parana. I cannot understand why he separated the fossils specifically, for his illustrations closely resemble the Cape specimens in size, variation in size, ribbing and absence of ribbing and appear to be identical. They were of Lower Devonian age.

Barbosa (1949) described stems from the Lower Devonian beds at Ponta Grossa, Parana, which he named *Haplostigma lenticularis*. Kräusel (1960) after examining these from several localities concluded that most of them were unrelated and transferred them to a new genus *Spongiophyton* but he renamed two fragments *Haplostigma irregularis* (Kräusel 1960, Pl. XI figs. 87 and 88) which are closely comparable with those from the Cape.

Frenguelli (1952a) described *Haplostigma furquei* from the Pre-Cordillera of San Juan, Argentina. His illustrations appear to be specifically identical with the Bokkeveld stems from the Cape.

From Antarctica a hollow mould of a stem preserved in dense quartzite has been described as *Haplostigma irregulare* (Plumstead 1962, Pl. I, figs. 1 and 2). It is closely comparable, both as regards the preservation of the fossil plant and the rock matrix with Witteberg specimens like that illustrated on Pl. XVI, fig. 1. Subsequently a Lower-Middle Devonian age was confirmed by associated fish remains. The specimen came from rocks of the lower Beacon System on the Upper Taylor Glacier in the Ross Sea area.

Perhaps the most important southern comparison is with Australia from which the earliest records of similar stems in the Southern hemisphere were published. Both Seward and Schwarz drew attention to the close resemblance between *Haplostigma irregulare* and *Cyclostigma australe* as described by Feistmantel (1890 Pl. II, fig. 7 and Pl. XI figs. 2, 3 and 4). The stems which he called *Cyclostigma* sp. came from Devonian rocks (horizon unknown) at Goonoo Goonoo in New South Wales and were associated with *Leptophloeum australe*. Feistmantel compared them with *Cyclostigma kiltorkense* but said the scars were more closely set. The second group of stems *Cyclostigma australe* were found with *Rhacopteris* and certain species of Lepidodendron in Lower Carboniferous rocks at Smith's Creek, Stroud, New South Wales. From Feistmantel's published drawings (and, as far as I know, there are no published photographs of the Australian *Cyclostigma*) there appears to be no difference between fossil plants from the two occurrences and both so much resemble the Cape specimens that Schwarz (1906) was prepared to regard them as specifically identical.

The comparison of modern photographs with drawings like those of Feistmantel (1890) is never altogether satisfactory and despite the similarity, it is not known whether *Cyclostigma australe* and *Cyclostigma sp*. are specifically identical with *Haplostigma*. The objections raised by Seward to the use of the terms *Cyclostigma* or *Bothrodendron* in Africa would apply equally to the Australian specimens. The term *Haplostigma* has not, to my knowledge, been applied in Australia and there have been very few references to *Cyclostigma* since Feistmantel's time.

I have discussed this matter in correspondence with Mrs. Mary White who was describing fossil plants from all areas of Australia for the C.S.I.R.O. in Canberra. She stated that she had not found *Cyclostigma* among specimens from any of the recently investigated areas. It is possible, however, that certain stems of this kind in Australia have been described as *Stigmaria* to which they bear a superficial resemblance.

In 1964 I made a very brief examination of some of the Devonian stems in the Natural History Museum in London. The specimens labelled *Cyclostigma australe* v. 24410 did not appear to be identical with those from South Africa save in size and distribution of scars. Many of the latter had radiating grooves around them which are not apparent in any of the African stems I have seen.

Comparison with Northern Hemisphere Devonian Plants

The older literature abounded in comparisons of Cape and Australian fossils with round scarred fossil stems from N. America, Ireland, Bear Island, etc. and many examples could be quoted of isolated stems illustrated by Dawson, Haughton, Nathorst (1902), Hoeg (1942), Zalessky, etc. which bear a close resemblance to some of the Cape Stems but Seward has shown that in certain features the genera to which these stems belong differ markedly. Further comparisons would be useless repetition.

Speculations on the common association of round and rhombic scarred stems in Devonian rocks

Reference must be made to this feature which recurs so frequently in Devonian literature. There would seem to be three possible causes. The first and most obvious is that the time range of these characteristic fossils overlaps, e.g. *Haplostigma* started earlier but existed with *Leptophloeum* in the Cape. In Australia also *Cyclostigma* and *Leptophloeum* have been recorded together and in Europe and China the same association is common.

Secondly, decorticated specimens of *Leptophloeum* as well as of the rather similar Devonian genera of *Bergeria* and *Blasaria* have a pattern of evenly spaced round scars thus justifying the frequent references in the past to a knorria form of stem.

This explanation cannot, however, be applied to the many southern hemisphere round scarred stems on which cuticle is still preserved, proving them to be outer surfaces.

A third possibility may not have been sufficiently explored and may still be kept in mind, namely that some, at least, of the round scarred stems represent the younger twigs of *Leptophloeum*. The suggestion is not new. It has been made in various forms by Feistmantel and others and it may be significant that it is very rare to find *Leptophloeum* stems narrower than 2.5 cm or Haplostigma wider. Recently Schweitzer (1965) has published a most interesting observation that *Bergeria mimerensis* and *Protolepidodendropsis* in West Spitzbergen are parts of the same plant.

Normally Devonian fossils are so fragmental that only isolated portions can be found and with time, other new relationships will undoubtedly be revealed. In South Africa the Bokkeveld *Haplostigma* occurs earlier than specimens of *Leptophloeum* and their relationship is therefore improbable.

Summary of *HAPLOSTIGMA* evidence and its systematic position

Knowledge of the genus *Haplostigma* has not increased very much since it was created in 1932 by Seward but it has been clarified by the removal of three other genera from it, and also by the evidence of possible vascular tissue in the spine-like leaves which would bring the genus nearer to the lycopods. It is obviously a primitive plant but in the absence of any known fructification further attempts at classification would be merely speculative.

Although only three stems have been illustrated on which the spiny projections are preserved, the quartzite moulds with deep hollows tapering upwards, indicate stems with persistent and strong spines which, like the stems, resisted decay until after the sediment had been cemented around them. This evidence is possibly not in agreement with the apparently soft and pliable smooth stems with smaller and closer scars, which occur on the type specimen on Plate XIII fig. 1. Both forms, however, occur at the same horizon and in the same area in Port Alfred and it would seem wiser to regard them at present as representing young and older aspects of the same plant than to separate them on comparatively slender evidence.

The fact that none of the recognised specimens of *Haplostigma* showed any but rounded scar patterns even when deeply decorticated suggest that specimens like the smaller stem on Pl. XIV, fig. 4 and the moulds on Pl. XV figs. 5 and 6, which up to now have been accepted as *Haplostigma* should be allocated to the long lists of indeterminable lycopods, at least pending further evidence, together with all those illustrated on Pl. XVI.

The geographical range of the genus, in all probability, includes South America, the Falkland Islands, East Antarctica and Australia and is thus confined to the Southern Hemisphere.

The stratigraphical range of the specimens described is from Lower Bokkeveld, which on marine invertebrate evidence is regarded as Lower Devonian in age to the Main Witteberg quartzite which is certainly not younger than Upper Devonian and much of it is probably of Middle Devonian Age.

SUB-DIVISION SPHENOPSIDA

CLASS PROTOARTICULATAE

Genus *CALAMOPHYTON* Kräusel and Weyland

1. General

In most Devonian plant assemblages there are a few plant fossils which may be regarded as forerunners of the articulates since they anticipate in various degrees the jointed stems and the whorls of branches and leaves which are so characteristic of this class of plants. None of the Devonian plants, however, exhibits the regularity in such features and habit of growth as are found in Carboniferous and later members of this plant division. Two genera are fairly well known: *Calamophyton* Kräusel and Weyland, and *Hyenia* Nathorst. In the northern hemisphere both are typically of Middle Devonian age. They have been described in numbers from Spitzbergen (Hoeg); Germany (Kräusel and Weyland); from Belgium (Leclercq and Andrews 1960) and the Greater Donetz Basin (Ischenko 1965) and recently from New York State, North America

(Bonamo and Banks 1965), but are little known from the southern hemisphere. Only Frenguelli (1954) has recorded *Hyenia argentina* from South America.

In discussing these genera Leclercq and Andrews (1960) have stated that the differences between *Calamophyton* and *Hyenia* are often difficult to determine for they are based on such features as the nature of the branching of the Sporangiophores of *Calamophyton* or the strong horizontal rhizome of *Hyenia* which gave rise to a number of upright shoots; but where neither of these features is preserved the differences may be negligible. Neither plant is known in its entirety and very little is known of their anatomy. They differ somewhat in their general habit of growth, *Calamophyton* normally being a stronger, larger plant with more conspicuous branching. Among the fossil plants from the Cape System there is only one which can, I believe, be included in this group and because of its size and branching it has been placed provisionally in the genus *Calamophyton*.

2. *Calamophyton capensis* sp. nov.

Pl. XVII figs. 1 and 2 and Pl. XVIII figs. 1-3

Locality:	Sweet Fountain (Estments farm) near Bathurst
Horizon:	Upper Bokkeveld
At Present:	Albany Museum, Grahamstown
Type Specimen:	No. 1809

The specimen, which has not been described previously, was collected many years ago from a quarry on the farm Sweet Fountain (formerly known as Estments Farm) which according to Rennie and Mountain (1942) lies three miles east of Bathurst railway station on the Kleinemond Road. The grey carbonaceous and highly micaceous shale is from the Bokkeveld Series and although the exact horizon is unknown, its age cannot be younger than Middle Devonian.

The specimen which is illustrated natural size on Pl. XVII fig. 1 consists of two main stems which are parallel and may have been parts of a single plant. Both are branched but that on the left is clearer. This stem is 19 cm long and approximately 1 cm wide at the base but tapers upwards. There are two apparent whorls of branches or digitate branching which simulates whorls—at the points marked a and b which are 4 and 14 cm respectively from the base. At both these points there are small transverse ridges which might be interpreted as nodes but which may be accidental. The outgrowths forming each "whorl" may be of branches, although no further branching is apparent on them, or they may be organs which functioned as leaves. The longest portion visible is 7 cm and they average 3-4 mm in width but do not appear to taper. They leave the main stem at an angle of approximately 30° and then curve outwards. Pl. XVIII fig. 1 is an enlargement of the lower "whorl" to show the branching and the apparent node.

The surfaces of all the wider stems have a film of light-greenish talc which contrasts clearly with the dark matrix of the rock. The mineral film often exhibits close transverse jointing but if it is removed the underlying stem is either smooth or finely striated longitudinally without any suggestion of joints. This can be seen on Pl. XVII fig. 2 which is a stem from which an oval cast, 15 mm wide, was separated. It is filled with sediment and compressed to a thickness of 1 mm The stem occurs on the lower part of the main surface of specimen 1809.

None of the branches of the type specimen can be seen to divide further but in the process of cleaving the stem shown in fig. 2, a small flake of rock was split off. On this surface there is a talc covered stem similar to the primary branches described above, 3-4 mm wide but with traces of several small branches on either side. See Pl. XVIII figs. 2 and 3. There is no marked transverse scar as in the larger specimen. The top branch on the right-hand side is the most complete. It curves outwards and upwards, dividing at one point into at least 4 branches each of which divides into two branches of unequal length and two of the longer sections can be seen to divide again. Some of the branch tips appear to be swollen and the whole system may well represent a fertile axis. The various portions lie at slightly different levels and are therefore difficult to photograph. Other fragments of small bifurcating stems occur on the same surface.

The whole rock specimen has a maximum thickness of 4 cm I was unwilling to risk damaging the main surface by further splitting of this type specimen but the abundance of plant material throughout its thickness suggests that further specimens of the plant might be found at the original site. On the same slab, small areas of *Haplostigma* occur and a few short lengths of *Palaeostigma* are preserved. The small oval scars on one of the latter stems are visible on the left hand side of Pl. XVII fig. 1 in the area marked c.

3. Discussion and Comparison

The preservation of this plant in the highly compressed Bokkeveld sediments is so poor that a reliable determination is impossible but its provisional inclusion in the genus *Calamophyton* appears to be justified. The best known specimens have been described by Leclercq and Andrews (1960) as *Calamophyton bicephalum* from the Middle Devonian of Belgium. Their material was excellent and plentiful but the painstaking separation of minute branches from the matrix by Professor Leclercq has probably never been surpassed by students of fossil plants and resulted in the most detailed reconstruction of the greater part of the plant. Both the main branching in pseudo-whorl-like manner and the monopodial and bifurcated branching of the small sterile and fertile axes can be matched to a certain extent at least in the imperfectly preserved Cape specimen.

Recently Schopf (1964) described *Calamophyton forbesii*, the first plant of this genus to be found in N. America. Although the species differs, his illustration on p. D.47 of a fertile shoot exhibits a type of monopodial branching very similar to that of the Cape branch, Pl. XVIII, figs. 2 and 3. Schopf suggested that the apparent irregularity in his "ascending system of fertile branches" might be due to dichotomy in alternating planes and regarded the habit as of specific significance. Its appearance in Cape, Belgian and Argentinian species as well, suggests that this feature may well be of generic significance.

Schopf pointed out also that the limited range and well established age of *Calamophyton* could make it a very useful marker of the Middle Devonian (lower Givetian) of both continents. This is in keeping also with the Middle Devonian age estimated for the Sweet Fountain occurrence.

The two parallel axes seen on Pl. XVII fig. 1 could be due to growth from a common horizontal rhizome as in *Hyenia* but there is no indication of the fine leaves of *Hyenia elegans* for example (Kräusel and Weyland 1932). There is more likeness to *H. sphenophylloides* (see Hoeg 1935 Pl. III) in which the leaves are verticillate but the lower half of each is simple and looks like a stalk. Perhaps the closest resemblance is to the plant described by Frenguelli (1954 p. 366 Pl. IV fig. 3 and Pl. V figs. 1-4) as *Hyenia argentina* from the Devonian of San Juan. The size, striated stems, type of branching and above all the curvature of all the small branches in one direction are features common to both species. From the present limited knowledge of both the South American and Cape plants they could be specifically identical. Frenguelli compared his plant only with *Hyenia*, but it would seem to be more in keeping with the more recently described species of *Calamophyton*. Until more is known of both plants it is preferable to leave them in separate species.

E. PROBLEMATICAL MEGAPHYLLOUS DEVONIAN PLANTS

Genus *PLATYPHYLLUM* Dawson

1. General

A number of large leafed plants have been described at various times from the Devonian of the northern hemisphere but their affinities are doubtful since, in most cases, neither the plant as a whole nor the reproductive organs are known. A possible exception is *Enigmophyton superbum* from the Upper Middle Devonian of Spitzbergen of which a number of specimens were described by Hoeg (1942a pp. 88-115 and Plates XXXVI-XL). He added an interesting discussion on the origin, relationships and nomenclature of such plants. More recently Andrews (1961 p. 54) has compromised by grouping such leaves under the heading "Problematical Megaphyllous Devonian Plants" in which he included *Platyphyllum*, *Cyclopteris*, *Ginkgophyllum*, *Psygmophyllum*, *Germanophyton* and *Enigmophyton*. This seems to be the best solution pending further discoveries which may allow more accurate classification.

Among the plant fossils from the Cape a single specimen has been found which has been placed in the artificial form-genus *Platyphyllum* Dawson which

Hoeg (1942b p. 101) proposed as the most suitable for the inclusion of detached fan-shaped leaves with parallel bifurcating veins. The preservation of the South African leaf fragment scarcely merits a specific name but one has been given to facilitate reference since this is at present the only known southern hemisphere representative of the genus.

2. *Platyphyllum albanense* sp. nov.

Pl. XIX fig. 1

Locality: Howisons Poort near Grahamstown
Horizon: Near the base of Witteberg Series
At Present: Albany Museum, Grahamstown
Type Specimen: No. 4487

This specimen which has not been described previously, is a small slab of dark carbonaceous micaceous shale with the locality reference of Howison's Poort. The latter is a mountain pass, south of Grahamstown, which is cut through a syncline of Witteberg Quartzite flanked both to north and south by Bokkeveld Shales. Professor Mountain of Rhodes University, Grahamstown, has informed me that there is a narrow carbonaceous band near the base of the quartzite in this locality. Since the rock matrix is similar it is probable that the specimen was collected from this horizon which contains also a number of small psilophyte remains described as *Dutoitia maraisia* sp. nov. in this report. A middle Devonian age is suggested.

The specimen which is illustrated on Pl. XIX fig. 1 has the impressions of the venation of portions of two overlapping leaves on different levels. The total leaf area is 3.5 by 2 cm and unfortunately no organic substance remains and neither the base nor any part of the margin of either leaf is preserved. Nevertheless the light coloured impressions of veins are clear and leave no doubt of the megaphyllous nature of the plant and of the type of venation. Each vein bifurcates twice, within the area and one of them three times.

Significance

The specimen although so incomplete is of importance as the earliest indication of a broad leafed plant in South Africa. In view of the great influx of Glossopteridae at a later date, any such record is significant, especially since the Proto-Glossopteridae described recently (Plumstead 1966) exhibit a transition from a bifurcating ginkgoalean type of venation to a reticulate one.

Comparison

In size and spacing the venation is closely comparable with a leaf *Platyphyllum brownianum* from Perry in the State of Maine. It was described originally as *Cyclopteris browniana* by Dawson (1863 Pl. XVII fig. 6) who, even at that time, questioned whether it was a fern or a ginkgoalean leaf. The plant was from Upper Devonian beds and was associated with *Leptophloeum* and *Psilophyton*. This type specimen of the genus was subsequently renamed *Rhacophyllum* by Lesquereux and *Psygmophyllum* by Arber, but was finally transferred by Hoeg (1942) to *Platyphyllum* (see photographs of the original specimen in Hoeg 1942b Pl. XLIII and also fig. 22, p. 100). The venation of the South African specimen also resembles that of *Enigmophyton* (cf. Hoeg 1942b, fig. 17 p. 90), but the latter is a true genus and is known in far greater detail.

? Archaeopteris— ? Psygmopyllum

Some poorly preserved plant remains were described by Schwarz (1906, p. 352) as *?Archaeopteris* and the single pinnules were stated to resemble those of *Archaeopteris obtusa* Lesquereux, a plant which was renamed *Psygmophyllum obtusa* by Arber (1912) and would therefore be included in this group. They were compared also with *Archaeopteris howitti* McCoy, which is found in Upper Devonian beds of Iguana Creek, Victoria, Australia. The leaves or pinnules were found by Schwarz in grey micaceous shales underlying Witteberg quartzites in Baviaans Hoek, Ceres. He stated that the borders were not much lacerated and that the preservation was too poor to show venation. Unfortunately the leaves were not figured, no museum numbers were quoted and the specimens cannot now be traced in the Albany Museum collection. They are mentioned here in the interests of completing the record and because it may be worthwhile to carry out a search in the original locality.

F. STEMS OF UNCERTAIN AFFINITIES

Pl. IV, figs. 1 and 2, and Pl. XIX, figs. 2-5

Among the plant fossils found in the Cape System are some stems of uncertain affinities. They are obviously of vascular plants and appear to be unrelated to any of the other plants described here, but their preservation is either too imperfect or fragmental to allow of more detailed classification.

A few of them, representative of different types, have been illustrated here with the object of indicating the existence in Africa of additional classes of plants during the Devonian and, by comparison, to demonstrate that similar stem types of the same age are known from other countries.

1. Stem Type A

Specimen 10741 S.A. Museum. Pl. IV, figs. 1 and 2

This stem has longitudinal grooves and short opposite branches. It occurs with *Palaeostigma sewardi* in the upper part of the Bokkeveld Series at Schietkraal in the Steytlerville district. The counterpart of this specimen—No. 10742 S.A.M. on which far more of the stem is preserved, was illustrated by Seward (1932, Pl. XXIII, figs. 4 and 6 and Pl. XXIV figs. 8 and 10). He stated that the stem might represent the vascular strands of the stems from which the cuticular surfaces (of *Palaeostigma* and *Haplostigma*) had been separated but that it might be a different type of plant. In the light of modern knowledge the latter view is more probable. The branches have rather small paired projections at regular intervals on the stem and in the axils of some of them there are bud-like growths, possibly sporangia. There are several apparently identical stems in the S.A. Museum, all from the Bokkeveld but without accurate localities.

2. Stem Type B
Spec. 3708. Albany Museum Pl. XIX fig. 2

This stem is from the Lower Witteberg Series at Alicedale Poort.

It is a longitudinally grooved stem of dimensions similar to those of stem A, save that the branches are much longer and are alternate. There is a pronounced thickening or swelling in the axils of several of the branches, which may be indicative of the development of an axillary bud or of sporangia, but none is clear. Other fragments of these branched stems occur on the same slab.

Comparison
Similar stems occur in a number of places. One was described recently from East Antarctica (Plumstead 1962, Pl. XVIII, fig. 7, p. 69 footnote) from beds of Upper Middle Devonian age in the Lashley Mts., where the stem was associated with fossil fish remains which provided an accurate dating.

Hoeg (1942b fig. 14, p. 55 and Pl. XVIII) illustrated a stem which he named *Hostimella* with similar thickening and some axillary buds but the main stem of his specimen branched dichotomously, of which there is no evidence in the Cape System.

3. Stem Type C
Specimen J.T. 13, Pl. XIX, fig. 3

Short lengths of comparatively broad, 2.5 cm stems which appear to be woody, occur on this specimen collected by Theron from the Upper Witteberg shales on the farm Soetendal Vlei in the Willowmore district. The stems probably represent inner surfaces but no vascular or leaf trace-scars are apparent.

