

PALAEONTOLOGIA AFRICANA

Volume 57 (Special Issue)
2023

Annals of the
Evolutionary Studies Institute
University of the Witwatersrand



Molteno *Kannaskoppia*

Mid-Triassic gymnosperm case study for
whole-plant taxonomy

Supported by
PALAEONTOLOGICAL
SCIENTIFIC TRUST



ISSN 2410-4418 [Online]

John M. Anderson & Heidi M. Anderson

EVOLUTIONARY STUDIES INSTITUTE

Director, Evolutionary Studies Institute

M.K. Bamford BSc (Hons), MSc, PhD (Witwatersrand)

Academic Staff

S. Badenhorst BSc Honours (Simon Fraser), PhD (UNISA)

J. Benoit BSc (Amiens), PhD (Montpellier)

J.N. Choiniere BSc (Massachusetts), PhD (George Washington)

P. Durand BCh, BSc, PhD (Witwatersrand), MSc (Kings College)

C. Henshilwood BA (Hons) (UCT), PhD (Cambridge)

C. Penn-Clarke BSc Honours, PhD (Witwatersrand)

R.M.H. Smith BSc (Manchester), MSc (Witwatersrand), PhD (Cape Town)

L. Wadley MSc (UCT), PhD (Witwatersrand)

Editorial Panel

J.N. Choiniere, Head Editor

M.K. Bamford, Associate Editor

B. Zipfel, Associate Editor

Responsible Editor for Volume 57 (Molteno *Kannaskoppia*)

M.K. Bamford

University Curator of Collections

B. Zipfel NHD Pod., NHD PS Ed. (TWR), BSc (Hons) (Brighton), PhD (Witwatersrand)

Support Staff

G. Chinamatira (CT Scanner Manager)

S. Jirah (Collections Manager)

T. Moletsane (Financial Officer)

Post-Doctoral Fellows

L. Ajikah

V. Buffa

K. Chapelle

A. Dabengwa

A. Duhamel

A. Effiom

R. Hanon

J. Jodder

S. Mnguni

L. Norton

M. van den Brandt

Technical and Administrative Staff

P. Bande (Technician)

W. Bilankulu (Technician)

C. Dube (Technician Supervisor)

G. Germishuizen (Senior Technician)

P. Keene (Manager of Blombos Collections)

B. Louw (Technician)

G. Mokoma (Technician)

T. Nemavhundi (Technician)

B. Nkosi (Casting technician)

N. Nkosi (Administrative Assistant)

A. Phaswana (Technician)

M. Ramalepa (Technician)

L. Sekowe (Technician)

C. Seshoene (Technician)

M. Seshoene (Technician)

PALAEONTOLOGIA AFRICANA

ANNALS OF THE EVOLUTIONARY STUDIES INSTITUTE
UNIVERSITY OF THE WITWATERSRAND

ISSN 2410-4418 [Online]

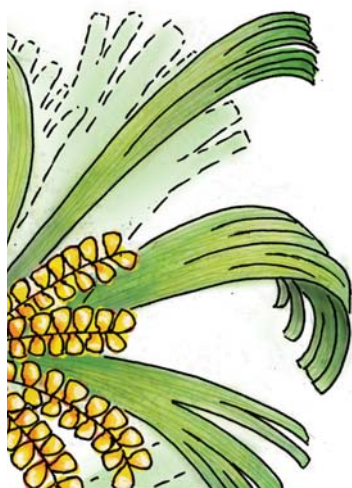
Volume 57 (Special Issue)

Molteno *Kannaskoppia*: Mid-Triassic gymnosperm case study for whole-plant taxonomy

By

John M. Anderson & Heidi M. Anderson

Colour photography by Christian Autotte



December 2023

Received 8 February 2023. Accepted 24 August 2023

Palaeontologia africana 57 (Special Issue): i–xiv + 1–324 — ISSN 2410-4418 [Palaeontol. afr.] Online only.
Permanently archived on the 1st of December 2023 at the University of the Witwatersrand, Johannesburg, South Africa.
The article is permanently archived at: <https://hdl.handle.net/10539/37107>

© 2023
EVOLUTIONARY STUDIES INSTITUTE
University of the Witwatersrand
Johannesburg

Articles contained in this volume (except where noted otherwise) are published under the
Creative Commons Attribution 4.0 Unported License (CC BY 4.0).
This license permits unrestricted use, distribution, and reproduction in any medium,
provided the original author and source are credited.

ACKNOWLEDGEMENTS

The Evolutionary Studies Institute gratefully acknowledges financial support for its
programmes by

THE COUNCIL'S RESEARCH COMMITTEE, UNIVERSITY OF THE WITWATERSRAND
and the

DSI-NRF CENTRE OF EXCELLENCE IN PALAEOSCIENCES

*

THE PALAEOONTOLOGICAL SCIENTIFIC TRUST (PAST)

A proud partner and major sponsor of *Palaeontologia africana* since 2001



CENTRE OF EXCELLENCE
PALAEOSCIENCES



Cover images: *Kannaskoppia vincularis/Rochipteris vincularis* (Kan 111 Ast spA) pp 124, 125. Watercolours by Heidi Anderson, 1995, 2001.

Title page images: bottom left: *Kannaskoppia telemagnus/Rochipteris telefolia* (Tell 111 Hei elo) p. 126; digital watercolours by Heidi & Clara Anderson, June 2020; bottom right: *Kannaskoppianthus matatiparvus/Rochipteris matatifolia* (Mat 111 Dic dub) p. 134; digital watercolours by Heidi & Clara Anderson, June 2020.

CONTENTS

	page		page
FOREWORD	iv	PART 3. THE WHOLE-PLANT GENUS & SPECIES	117
PREFACES	v	Molteno Habit & Habitat reconstructions.....	118
ABSTRACT	vi	Colour renderings of the Molteno whole-plant Petriellales species	122
ACKNOWLEDGEMENTS	vii	Chart 1. <i>Kannaskoppia vincularis</i> / <i>Rochipteris vincularis</i>	124
INTRODUCTION	viii	Chart 2. <i>Kannaskoppianthus telemagnus</i> / <i>Rochipteris telefolia</i>	126
Chart 1. Plant phylogeny.....	ix	Chart 3. <i>Kannaskoppianthus irregularis</i> / <i>Rochipteris distivena</i>	128
Chart 2. Co-evolution of plants & insects.....	x	Chart 4. <i>Kannaskoppianthus aasvoelensis</i> / <i>Rochipteris rollerii</i>	130
Fig. 1. Plant Timetree.....	x	Chart 5. <i>Kannaskoppianthus switzianthus</i> / <i>Rochipteris switzifolia</i>	132
Fig. 2. Insect Timetree.....	xi	Chart 6. <i>Kannaskoppianthus matatiparvus</i> / <i>Rochipteris matatifolia</i>	134
Chart 3. Molteno floristics	xii	Chart 7. <i>Kannaskoppianthus komanthus</i> / <i>Rochipteris komifolia</i>	136
Tab. 1. Observed vegetative diversity	xii	Chart 8. <i>Kannaskoppianthus lutinumerus</i> / <i>Rochipteris lutifolia</i>	138
Tab. 2. Gymnosperms, observed diversity	xiii	Chart 9. <i>Rochipteris obtriangulata</i>	140
PART 1. SAMPLING & OCCURRENCE	1	Chart 10. <i>Rochipteris cf. sinuosa</i>	142
Chart 1. Sampling the Molteno & Gondwana Triassic	2	Chart 11. <i>Rochipteris penensis</i>	144
Chart 2. Gondwana Triassic Megaplants	4	Chart 12. <i>Rochipteris pusilla</i>	146
Fig. 1. Geographic occurrence	4	PART 4. COLOUR PLATES	149
Fig. 1. Stratigraphic occurrence	5	Coverage	150
Chart 3. Molteno Fm. Megaplants	6	Table of contents	151
Chart 4. Molteno Fm., ecological occurrence.....	8	Colour plates, 26 localities (in stratigraphic sequence)	pls 152
Chart 5. Molteno Fm., stratigraphic occurrence	10	1. Cala Road (Cal 211 Hei elo).....	1–2 152
Chart 6. <i>Rochipteris</i> & affiliates – Molteno occurrence	12	2. Greenvale (Gre 121 Hei elo)	3–6 154
Chart 7. The 26 Molteno Petriellaceae sites	14	3. Greenvale (Gre 111 Equ sp)	7 158
PART 2. SYSTEMATICS	29	4. Boesmanshoek Pass (Boe 112 Dic cor)	8 159
Chart 1. Taxonomic approach	30	5. Cyphergat (Cyp 111 Dic cra).....	9–18 160
Chart 2. Sigma (as opposed to Alpha) taxonomy	32	6. Kannaskop (Kan 112 Hei elo)	19–22 170
Petriellales [(Molteno), taxonomic descriptions].....	34	7. Kannaskop (Kan 111 Ast spA)	23–40 174
<i>Kannaskoppia</i>	34	8. Telemachus Spruit (Tel 111 Hei elo)	41–46 192
<i>Kannaskoppia vincularis</i>	36	9. Kommandantskop (Kom 111 Sph/Dic)	47–50 198
<i>Kannaskoppianthus</i>	38	10. Vineyard (Vin 111 Dic odo).....	51–52 202
<i>Kannaskoppianthus telemagnus</i>	42	11. Lutherskop (Lut 311 Hei elo)	53–68 204
<i>Kannaskoppianthus irregularis</i>	43	12. Koningskroon (Kon 211 Ast 2spp).....	69–72 220
<i>Kannaskoppianthus aasvoelensis</i>	44	13. Peninsula (Pen 311 Hei elo)	73–78 224
<i>Kannaskoppianthus switzianthus</i>	45	14. Peninsula (Pen 411 Hei elo)	79–88 230
<i>Kannaskoppianthus matatiparvus</i>	46	15. Kapokkraal (Kap 111 Dic/Ris)	89–90 240
<i>Kannaskoppianthus komanthus</i>	47	16. Nuwejaarspruit (Nuw 111 Dic zub).....	91 242
<i>Kannaskoppianthus lutinumerus</i>	48	17. Winnaarspruit (Win 111 Hei elo).....	92–93 243
<i>Kannaskoppianthus telepentatus</i>	49	18. Hlatimbe (Hla 213 Dic elo)	94–96 245
<i>Rochipteris</i>	50	19. Umkomaas (Umk 111 Dic 2spp)	97–110 248
<i>Rochipteris vincularis</i>	54	20. Sani Pass (San 111 Dic cra)	111–112 262
<i>Rochipteris telefolia</i>	55	21. Matatiele (Mat 111 Dic dub).....	113–118 264
<i>Rochipteris distivena</i>	56	22. Little Switzerland (Lit 111 Dic/Hei).....	119–124 270
<i>Rochipteris rollerii</i>	57	23. Aasvoëlberg (Aas 111 Hei elo).....	125–142 276
<i>Rochipteris switzifolia</i>	58	24. Aasvoëlberg (Aas 211 Hei elo).....	143–144 294
<i>Rochipteris matatifolia</i>	59	25. Aasvoëlberg (Aas 311 Hei elo).....	145–152 296
<i>Rochipteris komifolia</i>	60	26. Aasvoëlberg (Aas 411 Dic/Sph)	153–162 304
<i>Rochipteris lutifolia</i>	61	BIBLIOGRAPHY	316
<i>Rochipteris obtriangulata</i>	62	GLOSSARY	320
<i>Rochipteris cf. sinuosa</i>	63	ABBREVIATIONS	323
<i>Rochipteris penensis</i>	64	INDEX	324
<i>Rochipteris pusilla</i>	65		
Palaeodeme sketches	66		
Hypodigm charts; Gondwana Triassic (GT)	102		
Chart 1. <i>Rochipteris</i> , South America	106		
Chart 2. <i>Rochipteris</i> , Africa	108		
Chart 3. <i>Rochipteris</i> , Antarctica, New Zealand	110		
Chart 4. <i>Rochipteris</i> , Australia	112		
Chart 5. <i>Kannaskoppia</i> & <i>Kannaskoppianthus</i>	114		

FOREWORD

Almost exactly two decades ago I had the privilege of writing the Foreword to *Heyday of the Gymnosperms*, the fourth volume to be published by John and Heidi Anderson in their monumental series that deals with the plant fossils of the Molteno Formation and places them in their broader context. Time has moved on, a further three books have been published, and I now have the honour to write the Foreword to the eighth volume in the series *Molteno Kannaskoppia: A Triassic Gymnosperm Case Study for Whole-plant Taxonomy*. This latest remarkable volume is built on a foundation of more than 50 years of hard work dedicated to understanding the plant fossils of the Molteno Formation. As John and Heidi note in their respective prefaces, it has been quite a journey, undertaken through an interval of momentous change that has left global biodiversity in tatters. In their focus on the world of the Upper Triassic, seen through the lens of the Molteno Formation, John and Heidi help to place our current moment in its appropriate context: the context of the deep history of our planet.

As I noted 20 years ago, in my experience there is no set of fossil plant assemblages that has been collected with the same intensity, uniformity of approach, and care that John and Heidi have lavished on the Molteno Formation. The scale and scope of their effort, which has resulted in a collection of more than 30 000 slabs from more than 40 localities and 100 different plant fossil assemblages, is unequalled. This huge effort in the field has been joined with intensive and equally methodical work in the laboratory and this volume presents John and Heidi's discoveries and observations in almost overwhelming detail. The presentation of results is also enlivened by John and Heidi's considerable artistic skills. Numerous locality sketches and reconstructions of ancient plants and vegetation are an important part of this book, and the line drawings of individual plant fossils, done with extreme care, are especially valuable. What emerges from John and Heidi's diligence and dedication to the plant fossils of the Molteno Formation is a more detailed glimpse into Triassic vegetation than that provided by any other set of localities anywhere in the world. John and Heidi's work takes its place alongside other classic works on Triassic plant fossils, such as those from Greenland, southern Sweden, and the southwestern United States. It is overshadowed by none of them.

As John noted in his Preface to the *Heyday of the Gymnosperms* (2003), the approach that he and Heidi adopted in their studies of the Molteno flora was unconventional; defined by "the production of a few stout monographs instead of numerous slender papers in journals". That approach has allowed them to view the plants and vegetation of the Molteno floodplain as a whole. John and Heidi have sought ancient ecologies and recognized characteristic associations of ancient plants that point towards ancient plant communities. Along the way, they have treated the distinctive and hugely diverse leaves of *Dicroidium* in detail, and they have produced monographs on the Molteno ferns and sphenophytes. Especially important and impressive has been their groundbreaking revelation of the variety of extinct seed plants that lived on the Molteno flood plain. These include undoubted relatives of *Ginkgo*, conifers, Pentoxylales, Bennettitales, corystosperms, and most likely Gnetales. Also prominent are a variety of plants, increasingly grouped as the Petriellales, which have ginkgo-like *Rochipteris* foliage to which John and Heidi have convincingly linked the seed-bearing organs *Kannaskoppia*, and the strange pollen organs *Kannaskoppianthus*.

John and Heidi's treatments of *Kannaskoppia*, *Kannaskoppianthus* and *Rochipteris* are based on extensive material from many localities, and are the key contributions of this volume. *Rochipteris* is widespread and there are clear links with *Kannaskoppianthus* in

a dozen plant fossil assemblages. *Kannaskoppia* is known from just one assemblage as branching axes bearing tiny cupules that most likely contained tiny seeds, but its great significance is that there are *Kannaskoppia* specimens unequivocally attached to shoots along with *Rochipteris* leaves. The importance of specimens that reliably establish the biological connections between the leaves, seed-bearing units and pollen organs cannot be overstated. As such, this volume adds substantially to what we know about seed plants that bore *Rochipteris* foliage.

In the many assemblages within the Molteno, and also elsewhere, *Kannaskoppia*, *Kannaskoppianthus* and *Rochipteris* are preserved in different ways. All modes of preservation have their limitations, but each assemblage adds new information to what we know about this strange Triassic plant. And John and Heidi have teased out as much detail as the material is likely to allow. As always in palaeobotany you have to do the best you can with what you have, rather than what you might hope for. The results are impressive, and the details of the fossils are illustrated in Christian Auttote's superb high-quality photographs, mostly in colour. It would be very hard to improve upon them.

John and Heidi's work will not be the final word on *Kannaskoppia* and *Kannaskoppianthus*, still less on the Petriellales as a whole. Nor would they claim it to be. No one with the right view of science has the privilege of definitive finality. But through the painstaking research included in this volume John and Heidi make a very substantial contribution. They add important new pieces to the puzzle of what these kinds of plants were like in life, right down to the extent to which the Molteno plants were fed upon by insects. *Kannaskoppia*, *Kannaskoppianthus* and *Rochipteris*, and the links now recognized among them, expand significantly our understanding of extinct seed plant diversity. This diminutive, perhaps almost herbaceous, seed plant appears to have been widespread across different parts of the southern hemisphere. John and Heidi's work has brought it into the spotlight.

Recently, I had the opportunity to spend time studying the Molteno collections, now housed and curated at the University of the Witwatersrand. It was eye-opening to be guided through them by John and Heidi. The sheer scale of the collections reflects the intensity of focused effort in the field, and that effort was more than repaid by the number of connections between reproductive and vegetative parts that it revealed. Five ovulate structures from different kinds of seed plants, and two kinds of pollen organs, are now linked securely with their corresponding foliage in the Molteno Formation, and there is also circumstantial evidence for other connections among reproductive and vegetative plant parts. This is a major contribution. These discoveries, observations and inferences provide indispensable anchor points for future palaeobotanical research. They raise new questions and will stimulate further palaeobotanical progress. Through their continuing work on the plant fossils preserved in the Molteno Formation, John and Heidi are leaving a truly impactful legacy: work that is of disproportionate value for understanding the plants of the past, and what they tell us about the plants of the present.

Sir Peter Crane FRS
President
Oak Spring Garden Foundation
1776 Loughborough Lane
Upperville, VA 20184
U.S.A.
peter@osgf.org
9 October 2022

PREFACES

On 28 June 2018, my 75th birthday, our Molteno Sphenophytes volume was published. My dream was that our final synthesis of the Molteno flora, along with accompanying fauna, be published on my 80th birthday, 28 June 2023! Heidi and I agreed to a five-year span from 2018 to 2023, to push for this to come about.

There's been a bit too much parallel focus for me also on a range of *Gondwana-Alive/Earth-Alive/Africa-Alive* (GA/EA/AA) projects, so now we're looking at a five-year plan from the year following publication of the current *Kannaskoppia* volume – (2023–2028).

The present *Kannaskoppia* volume will be our 8-eighth in the Molteno series to be published; leaving a further four volumes to be completed – ending with the overall Molteno synthesis (see Introduction).

Having begun our Molteno journey in around mid-1967, this will then have been a 60-year marathon. A marathon exploring – through our particular window – the heyday of the gymnosperms at the heart of Gondwana midway through the Triassic. Peering through a window at a most special moment in earth's history – at the height of the Triassic explosion of life in the aftermath of the end-Permian Extinction. A marathon one would not have exchanged for anything.

Our 60-year journey (1967 – c. 2027) encompasses a particularly special half-century in Earth history – from the inaugural Earth Day (22 April 1970) to the 50th Anniversary of Earth Day (22 April 2020). And that date, 22 April, happens to be rather special too, being the birthday of one of us, Heidi.

This has been a critical 50-year span, the very heart of the Anthropocene. In 1970, the human population was 3.7 billion, in 2020 it is close to 8 billion; and the car and truck population has exploded from around 200 million to 1.5 billion. The term 'global warming' had not yet been coined in 1970; though air pollution creating a 'greenhouse effect' appeared in the reporting around that first Earth Day. Whereto in the next 50 years?! My GA/EA/AA projects are concerned with just that.

My perspective is that a general knowledge of earth's history and the major trends and key turning points in the evolution of life on earth should be as crucial as the times-table and alphabet in everyone's education. We are not alone. The Molteno flora (and insect fauna) colours one of those key turning points!

At our home on Pretoria, I have over the decades built up an 'Earth-time' sculpture garden, indoors and outdoors, named 'The Amphitheatre, Microcosm of the World'. It touches on the geological, biological and cultural history of our planet through the past, present and into the future. One category of sculptures is termed 'Indoor-outdoor Sculptures'; and one of these is our 'Heyday of the Gymnosperms/Heyday of the Angiosperms' sculpture. 'The Heyday of the Gymnosperms' – otherwise known as the 'Little Molteno Room' – is the indoors component, whilst the 'Heyday of the Angiosperms' – otherwise known as the 'Trident Double Rainbow' – is the outdoor component. The indoors component consists of our converted garage, in which we house the Molteno specimens out on loan whilst completing the current volume; the outdoors component consist of a trident pathway leading to our front door, with the paths tracking through a rockery, home to a diversity of flowering plants with at least two species for each colour of the rainbow – red, orange, yellow, green, blue, indigo, violet – flowering each day of the year, 1 January to 31 December. In our indoor-outdoor sculpture, a brick wall separates the two components; in earth's history, 230 million years separates them!

John M. Anderson
Pretoria, South Africa, 2020

I sit here and finally put pen to paper for my preface – at dawn in Dorriggo, Australia. This Molteno monograph is very much John's book. It reflects his vision and spirit to follow a different approach in palaeobotany. It is his energy and determination that has resulted in the collection of most of the fossils described herein and he first found the fruit and leaves attached to a stem. These prize specimens were first described in our Molteno Heyday volume which was largely completed by the 10th Gondwana Conference held in Cape Town in 1998 but only published in 2003. But describing all the leaves, placing them in their habitat and bringing them alive with colour is only accomplished in this volume.

The geologist Brian Turner (who did a basin-wide study of the Molteno Fm. in the early 1970s), first took me to this roadside cutting at Kannaskop (Kan 111) as it had revealed some fossil plants. This was in June 1971 and on the same trip I collected leaf specimens (*Rochipteris*) from Aasvoelberg (Aas 111) and Kommandantskop (Kom 111). After completing our Molteno Gymnosperm volume (finally published in 1989) our plan was to complete the next one on the non-gymnosperms. Towards this aim we planned a field trip to gather more specimens of ferns and sphenophytes from some of the under-collected localities. John went to the road cutting at Kannaskop (Kan 111) to collect more ferns and made the fortunate strike of finding the attached *Kannaskoppia* specimens in 1989. Subsequently we made a concerted effort to obtain more specimens from this horizon. While in the field, John cajoled the local road grader (busy working nearby) to slightly enlarge the cutting and expose some slabs for us. We obtained some beautiful fern specimens (described as the whole-plant *Rooitodites pulchra* in our Fern volume of 2008) but there were unfortunately no more attached specimens in this large-scale dig. However, our focus shifted to describing these remarkable specimens – being the first record of attached fruit and leaves in the Gondwana Triassic. This plan expanded to describing the other fertile structures associated with leaves and after much trial and tribulations resulted in our 2003 book.

Our two daughters have provided us with four wonderful grandchildren who are now of a similar age to what they were when they accompanied us on some field trips in the 1980s. They grew up to help us navigate the digital world with the welcome assistance of our sons-in-law. For this current volume, Clara has been an important contributor. I was struggling with the watercolour renderings of my habitat drawings (in Dorriggo) and implementing John's colour suggestions (in Pretoria). She said (in London) "But Mummy that is easy with my new digital painting programme. One can adjust the colour of any leaf over and over again till Daddy is happy with it". I am very grateful to Clara for doing the digital colour renderings of the habitat pages with IT help from husband Hannes. The reason that she had time to embark on this project was due to the Covid-19 pandemic which caused a lull in their working lives as independent architects in London, U.K.

As mankind deals with the current Covid crisis, a much more serious threat looms. It is commonly referred to as 'Climate Change' but really it should be called the 'Sixth Extinction'. Of all the animals on earth, we are amongst the most vulnerable and have also been the direct or indirect cause of the extinction of numerous animals and plants. So great has been our impact that it merited the naming of the Anthropocene era. The future of man hangs in the balance but many of the plants will survive for hundreds, some for thousands and a few for millions of years. In the Molteno Flora we find plants related to the extant mosses, ferns, cycads, conifers and the *Ginkgo*. But many plants with seeds and fern-like foliage had their heyday in the Upper Triassic, and although long gone, they were the fore-runners to the angiosperms. One of these is the *Kannaskoppia* plant and in this monograph we try to bring it alive and stimulate further research into these special plants that lived some 230 million years ago in Gondwana.

Heidi M. Anderson
Dorriggo, Australia, 30 November 2020

ABSTRACT

The flora from the Upper Triassic Molteno Formation, southern Africa, is the most extensively collected and documented macro-flora in the Gondwana Triassic. The collection includes c. 30 000 catalogue slabs from 100 assemblages in 43 super-localities. Some 61 genera and 211 species have been described in a series of publications from the early 1980s covering most of the plant groups. In this volume, the genus *Kannaskoppia* and affiliates, in the order Petriellales, are described in greater detail than previously in 2003, and offer the opportunity to explore the question of whole-plant genera and species.

The ovulate strobilus, *Kannaskoppia*, with the single species *K. vincularis*, occurs in only one assemblage – where it is common with c. 50 specimens, including five with both the foliage and strobili found attached to shoots. This find remains unique for the Gondwana Triassic. The male strobilus, *Kannaskoppianthus*, with eight species recognized (four described as new), occurs in 12 assemblages; at two of these, both distinct species, it is found attached to shoots. The foliage *Rochipteris*, with 12 Molteno species recognized (seven described as new), is known from 26 of the 100 Molteno assemblages; at four of these, in three distinct species, the foliage has been found attached to shoots. For each of these 26 assemblages, geographic and stratigraphic information is provided, plus the associated flora and plant/insect records.

As in previous Molteno publications, the Palaeodeme approach is followed in the circumscription of species. All the Reference Palaeodemes are illustrated by line drawings and extensive photographs as are the more important Sister Palaeodemes.

A comprehensive revision of the Gondwana Triassic records of *Rochipteris* has resulted in 24 accepted species, of which seven occur only in the Molteno Flora. All previously illustrated material is listed in the hypodigm table and used for comparison and nomenclatural considerations with the Molteno specimens.

Whole-plant species from the Molteno have been recognized, based on considerations of affiliation and taphonomy. For each of these the habit and habitat are reconstructed in colour. Each is placed in its most-likely habitat within the Molteno Biome, with the seven primary habitats (ecozones) as recognized previously for the Formation. These plants are typically considered perennials to about one metre high that grew in a variety of habitats and were often associated with *Dicroidium/Umkomasia* or with *Heidiphyllum/Telemachus* trees.

The current study of *Kannaskoppia*, and affiliates, supports previous phylogenetic, anatomical and ecological studies that amongst the gymnosperms the order Petriellales constitutes a likely sister group of the angiosperms.

ACKNOWLEDGEMENTS

After the specimens themselves, the next best portrayal of a fossil-plant collection is the photographic plates. For the colour plates in this volume, we are indebted to Christian Autotte from Montreal, Canada. He has now made three dedicated trips to South Africa. These have occurred every other year:

18–31 August 2015 (2 weeks)

7–27 March 2017 (3 weeks)

5–25 March 2019 (3 weeks).

During the first year, he helped complete the colour plates for our *Sphenophyte* volume; and during the subsequent two, he did the colour photography for the *Kannaskoppia* volume. These three trips half-way round the world, Christian has made for the love of it – for the love of fossils, of photography and for travel. He has made his own way over here and has done all the photography free of charge, in exchange for a roof over his head (our roof), for meals, and for a special trip out somewhere more or less once a week. These weekly trips have included, amongst others places, the Cradle of Humankind, Pilanesberg, the Tswaing Crater, the Cullinan Diamond Mine and the Pretoria Zoo. And, of course there've been trips across to Johannesburg at intervals, for us to take specimens out on loan from the Evolutionary Studies Institute (ESI) where our Molteno Collection is housed.

Adela Romanowski (retired since Jan. 2002 from SANBI, and now living in New Zealand) processed and printed the black & white photographs, taken by one of us, HMA, back in the 1980s and 1990s. These have now been scanned in here to supplement the colour plates where necessary.

Conrad Labandeira, from the Smithsonian Institution, Washington, U.S.A. – specialist on fossil insects and plant–insect interaction in the fossil record – has done the background research enabling us to add focus on the insects (Part 1, pp 14–27) at the 26 assemblages (TCs) covered. He spent nine years visiting South Africa annually (2001–2009), working on our Molteno collections at SANBI, and staying here at our home in Pretoria; and made a further visit in 2014 to study the Molteno fossils after they had been moved to ESI.

Hannah Bonner of Mallorca, Mediterranean island off Spain, and Satu Jovero of Helsinki, Finland, have contributed greatly to the further exploration of the co-evolution between the plants and insects. Through the years 2016–2018, they worked closely with JMA researching and creating the Plant and Insect Timetrees presented on pp x, xi in our front matter.

Our Molteno volumes from the start, being full of figures, sketches and photographs, have absorbed considerable time and expertise on graphics and layout. For their great contributions in this towards the current volume, we wish to thank Ditshego Madopi and Petrus Krüger in particular. Ditshego has been working part time, on-and-off, for us on graphics and layout on our Molteno and '*Gondwana Alive/Africa Alive*' volumes now for some 10 years, since November 2013. Through to 2019, though now working full-time over in Johannesburg, she continued putting in a day or two each month, on weekends, at our place.

Petrus Krüger, a young bass-voice member of the Bach Choir, and a multi-talented musician – piano, organ, clarinet and recorder – has

put in numerous nimble-fingered hours. This shortly after having completed his bachelor's degree in Industrial Design at the Open Window Institute, Pretoria. Starting on 25 November 2019, he has put in regular time. By June 2023, with this volume now ready for the press, he has put in key time for 3.5 years.

We are grateful to Francis Thackeray and Paul Fatti, both retired professors – in Palaeoanthropology and Statistics, respectively, at the Witwatersrand University – for their insightful contributions to our debate on the recognition of species in palaeontology. Francis has contributed directly to this volume (Part 2, pp 31–33), concerning his particular focus on *Sigma* versus *Alpha* taxonomy.

For their help with literature and various information towards the compilation of our Hypodigm, we extend our thanks to Josefina Bodnar, Universidad Nacional de La Plata (UNLP), Museo de La Plata, Argentina; Steve McLoughlin, Department of Palaeobiology, Swedish Museum of Natural History, Sweden; and Benjamin Bomfleur, Forschungsstelle für Paläobotanik am Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität Münster, Germany. And for his recent involvement in helping with references to update our Gondwana Triassic correlation chart, we must thank Randy Irmis, University of Utah, Salt Lake City, U.S.A.

Since later 2008 our Molteno collection has been housed at the Evolutionary Studies Institute (ESI), Witwatersrand University, Johannesburg – where it was moved after our retirement from the South African National Biodiversity Institute (SANBI), in Pretoria. Since the mid-2010s, we are especially grateful to Marion Bamford, Director of ESI and Head of Palaeobotany, to Jonah Choiniere, Editor of *Palacontologia africana*; and to Bernhard Zipfel, collections manager. And we are most grateful to them for publishing our most recent Molteno volume; *Molteno Sphenophytes: Late Triassic Biodiversity in Southern Africa* in June 2018.

PAST (Paleoanthropological Scientific Trust), based at the Evolutionary Studies Institute (ESI) at Wits, have awarded us a grant towards publication of this volume. For this we are most grateful.

Our daughters, Clara and Hilary, not only helped with collecting on many field trips, when they were still pretty young, but with constant encouragement since. Clara did the colour rendering of the whole-plant sketches (Part 3, pp 116–147) – as a special 77th birthday present to JMA. Hannes du Plessis and Michael Netterberg, son-in-law and step-son, have both helped considerably on and off with their computer skills. We thank them all.

Peer reviewers are generally kept anonymous, but in this case both Benjamin Bomfleur and Josephina Bodnar have chosen to be named should we so wish. We are greatly appreciative of the effort they have put into so carefully going through the manuscript and for their edits and suggestions. Both have been particularly complimentary of the devotion we have put into sampling the Molteno and describing the flora, including this current *Kannaskoppia* volume.

Last but not least, are our spouses, Marijke Anderson-Marschal and Keith Holmes. Without their constant support and backing, completion of our more recent volumes and the current work would hardly have been possible.

INTRODUCTION

Throughout our 56-year span of collecting and describing the fossil flora of the Molteno (beginning back in 1967 at the Little Switzerland locality), we have been concerned with finding an approach to recognizing natural species (whole-plant species). And are thus piecing together a perspective on the patterns of ecology and biodiversity of the world back in the middle to later Triassic.

This remains core to the present volume, the eighth in our series on the Molteno and related works on its context within a southern Africa and global context. It is akin to our first in the series – that on *Dicroidium* (1983) – in that our focus is on a single ‘generic’ taxon, *Kannaskoppia* and its affiliates. *Dicroidium* presented a special challenge in being the most diverse and dominant genus throughout the Gondwana Triassic. Our conclusion was that the evolutionary history within such a genus, and the recognition of natural species (as opposed to morpho-species) within it, was anything but simple. Reticulate evolution, involving a mesh of palaeodemes (fossil populations) of differing variation, appeared the pattern. With continuously shifting patterns of topographic and climatic backdrop, populations of *Dicroidium* – essentially a woody taxon dominating forest and woodland habitats across Gondwana over tens of millions of years – were forever diverging and converging, and hybridizing. In such a successful genus, reticulate evolution appeared to be the order of the day.