Comparison
A somewhat similar stem in size and striated surfaces was illustrated by Grierson and Banks (1963, Pl. 41). It was of Middle Devonian Age and was part of a large cast of a dichotomously branched arborescent plant and the surfaces, comparable with those of Spec. J.T. 13 proved to be subsurfaces, for

when the cast was removed a pattern of leaf scars was revealed in the hollow mould beneath. The Cape specimens may also be of subsurfaces but the fragments are too small for further speculation.

4. Stem Type D

Specimen 11551 S.A. Mus. Pl. XIX, fig. 4

This broad bifurcating stem with suggestions of longitudinal striae on what is possibly an inner surface presents no signs of leaf scars or leaf traces. The stem was collected by Du Toit from the base of the Upper Witteberg shales on the road from Laingsburg to Ladismith.

5. Stem Type E

Specimen J.T. 19 Pl. XIX fig. 5

This specimen was collected by Theron from the Upper Witteberg shales on the farm Soetendal Vlei, Willowmore District.

A number of different portions of stem occur on the specimen and may possibly be part of the same branched stem. All the stems are finely striated. A subsurface layer at the base of the central stem exhibits a distinct ribbed effect. There is a suggestion that several of the stems are hollow and in parts there is regular jointing. These combined characters suggest a plant allied to Arthrophyta and the closest comparisons are with such stems of which only two of many are quoted e.g. *Hyenia argentina* Frenguelli (1954, Pl. V) from the top of the Middle Devonian of the Precordillera of San Juan and *Calamophyton sp.* Schopf (1964, figs. i, h and j) from the Middle Devonian of Maine, U.S.A.

6. Discussion

From these poorly preserved stems few conclusions can be drawn. The branched stems may have psilophytalean or possibly pteridospermous affinities; the others which are all from the Upper Witteberg shales suggest the introduction at this stage of larger and more advanced plant life.

SECTION IV—CONTROVERSIAL ALGAL FOSSILS

A. GENERAL

Two groups of what are presumed to be fossil algae, have been found in the rocks of the Cape System. The older were discovered recently and constitute the only known probable plant records from the Table Mountain Series. The second, *Spirophyton*, has long been regarded as an index fossil ranging from the Upper Bokkeveld to Middle Witteberg Series but its vegetable origin has been seriously questioned from time to time and is not now generally accepted. The subject is re-opened here because there has been a complete absence of adequate illustrations to accompany the previous discussions and also because many of the South African *spirophyton* appear to be incompatible with an invertebrate origin.

B. ALGAE?

1. cf. *Tontalia zollneri* Frenguelli

Plate XX figs. 1-4

Specimens T.D. 28a and T.D. 28b

Locality: De Doorns
Horizon: Upper Shale of Table Mountain Series
At Present: Geol. Surv. Museum Pretoria and Univ. of Witwatersrand Palaeo-botanical Collection.

The specimens figured on Plate XX are from the upper shale of the Table Mountain Sandstone at De Doorns, Western Cape Province, and are therefore probably of Upper Silurian age. They were collected by J. N. Theron of the Geological Survey and sent to me for determination. There were two small pieces of weathered, dark grey, somewhat carbonaceous shale, numbered TD. 28a and b, but these have been split further to expose fresh bedding planes.

The shale is not very fissile but on each rather uneven bedding plane a number of ramifying sinuous strands can be seen which do not appear on any vertical surface. On weathered surfaces Pl. XX figs. 1 and 2 they stand out well, being darker than the bleached matrix. They are also of slightly different texture and raised because the mineralisation is harder than that of the surrounding rock. On fresh surfaces the marks are far less conspicuous except when the rock is wet and the ramifying strands are then much lighter in colour than the matrix. The photograph on Pl. XX, fig. 4 of spec. 28b is of a fresh surface photographed under water. It represents the unweathered surface on the underside of the specimen in fig. 2 and is oriented in the same way. It can be seen that the markings on the two surfaces do not coincide in any way although the rock is less than 1 cm in thickness. The two surfaces of specimen 28a are even less alike. The strands vary in width from 0.5 to 0.9 mm but average 1 to 1.5 mm. They increase in width from the base upwards but the increase is not constant and they may swell or decrease a little. They branch, either dichotomously or laterally, and each branch terminates bluntly. In addition a few small projections, simple or branched, can be seen. An almost constant feature of each strand is a narrow central mark in the form of a groove, a ridge or a change in colour (see Pl. XX fig. 2).

On the fresh surfaces the appearance is different for very fine grains of pyrite can be seen, under magnification, concentrated along the centre of some of the strand. Others in which the pyrite is no longer visible have a faint brown iron stain outlining each margin.

The organic origin of these markings is not at all certain but is probable. If they had been due to sun cracks in the rock and to subsequent mineralisation along them, it would be difficult to account for the shape and nature of the separate short branches but of greater significance is the fact that the strands are confined to one surface and do not run through any thickness of the rock. They have neither the appearance nor the mineral composition of dendrites and cannot be attributed to small invertebrate trails, since the fluctuating widths and the branches could not be explained. I conclude therefore that these ramifying strands are in all probability of vegetable origin and represent branched cylindrical algal thalli.

In De Doorns specimens no marked directional growth can be seen although the branching in the upper half of Pl. XX fig. 1 is suggestive. It is shown enlarged in fig. 3. The surfaces available are, however, very small. In any case a thick growth of overlapping plants would mask the growth pattern of individuals. The central mark suggests tubular algal filaments with thick walls, or alternatively a vascular strand in primitive land plants, but the former is far more probable.

2. Discussion and Comparison

Tontalia zollneri from Argentina

Non-calcareous algae are far less common in fossil form than calcareous because the soft vegetative body is not easily preserved but some are known from a number of countries and are of many different ages. Very few have been described from the southern hemisphere but one from Argentina, *Tontalia zollneri* was described by Frenguelli (1952b) from the western part of the pre-Devonian Sierra de Tontal, which not only supports an organic origin but provides evidence of relationship, if not of actual specific identity, with the T.M.S. specimens.

Frenguelli stated that he knew of no similar algae of recent origin but suggested comparison with *Polysiphonia* of the Rhodophyceae. A very close parallel can be drawn between the South American and the Cape specimens.

Both had an elongate, cylindrical, tortuous thallus of comparable size branched both dichotomously and laterally. In both, the thalli were narrow at the base and broadened upwards to a rounded apex which Frenguelli suggested could be terminal sporangia. The Cape specimens fluctuated more in width than those from S. America. The distribution of thalli in both was haphazard. An important difference in form was that some of the thalli of Frenguelli's plant showed sub-regular transverse divisions which are not visible in the South African specimens. In preservation too there is a marked similarity. In both, the sinuous strands were dark in colour on a light background, both were raised above the surface, both were cylindrical and showed a concentration of iron. In *Tontalia* the central column was filled with quartz and the outer zone was carbonaceous but with an iron oxide stain. There were many small carbon particles in the matrix also.

The age of the Argentinian specimens is uncertain. They were classed by Frenguelli as probably Ordovician, being regarded as considerably older than the base of the overlying upper Devonian formation.

At the Internat. Geol. Congress in New Delhi in 1964 I was able to submit photographs of the Cape specimens to Prof. A. Amos of the Geology Department of the University of Buenos Aires who made the interesting observation that the same or very similar fossils occurred in the Furnas sandstone of Argentina in definite ecological and biogenic horizons. Since the Furnas Sandstone is regarded as the South American equivalent of the Table Mountain Sandstone the comment has an important significance. Frenguelli's specimen is No. 5307 in the Palaeobotanical Collection of the University of Buenos Aires.

From the northern hemisphere the most comparable fossil known to me is the genus *Buthotrephis*. The type specimen *B. gracilis* was described by Hall (1843) from an Ordovician limestone of New York State, and has been refigured by Banks (1961 Pl. 35) who described the plant together with another species from the Ordovician of Ontario as follows: "Thallus bush-like without any definite main axis, fasciculated from a broad attachment. Laminae (flattened branches) relatively broad, nearly constant in width, sinuately curved. Branches and lobes divided somewhat irregularly, sometimes branch dichotomously, sometimes branch laterally at moderate to wide angles. Apices of branches blunt, rounded." From this description and from the figure a number of features can be seen to be common to the Cape and American specimens. Another species *B. nidarosiensis* was described by Hoeg (1941 p. 188) from the Ordovician of Trondheim in Norway. His figure is even more like that from the Cape but the resemblance is less close than that between the two southern hemisphere fossils.

The range of *Buthotrepis* is given by Banks and Hoeg as Ordovician or Silurian. Kräusel and Weyland (1962 Pl. 30-33) have illustrated somewhat similar non-calcareous ramifying filamentous algal and psilophytic plants e.g. *Thamnocladus mosellae* and *Dawsonites jabachenis* from Lower Devonian beds in Germany but the former are smaller and the latter more stranded than the Cape specimens.

If the specimens from De Doorns are of vegetable origin as seems probable, they are the first plant fossils known from the Table Mountain Series but until better specimens are found an undisputed organic origin cannot be accepted. They have been figured and described with the object of encouraging further collecting.

C. SPIROPHYTON

Pls. XXI—XXVI

1. Brief History and Summary of the Controversy

It is probable that no single fossil or pseudo-fossil in Africa has given rise to more controversial discussions than the spiral markings known as *Spirophyton*. The arguments have centred in the origin—whether it was organic or inorganic and if the former, whether it was of animal or plant origin. Its stratigraphical value, within the Cape System of South Africa has never been questioned.

(*a*) 1842-1895—a vegetable origin assumed.

The earliest authors never doubted the vegetable origin of *Spirophyton*. According to Seward (1903) it was described first by Vanuxem in 1842 from Cauda Galli Grit of the Ithaca group, Madison County and later refigured by Hall 1863 under the name *Spirophyton Cauda-Galli* Vanuxem, being described as a *Devonian plant consisting of a slender axis bearing a thin and broad, spirally disposed "phyllome"*. This description does not altogether fit the Cape specimens but I have been unable to compare the original figure.

Dawson (1881) stated that *Spirophyton* had been found not only in the Cauda Galli grits of New York but also in Gaspe, N.Y., where it ranges from Upper Silurian to Lower Devonian. He made reference also to a plant of the same genus found by Prof. Hartt on the Rio Tapajos in Brazil in beds which had been referred to the Carboniferous but which he suspected to be of Upper Devonian age. This plant was named by Dawson, *Spirophyton brasiliense*. It is the only record known to me of *Spirophyton* in South America and I have been unable to confirm it.

It has been recorded from the Ordovician and from the Silurian of Australia but I have been unable to obtain the reference.

Dawson (1881) illustrated a specimen from the Middle Devonian of New York State which is definitely comparable with certain aspects of the South African *Spirophyton*.

In the 1st Annual Report of the Geological Commission of the Cape of Good Hope (1896), the Director Dr. Corstorphine drew attention to a peculiar alga referable to *Spirophyton Cauda-galli* of New York. He stated that one of his geologists, Schwarz, had first drawn attention to the close similarity and considered the specimens from the two widely separated areas, to be identical.

(*b*) 1895 Invertebrate borings proposed.

Meanwhile Fuchs (1895) had suggested that the markings of the overseas specimens were due to the spiral borings of an invertebrate, probably a worm, in sand.

(*c*) 1903 Inorganic origin due to eddying water.

A number of South African plant fossils which included specimens of *Spirophyton*, was sent to Prof. Seward of Cambridge by the Director of the Geol. Commission of the Cape of Good Hope. The *Spirophyton* had been collected ½ mile N.E. of Touws River Station on the farm Zoutkloof, 3 miles ESE of Ladismith, on the north bank of the Touws River at Letta's Kraal. The results were published in the Annals of the South African Museum in which Seward (1903, and Pl. XIV, figs. 1 and 2) figured two drawings of *Spirophyton* which until recently remained the only published illustrations of South African origin known to me. In this publication (p. 103) he expressed the opinion that the markings were merely pseudo-fossils, having an origin in the passage of an eddying current of water through a small vertical channel in the sand and stated that similar markings occurred in rocks of all ages.

(*d*) 1903 Vegetable origin reiterated in South Africa.

To this expression of opinion Dr. Rogers replied (1903 Rogers and Du Toit footnote on p. 16). "Mr. Seward concludes that *Spirophyton* was inorganic in origin, an opinion that is not concurred in by the staff of the Commission on account of the clear definition of the better specimens and the inadequate explanation offered on the supposition that they were of mechanical origin."

Most South African geologists continued to believe in an organic and preferably a vegetable origin. This was expressed by Du Toit who had perhaps a wider experience of S.A. formations than any other geologist of his time, and stated (1926, p. 198) "there could be little doubt that it is a vegetable impression, good examples having recently been obtained showing superimposed individuals spiralling in opposite directions". I have not seen any specimens exhibiting this feature since spiralling in one direction on a single surface has been consistent in all the specimens I have examined.

(*e*) 1954-1962 Modern view of worm-feeding burrows.

In the third edition of the Geology of South Africa, edited by Haughton (1954), he accepted the now current view stating that the S.A. *Spirophyton* was "identical with the N. American *Spirophyton* that characterises the Middle Devonian particularly and that is now recognized as having been produced by the burrowing worm *Taonurus*".

An animal origin is supported also by Hantzschel (1962 p. 220) who states emphatically that *Spirophyton* is a synonym of *Zoophycus* Massalongo 1855 and that it consists of feeding burrows formed possibly by worms. The illustration provided was a reproduction of the drawing by Dawson (1881).

(*f*) Plant origin still favoured in South Africa.

Meanwhile several South African geologists working in the Cape fold belt are still strongly in favour of plant origin. It is absurd that so marked a difference of opinion should have remained after a lapse of seventy years and it is probably due to the extreme scarcity of illustrations of *Spirophyton* not only in South Africa but throughout the world. It is possible that different authors may have been describing quite different objects. For this reason brief descriptions of the various forms of the fossil to which this name has been applied in South Africa, together with a series of photographs should serve a useful purpose especially since as far as can be ascertained *Spirophyton* has a greater development in South African Devonian rocks than elsewhere. It is only by these means that it will be possible to assess the validity of the views expressed by the various authors.

2. *Spirophyton* in South Africa

Stratigraphical occurrence and environment

It used to be believed that *Spirophyton* was confined to the Witteberg Series, being particularly common in the Main Witteberg quartzite. It is now known to be equally and possibly more common in the upper part of the Bokkeveld Series where it occurs in both sandstones and shales. Swart (1950) recorded that in the Wuppertal district of the western Cape, *Spirophyton* was actually more common in the 3rd Bokkeveld shale than in the Witteberg. In this area the Witteberg follows the 6th Bokkeveld shale conformably so that the fossils range from a marine through possibly brackish to what has been accepted as a fresh water environment. The presence of occasional trails and of fragments of land plants associated with certain specimens of *Spirophyton*, implies a shallow water or even a littoral zone and normally an arenaceous or sandy site was preferred.

Biological associations

Spirophyton normally occurs in large numbers and as a separate community in any particular area, but sometimes tracks of worms or other invertebrates cross the surface. Pl. XXI is the best example of this known to me but it is obvious that the worm? tracks are smooth and differ in diameter from the spiral strands. They cross the *Spirophyton* at random.

In a specimen recently presented to this University by Dr. A. J. Bruwer from his farm Mymering in the Ladismith district, there are several fragments of poorly preserved lycopod stems in the sandy matrix between specimens of *Spirophyton*. Both the plant debris and invertebrate trails are compatible with a littoral zone but appear to be in no way related to the spiral fossils.

Mineral Matrix

The preference of the organisms? for a quartz sand, and therefore a clear water environment has been mentioned already but large quantities of silvery mica are common in the matrix at many of the horizons on which *Spirophyton* occurs. In addition, red iron oxide is often conspicuous. It tends to concentrate in the fossils sometimes producing the impression of reddish rosettes on the white quartzite. It is uncertain whether this is due to easier porosity in the vicinity of the fossils or to an affinity or attraction between the organic matter and the iron-bearing solutions. In a number of cases a marked black colouration is a feature of *Spirophyton*. Unfortunately it has not been possible to test such specimens chemically and it is not known whether the black colour is due to manganese or iron oxides or to carbon. The latter, of course, would provide valuable confirmation of a plant origin. Seward (1931 p. 104) mentioned one specimen of Spirophyton from the Lower Carboniferous rocks of Scotland and now in Geol. Surv. Museum which has abundant carbon associated with the markings.

Appearance in the field

The spiral markings, in South Africa at least, are most commonly visible on bedding planes where they often occur in very close association. In diameter there is considerable variation which is apparent in the accompanying plates but in any particular area or horizon there is usually a marked uniformity in size. In thickness they rarely exceed 2 cm and consequently a number of individuals may overlap on a single surface. Statements have been made to the effect that *Spirophyton* occurred through several inches of rock but in all those I have examined, wherever the markings occur on both upper and lower surfaces of a rock specimen they represent different individuals and the positions do not coincide.

In the field *Spirophyton* may occur through several feet of sediments but the individual specimens replace one another continuously and probably represent a reef on which the organisms grew over a comparatively long period under uniform conditions.

Geographical distribution and historical record of the fossil

Since the Bokkeveld and Witteberg Series of the Cape System occur only in the fold belt bordering the Karroo System on the west and southern margins, the fossils are confined to this area but the complex folding results in many outcrops.

The earliest specimen was brought to the museum by a Dr. Watson, from the Ladismith district where many fine specimens are still to be found. In the second report of the Geological Commission of the Cape of Good Hope the Chief Geologist, Corstorphine (1897 p. 19), remarked that the curious spiral markings which occur throughout a considerable thickness of the Witteberg Series were possibly not of organic origin but that their presence throughout the sandstones was of great assistance in recognising the group. Meanwhile one of his assistant geologists, Schwarz (1897a p. 20), recorded that in the Worcester and Robertson districts, south of the Langebergen he found the sandstones in many places "crowded with *Spirophyton*", especially along the upper reaches of Sarah's River and also where the Breede River cuts through the beds at Roodeberg where beautiful impressions occur.

In the intensely folded area the quartzites of T.M.S. and Witteberg were very alike but *Spirophyton* in the latter could be used to distinguish them. Schwarz had compared them with the fossils described from the Devonian of New York and was convinced that they were identical and of a algal origin.

Later from the Robertson-Lady Grey district Schwarz (1897b) recorded *Spirophyton* in the rugged hills of the Elandsberg extending from six miles from Lady Grey to Robertson and occurring in the southern part of the town of Swellendam.

Rogers and Schwarz (1897 p. 64) stated that *Spirophyton* was found throughout a considerable thickness "probably more than half" of the Witteberg Series and appeared to have a wide distribution. Rogers and Schwarz (1898) reported it from two lines of high hills north of Caledon which are capped with Witteberg Sandstone. The fossil was found also in great abundance at Storms Vlei and in the Bredasdorp area west of Salt River Vlei where an inlier of Witteberg protrudes through younger beds. In 1899 Schwarz recorded (p. 35) *Spirophyton* beautifully preserved in Elands Kloof Mountains between Prince Albert on the east and Buffels River on the west at the contact of the Bokkeveld and Witteberg.

Schwarz (1903) found it on the road between Prince Albert and Klaarstroom on the farm Roosendal and also to the east of Kando's Poort.

Schwarz (1905 p. 282) again recorded *Spirophyton* from both upper Bokkeveld and Witteberg beds in the Laingsburg area and commented that geologists favoured a plant origin but palaeontologists mainly supported an animal one.

Following the fold belt eastwards Haughton (1935) found numerous *Spirophyton* in micaceous shales of the Bokkeveld beds at the west end of the farm Springbok Vlakte in the country east of Steytlerville but could not find it (Haughton 1928) in either Bokkeveld or Witteberg of the area described in the Port Elizabeth Sheet, where younger sediments mask many of the outcrops. Further inland Mountain (1946) had found the fossil to be common on the Grahamstown-Port Elizabeth road at West Hill and 3 miles S.E. of Grahamstown. Finally at the eastern extremity of the Cape System where the beds disappear into the Indian ocean Mountain 1962 reported *Spirophyton* in the country immediately inland from Port Alfred (the Kowie) presumably in Upper Bokkeveld beds.

There are undoubtedly many other South African occurrences of *Spirophyton* not recorded here but those mentioned serve to indicate its frequency as a zone fossil of upper Bokkeveld and lower to middle Witteberg from Wuppertal in the north-west along the whole fold belt to Port Alfred in the east. Unfortunately none of the survey records included photographs of this very familiar fossil. Some of the original specimens can be located in museums but many are without exact localities.

I propose to describe briefly below, and to illustrate, four forms of the spiral fossils, which for the purpose of this discussion will be termed *Spirophyton* A-D, and then to summarise the findings.

3. Description of the Specimens Illustrated

(*a*) *Spirophyton Type A* Pl. XXII figs. 1 and 2, and Pl. XXIV figs. 3 and 4

Type A appears to be the most common form. The fossils are usually crowded together and often overlap closely on a bedding plane. They vary somewhat in diameter but on any particular surface they are of approximately the same size. Each is round in plan, often bun-shaped, and consists of a compact form with a central column (either raised or hollow according to the aspect) surrounded by a dense mass of "strands" with a cyclic spiral to the left. The margin is usually a well defined circle for the strands curve downwards and their ends are rarely visible. The individual strands are approximately of the same length and each resembles an evenly twisted cord spiralling upwards to the left (see upper right hand side of fig. 1). Strands may overlap one another without losing their form or identity.

Sometimes only a portion of a *Spirophyton* is preserved. Plate XXIV, figs. 3 and 4 are believed to be portions of vertical sections of Type A. In each case they lie on bedding planes but it is suggested that the living plant may have been severed and only the vertical column and one side of spiralling strands has been preserved in a recumbent position. In fig. 4 part of a silica cast can be seen at the top of the vertical column, the straight smooth nature of which contrasts strongly with the much narrower, twisted strands which coil upwards and outwards from it.