What of the genus *Kannaskoppia*, also a gymnosperm but quite different ecologically – interpreted as a relatively small erect woody pioneering shrub occupying various habitats generally bordering water bodies, rivers, lakes or marshland. And like *Dicroidium*, it occurred widespread across Gondwana and through much of the Triassic. To what degree did it also undergo reticulate evolution? In view of its preferred habitat close to water bodies, and in that it was shrub-like rather than a canopy tree, its taphonomy was quite different. We find far more often than in *Dicroidium*, attached specimens – foliage, male and female. This offers us new possibilities in the recognition of natural species – whole-plant species. And this to a large degree is the theme of our current volume.

The Triassic Explosion of life

In recent years there has been a steady improvement in the correlation of Triassic deposits globally; which enables one to piece together the dramatic story of the Triassic more fully (Ruffell *et al.*, 2018).

The Carnian Pluvial Episode (CPE), a c. 4 million-year episode dating around c. 235–231 Ma midway through the Carnian – associated with major volcanic eruptions – marks a major global extinction event.

In the wake of this event, in the later Carnian, occurred an explosion of life. “the dinosaurs diversified explosively Marks the beginning of the ‘age of dinosaurs’ and their 165-million year rule of the Earth. This time also marks the origin or initial expansion of nearly all modern tetrapod groups, including turtles, crocodiles, lizards, and mammals.” (Ruffell *et al.*, 2018)

The main Dolomites were deposited in this time (the later Carnian) following the CPE; as was the Molteno – marking the heyday of the gymnosperms. It should be noted that to date there have been no absolute dates determined for the Molteno Fm., but based on our Gondwana Triassic correlations, it is plotted as falling within this explosive later Carnian Stage (c. 233–227 Ma).

Towards the Angiosperms

The order Petriellales, including *Kannaskoppia/Kannaskoppianthus/Rochipteris*, is currently recognized as the sister group to the angiosperms by Rothwell & Stockey (2016). In Chart 1 (p. ix), showing the radiation of the gymnosperms (Devonian to Triassic) and of the angiosperms (Lower Cretaceous), the order is highlighted

in yellow to emphasize its position. This places *Kannaskoppia* and its affiliates in a position of significance with respect to the origin of flowering plants.

Plant & Insect Timetrees & the exploration of colour

It is our intention, as always, to see the Molteno in the broadest perspective of earth-time and the evolution of plant and animal life. Where does it fit and how does it add to the picture?

Let us briefly consider the plant and insect timetrees (Chart 2, pp x, xi) in the wake of the end-Ordovician Extinction. The roots/origins of these timetrees occur in the Silurian and over the subsequent 430 million years through to the present, the vascular plants and insects have flourished interdependently to great diversity. Three main groups of plants occur; the pteridophytes, gymnosperms and angiosperms. The Molteno, midway through the Triassic, offers a clear expression of the heyday of the gymnosperms (And. & And., 2003; And., And. & Cleal, 2007). The Molteno likewise shows a marked diversity of insects, particularly the beetles which for the first time make up around half that total. Consider today’s world where colour reflects the interconnected worlds of the angiosperms (flowering plants) and the insects (and of the birds). The world of colour probably expanded rapidly with the diversification of gymnosperms and insects following the end-Permian Extinction. We have added colour of our own choice to the reconstructions of the ‘whole-plant’ as presented in Part 3.

Molteno plant biodiversity

To clearly emphasize the plant diversity of the Molteno, we include the two tables (floristics in general and the gymnosperms in particular, Chart 3, pp xii, xiii), following the plant and insect timetrees. We currently recognize a total diversity of 61 genera and 211 species of vegetative taxa; and 38 genera and 143 species of gymnospermous whole-plant taxa. Though we have collected extensively and intensively from 100 Molteno assemblages (69 localities, up to 1 km diameter), it is clear from our sampling history, that should that number of assemblages be doubled by the next generation, many more species would come to light.

Volumes published

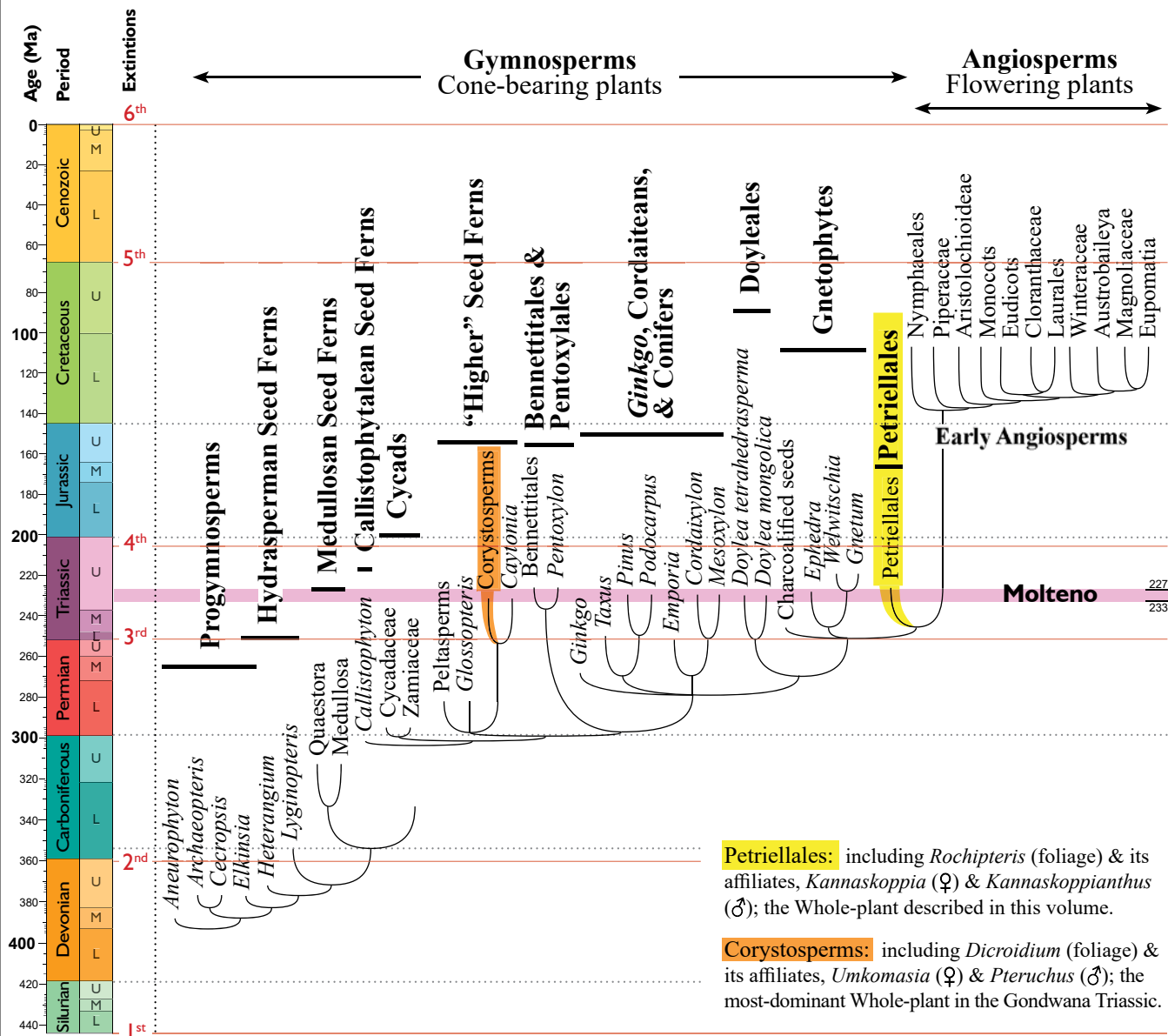
1. 1983 – ‘*Dicroidium*’ (Molteno, vegetative)
2. 1985 – ‘*Prodromus of South African Megaflores*’, *Devonian to Lower Cretaceous*
3. 1989 – ‘*Gymnosperms*’ (excluding *Dicroidium*)
4. 2003 – ‘*Heyday of the Gymnosperms*’ (Molteno, fructifications)
5. 2007 – ‘*Brief History of the Gymnosperms*’ (global review, Late Devonian to Present)
6. 2008 – ‘*Molteno Ferns*’
7. 2018 – ‘*Molteno Sphenophytes*’
8. Current volume – ‘*Kannaskoppia*’

Volumes in preparation

The aim, ideally, is to complete the Molteno series over a five-year span (2023–28) following publication of the *Kannaskoppia* volume.

9. Mosses, Liverworts, Lycopods and other non-gymnosperms (including palynology)
10. Unaffiliated gymnosperms (including cones, scales, seeds, foliage and palynology)
11. Molteno insects and other fauna; a full overview of the insects and their plant interactions, along with the remaining fauna, fish, conchostraca and spiders (and the ‘silent’ tetrapods).
12. Molteno synthesis; window onto the heyday of the gymnosperms; overall synthesis of the flora and fauna, including dating, ecology and biodiversity.

Chart 1. PLANT PHYLOGENY (from the Gymnosperms to the Angiosperms).



The Triassic Explosion of life & Heyday of the gymnosperms

The aim here, in Chart 1 and in Chart 2 overleaf, is to emphasize the position of the Molteno Fm. at this critical moment in the evolution of life on Earth – in the aftermath of the 3rd Global Extinction event ending the Permian Period.

As regards the closely interdependent plants and insects, the Molteno, in the richly diverse assemblages it has yielded, portrays this moment around midway through the Triassic more fully than any other formation globally.

Molteno (age & duration)

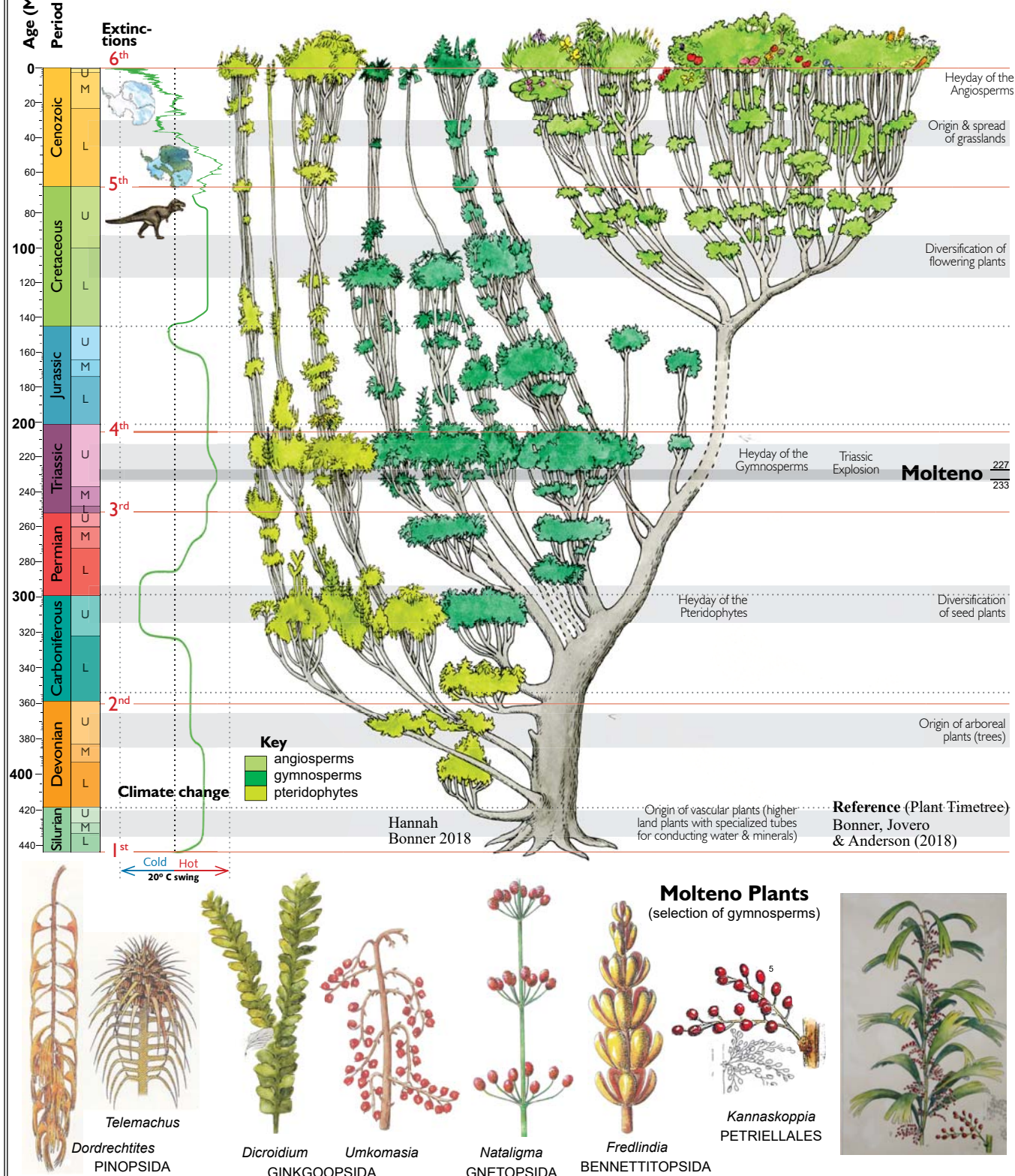
The precise age and duration of the Molteno Fm. remains uncertain. In the figure above and on the Plant and Insect Timetrees overleaf, it is shown as having accumulated through six million years, from 233–227 myrs in the Carnian, midway through the Triassic. For further discussion, see Part 1 (p. 10).

References

Phylogeny: adapted from Rothwell & Stockey (2016).
Gymnosperms: adjusted to Geol. Timescale as per And., And. & Cleal (2007).
Angiosperms: for Angiosperm Phylogeny poster, see Hilger (2014).
Geol. Timescale: IUGS (2018). aligned with Plant & Insect Timetrees overleaf.

Chart 2. CO-EVOLUTION OF PLANTS & INSECTS.

Fig. 1. Plant Timetree.

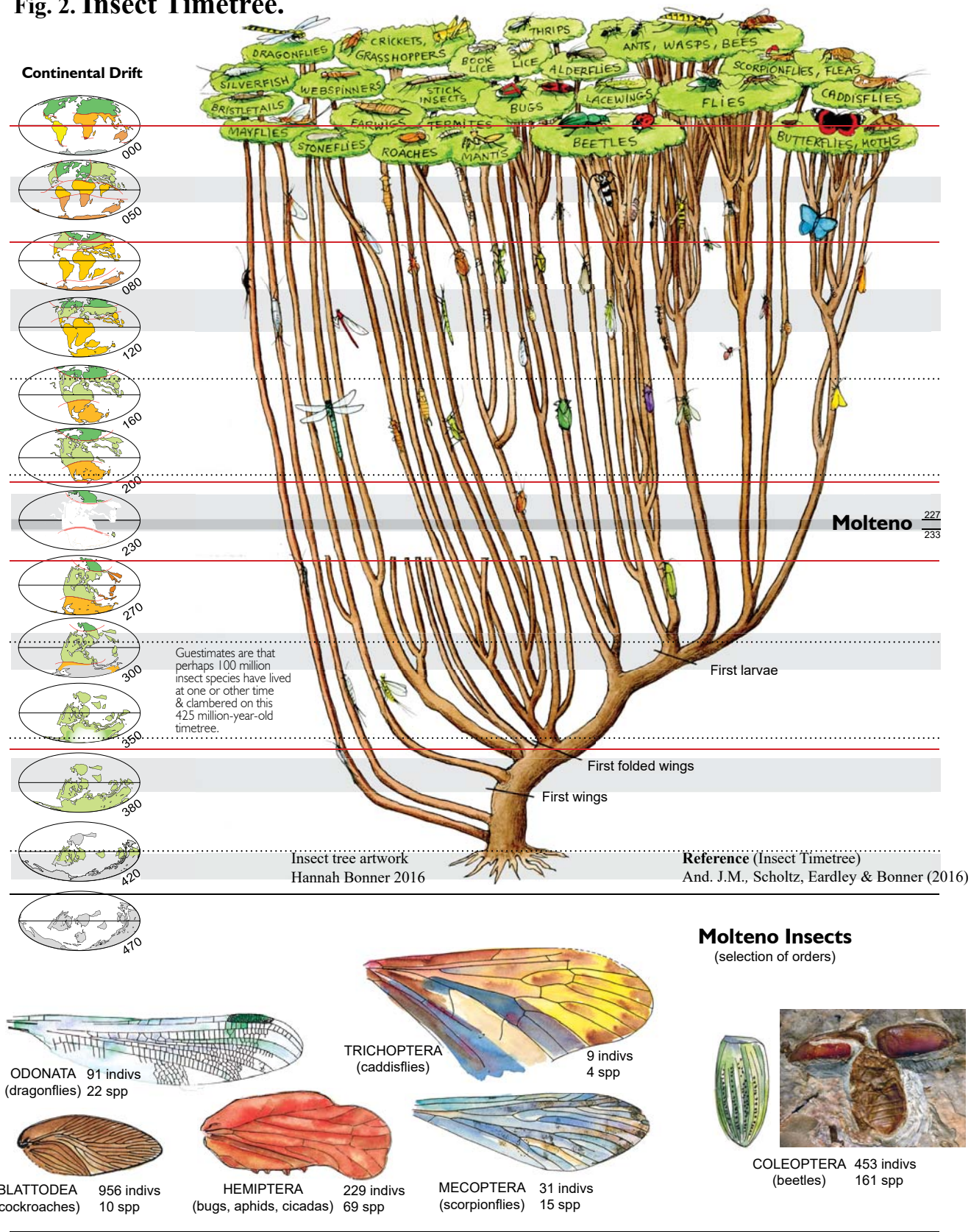


Moltano window onto co-radiation of gymnosperms & beetles

The plants and insects share a close co-evolutionary history from around 440 million years back in the early to middle Silurian. Particularly clear, for instance, is the parallel radiation of the angiosperms (flowering plants) and of the 'Big Four' orders of pollinating insects, the Coleoptera (beetles), Diptera (flies), Lepidoptera (butterflies & moths), and the Hymenoptera (Ants, wasps & bees), from the early Cretaceous at around 140 million year ago.

In the Triassic explosion of life, we see the 'heyday of the gymnosperms' and the earliest great diversification of the beetles. For the first time they constitute around half the total diversity of the insects – as in today's world. The evidence for the close interdependence of the beetles and gymnosperms in the Moltano is clear. The beetles were most likely the primary pollinators of the diversity of gymnosperms in the Moltano and across Gondwana at the time.

Fig. 2. Insect Timetree.



Colour in the later Carnian explosion of diversity

Surely, as in today's world, colour must have played a significant part in the interaction of life. The early dinosaurs (p. 10) – as in the avian world of today – are widely recognized as having joined this new world of colour (Greshko, 2020). It is interesting to note that the earliest known direct evidence of insect pollination amongst the angiosperms is of a pollen-covered beetle in amber (from India) at c. 100 myrs (Imbler, 2019).

Molted insects (overview)

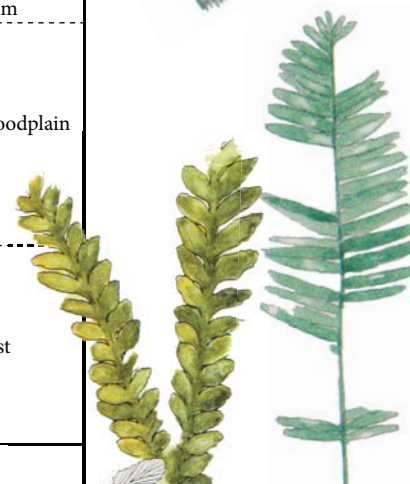
c. 2300 specimens from 43 of the 100 TCs (2021)
Based on a preliminary sorting of the full collection in the late 1990s:
43 TCs, 2056 indivs, 18 orders, 117 genera, 333 species.
Beetles – make up almost half the total diversity, much as today's insect world
Cockroaches – make up almost half the total abundance, but show little diversity (And. & And. *et al.*, 1996; And. J.M., Kohring & Schlüter, 1998; And. J.M. (ed.), 1999; And. J.M. *et al.*, 1999).

Chart 3. MOLTENO FLORISTICS.

DIVISION CLASS Genus	spp	fre- quency	abundance	plant form	preferred habitat
BRYOPHYTA					
<i>Muscites</i>	1	1	17	rare	
HEPATOPHYTA					
<i>Marchanites</i>	12	12	18	rare	mosses & liverworts
INCERTAE SEDIS					
<i>Thallites</i>	9	12	4	v. rare	
2 genera	3	3	v. rare		
LYCOPHYTA					
5 genera	13	13	8	v. rare	herbaceous
SPHENOPHYTA (horsetails)					
<i>Schizoneura</i>	2	23	7	dominant	horsetails: reed-like, herbaceous to tall bamboo-like
<i>Paraschizoneura</i>	4		4	occasional	
<i>Moltenomites</i>	2		5	occasional	
<i>Balenosetum</i>	1		2	occasional	
<i>Asinisetum</i>	1		8	dominant	
<i>Zonulamites</i>	4		27	dominant	
<i>Townroviomites</i>	3		3	occasional	
<i>Equisetites</i>	6		19	dominant	
FILICOPHYTA (ferns)					
<i>Drepanozamites</i>	2	37	3	v. rare	ferns
<i>Asterotheca</i>	3		6	occasional	
<i>Osmundopsis</i>	4		6	v. rare	
3 genera	8		18	common	
<i>Dictyophyllum</i>	3		8	v. rare	
<i>Cladophlebis</i>	8		35	occasional	
8 genera	9		16	rare	
PINOPHYTA					
PINOPSIDA (conifers)					
<i>Heidiphyllum</i>	1	5	62	dominant	shrub to tall tree
<i>Clariphyllum</i>	1		2	rare	
<i>Rissikia</i>	2		21	common	
<i>Pagiophyllum</i>	1		1	v. rare	
CYCADOPSIDA					
<i>Pseudoctenis</i>	9	18	21	occasional	cycad-like generally small
<i>Jeanjacquesia</i>	3		3	v. rare	
<i>Cenis</i>	2		2	v. rare	
<i>Moltenia</i>	4		5	v. rare	
GINKGOOPSIDA					
<i>Lepidopteris</i>	2	67	30	common	med. shrub shrub small tree shrub or small tree shrub to tall tree shrub to small tree shrub to med. tree shrub to large tree slender shrub
<i>Scytophyllum</i>	1		1	v. rare	
<i>Kurtziana</i>	16		13	rare	
<i>Dejerseya</i>	1		5	common	
<i>Ginkgoites</i>	6		19	occasional	
<i>Paraginkgo</i>	1		2	occasional	
<i>Sphenobaiera</i>	9		43	dominant	
<i>Dicroidium</i>	19		75	dominant	
<i>Rochipteris</i>	12		26	occasional	
INCERTAE SEDIS					
<i>Batiopteris</i>	5	7	10	rare	creeper herbaceous undergrowth herbaceous undergrowth
<i>Saportaea</i>	1		1	v. rare	
<i>Linguifolium</i>	1		9	rare	
BENNETTITOPSIDA					
<i>Halleyoctenis</i>	3	11	10	common	cycad-like shrub to small tree
<i>Taeniopteris</i>	8		38	common	
GNETOPSIDA					
<i>Gontriglossa</i>	1	7	8	occasional	small shrub small shrub small shrub large tree shrub or tree
<i>Graciliglossa</i>	1		1	occasional	
<i>Cetiglossa</i>	2		1	v. rare	
<i>Yabeiella</i>	1		29	occasional	
<i>Jungites</i>	2		1	rare	

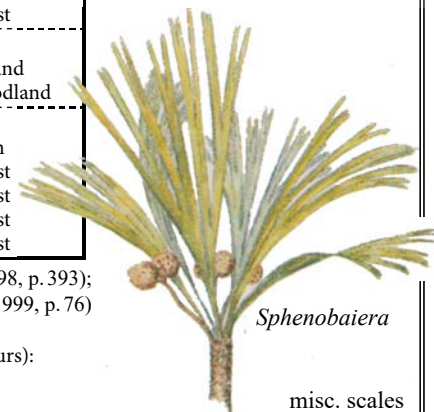


Heidiphyllum



Pseudoctenis

Dicroidium

Kannaskopianthus/
Rochipteris

Sphenobaiera

misc. scales

updated after: And., And. & Cruick. (1998, p.393);
And, J.M. (ed.) (1999, p. 76)

Tab. 1. Observed vegetative diversity.

Non-gymnosperms: 34 genera, 98 species

Gymnosperms: 27 genera, 115 species

Total vegetative: 61 genera, 211 species

Species: based on full taxonomic review of Molteno flora

Sampling: based on the 100 sampled taphocoenoses (TCs)

Frequency: the number of TCs in which the genus occurs

Abundance (the norm in the TCs in which it occurs):

very rare – 1–5 individuals

rare – 5–10 individuals

occasional – 10 individuals to 1%

common – 1%–5%

dominant – dominates the communities

 the five genera illustrated to right

Sources:

Bryophyta-Lycophyta: volumes in prep.

Sphenophyta: And. & And. (2018, tab. 2, p. 71)

Filicophyta: And. & And. (2008, tab. 1, p. 5)

Pinophyta: And. & And. (2003, tab. 15, p. 21)

Molteno sketches: HMA & JMA

DIVISION CLASS ORDER Genus	species		species		species	whole- plant (MNSs)
Ovulate		Foliage		Microsporangiate		
PINOPHYTA (gymnosperms)						
PINOPSIDA (Coniferopsida)						
DORDRECHTIALES						
<i>Dordrechites</i>	3	—	—	—	—	3
VOLTZIALES						
—	—	—	—	<i>Fredianthus</i>	1	1
—	—	—	—	<i>Lutanthus</i>	3	3
<i>Telemachus</i>	6	<i>Heidiphyllum</i>	1	<i>Odyssianthus</i>	1	6
—	—	<i>Clariphyllum</i>	1	—	—	1
PINALES (Coniferales)						
<i>Rissikistrobus</i>	3	<i>Rissikia</i>	2	<i>Rissikianthus</i>	4	4
—	—	<i>Pagiophyllum</i>	1	—	—	1
ORDERS indet. (2 total)						
<i>Gypsistrobus</i>	1	—	—	—	—	1
<i>Avistrobus</i>	1	—	—	—	—	1
—	—	—	—	<i>Helvetianthus</i>	1	1
CYCADOPSIDA						
CYCALES						
—	—	<i>Pseudoctenis</i>	9	<i>Androstrobus</i>	2	9
—	—	<i>Jeanjacquesia</i>	3	—	—	3
—	—	<i>Ctenis</i>	2	—	—	2
—	—	<i>Moltenia</i>	4	—	—	4
GINKGOOPSIDA						
PELTASPERMALES						
<i>Peltaspermum</i>	5	<i>Lepidopteris</i>	2	<i>Antevsia</i>	1	5
—	—	<i>Scytophyllum</i>	1	—	—	1
MATATIELLALES						
<i>Matatiella</i>	4	<i>Kurtziana</i>	16	—	—	16
—	—	<i>Dejerseya</i>	1	<i>Switzianthus</i>	2	2
GINKGOALES						
<i>Avatia</i>	1	<i>Ginkgoites</i>	6	<i>Eosteria</i>	2	6
—	—	<i>Paraginkgo</i>	1	—	—	1
HAMSHAWVIALES						
<i>Hamshawvia</i>	4	<i>Sphenobaiera</i>	9	<i>Stachyopitys</i>	6	9
UMKOMASIALES						
<i>Umkomasia</i>	8	<i>Dicroidium</i>	19	<i>Pteruchus</i>	3	19
<i>Fanerotheca</i>	4	<i>Dicroidium</i>	—	—	—	4
PETRIELLALES						
<i>Kannaskoppia</i>	1	<i>Rochipteris</i>	12	<i>Kannaskoppianthus</i>	4	12
ORDER indet.						
<i>Cetifructus</i>	1	—	—	—	—	1
CLASSES indet. (5 total)						
ALEXIALES						
<i>Alexia</i>	1	—	—	—	—	1
HLATIMBIALES						
<i>Hlatimbia</i>	1	<i>Batiopteris</i>	5	—	—	5
ORDERS indet. (3 total)						
<i>Hystricia</i>	1	—	—	—	—	1
—	—	<i>Saportaea</i>	1	—	—	1
—	—	<i>Linguifolium</i>	1	—	—	1
BENNETTITOPSIDA						
FREDLINDIALES						
<i>Fredlindia</i>	1	<i>Halleyoctenis</i>	3	<i>Cycadolepis</i>	1	3
—	—	—	—	<i>Weltrichia</i>	2	2
—	—	—	—	<i>Leguminanthus</i>	1	1
PENTOXYLALES						
<i>Lindtheca</i>	1	<i>Taeniopteris</i>	8	—	—	8
GNETOPSIDA						
NATALIGMALES						
<i>Nataligma</i>	1	<i>Gontriglossa</i>	1	—	—	1
ORDER indet.						
—	—	<i>Gracilglossa</i>	1	—	—	1
—	—	<i>Cetiglossa</i>	1	—	—	1
FRAXINOPSIALES						
<i>Fraxinopsis</i>	3	<i>Yabeiella</i>	2	—	—	3
—	—	<i>Jungites</i>	2	—	—	2
20 genera	51	27 genera	115	15 genera	35	145

Tab. 2. Gymnosperms; observed diversity.

Female: 8 classes, 18 orders, 18 families, 20 genera, 51 species

Male: 4 classes, 11 orders, 13 families, 15 genera, 35 species

Foliage: 8 classes, 17 orders, 24 families, 27 genera, 115 species

Whole-plant: 12 classes, 23 orders, 32 families, 38 genera, 145 species

MNSs (minimum number of species): diversity recorded for whole-plant species is a minimum

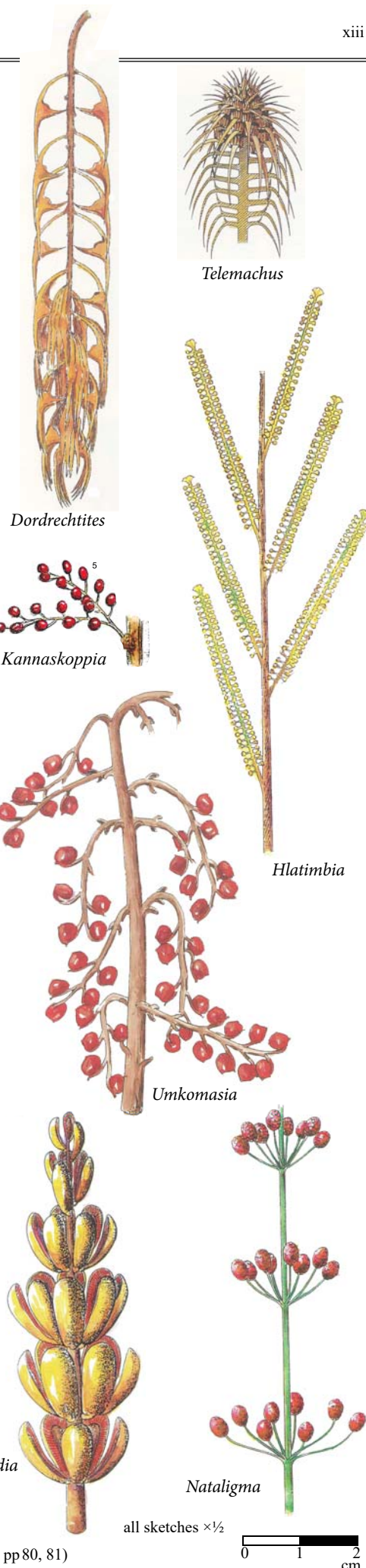
Families: for complete classification including families, see And. & And. (2003, pp 54, 55)