(*b*) *Spirophyton Type B* Pl. XXIII figs. 1-3

Type B is less common. It is normally much larger and does not occur in closely packed associations like Type A but as well spaced individuals. Occasionally one may be seen on the same plane as a number of Type A *Spirophyton*. Type B is often black in colour and contrasts strongly with the white quartzite.

In the "B" form the strands are grouped into elongated tapering units, each of approximately twelve spiralled strands giving the whole fossil a flower-like appearance. Pl. XXIII fig. 1 is a photograph taken by Theron of a bedding plane in Witteberg quartzite on which a large specimen 18 inches in diameter is preserved. I am indebted to him for allowing me to reproduce it. The scale is indicated roughly by the tuft of grass in the top left hand corner.

The specimen on Pl. XXIII fig. 2 illustrates a portion of one of these forms. The dark point on the left indicates that the separation into groups was not confined to a single plane for it represents the emergence of the terminal portion from a lower level.

The general spiral is less apparent in form B than in A but the spiralling of individual strands is consistent and can be seen on the right hand side of fig. 2.

The dark colouring in both these specimens is possibly carbon.

In his thesis Theron (1962) expressed the view that form B represented an older plant which had opened and that what I have called type A was a closed bud-like form. I think it is more probable that they represent different species of related organisms.

(*c*) *Spirophyton Type C* Pl. XXIV figs. 1 and 2

This form is still less common than B. and differs from it considerably. The circular form is absent and instead a group of cylindrical and feather-like branches fan upwards from a point which may correspond to the central column of forms A and B. Each branch consists of a number of short spiralling strands spreading upwards and outwards and possibly densely packed around a central column which is not visible.

At a lower level on the right hand side of Pl. XXIV fig. 1, several other groups can be seen emerging, suggesting that the vertical depth of each group was small.

In both the specimens illustrated the organic portions have a shiny black colouration which may be carbonaceous.

(*d*) *Spirophyton Type D* Pl. XXV figs. 1 and 2

This is a form similar to that illustrated by Seward (1903 Pl. XIV figs. 1 and 2) which led him to believe that the markings were due to eddying currents of water. On the right hand side of Seward's fig. 1 the spiralling of several individual strands can be seen and on the present specimen in fig. 1 they are faintly preserved although not clearly in the photograph.

These D forms usually cover a larger area than any of the convex "bun-like" A forms. They always lack clear outlines and definition. For this reason it seems probable that the large, almost formless, markings represent dead or dehydrated specimens which have possibly been detached and stranded in an alien environment and exposed until they became a flaccid and dried gelatinous film with little bulk or substance, spread out on loose sand before being buried. It is possible that Pl. XXIV fig. 1 illustrates a stage intermediate between those 'A' types on Pl. XXII and Pl. XXIV fig. 2 in which the D type has been flattened and lost its clear marginal outlines and individual spiral strands are no longer visible. Against this view the much larger areas covered by most D. forms may be indicative of a more spreading and flatter species.

4. Summary of Discussion on Origin of Spirophyton

(*a*) The preservation of forms A, B and C with well defined outlines and details of structure is completely incompatible with an inorganic or mechanical origin and an organic origin is now generally accepted.

(*b*) Despite the statements by Seward (1903) and others that similar markings occurred throughout geological time, the particular fossils described here appear to have a limited distribution both in time and space which implies that they were caused by organisms with a limited evolutionary span and with restricted environmental requirements. These are characteristic of Lower Palaeozoic but especially of Middle Devonian rocks formed in shallow water or possibly in a littoral zone preferably with a sandy base. The South African occurrences imply a transition from marine through brackish to fresh water.

(*c*) The four forms described here as *Spirophyton* Types A-D differing in size and shape all have in common a tendency to colonize, often forming a close association of individuals. This is particularly marked in the A form and suggests that they were preserved where they were growing, on sand banks and probably with some form of anchorage.

(*d*) The four types all exhibit a well developed spiral form which suggests a generic relationship.

(*e*) In considering an animal origin the forms must have been due either directly to the preservation of soft bodied organisms i.e. *body fossils* or be the result of some animal activity such as boring i.e. *trace fossils*. In the first case an Anthozoan origin is probably the only one which could be considered and in fact forms like B do suggest the modern sea anemones in shape, size and form but these animals are apparently unknown in fossil form. In any case the individual spiralling strands cannot be explained and the food problem of probably thousands of immobile organisms of not inconsiderable size, on a single sand bank would be considerable, since unlike coral reefs, signs of other life associated with them are very rare.

In the second case—where the markings are attributed to burrows or food storage canals the dual spiralling is even more difficult to explain. The mechanical problems produced by inter-winding and spiral canals would be insupportable unless each burrow had a strong casing and even then, very close contact would create a sponge within a confined space. The very close packing militates also against a collection of food storage canals. Food is stored to be used and in the extensive horizons of Form A, the tightly spiral strands are preserved intact.

(*f*) On the other hand if a plant origin were considered, a close association of colonies of algae is quite acceptable. The known distribution of *Spirophyton* in horizontal lenses of some considerable areal extent, and forming beds a couple of feet in thickness is compatible with an algal reef. Although, as far as I know, nothing resembling the collective Devonian *Spirophyton* has been recorded on modern algal reefs, single spiral forms of living algae are known e.g. *Spirulina princeps*, one of the Cyanophyceae (Tilden 1935). It is possible that the individual spiral strands were each encased in a thin membrane so that the form could be preserved. Fragments of *Spirophyton* are often preserved with the details of their structure undamaged. This would be difficult to explain if a composite series of burrows had been fractured but a torn portion of seaweed could remain intact and, in fact, might represent a common form of vegetative reproduction.

The loss of form and bulk, similar to that which is apparent in specimens like Type D, can often be seen in dried-out films of previously bulky gelatinous seaweeds. The shapes of forms like *Spirophyton A* were probably protected by a coating of sand and mica particles while they were living or while still in growth positions. In fact specimens occur in which the accumulating sand layers terminate against the bun-shaped fossil.

(*g*) In the absence of actual animal or plant tissue no observations can be conclusive but they are at least suggestive and seem to support the original choice of the name *Spirophyton* implying a spiral plant rather than the alternative and so-called synonym of *Zoophycus*.

(*h*) Algal reef zones play an important role in many South African formations and throughout the world the considerable contribution of algae in rock-forming processes is being recognized increasingly.

SECTION V — SUMMARY OF THE FOSSIL FLORA OF THE CAPE SYSTEM — ITS SIZE, COMPOSITION, ENVIRONMENT, AGE AND IMPORTANCE IN AFRICA

A. SIZE OF THE FLORA

No Devonian flora in the world is comparable in size or variety with those which successively mark each later geological period.

Ten genera and sixteen species of early vascular plants have been described and in addition, a number of stems cannot be accurately classified because their preservation is too poor. Some of them are undoubtedly related to lycopods (Pl. XVI) but at least five others (Pl. XIX) are of genera not otherwise represented in the collection.

There are two genera and four species of problematical fossils believed to be algae.

This total is small when compared with any of the famous Devonian floras of the world like those of New York, Gaspe, Ireland, Spitzbergen, Bohemia, Germany and the Donetz Basin but it has one real advantage. The plants occur in the continuous stratigraphic succession of a geological system distributed over a comparatively wide area. This makes the chronological sequence of the plants far easier to determine than where only isolated small basins of Devonian rocks are preserved.

As interest grows and exploration is extended I have no doubt that a number of other Devonian plant fossils will be discovered in some of the richer of the Cape sites named, as well as in the new areas, but it will now be much easier to fit them into the chronological stratigraphical table provided.

B. ENVIRONMENT

In several places plant fragments have been found associated with marine invertebrates in the Lower Bokkeveld. The fossil plants of the Upper Bokkeveld and Witteberg Series are far more numerous and have always been regarded as of fresh water or land origin. These too are sometimes found associated with small invertebrate, eurypterid and fish remains and Swart (1950, p. 474) who made a detailed lithological study of the Cape System in the western area has stated that at Wuppertal the conditions of deposition of the lower Witteberg must have been identical with those of the Bokkeveld sandstones. He has suggested that shallow marine conditions persisted into Lower Witteberg times and that no evidence exists for regarding the beds as a lacustrine deposit. It is possible that there was a gradual closing of the passage between the Cape Basin and the ocean and that, in consequence, the water became less saline. The survival of *Spirophyton* through the whole deposition of the main Witteberg quartzite is significant in this connection for whether or not its vegetable origin is accepted it is normally found in a marine environment. Caster (1952) stated that it was characteristic of near shore marine sands in other areas from Lower Devonian to Pennsylvanian times. (Incidentally evidence for the later age of *Spirophyton* is unknown to me unless it was based on Du Toit's assessment of the age of the Witteberg.)

It is possible that a brackish shallow shoal and sand bank environment prevailed in the area throughout the period.

C. SUGGESTIONS ABOUT THE ENVIRONMENT OF PSILOPSIDA

Several of the plants described must have lived partly in water. There is, for example, little direct evidence of a land environment for *Palaeostigma* other than the thick cuticle. I have suggested that the small oval elevations were of the nature of bulbils—detachable vegetative buds capable of growing into a new plant. Such an arrangement can be envisaged as intermediate between a Thallophyte stage—where vegetative propagation from severed fragments of algae was probably the most common form, and the forms of reproduction found in permanent land plants of later periods. The small outgrowths on *Rhynia gwynne vaughni* and the axillary buds in the axils of some Devonian branched stems might equally serve the same purpose. There has, however, been a growing body of opinion among certain palaeobotanists which culminated in the views of Pant (1962) mentioned on pp. 26-27 that the actual plant on which such buds grew, represented the gametophyte stage which could be without vascular tissue and could be aquatic while the sporophyte stage was terrestrial or mainly so. If this should prove to be true of other psilophytes, beside *Rhynie gwynne vaughni*, as may well be the case, the close proximity of psilophyte floras to swamps and lakes would be explained. The vast numbers of outgrowths on a plant like *Palaeostigma* suggest that the method was not always efficient as a means of propagation and was gradually discarded. Many of the Upper Witteberg plants were fragments of higher and more diverse plant orders and appear to have been of drift origin.

D. THE COMPOSITION OF THE FLORA

The study has revealed a far greater variety of plants than had been known previously. Such variety is now known to be characteristic of all recently studied Devonian floras (see Banks 1965). All the plants, without exception, belong to what has sometimes been called the Psilophyte stage in the history of plant life in which true psilophytes are present and only the primitive, simple or archaic forms of other vascular plant divisions.

There is one notable and perhaps significant absentee from the Cape plant assemblage. There are no early ferns or pteridosperms. I do not know of any other Devonian flora of this size which has no representative of this group. One possible explanation might be found in the predominantly arenaceous nature of the sediments, for Frenguelli (1952c) stated that in Argentina he detected a marked preference of lycopods for sandy, and of ferns for clay environments among the Upper Devonian and Lower Carboniferous fossiliferous horizons. There would seem, however, to be enough shaley bands especially in the Upper Witteberg to invalidate this distinction. Differences of altitude can scarcely be considered for all the fossil plant fragments found at this level appeared to have been of drift origin. For the time being it is necessary to assume that the flora consisted predominantly of lycopods and psilophytes.

It is, however, interesting to record that the 'fern' complex remained insignificant throughout the rest of the Palaeozoic in Southern Africa compared with its great fulfilment in most other areas.

E. AGE OF THE FLORA

1. Age based on fossil plants

The primitive nature of the plants described is most apparent and leads inevitably to a discussion of its age. In Table III the Cape plants are compared with the species most nearly related in the southern as well as in the northern hemisphere. It will be seen that although a small number of the plant-genera are known to range beyond the Devonian, all of them are more characteristic of this period. In the case of the exceptions the appearance of a definitely Carboniferous genus such as *Rhacopteris* invariably proclaims the younger age. No such plant has been found up to now in Cape sediments and consequently, judged on floral evidence alone, not only the Bokkeveld but the whole of the Witteberg Series must be regarded as of Devonian Age. It must be assumed that at the time when *Rhacopteris* and associated Carboniferous plant fossils made their appearance in Argentina and in Australia, the lowest of the great thickness of glacial deposits in the Cape had already begun to accumulate. In both Argentina and parts of Australia in the Tupe and the Kuttung Series respectively, tillites are found interspersed with sediments containing *Rhacopteris* and lycopods which are more highly developed than those from the Cape. Along the southern margin of the Karroo the thickness of the tillite is immense and must represent a very great span of time.

It is possible that sediments containing the missing Lower and Middle Carboniferous flora may yet be found in a few areas further north protected from erosion by overlying Karroo rocks. In the meantime the only positive

TABLE 3

SHOWING THE TIME RANGE OF THE MOST NEARLY RELATED OR SIMILAR SPECIES FROM BOTH HEMISPHERES

Cape Plant Fossils	Localities	Horizon	Nearest Known Southern Hemisphere Species	Localities	Age	Nearest Known Northern Hemisphere Species	Localities	Age	Conclusions
Protolepidodendron eximium Frenguelli	Vondeling Willowmore District	Upper Witteberg (360′ below the base of the tillite)	*Protolepidodendron eximium* (Frenguelli 1954) see *Drepanophycus eximius* (Frenguelli) Menendez (1965)	Charnela Juan San Argentina	Upper part of Mid. Devon	*Protolepidodendron scharyanum* (Kräusel and Weyland 1932) *Eleutherophyllum drepanophyciforme* (Remy & Remy 1960)	Germany ,,	Mid. Devon Lowest Namurien	
Protolepidodendron theroni sp. nov.	Vondeling Willowmore District ,,	Main Witteberg 1,900′ below the tillite 2nd Bokkeveld Sdst.	*Protolepidodendron lineare* (Walkom 1928)	Yalwal N.S.W. Australia	Upper Devon	*Protolepidodendron pulchra* (Hoeg 1942)	Spitzbergen	Upper Mid. Devon.	
Archaeosigillaria caespitosum Schwarz nov. comb.	1. Ceres District 2. Willowmore Dist. 3. Steytlerville Dist.	Witteberg Main Witteberg 2,000′ below Tillite Low. Witteberg	*Cyclostigma confertum* (Frenguelli 1954) *Archaeosigillaria conferta* (*Frenguelli*) Menendez (1965a)	San Juan Argentina	Mid. Devon	*Archaeosigillaria vanuxemi* (Grierson & Banks 1963)	New York State	Upper Devon. but vast majority of specimens Mid. Dev.	
Leptophloeum australe (McCoy) Walton	Grahamstown District Touws River }	Low. Middle Witteberg Witteberg	*Leptophloeum australe* Carruthers (Feistmantel 1890) (White, etc.)	Queensland N.S.W. Victoria W. Aust. Bolivia	Uppermost Mid. Devon. to Upper Devon. but mainly latter	*Leptophloeum rhombicum* (Dawson 1861)	U.S.A., China, etc.	Upper Devon.	
Platyphyllum albanense sp. nov.	Grahamstown District Howisons Poort	Low. Witteberg	?			*Platyphyllum brownianum* (Hoeg 1942)	Maine U.S.A.	Up. Devon.	
Calamophyton capensis sp. nov.	Bathurst District Farm Sweet Fountain	Bokkeveld Series	*Hyenia argentina* (Frenguelli 1954)	San Juan Argentina	Lower Devon.	*Calamophyton bicephalum* (Leclercq & Andrews 1960)	Belgium	Mid. Devon.	
Haplostigma irregulare (Schwarz) Seward	Port Alfred Bathurst District Steytlerville District and Uitenhage District	Bokkeveld 2nd Bokkeveld Shale (Lower Bokkeveld also ? in Witteberg quartzite	*Haplostigma furguei* (Frenguelli 1952) *Haplostigma irregularis* (Kräusel 1960) *Haplostigma irregulare* (Plumstead 1962) ? *Cyclostigma australe* (Feistmantel 1890)	San Juan Argentina Parana Antarctica N.S.W. Australia	Low. Dev. Low. Dev. Low. Mid. Dev. Devonian —Low Carbon	*Cyclostigma kiltorkense* (see Johnson 1913)	Ireland	Upper Devon.	
Drepanophycus schwarzi sp. nov.	Port Alfred	Bokkeveld	?			*Drepanophycus* cf. *spinosus* (Banks 1960)	New York	Lower Givetian (Mid. Devon.)	
Drepanophycus kowiense sp. nov.	Port Alfred	Bokkeveld	?			*Drepanophycus gaspianus* (Kräusel & Weyland 1948)	Gaspe Canada and New York	Lower Devonian	
Palaeostigma sewardi Kräusel and Dolianiti	Port Alfred Bathurst District Steytlerville District	Bokkeveld	*Palaeostigma sewardi* (Kräusel and Dolianiti 1957)	Brazil	Low. Devon.	cf. *Rhynia gwynne vaughni* (Kidston & Lang 1917 & 1924)	Scotland	Mid. Devonian	
Dutoitia pulchra Hoeg	Knysna District	Bokkeveld				*Psilophyton* (Dawson 1862)	Canada }	Low. Mid. Devonian	
Dutoitia alfreda sp. nov.	Port Alfred	Bokkeveld	*Hostimella* etc (Lang & Cookson 1930 and Cookson 1935)	Victoria Australia	Up. Sil. to Lowest Devonian	*Rhynia* (Lang 1931-32) *Cooksonia* (Obhrel 1962)	Scotland } Bohemia	Up. Sil.	
Dutoitia maraisia sp. nov.	Grahamstown District Howisons Poort	Low. Witteberg							
Psilophytalean stems	De Doorns	3rd Bokkeveld Sandstone	Baragwanathia Flora (Lang and Cookson 1930 & Cookson 1935)	Victoria Australia	Up. Sil.—Low. Devon.	Rhynie Flora etc. (Lang 1931-32)	Scotland	Mid. Devonian	
Stems A and B—Branched stems with axillary tubercles	A. Steytlerville District B. Alicedale Poort	Up. Bokkeveld Low. Witteberg	Walhalla, Victoria—(Lang & Cookson, 1930 and 1935) also 'Psilophyte stem'—White	Victoria and N.E. Queensland	Up. Silur "Prob. Low. Devonian"	Hostimella etc. (see Hoeg 1942, p. 173)	Spitzbergen	Low.-Mid. Devonian	
Controversial ? algal fossils *Tontalia zollneri* Frenguelli	De Doorns	Upper Shale of Table Mountain Sediments	*Tontalia zollneri* Frenguelli	Sierra de Tontal Argentina	Pre-Devonian also Furnas Sandstone	cf. *Buthotrephis gracilis* (Hall 1843) *Buthotrephis nidarosiensis* (Hoeg 1940)	New York State Trondheim Norway	Ordovician-Silurian Ordovician	Pre-Devonian
Controversial ? algal fossils *Spirophyton* Vanuxem	All areas	Upper Bokkeveld and Lower—Mid. Witteberg	*Spirophyton* ? (not illustrated)	Australia	Ordov.—Silurian	*Spirophyton cauda galli* (Dawson 1881)	Madison County U.S.A.	? Up. Sil. Low. Devon. Mid. Devonian	Best known from Mid. Devonian of New York

CONCLUSIONS ABOUT AGE:

From both hemispheres the fossil plants most nearly related to those of the Cape System fall within the boundary of the Devonian System. The evidence from the Upper Witteberg Series depends largely on *Protolepidodendron eximium* and its close relationship to Argentinian specimens found there in association with *Archaeosigillaria* and *Calamophyton* and regarded as of uppermost Middle Devonian age. This is undoubtedly true for the Argentinian specimens but the species may have a long range. The onset of glaciation along what is now the Cape Fold Belt, if the tillite lies conformably on the Upper Witteberg Beds as believed, cannot have been far from the base of the Carboniferous and may have been a little before or soon after.

available evidence must be accepted. In particular the presence of *Protolepidodendron eximium* approximately 360′ below the base of the tillite in the Willowmore District is significant since its only other known occurrence is in San Juan where Frenguelli found it in Upper Middle Devonian sediments. It may, of course, merely indicate that the species has a longer range. The presence of *Leptophloeum australe* is claimed throughout the main Witteberg quartzite although I do not know of any exact measurement of its highest occurrence. The species does not extend beyond the Upper Devonian. The comparative age table provides other examples in support of an Upper Devonian age to include the Upper Witteberg sediments.

2. Comparative Age Table (See Table 3)

3. Age based on fossil fish

Against this evidence the age of fish associated with plants in the lenses of shale below the tillite must be considered. Theron (1960, p. 406) footnote quotes the age evidence based on fish in these nodules as determined by the more recent work of Dr. B. G. Gardiner of the University of London on fishes: " . . . a series of nodules from the Lower Dwyka Shales (i.e. now Upper Witteberg Shales) of the Willowmore District has been collected by Dr. Crompton. These nodules occurring well below the tillite contain a much larger fauna than do the nodules from the Upper Dwyka Shales, there being several genera of deep bodied Platysomids, Cycloptychius, Mesopoma, as well as some completely new genera. As far as I can judge it is a typical Lower Carboniferous Palaeoniscoid fauna, and as such I think it is reasonable to link these Lower Dwyka Shales with the Karroo System rather than, as was the custom in the past, to link them with the Witteberg System of Devonian age."

More recently Marais (1963) described and illustrated another rich occurrence of Palaeoniscoid fossil fish from a large calcareous siltstone lens in the upper part of the Upper Witteberg Series in the Janseville District, south of Lake Mentz. He concluded that the stage of development of three species of fish indicated a late Middle or early Upper Devonian age.

Later Jubb (1965) described one of the forms from this site as a new genus and species *Mentzichthys walshi* and considered it to be of Lower Carboniferous age since of known Palaeoniscids the genus appeared to be most closely related to the Lower Carboniferous genus *Cycloptychius*. He considered that the mass extermination and perfect preservation of the fish had probably been caused by freezing and asphyxiation as a result of the early stages of the approaching Ice Age. The age of this deposit based on fish is not conclusive but favours a slightly younger age than that indicated by the plants alone.

F. EVOLUTIONARY SIGNIFICANCE

The place of the plant fossils of the Cape System in the history of plant life in Southern Africa is an important one.

It represents the complete transition in the plant world from the stage when the whole life cycle of each plant had to be enacted in an aquatic environment so that only forms of Thallophyta were known. This ended with the T.M.S. The Bokkeveld sediments preserved evidence of the semi-aquatic stage suggested by plants like *Palaeostigma* and the psilophytes generally which could never have lived very far from water.

In the Upper Bokkeveld a Pterophyte Stage was introduced with early and primitive members of Lycopsida especially, Sphenopsida and possibly early gymnosperms, if *Platyphyllum* can be placed in this category.

It is only near the top of the Witteberg Series that signs of more advanced and varied plant life appeared in the form of small pieces of drifted stems.

During the immensely long period of glaciation which followed, the plant life of southern Africa must either have been preserved in some small sheltered areas or survived in adjacent lands. In either case the adaptations to the unfavourable frigid conditions must have resulted in the development of the rich and strange southern coal flora which made its appearance in some parts of the country before the termination of the final glaciation and the restoration of temperate conditions.

G. THE RELATIONSHIP BETWEEN THE FOSSIL PLANTS OF THE CAPE SYSTEM AND OTHER DEVONIAN FLORAS

Of the classified plants described in this monograph there are no less than seven which on the evidence available appear to be specifically identical with fossil plants described from various parts of eastern South America. With Australia, *Leptophloeum australe* is identical and a number of others closely related. The affinities with Devonian plants of the northern hemisphere are far more general, i.e. there are generic but no specific identities. The conclusion is inevitable that an affinity between plants of the southern hemisphere was apparent as early as the Devonian Period and that this was far closer than the relationship between Africa and the N. American or Eurasian areas where the comparison amounts to a common stage of development rather than to identical plants.

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PLATE I—*Dutoitia alfreda* sp. nov.

Bokkeveld Series—Port Alfred.

Fig. 1 Type specimen.
Spec. 4418 (× 1) Albany Mus.

Fig. 2 Part of the type specimen enlarged to show:
(*a*) a large obovate erect terminal sporangium.
(*b*) transverse section of a sporangium with small round spores?
(× 3)

Fig. 3 Part of a single plant to show branching. Spec. 4173 (× 2) Albany Museum.

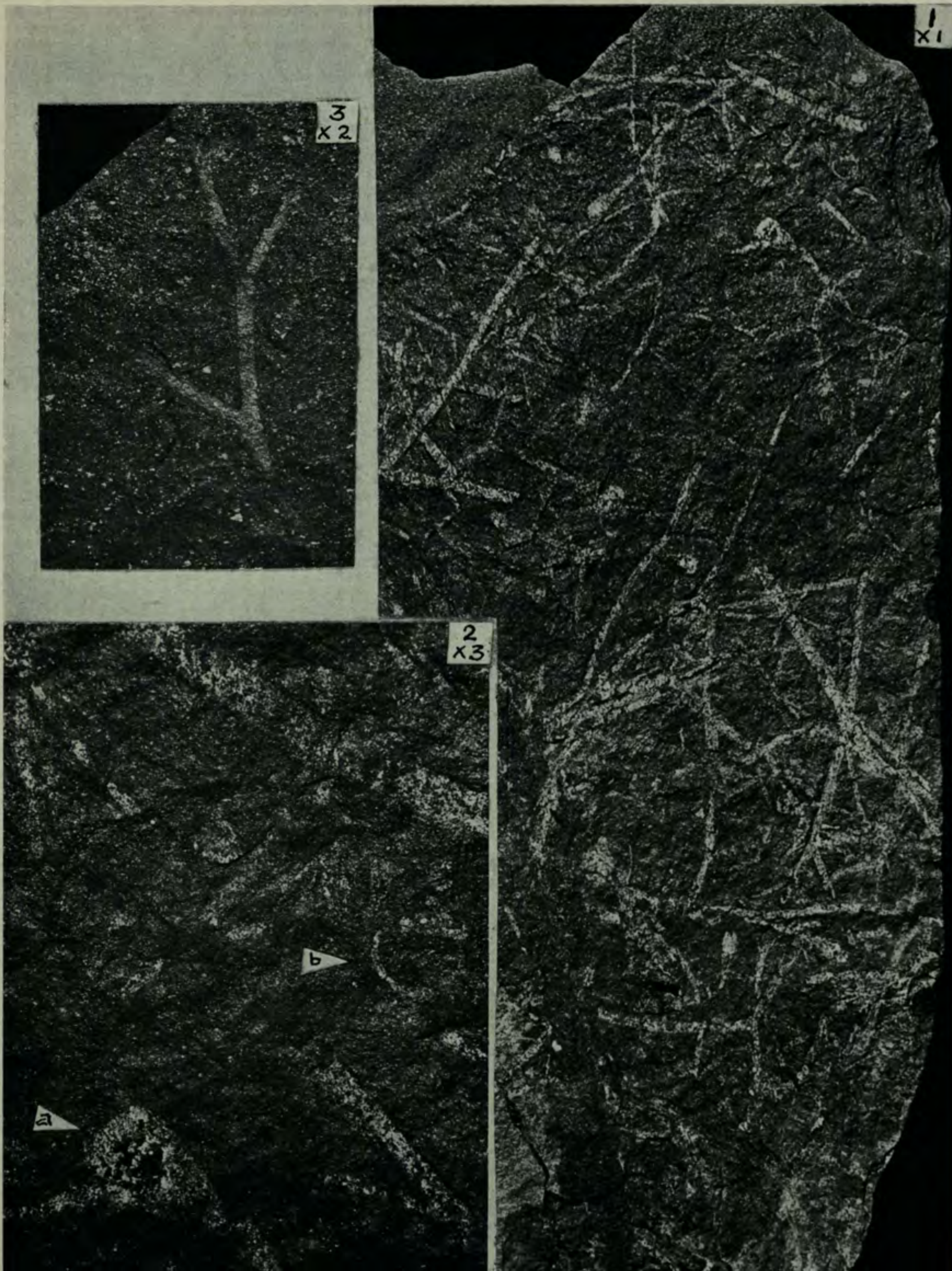

PLATE I—*Dutoitia alfreda* sp. nov.

PLATE II—*Dutoitia maraisia* sp. nov.

Howison's Poort Grahamstown—near base of Witteberg Series.

Fig. 1 Type spec. (× 1)

Fig. 2 Type specimen enlarged to show

(*a*) thin axes branching at a wide angle

(*b*) several broad axes

(*c*) a stem with projections

(*d*) pendulous terminal sporangium

(× 2)

Fig. 3 Another specimen showing fragments of branched stems as well as

(*a*) a pendulous terminal sporangium

(*b*) a stem with projecting spines

(× 1)

These specimens are in the B.P.I. (Pal) Collection, University of the Witwatersrand.

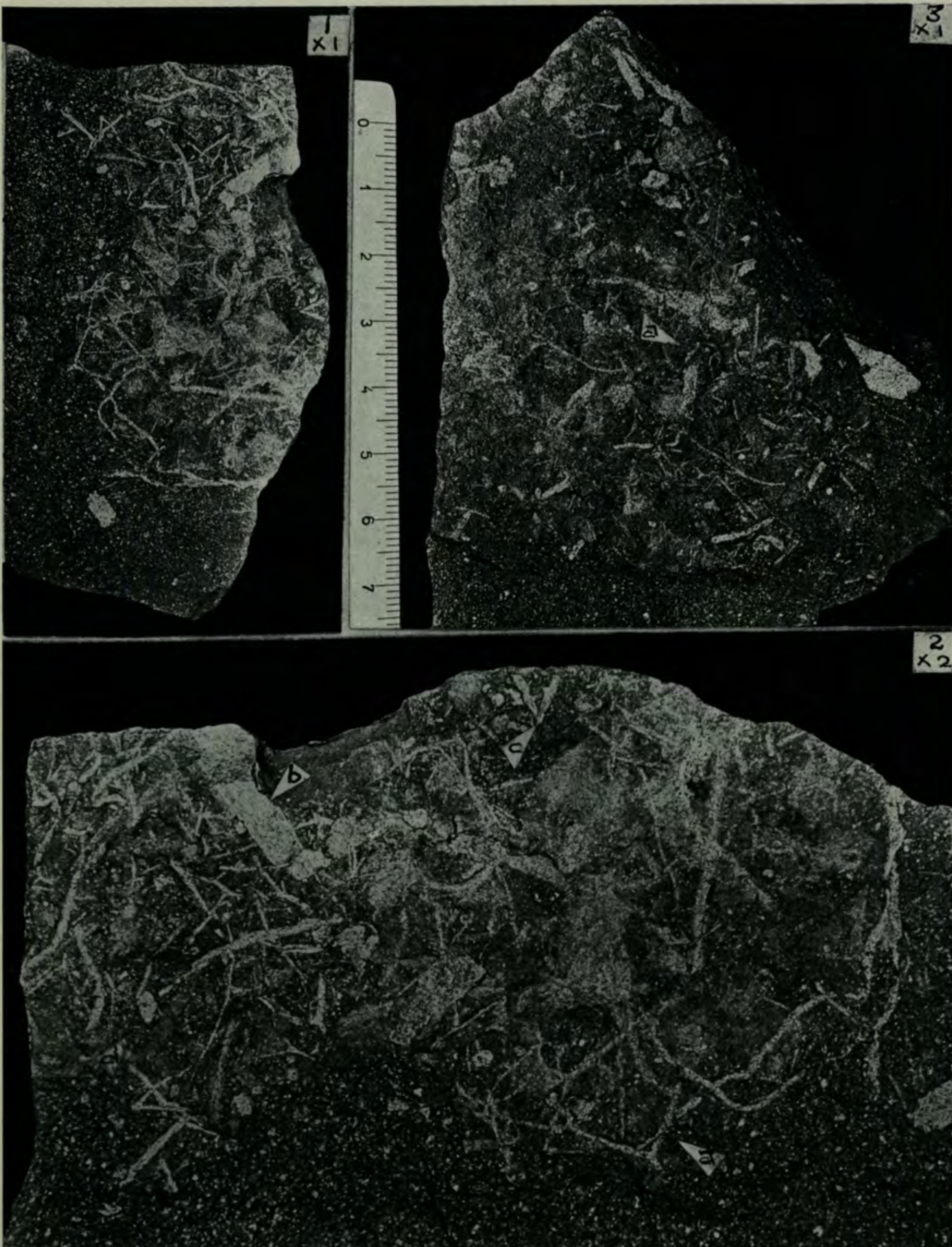

PLATE II—*Dutoitia maraisia* sp. nov.

PLATE III—Psilophytalean Axes ?

Figures 1—8 from the 3rd Bokkeveld Sandstone, De Doorns.

Figures 9 and 10 from the Farm Uitkomst, Bokkeveld, Hex River.

Fig. 1 Two stems longitudinally corrugated—note the irregular spacing of the small round scars.
Spec. T.D. 77B (× 3)

Fig. 2 Stems showing irregular elevations tapering downwards, corrugated stems and (*c*) a small branched axis.
Spec. T.D. 77B (× 3)

Fig. 3 Stem with small elevations and a partly developed groove which may imply a vascular strand. The clean edges of the left hand side at the top may indicate a dichotomous branching.
Spec. T.D. 80 (× 3)

Fig. 4 A finely stranded stem exhibiting inner and outer surfaces.
Spec. T.D. 80 (× 3)

Fig. 5 Two stems showing the irregular distribution of elevations and depressions.
Spec. T.D. 79 (× 3)

Fig. 6 Showing the irregular shape and size of some elevations.
Spec. T.D. 79 (× 3)

Fig. 7 A stem fragment with regular elongated elevations. (This must be viewed from the left.)
Spec. T.D. 83 (× 3)

Fig. 8 The specimen in Fig. 7 enlarged to show fine cell? structure.
Spec. T.D. 83 (× 6)

Fig. 9 A small punctate stem.
Spec. 57f, S.A. Mus. (× 3)

Fig. 10 The concave counterpart of the spec. in Fig. 9.
(× 1)

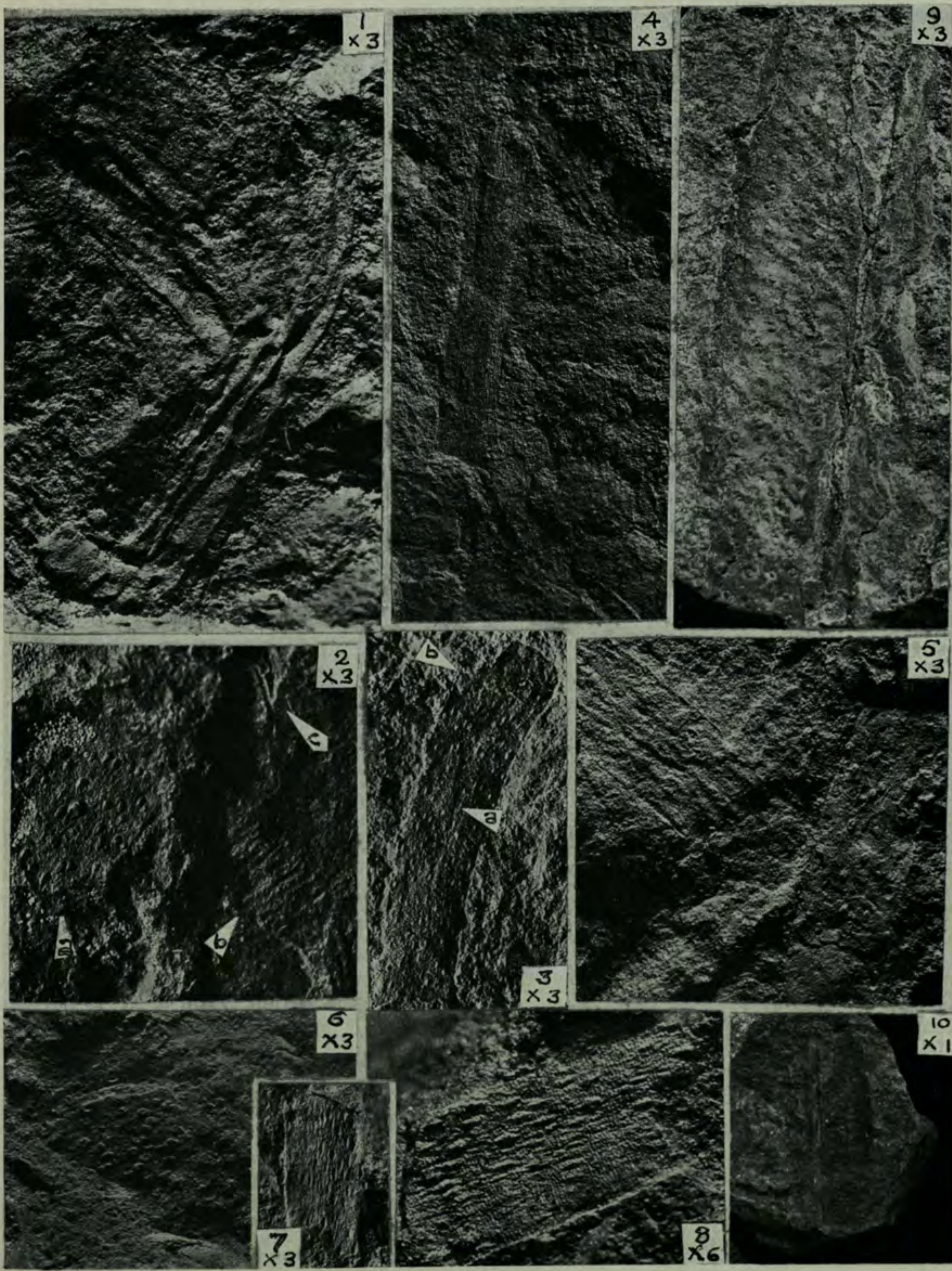

PLATE III—Psilophytalean Axes?

PLATE IV—*Palaeostigma sewardi* Krausel and Dolianiti.

Fig. 1 A single specimen exhibiting the transversely elongated depressions and elevations characteristic of the genus.

Schietkraal, Steytlerville Dist. Upper Bokkeveld Series.

Spec. 10741 (× 1) S.A. Mus. Counterpart of Type Specimen.

Fig. 2 Specimen in Fig. 1 enlarged

(× 2)

Fig. 3 New specimens

Farm Sweet Fountain (Estments) near Bathurst—Bokkeveld Series.

Whole surface of graphitic phyllite covered with tangled stems.

Spec. 4344 (× 1) Albany Mus.

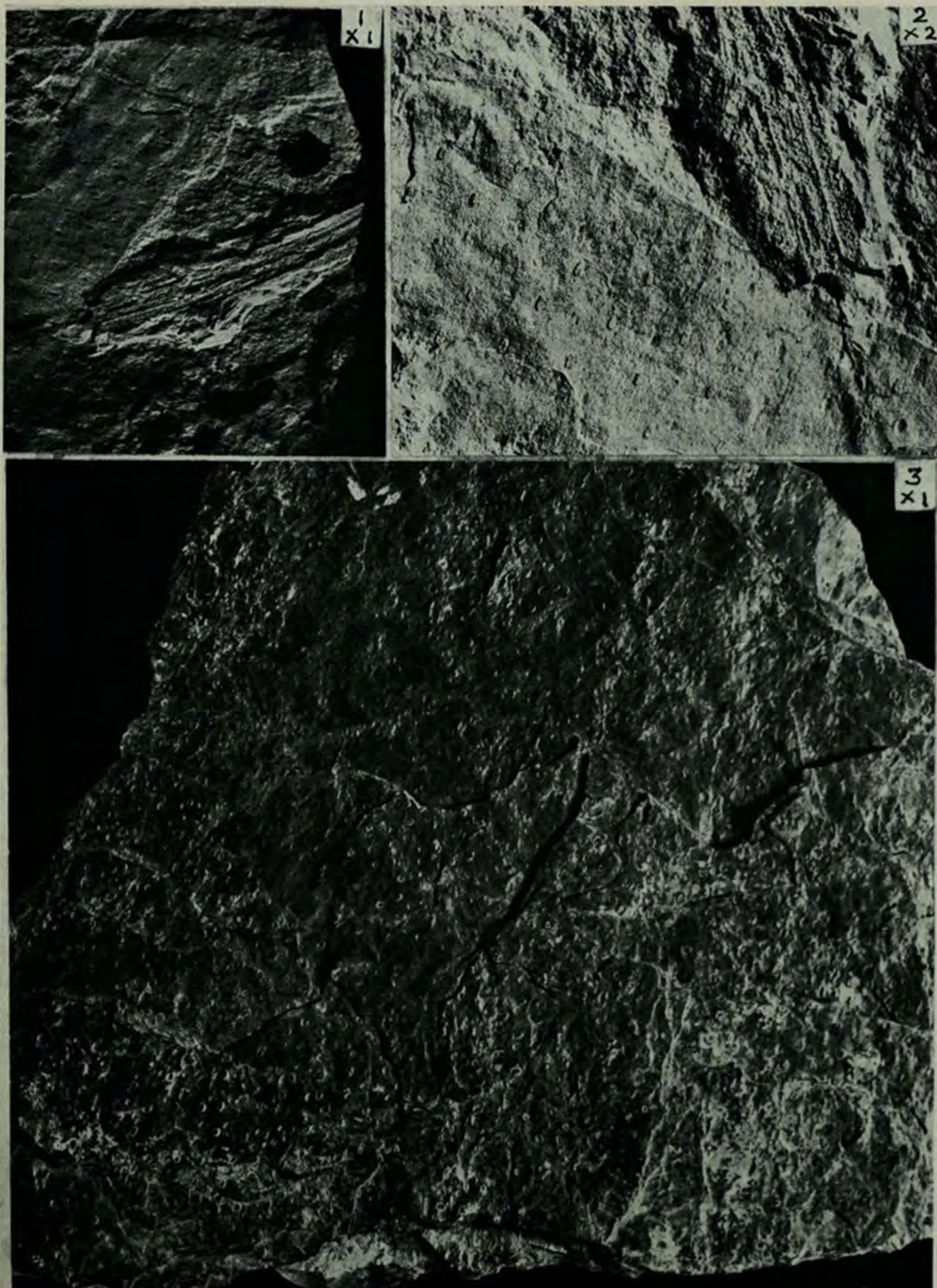

PLATE IV—*Palaeostigma sewardi* Krausel and Dolianiti

PLATE V—*Palaeostigma sewardi* Krausel and Dolianiti.

Farm Sweet Fountain—near Bathurst, Bokkeveld Series.

Fig. 1 A single stem
(× 3)

Fig. 2 The same specimen magnified to show the structure of the epidermis
(× 10)

Fig. 3 Same specimen showing stages of the separation of the "elevations". It is suggested here that the raised projections are vegetative buds which separate from the stems when mature, leaving smooth saucer-like depressions. Note the radiating structure of one of the bulbils which has been damaged.