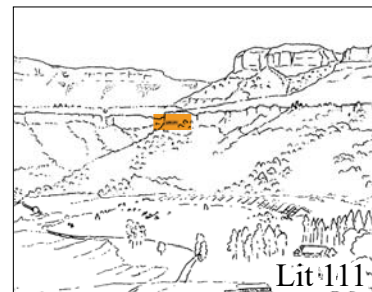
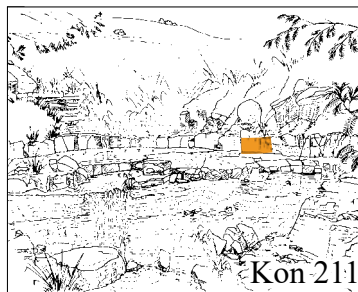
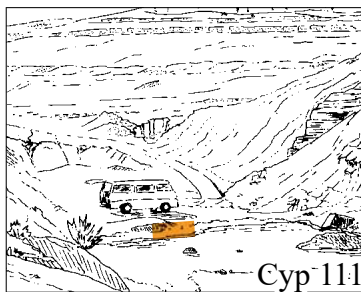
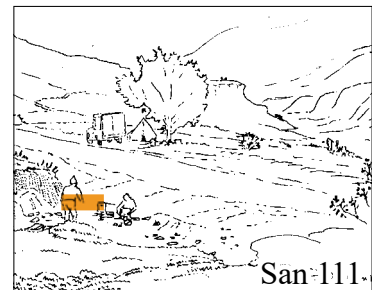
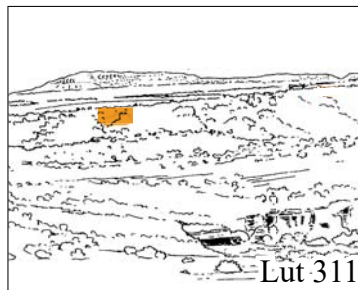
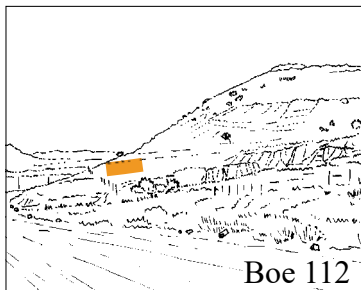
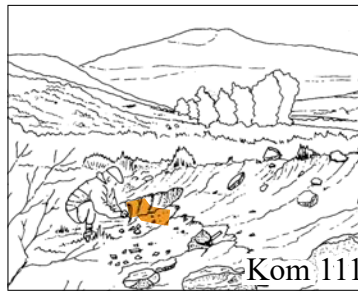
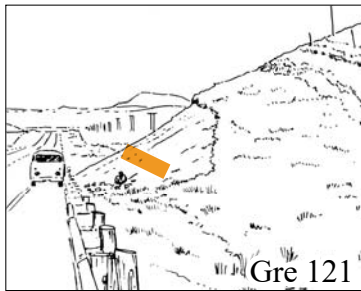
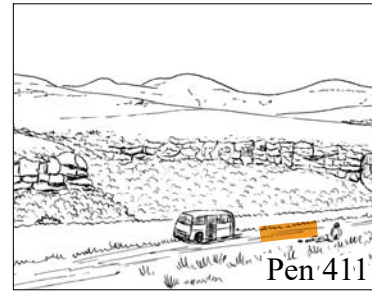
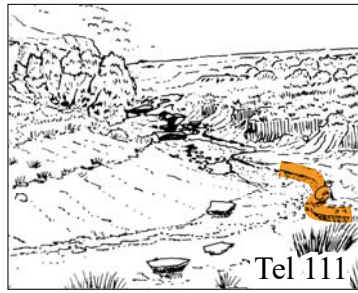
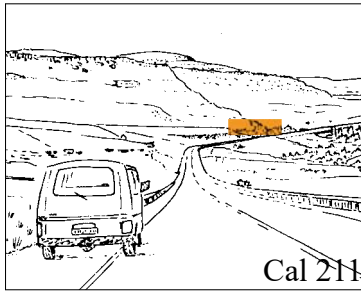
Multi-organ genera: 16 recognized in Molteno (see And. & And., 2003, tab. 12, p. 18)

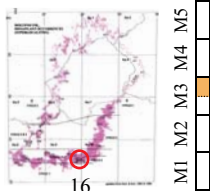
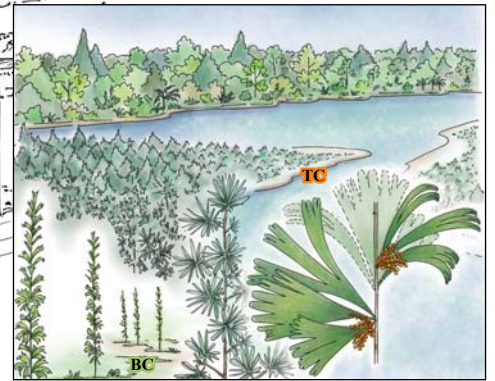
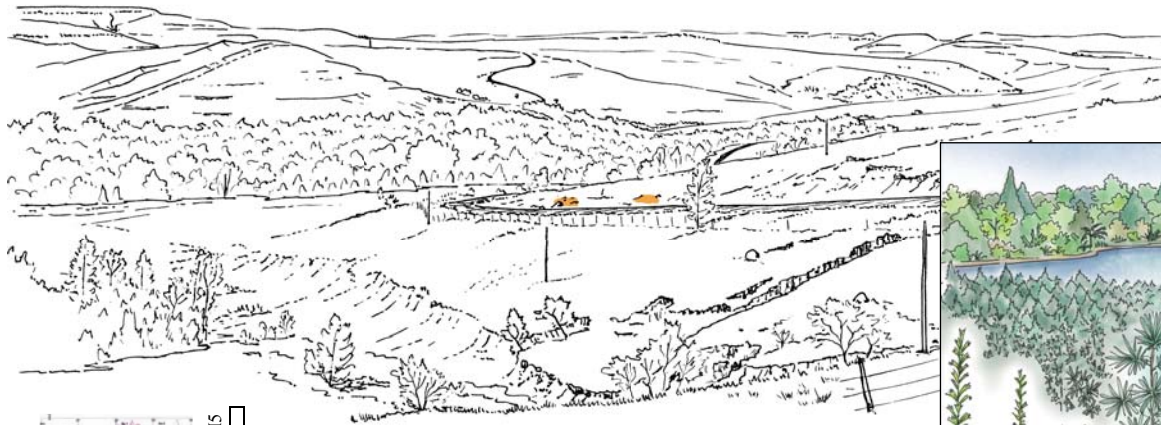
ovulate genera illustr. to right

Table: And. & And. (2003, tab. 15, p. 21)

Molteno reconstructions: And J.M. (ed.) (1999, pp 80, 81)

all sketches $\times \frac{1}{2}$ 0 1 2
cm





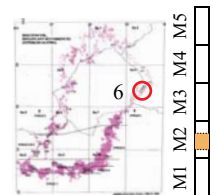
16 Kan 111, 112

PART 1

SAMPLING & OCCURRENCE

The three affiliated organs, *Rochipteris* (foliage), *Kannaskoppia* (ovulate) and *Kannaskoppianthus* (microsporangiate) of the family Petriellaceae, are recorded from 26 of the 100 Molteno assemblages (TCs). These are tabled in stratigraphic sequence with abundance data for the taxa found. The Molteno Formation sampling is set within the context of the Gondwana Triassic.

At the core of the chapter is a systematic coverage of the 26 sites, including a pen sketch of each, at which these TCs occur – listing habitat, number of slabs collected, man-hours cleaving, the fossil flora recovered (dominants, biodiversity, Petriellaceae found, affiliation) and taphonomy. The insects and plant–insect interactions found in the TC are also summarized.



6 Umk 111

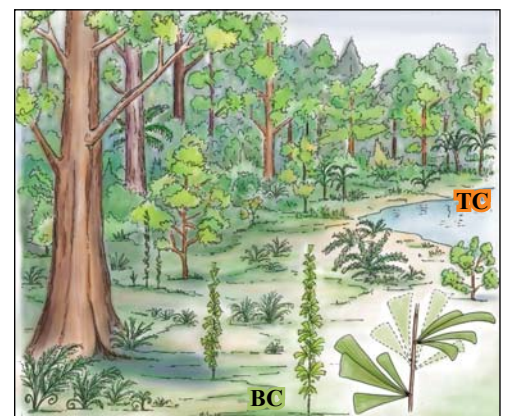


Chart 1. SAMPLING THE MOLTENEO & GONDWANA TRIASSIC.

The Molteno Fm.

The *Kannaskoppia*/*Kannaskoppianthus*/*Rochipteris* material described herein is based almost exclusively on our own extensive collections – belonging to the South African National Biodiversity Institute (formerly the National Botanical Institute), Pretoria, (PRE/F/-) and the Evolutionary Studies Institute, ESI (formerly the Bernard Price Institute, Witwatersrand University, Johannesburg (BP/2/-). These fossils are presently all housed in the Molteno collection at ESI. The transfer of the collection to ESI was undertaken during March to July 2010, with the Pretoria collection (PRE/F/-) now on permanent loan to that institute. The Molteno material collected and originally described by Seward (1903, 1908) and Du Toit (1927) is housed in the Iziko Museum (formerly South African Museum), Cape Town (SAM-PV-K).

For sampling strategies, methods and approach, see And. & And. (1983, pp2–29; 1989, pp5–17; 2003, pp2–11). A table and map of the 43 Superlocalities (10 km diameter grid) and the 100 assemblages (taphocoenoses, TCs) are given in And. & And. (1989, p.29), And. & And. (2003, pp8,9) and repeated in this volume (Chart 3, pp 6, 7). These are referred to throughout the volume in their abbreviated form (see Glossary). *Rochipteris* and affiliates – rarely over 1% of the flora – occur in 26 taphocoenoses (TCs) (Chart 6, pp 12, 13).

Evenness of sampling

Geographic (Fig. 1a)

The Molteno outcrop – considering plant-bearing continental deposits on a Gondwana-wide scale – is especially extensive (c. 400 × 200 km) and well exposed. With the greatest thicknesses (up to 500 m) along the southern outcrop, the number of assemblages decreases to the north; as is clearly evident in the outcrop map.

Ecological (Fig. 1b)

In the Molteno Biome, we recognize seven primary habitats (Chart 4, pp 8, 9): some are far more prolific than others in regard to productive fossil-plant deposits. The seven Molteno habitats remain unequally represented in the collection (Chart 4, p. 9). Coverage ranges from a maximum of 32 TCs for the *Dicroidium* woodland, to a minimum of two TCs for the mature *Dicroidium* riparian forest. The *Heidiphyllum* thicket, most relevant in this volume, is second best covered with 24 TCs.

Stratigraphic (Fig. 1c)

As Gondwana, the southern half of Pangaea, drifted north through the Triassic (see Fig. 2, p. 3), an active margin developed between Antarctica and southern Africa. The repeated upward-fining cycles of sedimentation (members) are a consequence of pulses of uplift. The fullest sequence of members is encountered in the SE where all six cycles are recognized.

Intensity of sampling

Tab. 1. Molteno sampling.

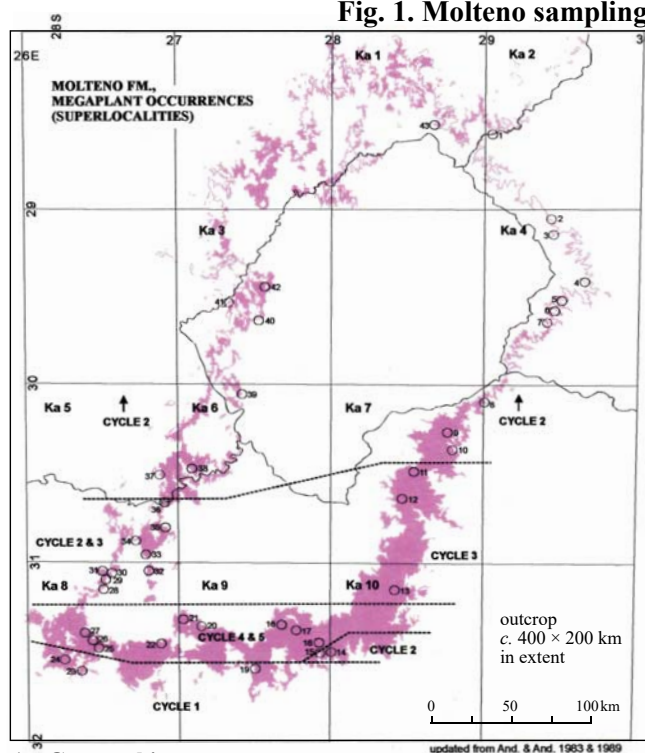
Geographic grid (hierarchy)	Grid diam.	
subregions	100 km	10
superlocalities	10 km	43
localities	1 km	69
sublocalities	100 m	80
supersites	10 m	85
TCs (assemblages)	–	100
Slabs (approx.)	–	27 200

Collecting programme: 1967–1998 (31 years); 85 field trips.

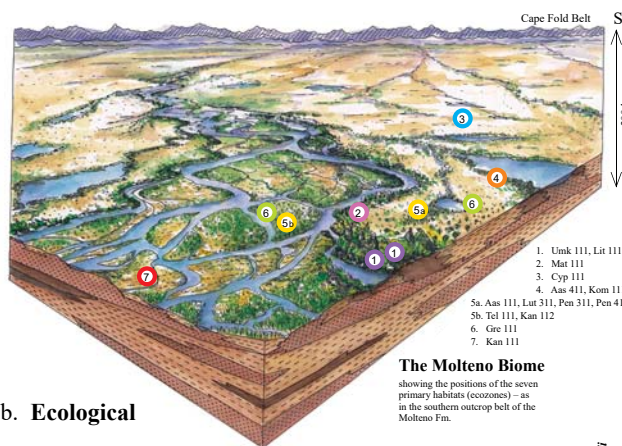
Extensiveness of sampling: 100 taphocoenoses (assemblages) from 69 localities (areas to 1 km in diameter).

Intensity of sampling: c. 27 200 catalogued slabs including c. 300 000 identifiable vegetative specimens (individuals). – from And. & And. (2003, pp2, 3)

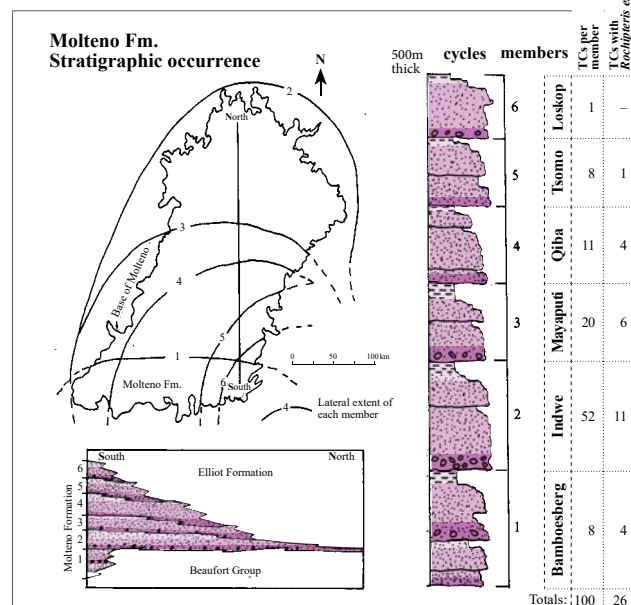
Fig. 1. Molteno sampling.



1a. Geographic



1b. Ecological



1c. Stratigraphic

The Gondwana Triassic (GT)

Although Gondwana Triassic plants have been sampled for around 175 years (Morris 1845, McCoy 1847 and later), major potential remains for further extensive collections and revision.

Colonization success (Prominence)

For *Kannaskoppia* – as in our earlier volumes – we consider the success of the taxon in colonizing Gondwana through the Triassic (see Part 2, Systematics, p. 50). *Rochipteris* ranks fourth in this regard amongst the gymnosperm plant genera through the supercontinent – following *Dicroidium*, *Heidiphyllum* and *Sphenobaiera*. For this purpose, clearly the more comprehensive and comparative the sampling across the supercontinent, the more meaningful the results – a sense of the disparity continent by continent follows.

Tab. 2. Gondwana Triassic sampling.

	regions	formations	localities
South America	4 basins	18 fms	49 locs
Southern Africa	4 basins	5 fms	81 locs
India	2 basins	4 fms	8 locs
Antarctica	2 basins	5 fms	21 locs
Australasia	10 basins	37 fms	228 locs

And. & And. (2018, pt2, tab. 4)

The level of sampling around the Gondwana Triassic (GT) has increased substantially in the past four decades since 1983 (see Hypodigm, Part 2, pp 106–115). This is especially the case for Antarctica, where new localities and collections have increased significantly (e.g. Bomfleur *et al.*, 2013, 2014). An overview of megaplant sampling levels across the supercontinent during the Triassic is given in And. & And. (2003, pp 2, 3). “By far the fullest succession of megaflores is preserved in the series of basins stretching down the eastern tectonic margin of Australia.” It would be useful for an updated compilation to be undertaken.

On a sampling scale of 1 to 5 (reconnaissance to comprehensive), we might rate the Molteno Formation grade 4 (approaching optimal) and most other GT formations about 2 (basic).