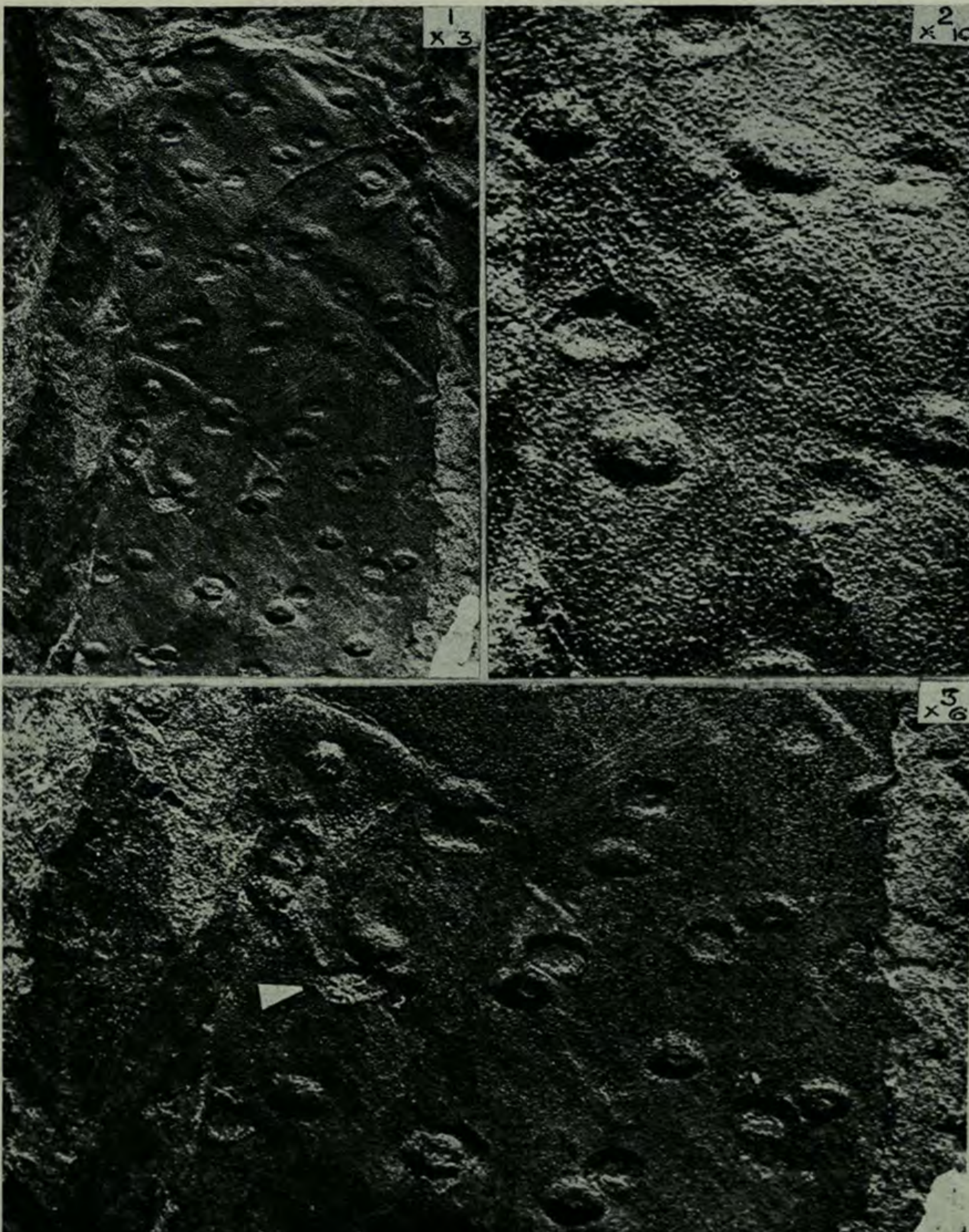

PLATE V—*Palaeostigma sewardi* Krausel and Dolianiti

PLATE VI—*Palaeostigma sewardi* Krausel and Dolianiti.

Farm Sweet Fountain (Estments)—near Bathurst, Bokkeveld Series.

Specimens to illustrate the suggested occurrence of elevated and depressed scars on the same surface rather than belonging to upper and lower cuticular surfaces as suggested by Seward (1932).

Fig. 1 Showing remnants of 'bulbils' in three saucer-like depressions.
($\times$ 6)

Figs. 2, 3, 4 Showing the haphazard arrangement of scars with bulbils sometimes above and sometimes below or else still occupying the depressions. The size of the dimple on the top of each bulbil is regarded as an indication of its maturity. Those which are ring shaped being ready for separation.
($\times$ 3)

Fig. 5 Stem with elevations exhibiting a slit instead of the normal crater-like apex of mature bulbils.

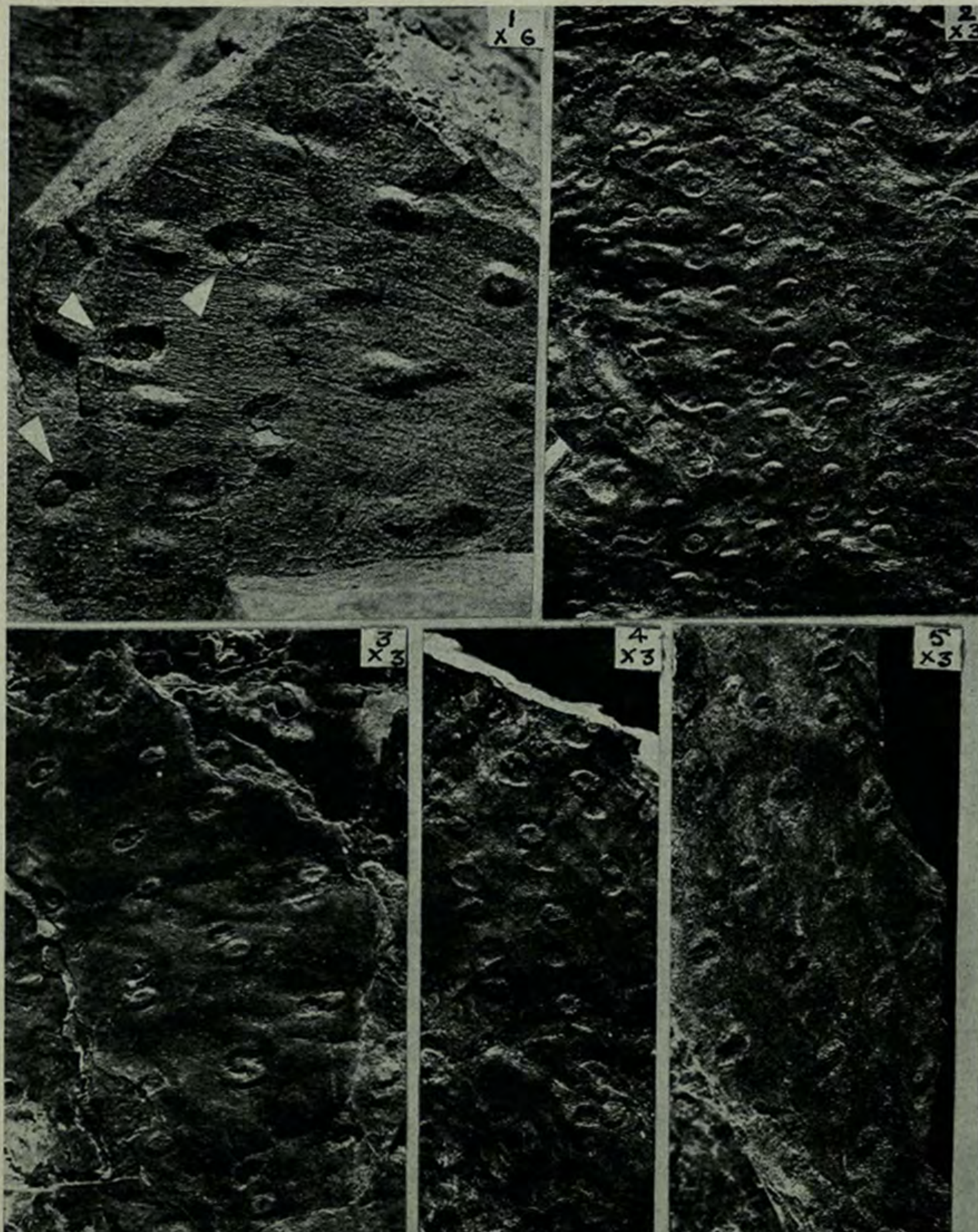

PLATE VI—*Palaeostigma sewardi* Krausel and Dolianiti

PLATE VII—*Palaeostigma sewardi* Krausel and Dolianiti.

Loc: Sweet Fountain near Bathurst.

Fig. 1 A smooth stem on which bulbils are beginning to form. (× 3)

Fig. 2 To show the preservation of a small patch of brownish cuticle (arrow). (× 3)

Fig. 3 An isolated detached bulbil on the right-hand side? (arrow)

Fig. 4 Note the remnants of tissue in the hollow saucer-like depressions near the top of the photograph and the radiating structure visible in some of both saucers and elevations due to damaged and partly sectioned bulbils.

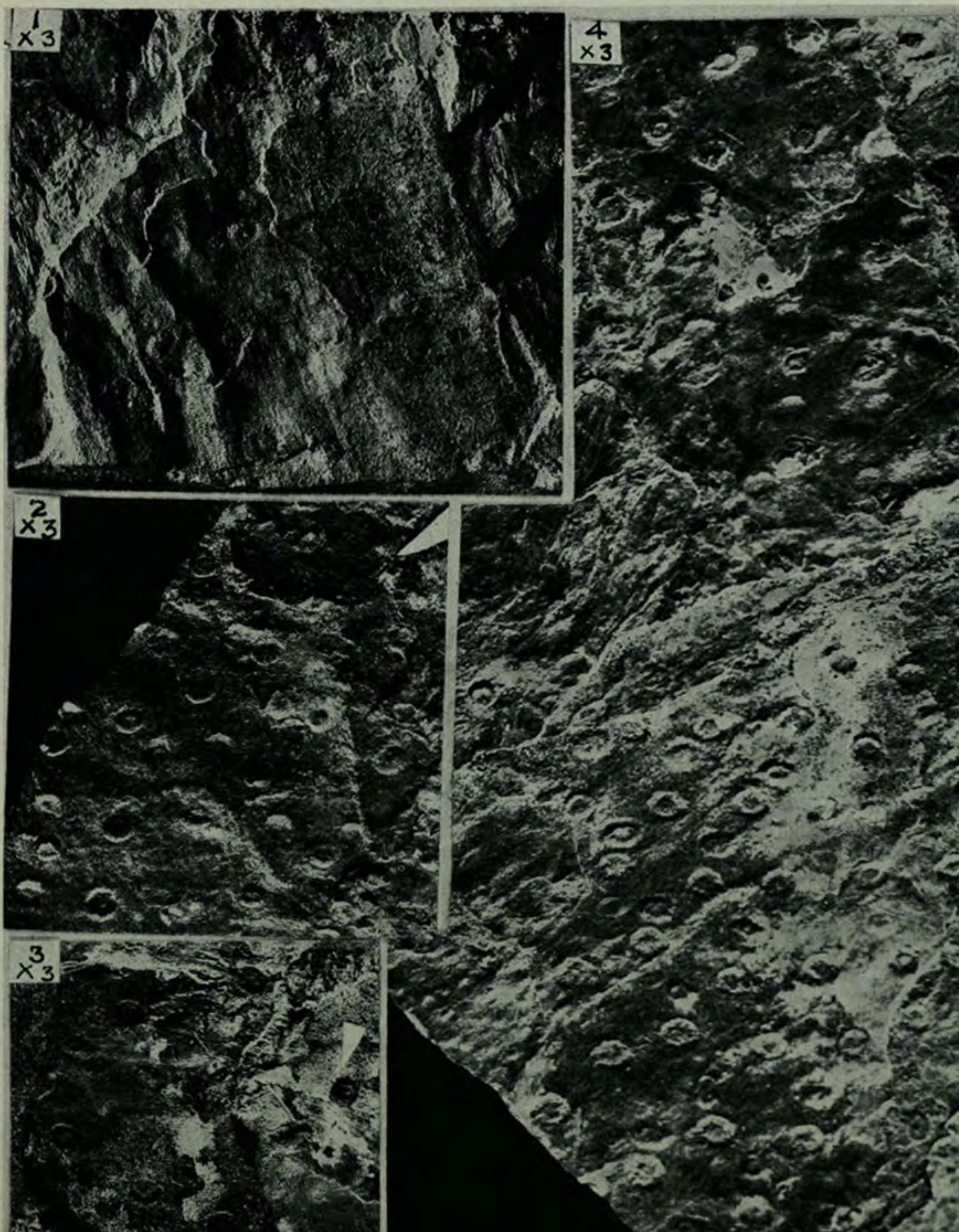

PLATE VII—*Palaeostigma sewardi* Krausel and Dolianiti

PLATE VIII—*Drepanophycus* Göppert.

Fig. 1 *Drepanophycus schwarzi* sp. nov.
Port Alfred—Bokkeveld shales
(The lower stem is *Haplostigma irrequlare*)
Type spec. 2903. (× 1) S.A. Mus.

Fig. 2 Specimen in Fig. 1 enlarged to show the bifurcating branch on the right hand side, the thick falcate spines and two different stem levels.
Type spec. 2903 (× 2) S.A. Mus.

Fig. 3 *D. schwarzi*? poor preservation.
Port Alfred—graphitic phyllite of Bokkeveld Series.
Spec. 4165 A (× 1) Albany Mus.

Fig. 4 *D. schwarzi*? a branched specimen.
Port Alfred. Bokkeveld phyllite.
Spec. 4165 B (× 1) Albany Mus.

Fig. 5 *D. kowiense* sp. nov.
Port Alfred. Bokkeveld phyllite.
Note the alignment of scars, the short thick spines on alternate rows of the left hand margin and the decorticated surface on the left.
Spec. 4173 C (× 2) Albany Mus.

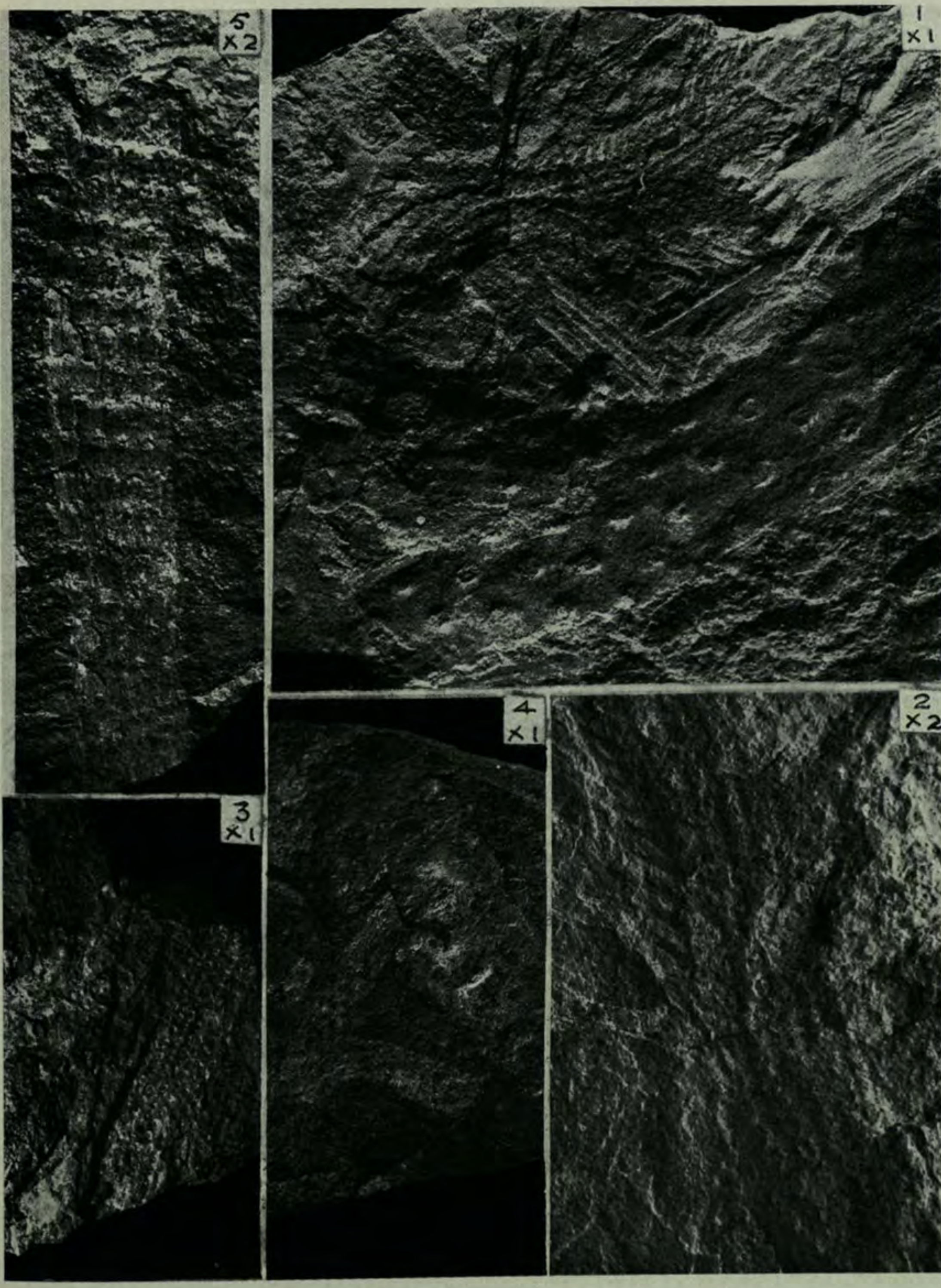

PLATE VIII—*Drepanophycus schwarzi* sp. nov. and *D. Kowiense* sp. nov.

PLATE IX—*Protolepidodendron eximium* Frenguelli.

Fig. 1 Specimen of *P. eximium* showing a curved and bifurcating stem in the upper half of the photograph.
Farm Soetendalsvlei, Willowmore District.
Upper Witteberg Shales.
Spec. J.T. 3 (× 1)

Fig. 2 Ramifying stems of *P. eximium*.
Farm Soetendalsvlei, Willowmore District.
Upper Witteberg Shales.
Spec. J.T. 22 (× 1)

Fig. 3 Showing the bifurcating tip of one of the spines.
Spec. J.T. 22 (× 4)

Fig. 4 Enlargement of the stem to show the long tapering spines along each margin and a small spherical object, a possible sporangium, near the tip of one of them.
Spec. J.T. 22 (× 3)

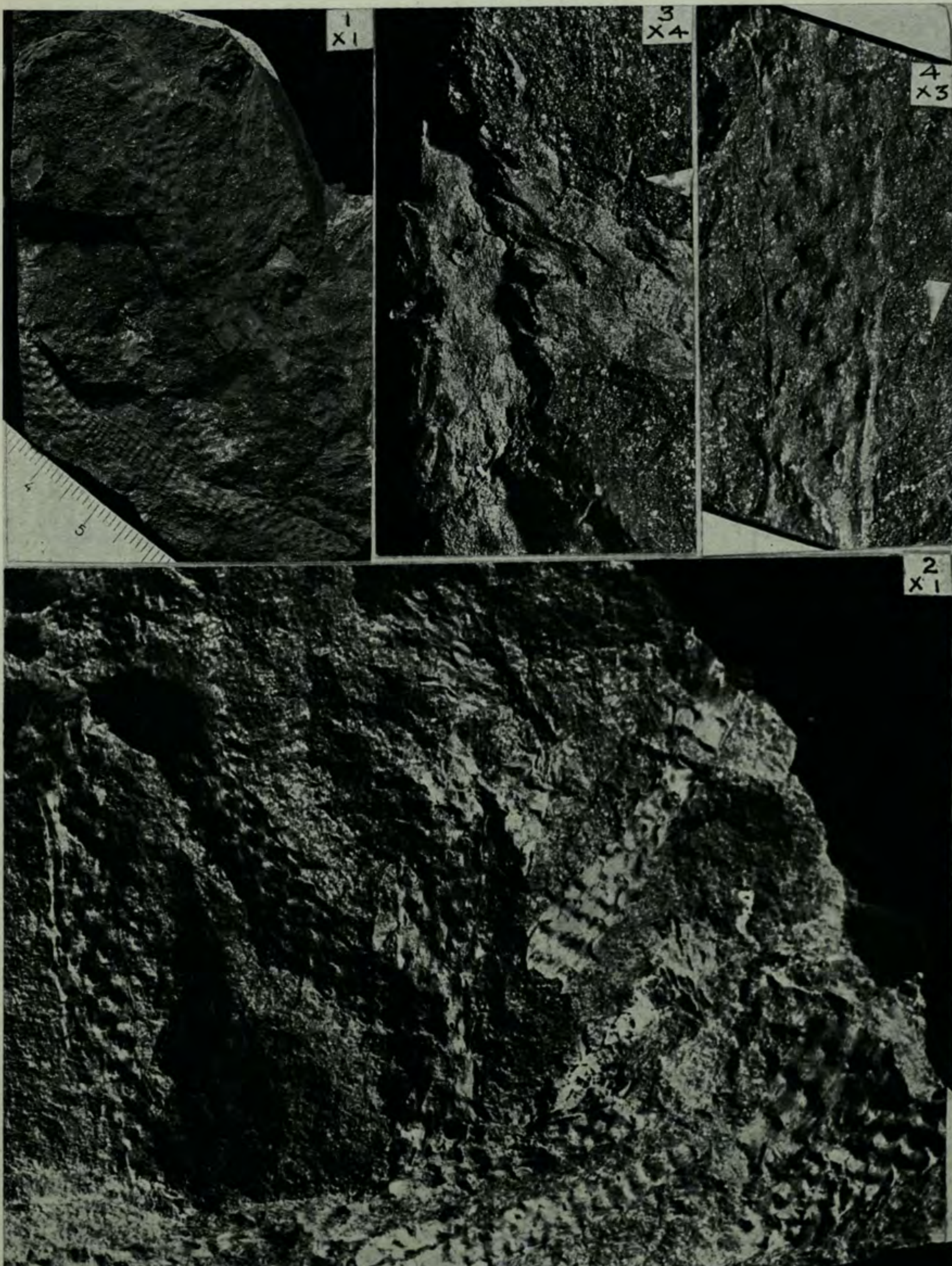

PLATE IX—*Protolepidodendron eximium* Frenguelli

PLATE X—*Protolepidodendron theroni* sp. nov.

Fig. 1 A limonite replacement of a stem. Note the bifurcating mould at the base.
Near Vondeling—Main Witteberg Series.
Type spec. J.T. 31 (× 1)

Fig. 2 Enlargement of type specimen with different lighting to emphasize the leaf cushions.
Type Specimen J.T. 31 (× 2)

Fig. 3 Transverse section of the stem shows the projecting leaf cushions but no structure.
Spec. J.T. 31 (× 3)

Fig. 4 Enlargement to show the angle of branching of the stem mould at the base and a bifurcating spine just above the quartz vein. (× 2)

Fig. 5 The bifurcating mould and part replacement of a stem with diamond shaped scars.
Vondeling Dist.—Second Bokkeveld Sandstone.
Spec. J.T. 24 (× 1)

PLATE X—*Protolepidodendron theroni* sp. nov.

PLATE XI—*Archaeosigillaria caespitosum* Schwarz nov. com.

Fig. 1 Type specimen of *Archaeosigillaria caespitosum* Schwarz nov. com.
Ceres—Lower Witteberg Series.
Note the scars on the inner side at the top of the stem showing it to be the right hand branch of a stem.
Type Spec. 142. (× 1) Albany Mus.

Fig. 2 Different view of type specimen in Fig. 1 to show round scars on the left and hexagonal ones on the right.

Fig. 3 A limonite replacement of a branched stem of *Archaeosigillaria caespitosum*.
Vondeling—Main Witteberg Series.
Spec. J.T. 30 (× 1) Geol. Mus. Stellenbosch University.

Fig. 4 Enlargement of fig. 3 with reversed lighting to show details of scars.

Figs. 5 and 6 A clay cast of a small stem of ?*A. caespitosum* with counterpart.
Specs. 4172 b & c (× 1) Albany Mus.

Fig. 7 Mould of ?*Archaeosigillaria caespitosum*.
Spec. 4140 (× 2) Albany Mus.

Fig. 8 Small rhombic scars of a partly carbonised compression of ?*A. caespitosum*.
Nourse Poort near Steytlerville—Lower Witteberg Shales.
Spec. 10739 S.A. Mus. (× 1).

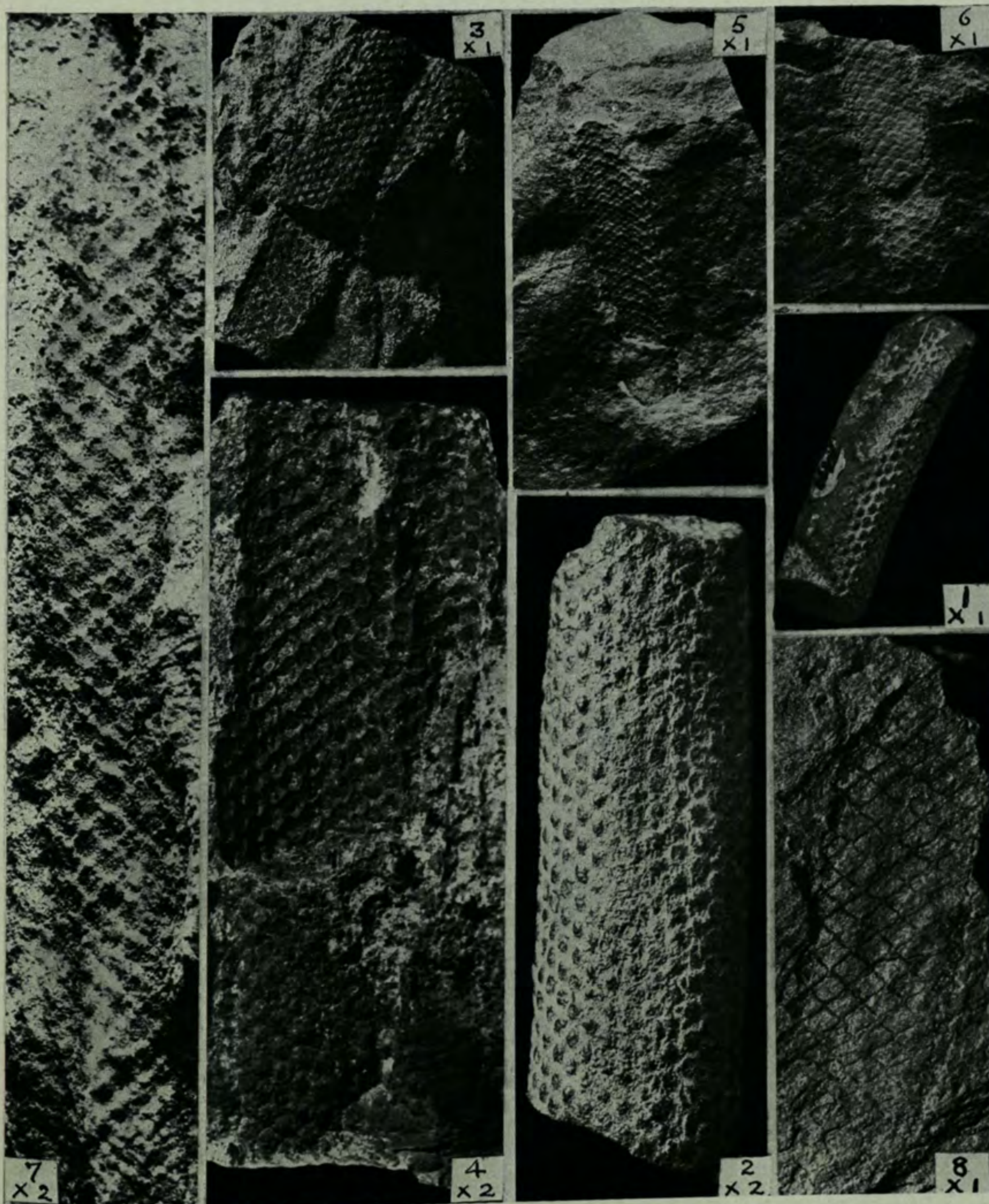

PLATE XI—*Archaeosigillaria caespitosum* Schwarz nov. com.

PLATE XII—*Leptophloeum australe* (McCoy) Walton.

Fig. 1 *L. australe* (formerly the type of *Lepidodendron albanense* Schwarz)
Witteberg Series S. of Grahamstown
Spec. 150 Albany Museum (× 1)

Fig. 2 *L. Australe*. A mould in dense quartzite showing a round vascular scar in the upper angle of several of the rhombic scars.
Witteberg Series—Howisons Poort, S. of Grahamstown.
Spec. 4088 A.M. (× 1)

Fig. 3 *L. australe*. A partly compressed cast of stem with vascular strands replaced by limonite.
Witteberg Series, Touws River.
Spec. 11403 South African Museum (× 1)

Fig. 4 *L. australe*. Specimen in Fig. 3 photographed at right angles to the elongation showing the double margin between the scars (lower right hand side) which is so characteristic of the species.
Spec. 11403 S.A.M. (× 1)

Figs. 5 & 6 *L. australe*. Upper and lower surfaces of specimen in Fig. 3 showing some of the vascular strands replaced by limonite and the amount of compression suffered by the stem cast.
Spec. 11403 S.A. M. (× 1)

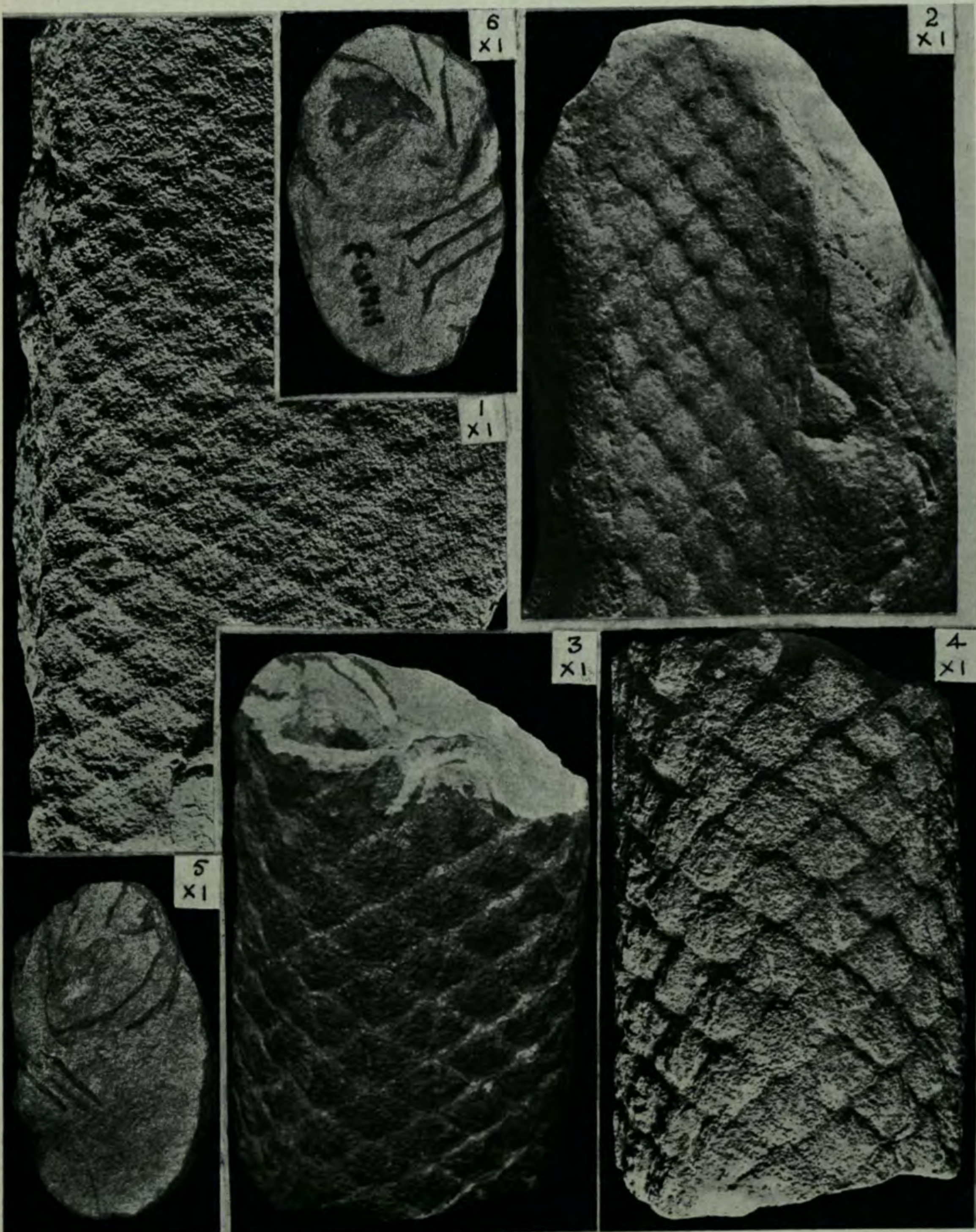

PLATE XII—*Leptophloeum australe* (McCoy) Walton

PLATE XIII—*Haplostigma irregulare* (Schwarz) Seward

Fig. 1 Type specimen *H. irregulare* originally the type of *Bothrodendron irregulare* (Schwarz 1906).
Farm Sweet Fountain (Estments) graphitic Bokkeveld Shales.
Type Spec. 165 (×I) Albany Mus.

Fig. 2 *H. irregulare*—Paratype
Originally erroneously described as *Bothrodendron leslii* (Seward 1903).
Bokkeveld shales.
Matroosberg, Western Cape.
Spec. B. S.A. Mus. (× 1)

Fig. 3 *H. irregulare*. An enlargement of the lower stem in Fig. 1 to show bifurcation.
Type spec. 165. Albany Mus. (× 2)

Fig. 4 *H. irregulare*—Paratype.
Originally described as a lepidodendroid stem (Seward 1903).
Bokkeveld Shales, Port Alfred.
Spec. V236. Nat. Hist. Mus. Lond. (× 1)
Photo by Dr. W. Chaloner

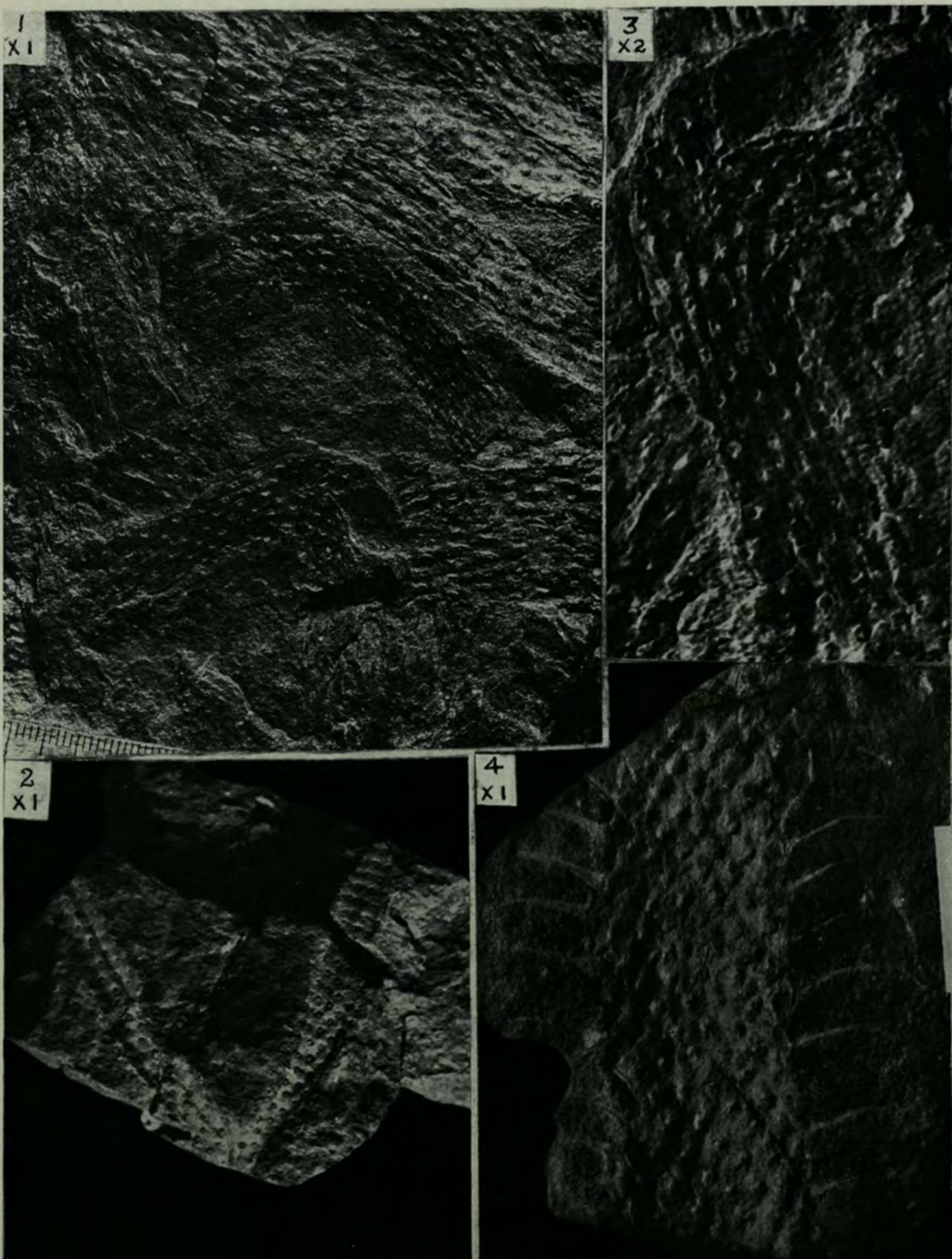

PLATE XIII—*Haplostigma irregulare* (Schwarz) Seward

PLATE XIV—*Haplostigma* Seward.

Fig. 1 *H. irregulare*
Originally described as *Bothrodendron irregulare* (Seward 1909). Notice the thickening beneath the scars on the left hand stem.
Bokkeveld Shales, Port Alfred.
Spec. 2903, S.A. Mus (× 1)

Fig. 2 *H. irregulare* showing long spine-like outgrowths like those on Pl. XIII, Fig. 4, but in this partly decorticated specimen strands of possible vascular tissue project from the middle of the stem and along the outgrowths.
Bokkeveld Shales, Port Alfred.
Spec. 2909, S.A. Mus. (× 1)

Fig. 3 *Haplostigma irregulare* — stem with upper and lower surfaces exposed and with the long outgrowths truncated (by dryness?) to resemble short thick falcate spines.
Bokkeveld Shales, Port Alfred.
Spec. 2905, S.A. Mus. (× 1)

Fig. 4 *Haplostigma irregulare*. Two stems of different sizes and different degrees of decortication but possibly of the same species. Note the small outgrowths on the left hand side of the smaller stem. Bokkeveld Shales, Port Alfred.
Spec. $2909A_2$ S.A. Mus. (× 1)

Fig. 5 *H. irregulare*. A large stem with two surfaces exposed.
Bokkeveld Shales, Port Alfred.
Spec. 2905, S.A. Mus. (× 1)

Fig. 6 *H. irregulare*. The only specimen known from the Cape System in which dark cuticular tissue is still preserved. Unfortunately the source of this specimens was not recorded.
Spec. 3750 Albany Mus. (× 1)

Fig. 7 *H. irregulare*. Two stems showing different aspects. The smaller one may form a link with the smaller stem in Fig. 4.
near Steytlerville.
Spec. 10742. S.A. Mus. (× 1)

Fig. 8 ? *H. irregulare*. A stem with very small flat scars and pronounced transverse ribbing which is included, doubtfully in this genus. See text.
Near Steytlerville.
Spec. 10746 S.A. Mus. (× 1)

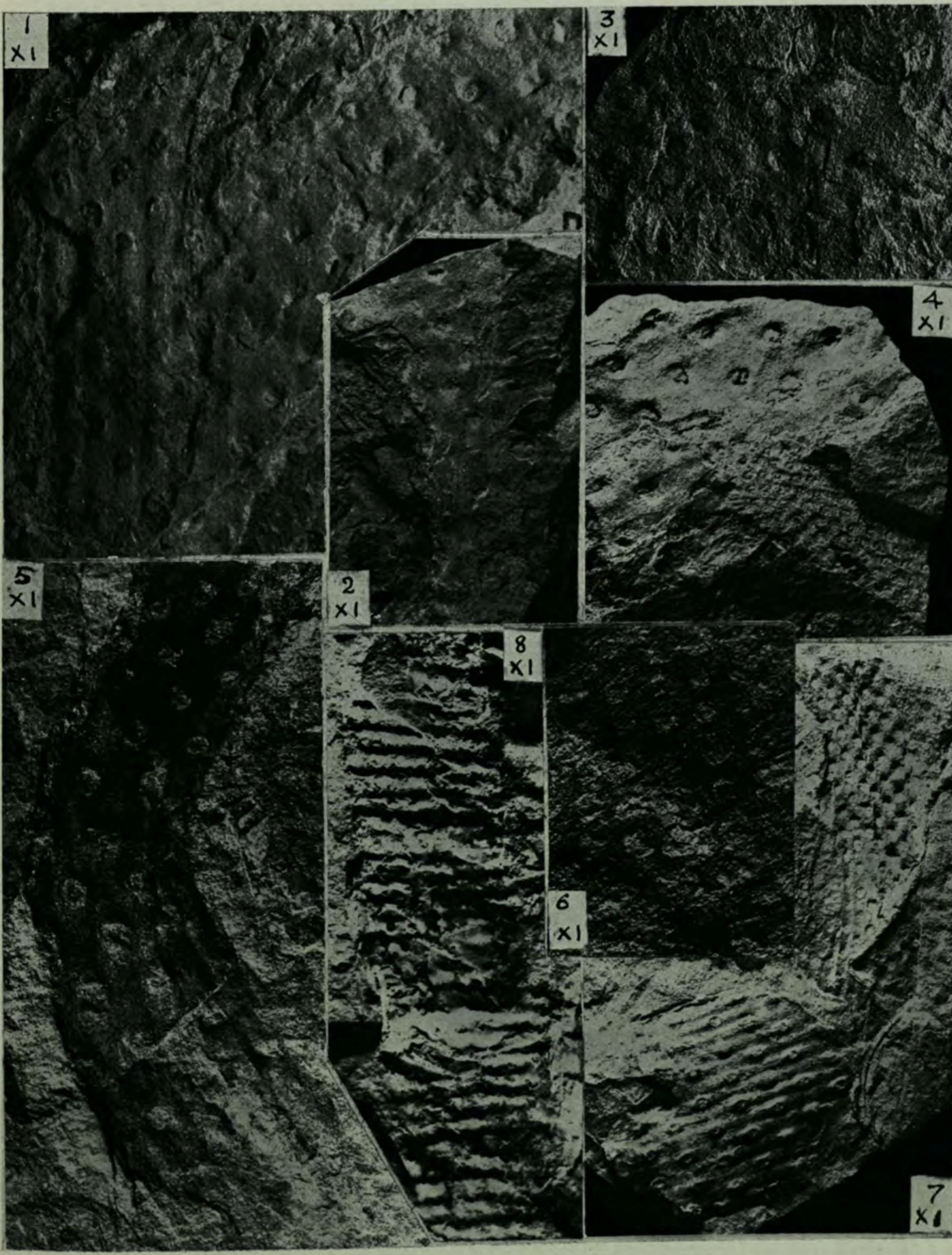

PLATE XIV—*Haplostigma irregulare* (Schwarz) Seward

PLATE XV—*Haplostigma* Seward.