Global Triassic correlations

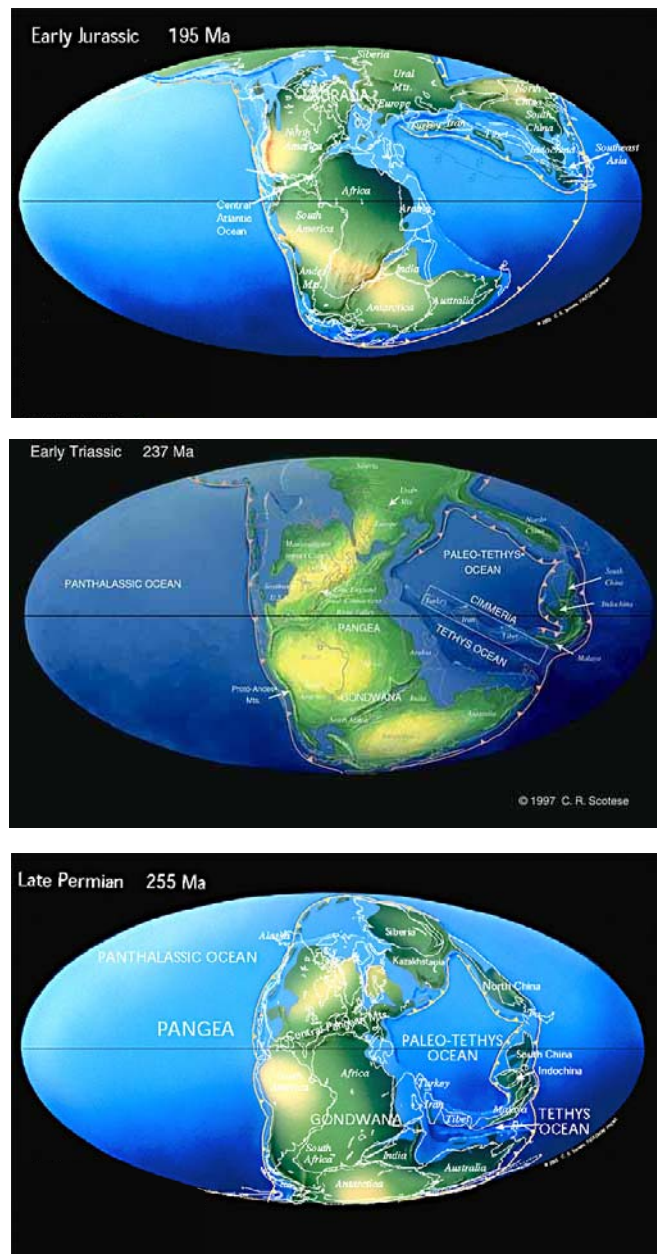
The biostratigraphic and chronostratigraphic correlation of global Triassic strata is still in a considerable state of flux (Lucas *et al.*, 2012; Ogg *et al.*, 2014). After their recent review of the status of the Triassic Timescale, Ogg *et al.* (2014) concluded, “Unfortunately, there are lingering major uncertainties on the age ... and durations for most of the Triassic stages. In particular, establishing a robust Late Triassic time scale requires definitive radio-isotopic dates”

In the few years since, as noted by Ruffell *et al.* (2018), our knowledge of the Triassic is clearly improving: “Dating methods and databases have improved. Importantly, correlations between late Triassic continental red beds and marine limestones are facilitated by magnetostratigraphy, carbon-isotope excursions, palynology and occasional radioisotopic dates.”

Our aim, along with several colleagues (see Introduction), is to complete the holistic study of the Molteno – megaflores and palynomorphs, insects, plant–insect interactions, radio-isotopic dating, bio- and eco-stratigraphy – over the next five years or so. Included will be a review of the correlation of Gondwana Triassic plant and insect-bearing strata tied as closely as possible to the global Triassic standard. We have since our latest Molteno volume on the Sphenophytes (And. & And., 2018), attempted a partial update of our ‘Gondwana Triassic, stratigraphic occurrence of megaplants’ (Chart 2, Fig. 2, p. 5).

This, then, supercedes the correlations appearing in our *Brief History of the Gymnosperms* (And., And. & Cleal, 2007).

Fig. 2. Gondwana Triassic in context.



From: Chris Scotese (1997)
Paleomap Project

Chart 2. GONDWANA TRIASSIC MEGAPLANTS.

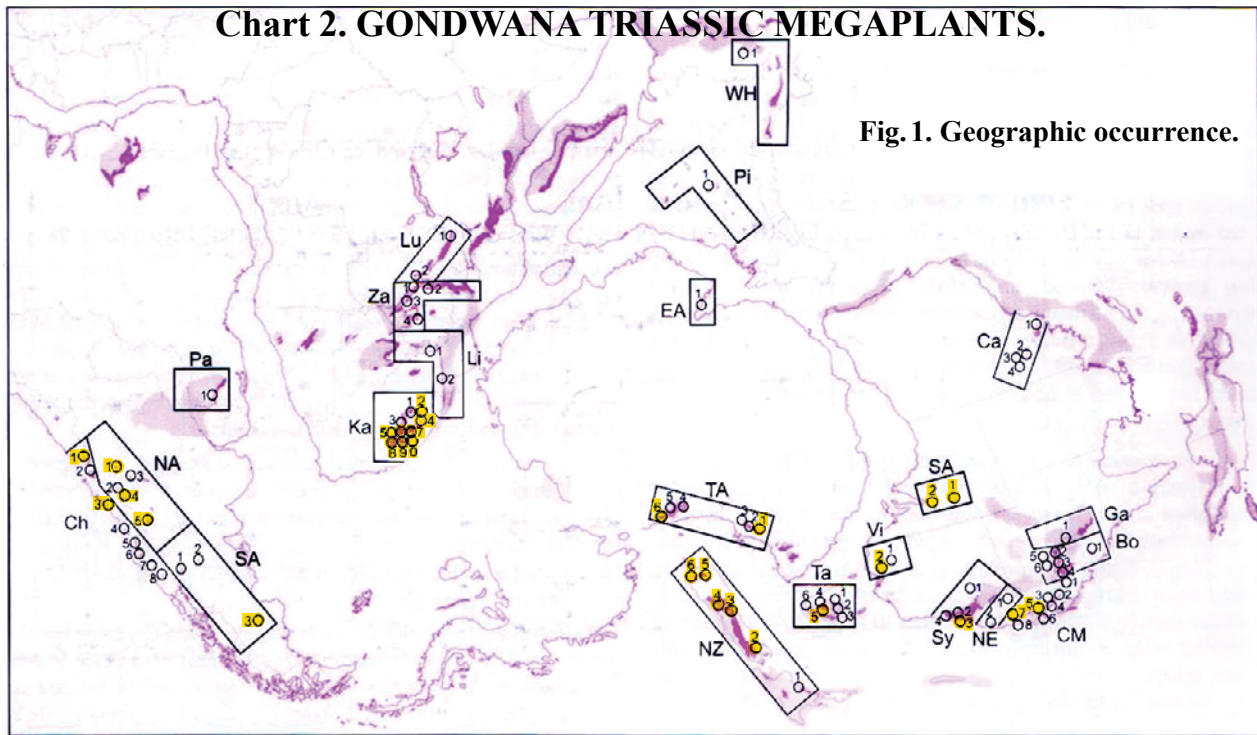


Fig. 1. Geographic occurrence.

30 Subregion (degree square), with *Roehamptonia* (& affiliates)

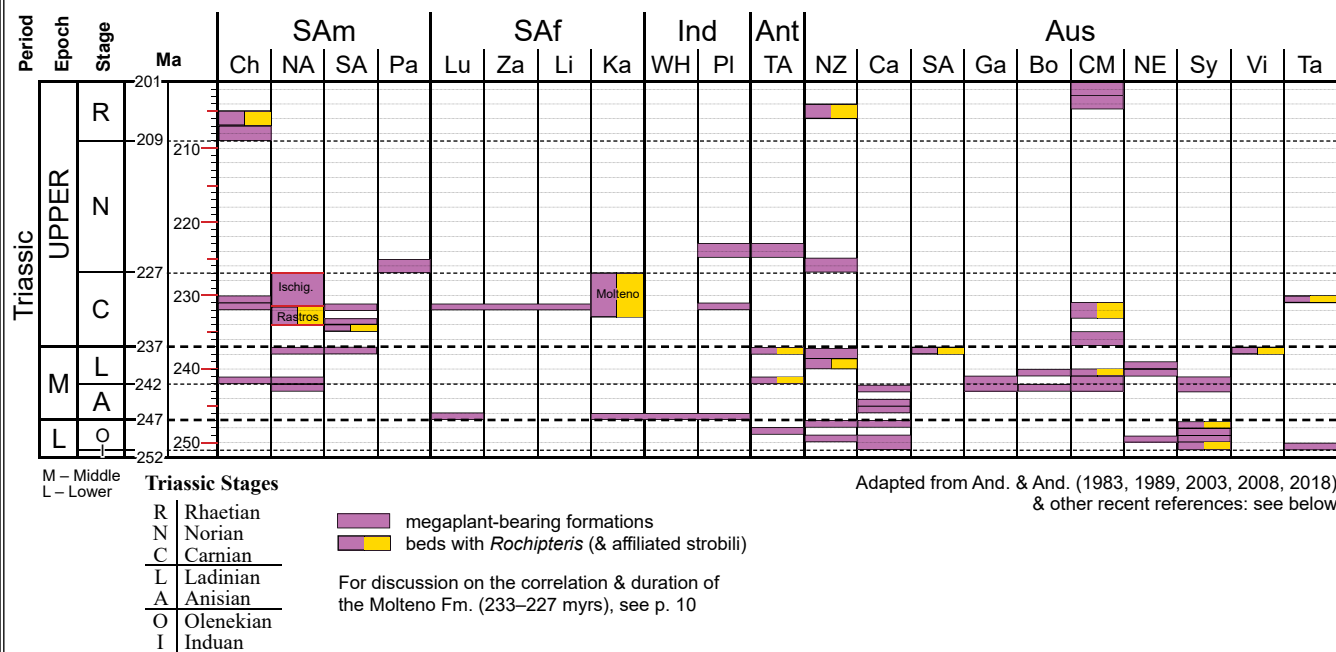
Updated from And. & And. (1983, 1989, 2003)

Tab. 1. Gondwana Triassic, productive degree squares.

SUPERREGION (continent)	Degree square	Quantity	Quality	Cuticle	Publ. cover	Biozones	Localities
REGION (basin)	Lat.	Long.					
Subregion (° square)							
SOUTH AMERICA (SAm)							
CHILE (Ch)							
1 Copiapo	27	70	3	3	-	2	1 3
2 Alto del Carmen	29	71	•	•	-	1	1 1
3 Los Vilos	32	72	2	2	-	2	1 2
4 Curicó	34	72	•	•	-	1	1 1
5 Pocillos	36	73	•	•	-	1	1 1
6 Concepción	37	73	3	3	-	2	2 2
7 Temuco	38	73	•	•	-	1	1 2
8 Valdivia	39	73	•	•	-	1	1 1
N. ARGENTINA (NA)							
1 Ischigualasto	29	69	3	3	3	2	3 13
2 Barreal	31	70	4	4	2	4	2 6
3 Marayes	31	68	2	3	-	2	1 1
4 Cacheuta	32	70	4	4	3	3	3 10
5 Llantenes	35	69	3	3	-	3	2 2
S. ARGENTINA (SA)							
1 Paso Flores	40	72	2	3	-	2	1 1
2 Los Menucos	40	69	1	2	-	1	1 1
3 El Tranquilo	47	70	2	3	-	2	1 1
PARANA BASIN (Pa)							
1 Santa Maria	29	54	2	3	-	2	1 1
SOUTHERN AFRICA (SAf)							
LUANGWA VALLEY (Lu)							
1 N. Luangwa V.	10	32	1	1	-	1	1 •
2 W. Luano V.	14	29	•	•	-	1	1 •
ZAMBEZI VALLEY (Za)							
1 Kafue V.	15	28	•	•	-	1	1 •
2 Urungwe	16	30	1	1	-	1	1 1
3 Lake Kariba	17	27	3	3	-	2	1 8
4 Gwelo	19	29	2	2	-	2	1 1
LIMPOPO VALLEY (Li)							
1 Soutpansberg	22	30	1	1	-	1	1 1
2 Komatipoort Cf.	25	31	1	1	-	1	1 1
KAROO BASIN (Ka)							
1 Bethlehem	28	28	1	3	5	2	1 1
2 Bergville	28	29	5	5	5	4	1 1
3 Maseru	29	27	5	5	3	4	1 4
4 Underberg	29	29	5	5	3	4	1 9
5 Allwal North	30	26	5	4	-	4	2 13
6 Zastron	30	27	4	4	-	4	1 2
7 Matatiele	30	28	4	4	-	4	1 5
8 Molleno	31	26	5	4	-	4	1 19
9 Elliot	31	27	4	4	-	4	2 14
10 Maclear	31	28	4	4	-	4	1 1
INDIA (Ind)							
W. HIMALAYAS (WH)							
1 Salt Range (W)	33	71	2	2	-	2	1 1
PENINSULA INDIA (Pi)							
1 S. Rewa/Tiki	24	81	3	3	3	3	3 7
ANTARCTICA (Ant)							
TRANSANTARCTIC MTS. (TA)							
1 Allan Nunataks	76	155	3	4	-	2	1 3
2 Taylor Glacier	77	155	3	4	3	1	2 9
3 Portal Mt.	78	155	2	3	-	1	1 1
4 Beardmore Gl.	84	160	•	•	•	•	1 2 3
5 Mt. Bumstead	85	170	2	4	-	2	1 1
6 Shackleton Gl.	85	180	2	4	-	1	1 1
EASTERN ANTARCTICA (EA)							
1 Prince Charles Mts	70	68	3	3	5	3	1 3
AUSTRALASIA (Aus)							
NEW ZEALAND (NZ)							
1 SW Auckland	38	174	1	1	-	4	1 1
2 Nelson Syncline	41	173	1	1	-	4	2 3
3 Mt. Potts	43	170	3	3	-	4	1 1
4 Benmore Dam	44	170	3	3	-	4	1 3
5 Southland Syncl. (NW)	45	168	2	1	-	4	5 10
6 Southland Syncl. (SE)	46	169	2	1	-	4	2 7
CANNING BASIN (Ca)							
1 Derby	17	123	2	3	2	2	1 2
2 Mt. Erskine	19	126	2	3	-	1	2 4
3 Mt. Ernest	20	126	2	2	-	1	2 8
4 Gregory Lake	20	127	2	2	-	1	2 3
SOUTH AUSTRALIA (SA)							
1 Leigh Creek Cf.	30	138	3	3	5	3	1 1
2 Springfield Cf.	32	138	3	3	-	3	1 1
GALILEE BASIN (Ga)							
1 Lennox	22	146	1	2	-	1	1 3
BOWEN BASIN (Bo)							
1 Carborough	21	148	1	2	-	1	1 1
2 Springsure Shelf	24	147	1	2	-	1	1 1
3 Springsure Anticl.	24	148	1	2	-	1	1 1
4 Dawson Range	24	149	1	2	-	1	1 1
5 Carnarvon Range	25	148	1	2	-	1	1 1
6 Taroom	25	149	1	2	-	1	1 3
CLARENCE/MORETON BASIN (CM)							
1 Callide Cf.	24	150	2	4	5	2	1 1
2 Gayndah	25	151	1	3	-	1	1 2
3 Tarong	26	151	2	2	2	1	1 5
4 Esk Trough (N)	26	152	3	4	-	2	1 17
5 Ipswich/Esk	27	152	5	5	5	4	3 54
6 Brisbane	27	153	4	5	4	3	2 14
7 Nymboldia	29	152	4	5	-	3	1 4
8 Red Cliff	29	153	2	4	3	2	1 2
NEW ENGLAND FOLDBELT (NE)							
1 Delungra	39	150	2	3	1	3	1 2
2 Lorne Basin	31	152	3	3	-	4	1 4
SYDNEY BASIN (Sy)							
1 Dubbo	32	148	3	4	-	2	1 2
2 Blue Mts.	33	150	2	3	-	3	2 5
3 Sydney	33	151	4	4	3	3	2 23
4 Pictou	34	150	2	3	-	2	2 4
VICTORIA (Vi)							
1 Yandolt Hill	36	143	1	1	-	2	1 1
2 Bald Hill	37	144	1	1	-	2	1 1
TASMANIA (Ta)							
1 Poatina	41	146	•	•	•	•	1 1 1
2 Ben Lomond	41	147	3	4	3	2	1 2
3 NE coast	41	148	3	4	3	2	1 17
4 Derwent Valley	42	146	3	4	3	2	1 2
5 Hobart	42	147	3	4	3	2	2 8
6 South Cape	43	146	1	3	3	2	1 2

22 regions
85 productive degree squares (subregions)
94 biozones (megaflores)
391 localities (69 Molleno, 322 non-Molleno)

Fig. 2. Stratigraphic occurrence.



Tab. 2. Gondwana Triassic, megaplant-bearing formations.

SOUTH AMERICA Chile (CH) 207 La Ternera " El Puquen " Gomero " Tralcan 209 Gomero " Tralcan 231 Quilacoya 232 Quilacoya 242 (Alto Del Carmen) " Atacama N. Argentina (NA) 232 Ischigualasto " Q. de la Mina 228 C. de Piedra 230 L. Carrizal " Cacheuta 233 Panul " Potrerillos " Llantenes 234 Los Rastros " Cortaderita " Chihuiu (U) 238 Ischichuca " Barreal 242 Las Cabras (M/U) 243 Las Cabras (L)	S. Argentina (SA) 232 Paso Flores 235 El Tranquilo 238 Los Menucos Parana Basin (Pa) 227 Santa Maria SOUTHERN AFRICA Luangwa Valley (Lu) 232 'U. Grit' 247 Ntawere Zambezi Valley (Za) 232 'Flags' Limpopo Valley (Li) 232 (Molteno) Karoo Basin (Ka) 233 Molteno 247 Burgersdorp	INDIA W. Himalayas (WH) 247 Landa Peninsular India (PI) 225 Tiki 232 Chicharia 247 Parsona ANTARCTICA (TA, EA) Transantarctic Mts. 238 Falla " Lashly C 242 Fremouw 249 Lashly A Eastern Antarctica 225 Flagstone Bench AUSTRALASIA New Zealand (NZ) 206 (Southland) 227 (Southland) 239 Tank Gully " Black Jacks " Long Gully 240 (Southland) 250 "	Canning Basin (Ca) 248 Culvida 250 Erskine 251 Blina Southern Australia (SA) 238 Leigh Creek " Springfield Galilee Basin (Ga) 242 Moolayember 243 Clematis Bowen Basin (Bo) 242 Moolayember 243 Clematis Clarence/Moreton Basin 203 Raceview 205 Aberdare 232 Callide " Ipswich (U) 233 Tarong " Ipswich (L) " Tingalpa " Red Cliff 241 Esk " Nymboida 242 Nera 243 Bryden	New England Foldbelt 240 Gragin 241 Gunnee 250 Camden Head Sydney Basin (Sy) 242 Benolong " Wianamatta 243 Hawkesbury 248 Burrallow " Gosford (U) " Newport (U) 249 Newport (M) 250 Garie " Newport (L) 251 Banks Wall " Gosford (L) " Bald Hill 251 Patonga " Bulgo Victoria (Vi) 238 Yandoit " Bald Hill Tasmania (Ta) 231 Brady " New Town 251 Knocklofty
--	--	---	--	---

Ma – age marking base of Formation bar
 (rounded off to the closest million)

Adapted from And. & And. (1989, p. 30; 2003, p. 7)

beds with *Rochipteris* (& affiliated strobili)

Rochipteris (and affiliated strobili) are recorded from 21 Formations in the Gondwana Triassic as shown in Tab. 2 (above). Of these, the Molteno is by far the most productive, with 20 Superlocalities (Chart 3, p. 6) yielding a total of 12 species from the 26 TCs. For Gondwana species distribution, consult the Hypodigm Charts (pp 102–115).

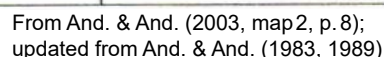
The Triassic explosion of biodiversity

In the story of life on earth, the Triassic explosion – plants, insects, tetrapods (the origin of dinosaurs) – following the end-Permian extinction, the Triassic strata tell a most compelling chapter.

Recent references

Mancuso *et al.* (2020): origin of dinosaurs
 Smith *et al.* (2018): Australian Triassic palynostratigraphy
 IUGS (2018): International geological time-scale
 Ruffel *et al.* (2018): Carnian, extinctions & biodiversity explosion
 Marsicano *et al.* (2016): origin of dinosaurs, Ischigualasto Fm.

Fig. 1. Molteno Fm., megaplant occurrences (Superlocalities).



1. Little Switzerland	12. Tina Bridge	23. Bamboesberg	34. Elandspruit
2. Champagne Castle	13. Waldeek	24. Aasvoëlberg	35. Kraai Rivier
3. Injasuti Valley	14. Konings Kroon	25. Boesmanshoek Pass	36. Lutherskop
4. Mooi River	15. Peninsula	26. Cyphergat	37. Nuwejaarspruit
5. Hlatimbe Valley	16. Kannaskop	27. Molteno	38. Winnaarspuit
6. Umkomaas Valley	17. Navar	28. Kleinhoek	39. Qualasi Hill
7. Sani Pass	18. Cala Road	29. Kapokkraai	40. Morija
8. Mngeni Valley	19. Askeaton	30. Kommandantskop	41. Makoaneng
9. Qachasnek	20. Greenvale	31. Kullfontein	42. Mazenod
10. Matatiele	21. Dordrecht	32. Telemachus Spruit	43. Golden Gate
11. Kenegapoort	22. Birds River	33. Vineyard	

-  TCs with *Rochipteris* & affiliates
-  TCs with attached fruiting &/or foliage specimens
-  TCs with *Kannaskoppia*
-  TCs with *Kannaskoppianthus*

Tab.1. Molteno 'localities' & assemblages.

Degree square	Superlocality	Supersite	Assemblage	Supersite (informal)	Degree square	Superlocality	Supersite	Assemblage	Supersite (informal)
Ka 2	1 Little Switzerland ♂	Lit 111	Dic/Hei	–	22	Birds River	Bir 111	Sph 2spp	Tenant Dam
↑	2 Champagne Castle	Cha 111	Dic odo	Champagne Hotel	"	"	" 211	"	Cloete Shale
"	"	" 211	Dic dub	Wonder Valley	"	"	" 311	Hei/Sph	van Biljoen Shale
3	Injasuti Valley	Inj 111	Dic odo	Injasuti Camp	23	Bamboesberg	Bam 111	Dic dub	–
"	"	" 211	Dic dub	Forest Patch	24	Aasvoëlberg	Aas 111	Hei elo	Turner Shale
4	Mooi River	Moo 111	Dic zub	–	"	"	" 211	"	Proppie Shale
5	Hlatimbe Valley	Hla 111	Equ sp	Homestead Boulder	"	"	" 311	"	Easter-Egg Shale
"	"	" 211	Dic 3spp	Tom's Outcrop	"	"	" 411	Dic/Sph	Fredlindia Slate
"	"	" 212	"	Eddie's Outcrop	"	"	" 511	Dic elo	Erard Slate
"	"	" 213	Dic elo	<i>Batiopteris</i> Corner	"	"	" 611	Hei elo	Aasvoëlberg Pass
6	Umkomaas Valley	Umk 111	Dic 2spp	Waterfall Locality	25	Boesmanshoek Pass	Boe 111	Lep sto	<i>Equisetum</i> Ridge
7	Sani Pass	San 111	Dic cra	–	"	"	"	Equ sp	"
8	Mngeni Valley	Mng 111	Dic 2spp	–	"	"	"	Dic/Hei	"
9	Qachasnek	Qac 111	Hei/Dic	–	"	"	" 112	Dic cor	<i>Coriaceum</i> Flats
10	Matalele ♂	Mat 111	Dic dub	–	26	Cyphergat	Cyp 111	Dic cra	Open Cast
11	Keneġapoort	Ken 111	Dic cra	–	"	"	"	Hei elo	–
12	Tina Bridge	Tin 111	Sch sp	Tina Road	27	Molteno	Mol 111	Sph pon	Slate Quarry
"	"	" 121	Sph 2spp	Tina Quarry	28	Kleinhoek	Kle 111	Equ sp	Kleinhoek Cutting
"	"	" 131	Hei/Ast	Tina Stream	"	"	"	Hei elo	"
Ka 10	13 Waldeck	Wal 111	Dic odo	"	"	"	" 211	Hei/Dic	"
↑	14 Konings Kroon	Kon 111	Dic odo	Du Toit Chert	"	"	"	Sph pon	Kleinhoek Slate
"	"	"	Sch sp	"	29	Kapokkraal	Kap 111	Dic/Ris	–
"	"	"	Hei elo	"	30	Kommandantskop	Kom 111	Sph/Dic	–
"	"	" 211	Ast 2spp	Rooipoort Donga	31	Kullfontein	Kul 111	Sph pon	–
"	"	"	Hei elo	"	32	Telemachus Spruit	Tel 111	Hei elo	–
"	"	" 221	Ast 2spp	Stream	33	Vineyard	Vin 111	Dic odo	Homestead
"	"	" 222	Dic odo	Rosy Chert	"	"	" 211	Sch sp	Cheese Factory
"	"	" 223	"	Keith Chert	34	Elandspruit	Ela 111	Dic odo	Anne Roadside
15	Peninsula	Pen 321	Dic/Ris	<i>Rissika</i> Chert	"	"	" 112	Equ sp	Zorba Stream
"	"	" 211	Dic/Equ	Isaac Chert	"	"	"	Dic/Hei	"
"	"	" 221	"	Volker Chert + 222	35	Kraai River	Kra 111	Dic odo	Jigsaw Chert
"	"	" 511	Equ sp	Mudpatch Chert	"	"	" 211	Equ sp	Plaatkop Track
"	"	" 421	Dic odo	360° Chert	"	"	" 221	beetles	Plaatkop Beetles
"	"	" 431	Dic/Equ	180° Chert	"	"	" 311	Dic odo	Glenburn
16	Kannaskop ♀♂	Kan 111	Ast spA	<i>Kannaskoppia</i> Siltstone	36	Lutherskop	Lut 111	Hei/Dic	Potgieter's Place
↑	17 Navar	Nav 111	Equ sp	Elliot Quarry	"	"	" 211	Equ sp	Turner's Tributary (1)
"	"	"	Dic odo	"	"	"	" 221	"	Turner's Tributary (2)
18	Cala Road	Cal 111	Equ sp	Cala Cutting	"	"	" 311	Hei elo	Oom-Piet's Campsite
"	"	"	Dic/Sph	"	"	"	" 411	Equ sp	Orange View
"	"	" 211	Hei elo	Cala Bolders	"	"	" 412	Hei/Dic	"
19	Askeaton	Ask 111	Equ sp	–	"	"	" 511	Hei elo	Sonya's Hillock
20	Greenvale	Gre 111	Sph pon	<i>Equisetum</i> Cutting	37	Nuwejaarspruit	Nuw 111	Equ sp	Clara's Ditch
"	"	"	Equ sp	"	"	"	"	Dic zub	"
"	"	" 121	Hei elo	<i>Telemachus</i> Shale	"	"	" 211	Dic 2spp	Wolfy's Adit
21	Dordrecht	Dor 111	Hei elo	–	Ka 6	38 Winnaarspruit	Win 111	Hei elo	–
↓					39	Qualasi Hill	Qua 111	Dic odo	–
					40	Morija	Mor 111	Dic zub	–
					41	Makoaneng	Mak 111	"	–
					42	Mazenod	Maz 111	Dic cra	Luka
					"	"	" 211	Hei/Dic	Lechesa
					Ka 1	43 Golden Gate	Gol 111	Dic dub	–

From And. & And. (2003, tab.5, p.9)

Superlocalities: numbered in clockwise order around the Molteno outcrop (see map opposite)

Supersites: arranged chronologically, within each superlocality, according to date of discovery (earliest above)

Assemblages: arranged stratigraphically for each supersite (youngest above)

Informal names: all distinct supersites within a superlocality have been given a familiar name for ease of communication (assemblages within a supersite retain only the formal code name)

Extensiveness of sampling

10 degree squares/subregions (ca 100 km diam. grid)

43 superlocalities (10 km diam. grid)

69 localities (1 km diam. grid)

80 sublocalities (100 m diam. grid)

85 supersites (10 m diam. grid)

100 assemblages (taphocoenoses, TCs)

■ The 26 Molteno TCs with *Rochipteris* & affiliates

● TCs with attached fruiting and/or foliage specimens

♀ TCs with *Kannaskoppia*

♂ TCs with *Kannaskoppianthus*

Note: our collection from Pen 222 is combined with Pen 221 (they are taken as representing the same assemblage); likewise, Kon 221 is combined with Kon 211.

Chart 4. MOLTENO Fm., ECOLOGICAL OCCURRENCE.

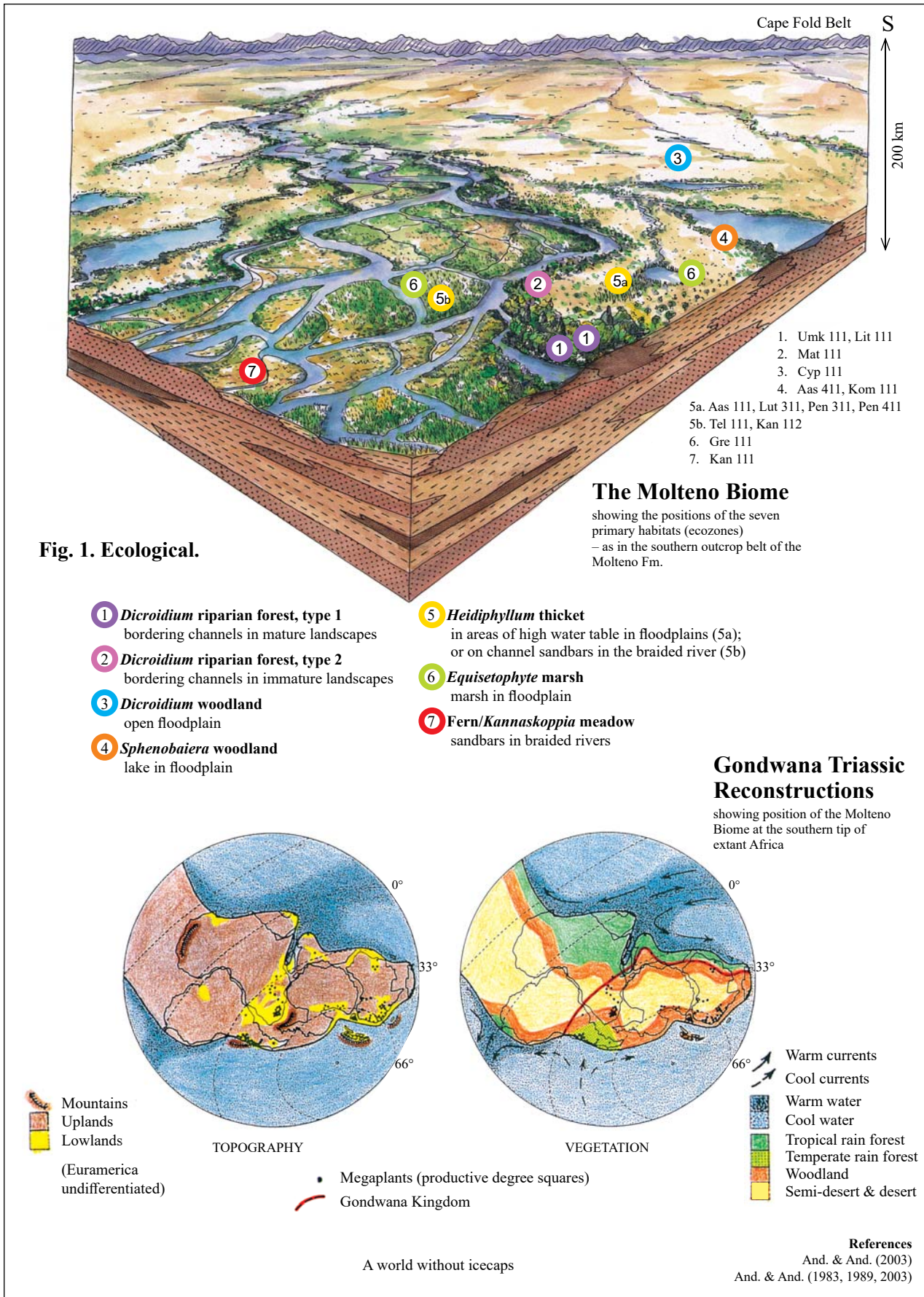
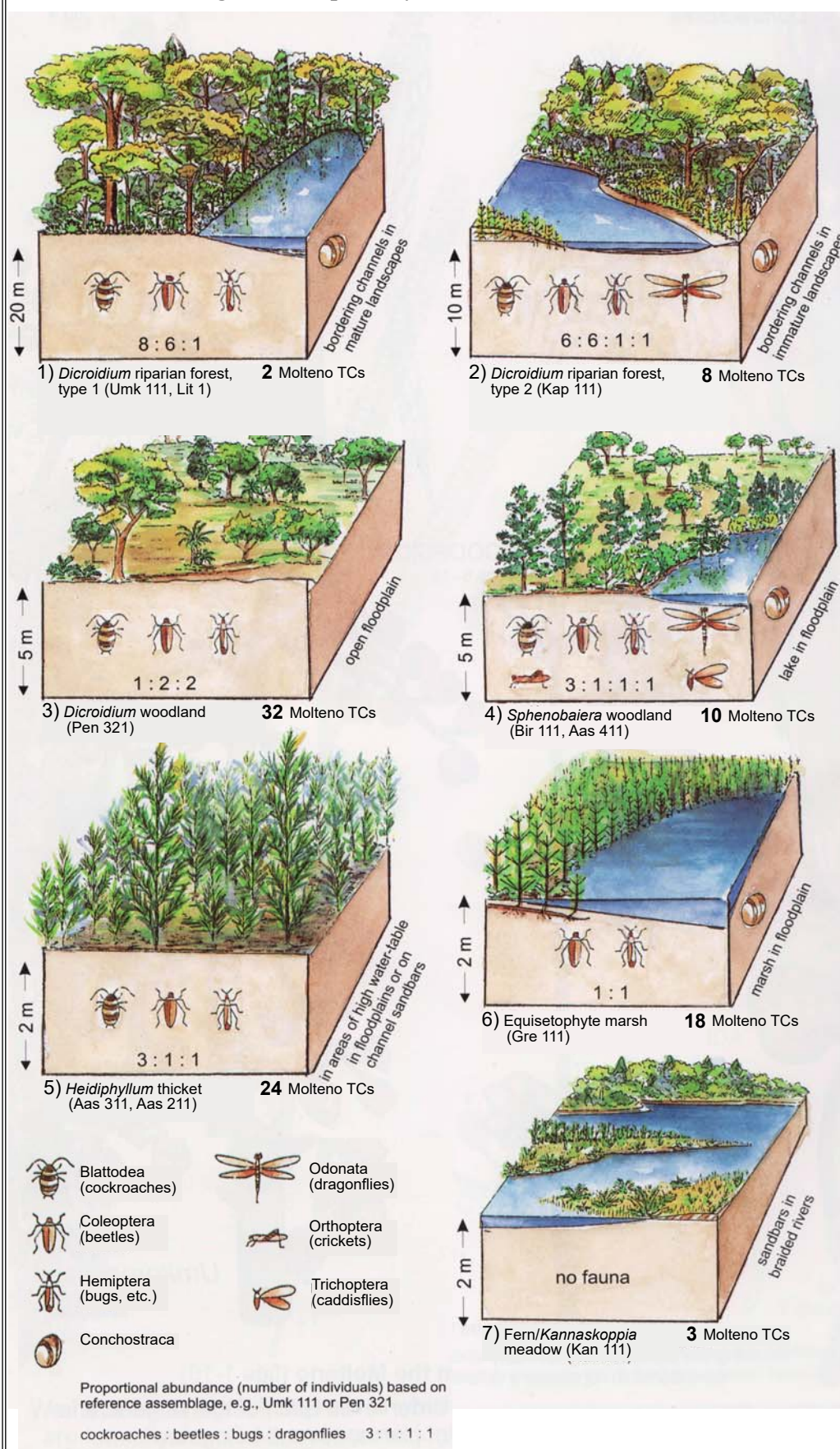