Specimens preserved in quartzite.

Fig. 1 This is the commonest type of hollow mould in quartzite in which the round cavities extend outwards and upwards. Part of the quartzite mould, with hollow impress of the vascular strand, is preserved at the base.
Witteberg Quartzite. Elandsvlei. De Doorns Dist. Spec. TX 18 (× 1)

Fig. 2 A mould similar to that in Fig. 1 in which casts of the stiff outgrowths fill some of the hollows.
Quartzites Witteberg? Groot Rivier Heights, Steytlerville Dist.
Spec. 161. A. Mus. (× 2)

Fig. 3 A small cast of a doubtful *Haplostigma* stem with oval projections and a chequer board pattern which is unusual. (Formerly *Lepidodendron kowiense* Schwarz).
Probably Witteberg. Cold Bokkeveld, Ceres Dist.
Spec. 143. A. Mus. (× 1)

Figs. 4, 5 and 6.
Specimens with impressions of different stages of decortication of ?*Haplostigma*
4. An unlabelled specimen S.A. Mus. from Witteberg Series, Ladismith, Cape.
5. Spec. 1075 (× 1)
6. Spec. 11650 (× 1) S.A. Mus.

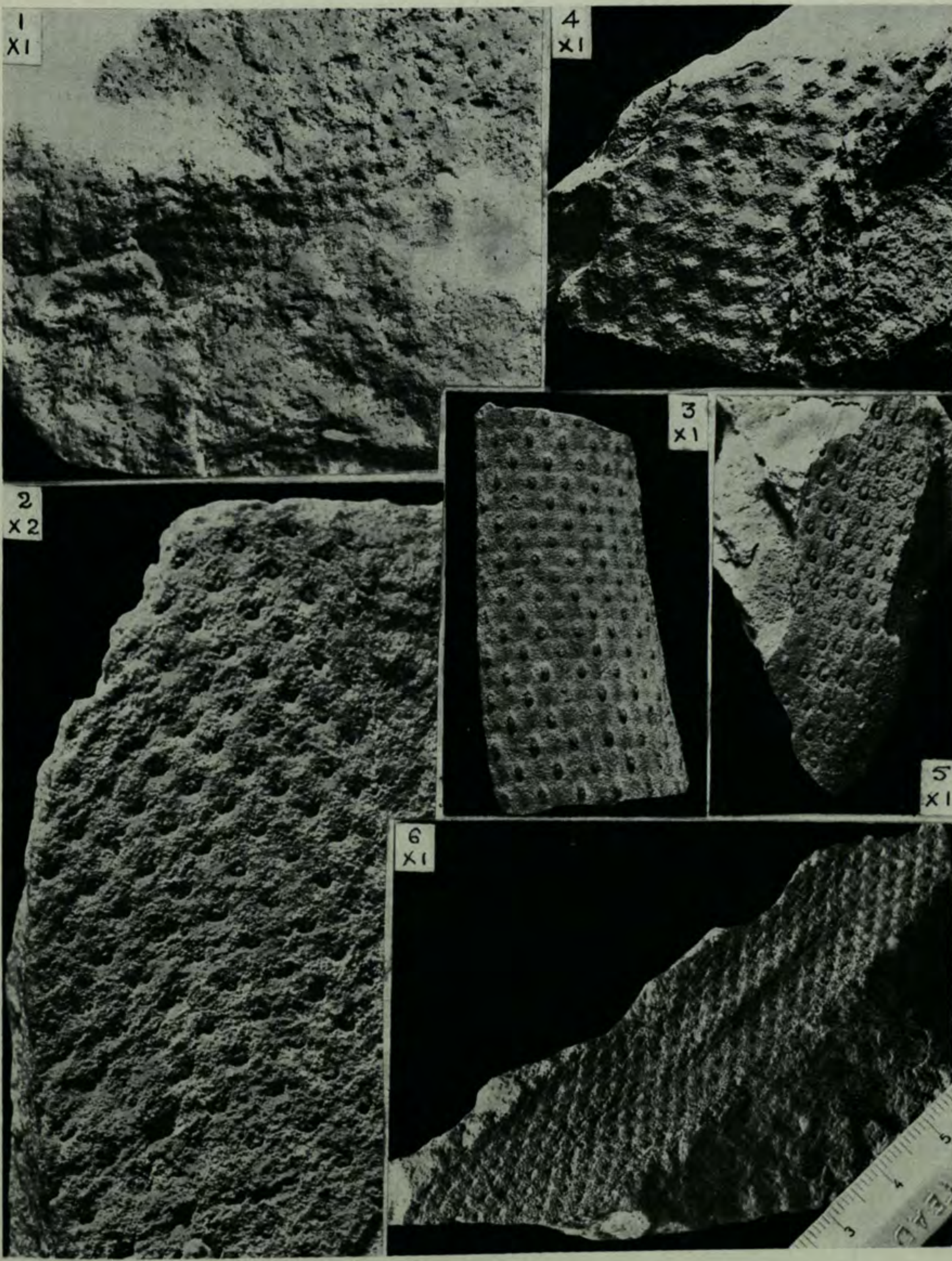

PLATE XV—*Haplostigma* Seward

PLATE XVI—Indeterminable lycopod stems preserved in quartzite—to illustrate different forms of preservation.

Fig. 1 The largest cast of a lycopod stem known from the Cape System — the pattern of leaf scars is indecisive. The scale in this photograph is a twelve inch ruler.
Spec. in Stellenbosch Univ. Geol. Mus.
Photo. J. Theron. Stellenbosch.

Fig. 2 A compressed cast and both sides of the mould of an indeterminable lycopod stem.
Second Bokkeveld Sandstone, Vondeling.
Spec. J.T. 26 (× 1)

Fig. 3 A hollow mould of a bifurcating stem with indications of short spiny outgrowths.
Second Bokkeveld Sandstone, Vondeling.
Spec. J.T. 25 (× 1)

Fig. 4 Mould of a narrow stem with clear oval scars sometimes dimpled — cf. Plate XV, Fig. 5.
Affinity unknown.
Witteberg Quartzite, Ladismith Dist. Cape
Spec. Presented by Dr. A. J. Bruwer — Witwatersrand University. (× 1)

Fig. 5 Specimen in Fig. 4 (× 2) to show details of scars.

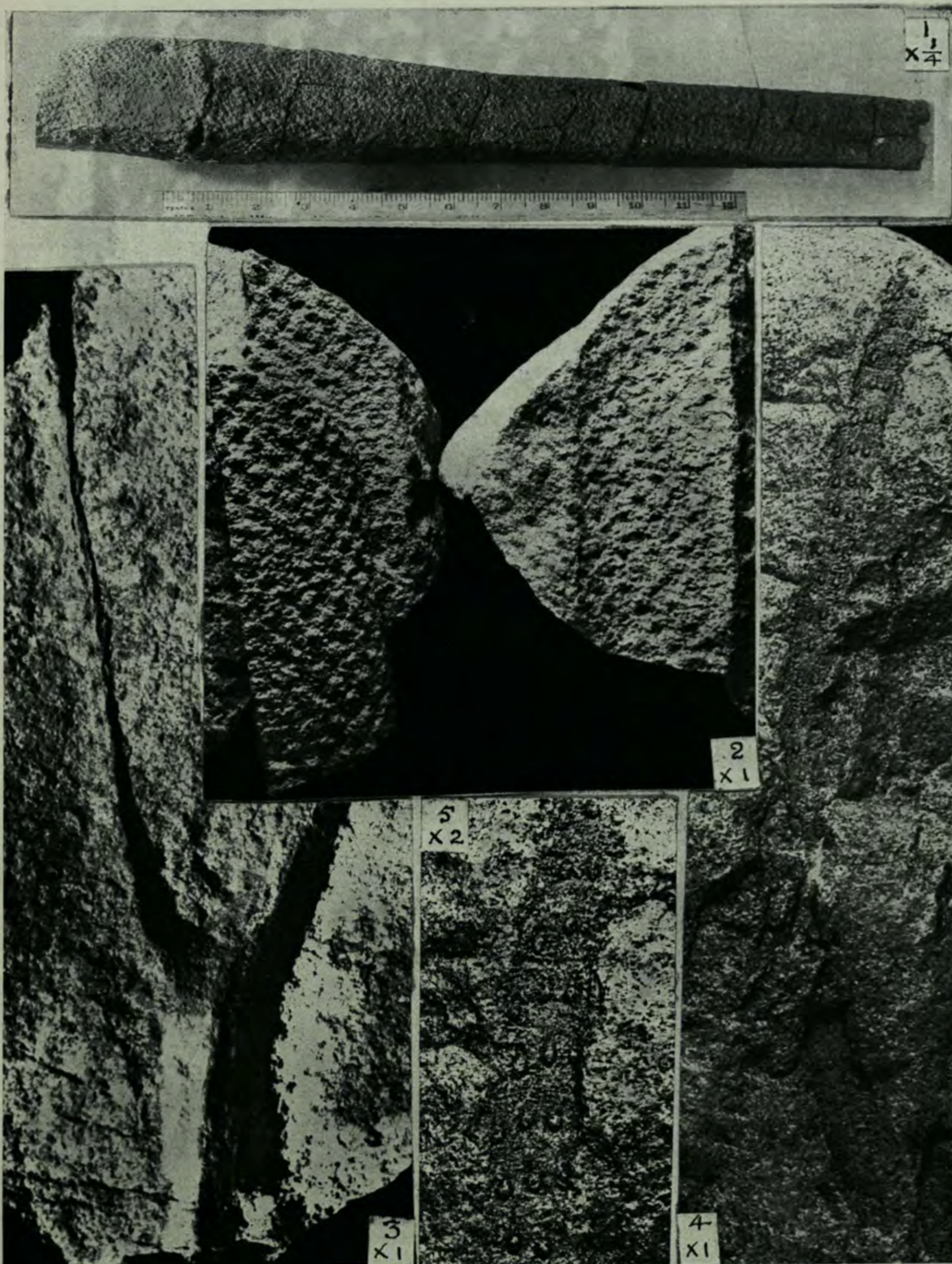

PLATE XVI—Indeterminable lycopod stems preserved in quartzite

PLATE XVII—*Calamophyton capensis* sp. nov.

Fig. 1 Type spec. *Calamophyton capensis* sp. nov.
Farm Sweet Fountain, Bathurst District.
Upper Bokkeveld shales.
N.B. Two parallel whorled stems with nodal? positions of left hand stem marked 'a' and 'b'.
Small portion of *Palaeostigma* stem visible at 'c'.
Spec. 1809 Albany Mus. (× 1)

Fig. 2 Portion of a broad finely striated stem cast — lower part of the type specimen.
Type spec. 1809, Albany Mus. (× 1)

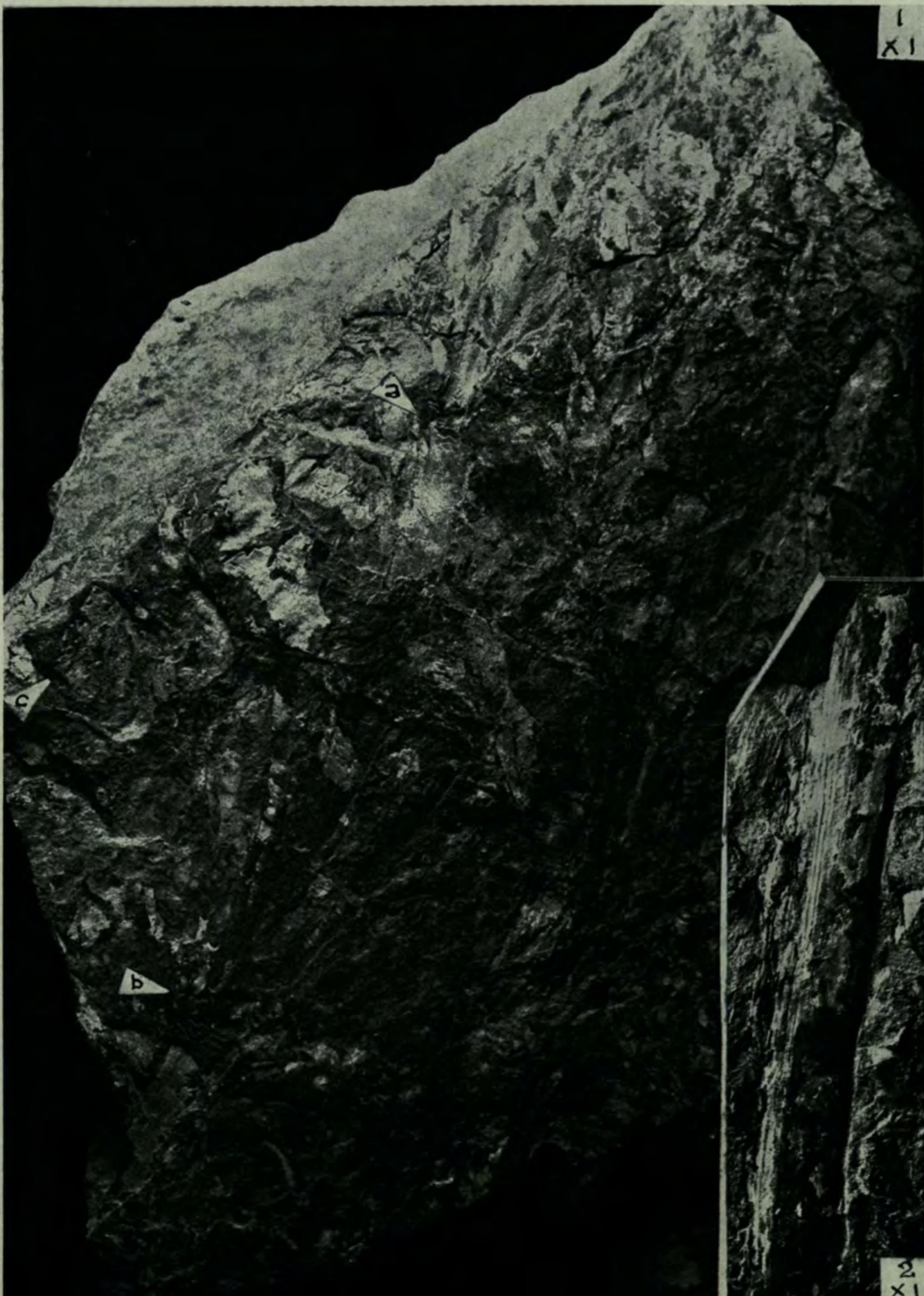

PLATE XVII—*Calamophyton capensis* sp. nov.

PLATE XVIII—*Calamophyton capensis* sp. nov.

Fig. 1 The lower part of the left hand stem shown on Pl. XVII, Fig. 1 enlarged.
Farm Sweet Fountain, Bathurst District.
Upper Bokkeveld Shales.
N.B. The apparent whorl of branches, and the transverse jointing of a film of talc. This gives the impression of short joints but beneath the film the stems are smooth or finely ribbed.
Type spec. 1809 Albany Mus. (× 2)

Fig. 2 A portion of rock split from the type spec. showing a number of small branches.
Spec. 1809 A (× 1)

Fig. 3 Specimen showing branching enlarged.
Spec. 1809 A (× 2)

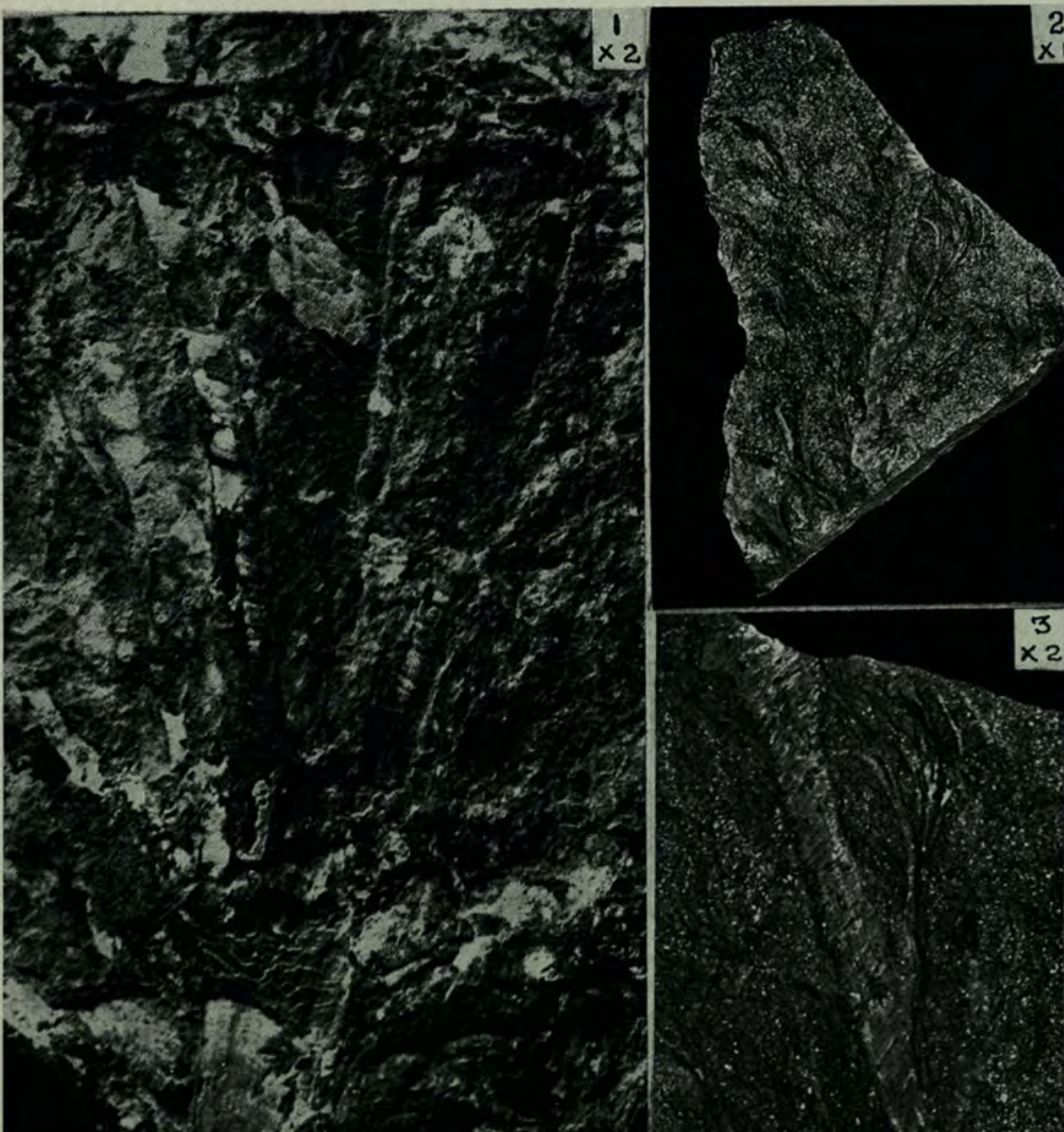

PLATE XVIII—*Calamophyton capensis* sp. nov.

PLATE XIX—*Platyphyllum albanense* and indeterminable stems.

Fig. 1 *Platyphyllum albanense* sp. nov.
The bifurcating venation of parts of two overlapping leaves represent the only known specimens of a large leafed plant from the Cape System.
Howisons Poort near Grahamstown — near base of Witteberg Series.
Type spec. 4487 (× 2) Albany Mus.

Fig. 2 Stem B. A branched and longitudinally grooved stem with thickened axils.
Alicedale Poort — Lower Witteberg Series.
Spec. 3708 (× 1) Albany Mus.

Fig. 3 Stem C. Broad smooth? woody stems.
Willowmore Dist. Upper Witteberg Shales.
Spec. J.T. 13 (× 1)

Fig. 4 Stem D. A large dichotomously branched stem, probably decorticated, with faint longitudinal striae.
Laingsburg Dist.—base of Upper Witteberg Shales.
Spec. 1155 (× 1) S.A. Mus.

Fig. 5 Stem E. Finely striated and jointed stems possibly part of the same system of branching.
Willowmore Dist. Upper Witteberg Shales.
Spec. J.T. 19 (× 1)

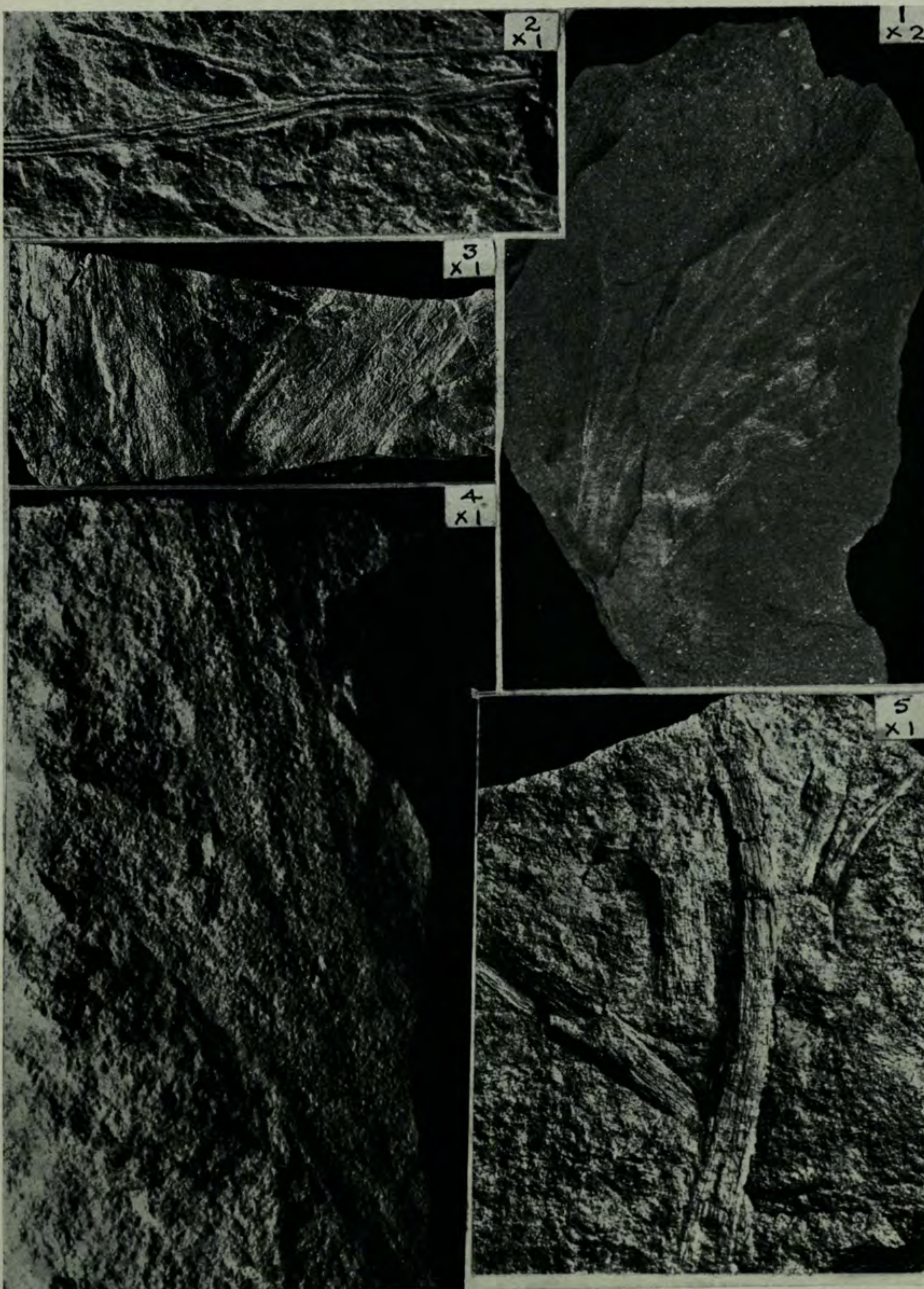

PLATE XIX—*Platyphyllum albanense* sp. nov. and indeterminable stems

PLATE XX—Controversial algal fossils from the Table Mountain Series cf. *Tontalia zollneri* Frenguelli.

Fig. 1 Weathered and bleached carbonaceous shale covered with branched cylindrical algal thalli?, raised slightly above the surface. Upper shale of T.M.S. — De Doorns. Spec. T.D. 28a (× 1)

Fig. 2 The same specimen as Fig. 1 showing the approximate parallel growth and fluctuating width of some of the thalli. Note the dichotomous and lateral branching and the joint central mark indicative of the cylindrical nature of each branch.
Spec. T.D. 28a (× 2)

Fig. 3 Another weathered specimen exhibiting the same features. Upper shale T.M.S.
Upper surface Spec. T.D. 28b (× 1)

Fig. 4 The unweathered lower surface of the spec. in Fig. 3 oriented in the same position and photographed under water to produce a contrast in colour. Note the thalli? on the two surfaces do not coincide in any particular although the specimen is less than 1 cm in thickness.
Lower surface Spec. T.D. 28b (× 1)

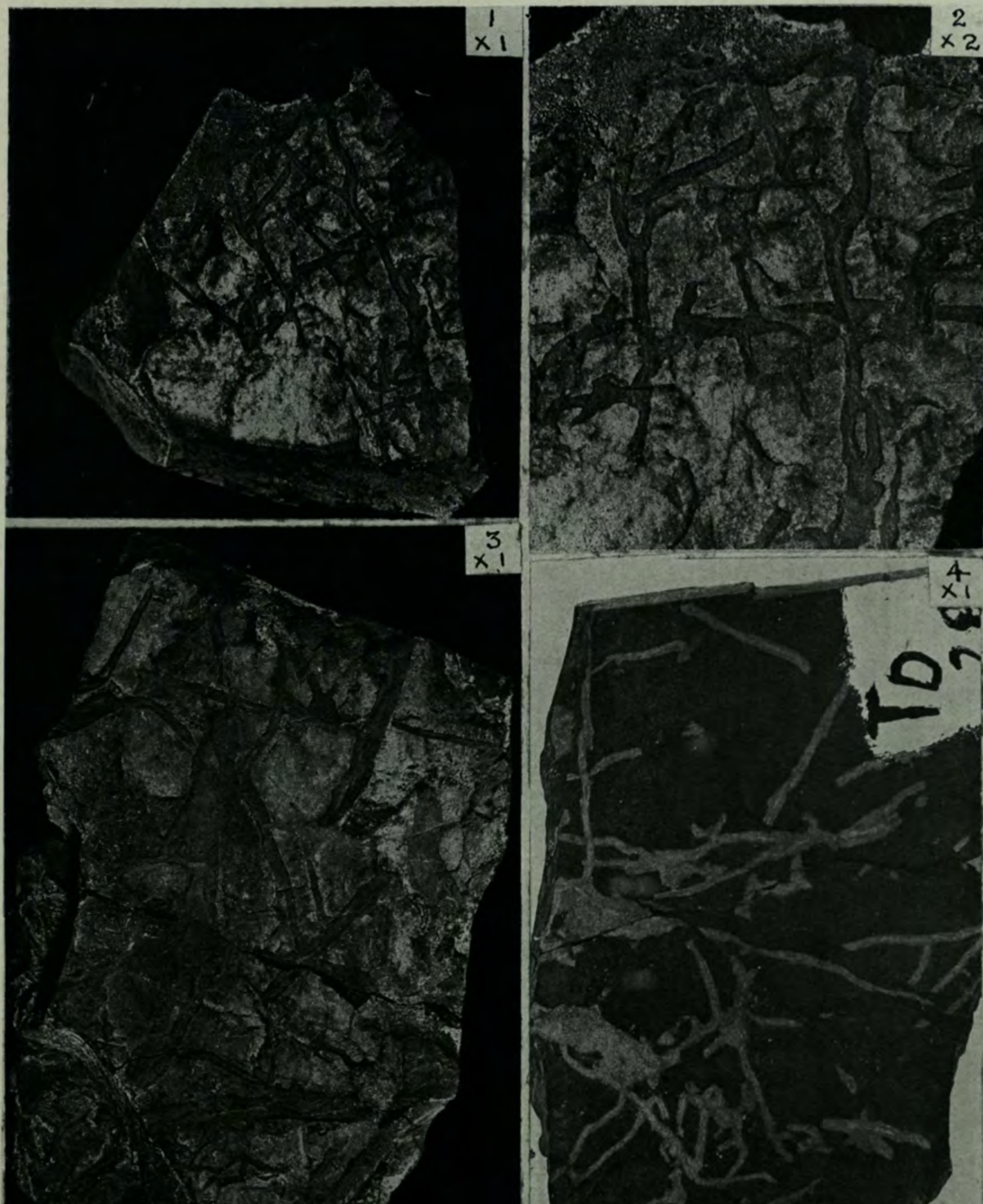

Plate XX—Controversial algal fossils cf. *Tontalia zollneri* Frenguelli

PLATE XXI—*Spirophyton* with invertebrate tracks superimposed.

Fig. 1 Two portions of rather formless *Spirophyton* possibly from an exposed littoral zone, crossed by trails of worms or other invertebrates which bear no relationship to them. Near Vondeling, Willowmore District, Lower Witteberg Sdst.
Spec. J.T. 39 (× 1)

PLATE XXI—*Spirophyton* with invertebrate tracks superimposed

PLATE XXII—*Spirophyton* Type "A"—the common type.

Fig. 1 Highly micaceous quartzite with several *Spirophyton* overlapping one another. Note the round compact closed spiral form, the central column and the tight spiral twisting of individual strands which is well illustrated on the right-hand side. Loc. Upper Bokkeveld — 100 ft. below lowest Witteberg quartzite near Touwsberg. University of the Witwatersrand Spec. in B.P.I. Pal. Col. (x 1) Presented by R. B. King.

Fig. 2 Highly micaceous red sandy shale with numbers of small *Spirophyton* overlapping one another on the bedding plane. Loc. Upper Bokkeveld near Touwsberg. University of the Witwatersrand Spec. in B.P.I. Pal. Coll. (× 1) Presented by R. B. King.

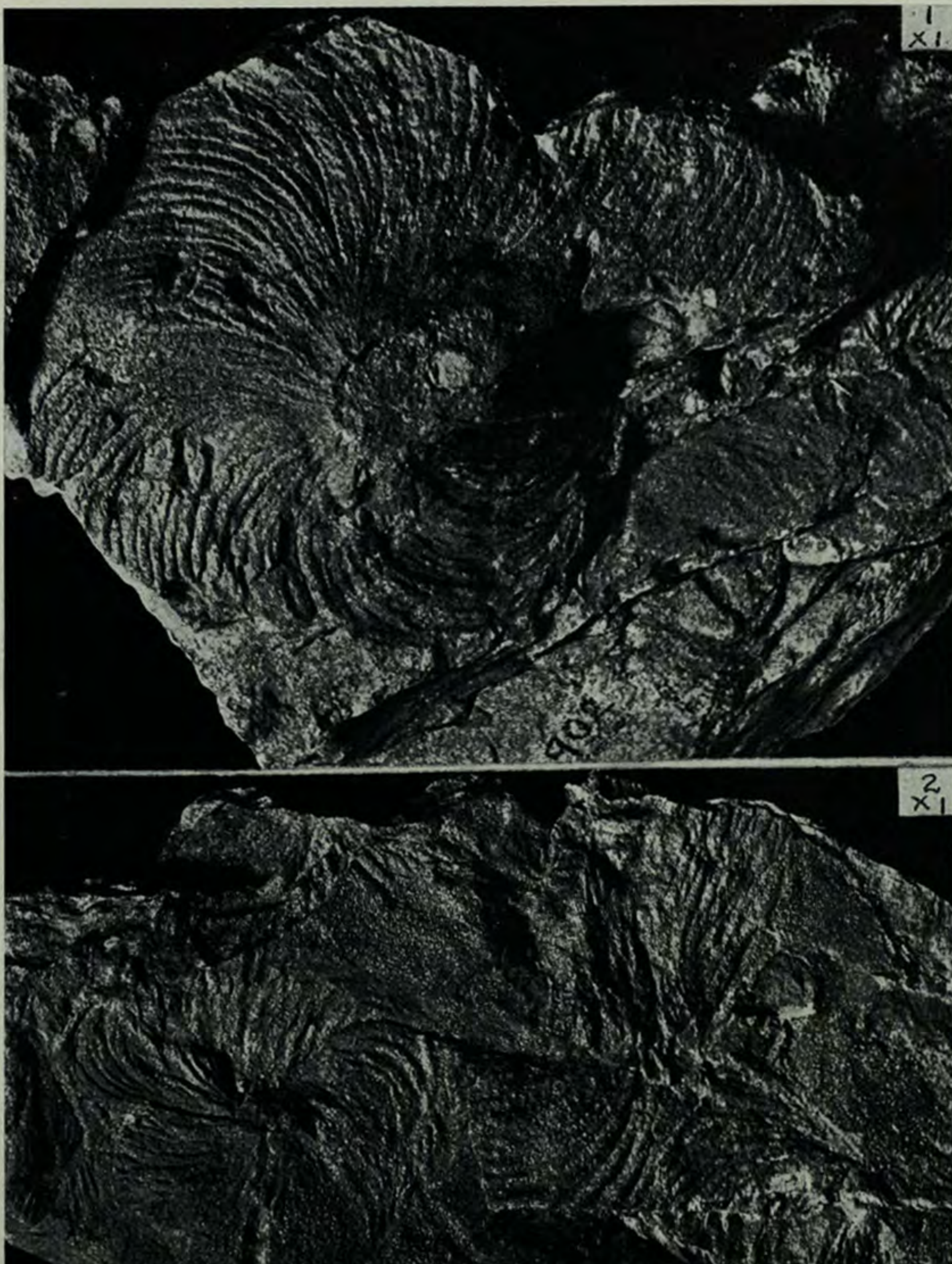

PLATE XXII—*Spirophyton* Type "A"—the common type

PLATE XXIII—*Spirophyton* Type "B"—Note the dark carbon? colouring.

Fig. 1 A large specimen of *Spirophyton* "B" 18 cm in diameter, exposed on a bedding plane. Fragments of others are visible also. Note the grouping of 10-12 individual twisted strands" into petal like units. The general open spiral form is apparent but is less pronounced than in Type "A"
Photo taken in the field by J. Theron.

Fig. 2 Part of *Spirophyton* "B" on a bedding plane. The spiral twisting of individual strands is visible on the right hand side . Locality unknown.
B.P.I. Pal. Coll. (× 1)

Fig. 3 Fragments of *Spirophyton* "B", invertebrate remains and trails preserved in a disturbed littoral zone. Loc. Lower Witteberg Sdst. Vondeling.
Spec. J.T. 35 (× ½)

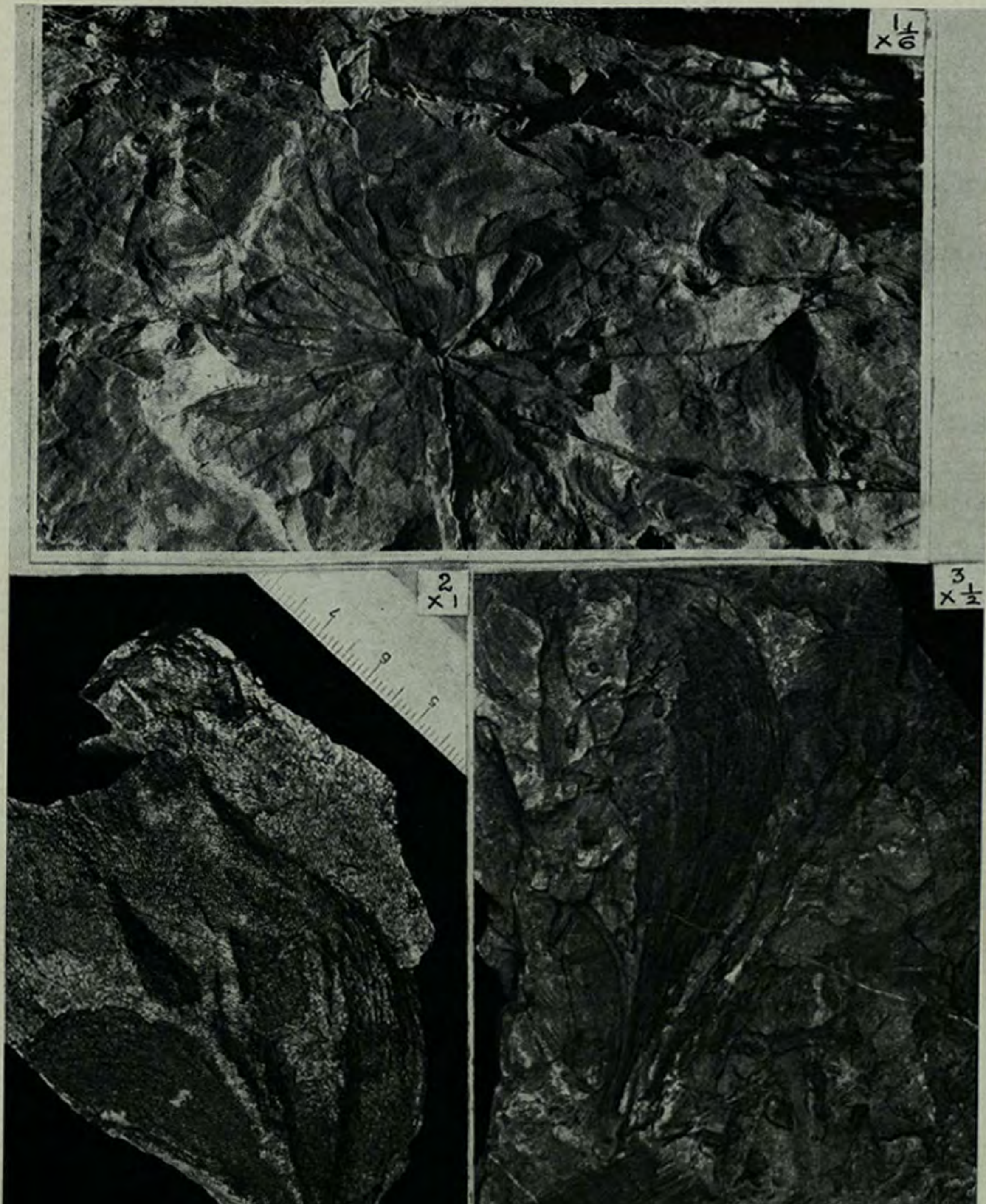

PLATE XXIII—*Spirophyton* Type "B"—Note the dark carbon colouring

PLATE XXIV—*Spirophyton* Type "C".

Fig. 1 Small branched type — several groups of these are visible on different bedding planes. Loc. Uncertain but believed to be Touwsberg.
University of the Witwatersrand B.P.I. Pal. Coll. (× 1) Presented by R. B. King.

Fig. 2 Part of Fig. 1 enlarged. The spiral twisting of individual strands is not visible in the photograph but can be seen with the naked eye.
(× 2)

Figs. 3 and 4 Two specimens believed to represent portions of vertical sections of Type "A" Both now lie on bedding planes. Note the silica cast in the upper part of the central column in Fig. 4.
(× 1).

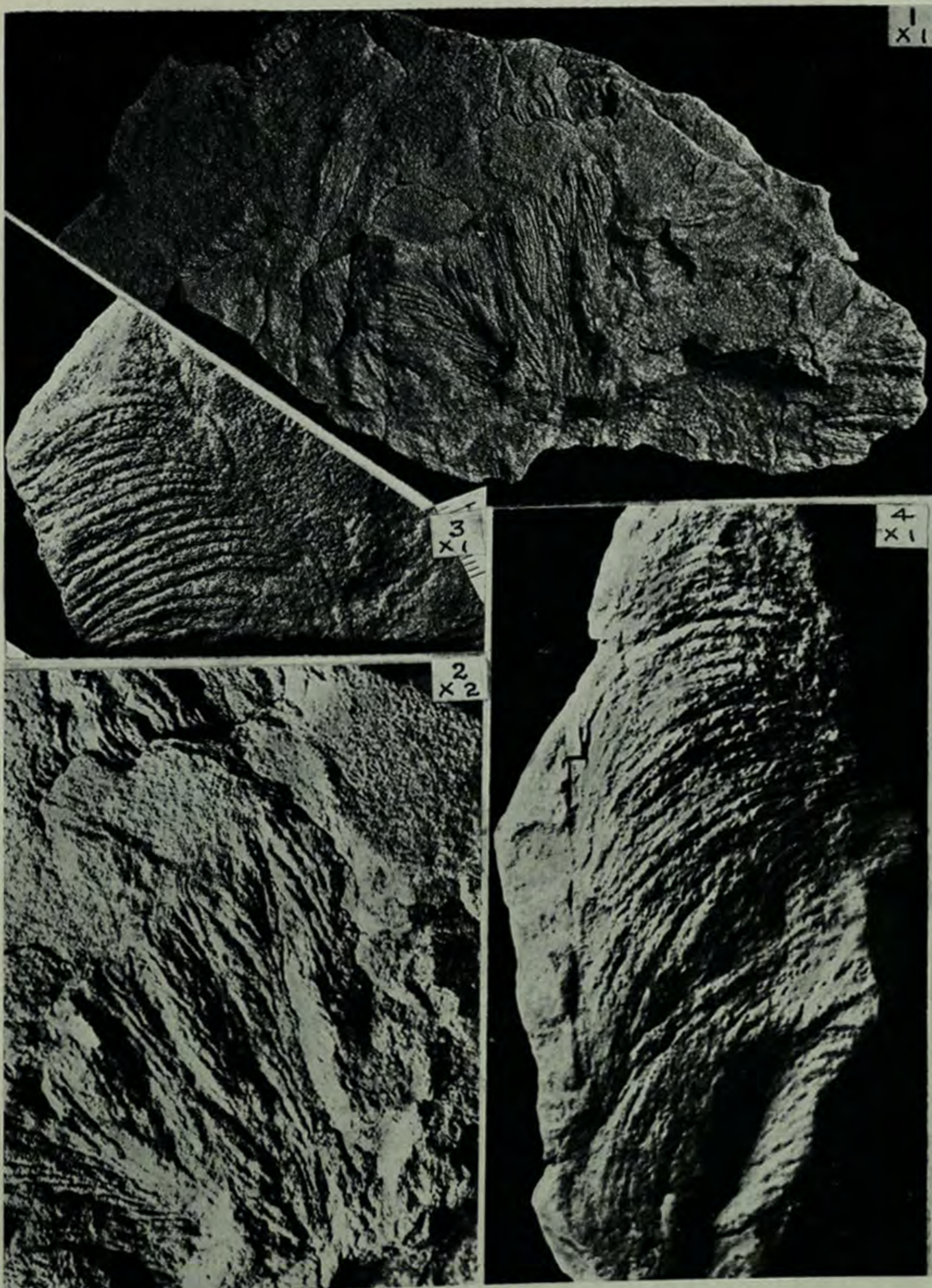

PLATE XXIV—*Spirophyton* Type "C" and Type "A"

PLATE XXV—*Spirophyton* Type "D".

Figs. 1.
and 2 are believed to represent different degrees of dried and collapsed algal colonies. In Fig. 2 the spiralling of individual strands is barely visible. Forms like this probably suggested an inorganic origin due to eddying currents (Seward 1903).

PLATE XXV—*Spirophyton* Type "D"

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