Fig. 2. Seven primary habitats of the Molteno.**Seven primary habitats**

Near the centre of Gondwana at around 50°S in a world without icecaps, lay the diversely vegetated Molteno Biome. It occupied an extensive inland basin spreading some 1000 km N-S between the upland hillslope of the Kaapvaal Craton to the north and the actively folding Cape Mountains to the south. Across the central portion of this depositional basin (the preserved remnant of the Molteno Fm.), we recognize the seven primary habitats illustrated here (Cairncross, And. & And., 1995, figs 12, 13).

Plants (comprising the 7 habitats)

A considerable diversity of plants made up the flora of these seven habitats. We currently recognize 211 vegetative species (Chart 3, p. xii), with a statistically calculated *c.* 876 species preserved in the Molteno Formation, and an estimated 2000 species existing in the Late Triassic Molteno Biome (as projected from the 204 species as recognized in 1999). This species-level (gymnosperm-dominated) diversity would be similar to that growing in an equivalent (though angiosperm-dominated) environment in the extant world (And., And., Fatti & Sichel, 1996; And. J.M., 1999).

Insects (reflecting the 7 habitats)

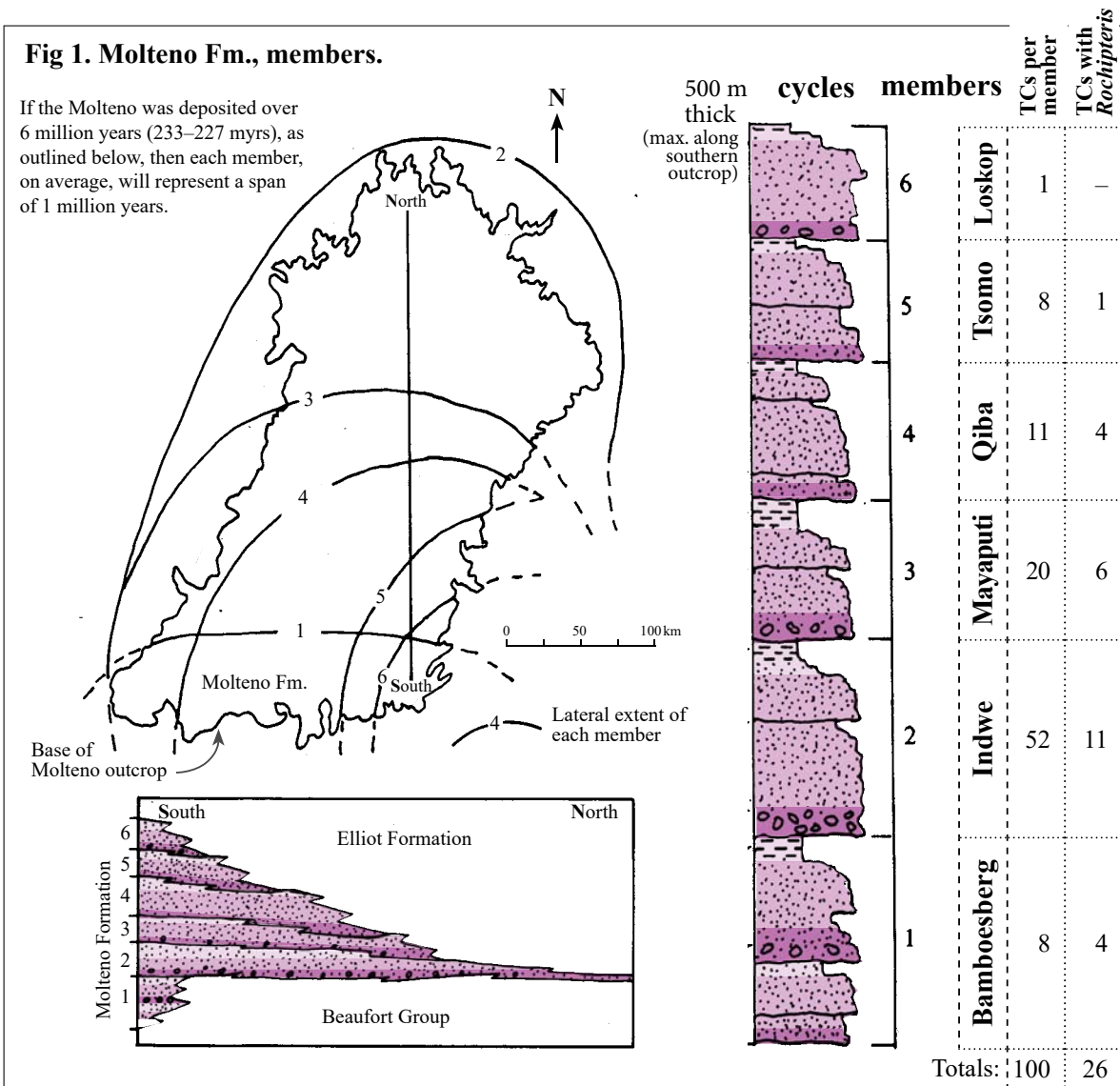
The Molteno insect collection is sufficiently numerous (*c.* 2300 individuals) and diverse (*c.* 350 species) to reveal a distinctive pattern of occurrence (or signature) for the four most prominent insect orders – cockroaches, beetles, bugs and dragonflies – in the seven habitats. Total diversity in the basin at the time of deposition is statistically estimated at 20 000 species. The insect tally – considering all 16 orders found – is shown in the following pages for the 26 TCs covered in this volume (And., Kohring & Schluter, 1998).

Conchostraca (scarce but revealing)

These small, mainly freshwater crustaceans, after the insects, are the most significant faunal element in the Molteno. With some three genera (8 species), they are known from 20 plant assemblages – in several cases ‘in relative abundance on certain bedding planes’. Though they have been found in deposits associated with most habitats, their occurrence is uneven: being most abundant in riparian forest TCs (types 1 and 2) and *Sphenobaiera* woodland TCs (And., And. & Cruickshank, 1998, tabs 3, 4, p. 401; Kohring, 1998).

Adapted from:
And. J.M. (1999, p. 79)

Chart 5. MOLTENO Fm., STRATIGRAPHIC OCCURRENCE.



Molteno Fm., age & duration

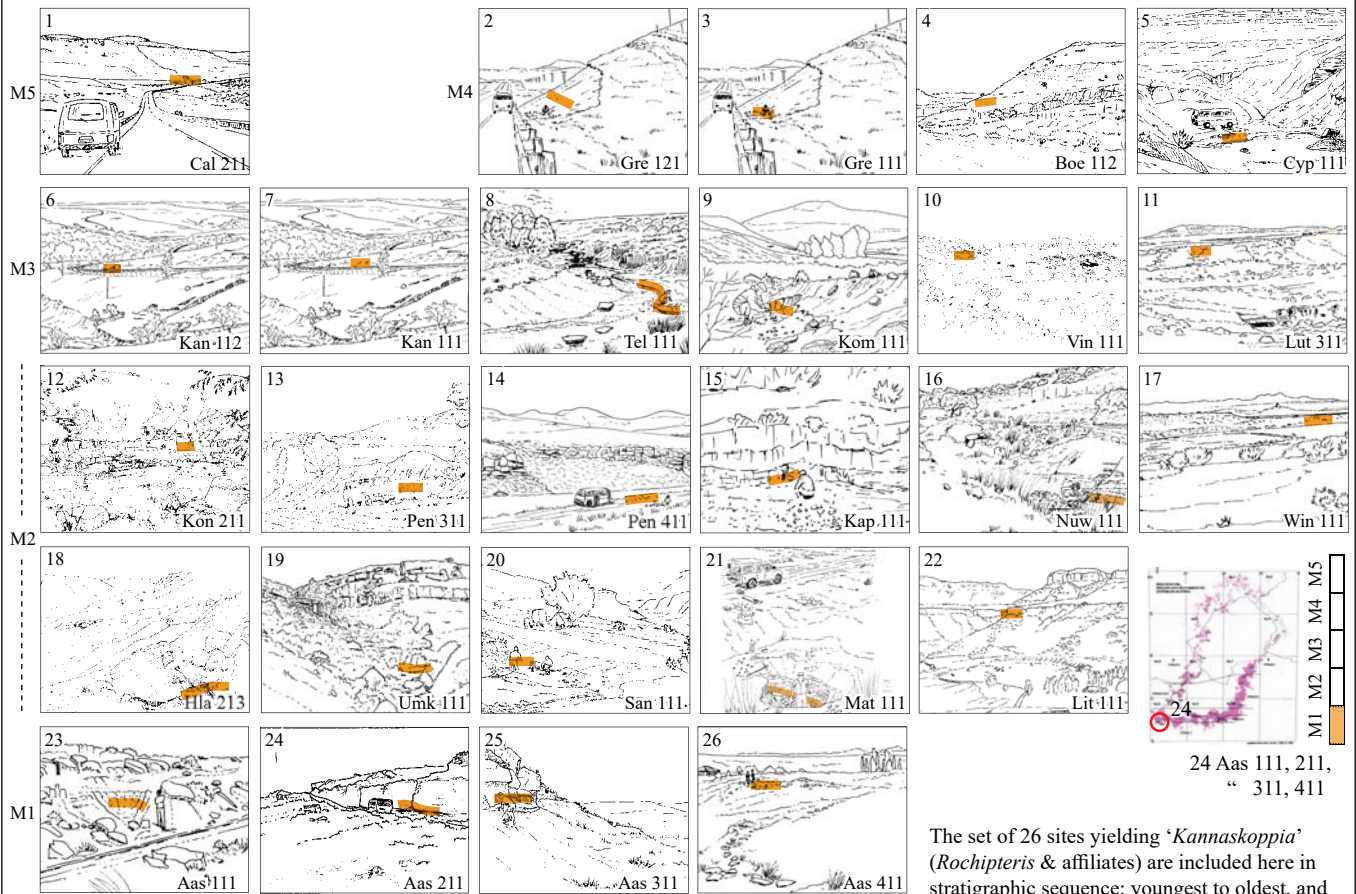
In the absence of any radiometric dates, no precise positioning of the Molteno is possible. Our updated Gondwana Triassic (GTr) correlation chart (Fig. 2, p. 5) shows the Molteno as occupying the later half of the Carnian, the Tuvanian, from 233–227 million years (an interval of 6 myrs). This is based on the correlation of plants through the GTr, and on its lithostratigraphic position within the Karoo Supergroup between the tetrapod-bearing strata of the *Cynognathus* Zone below and the Elliot Fm. above (see Smith *et al.*, 2020).

The *Cynognathus* Zone: As with the Molteno, there are still no radiometric dates for the *Cynognathus* Zone, and the placing of it in the Lower to Middle Triassic, from the late Olenekian to the end of the Ladinian, possibly just into the Carnian, is based on the global correlation of tetrapod faunas (Hancoxno *et al.*, 2020).

The Elliot Fm.: Until very recently, there were likewise no radiometric dates for the Elliot Fm. Now, with their comprehensive revision of the bio- and lithostratigraphy of the formation, Bordy *et al.* (2020) record a number of good U-Pb dates. These, together with their magneto-stratigraphic studies, have enabled them to constrain the formation far more confidently than previously. They plot the Elliot as running from around the mid-Norian in the Upper Triassic (at 220 Ma) to the close of the Sinemurian in the Lower Jurassic (at c. 191 Ma) – a duration of 29 myrs.

It is significant to note that disconformities separate the Molteno from these tetrapod-bearing strata above and below. Based on the current correlations of the *Cynognathus* Zone (ending at c. 237 Ma) and the Elliot Fm. (starting at c. 220 Ma), the maximum possible duration of the Molteno would be 17 myrs. However, considering the disconformities, it is clearly some degree less. Until radiometric dates are obtained for the Molteno, and based on current GTr plant correlations (which need major revision, including palynology), the formation is plotted in Fig. 2 (p. 5) as running 6 million years from 233–227 Ma, the duration of the Tuvanian. (In the previous Molteno volumes, the Fm. has been plotted as spanning 2 million years.)

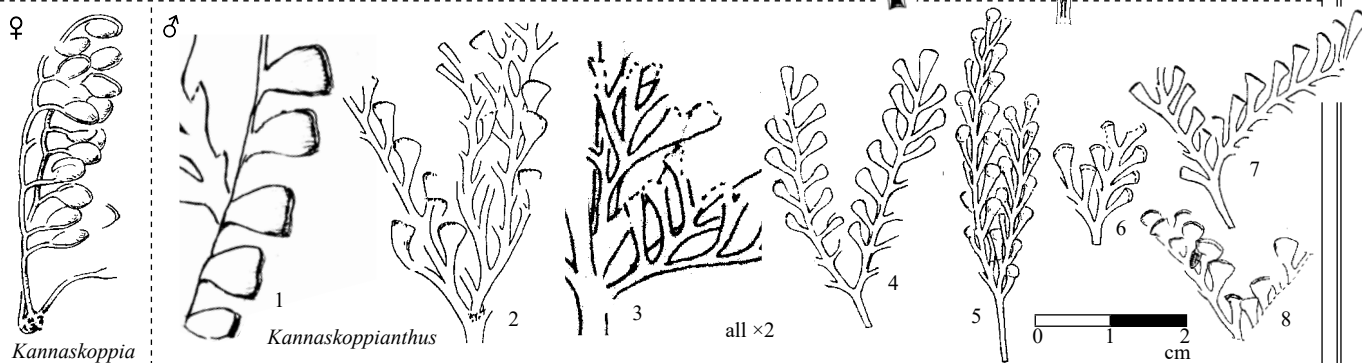
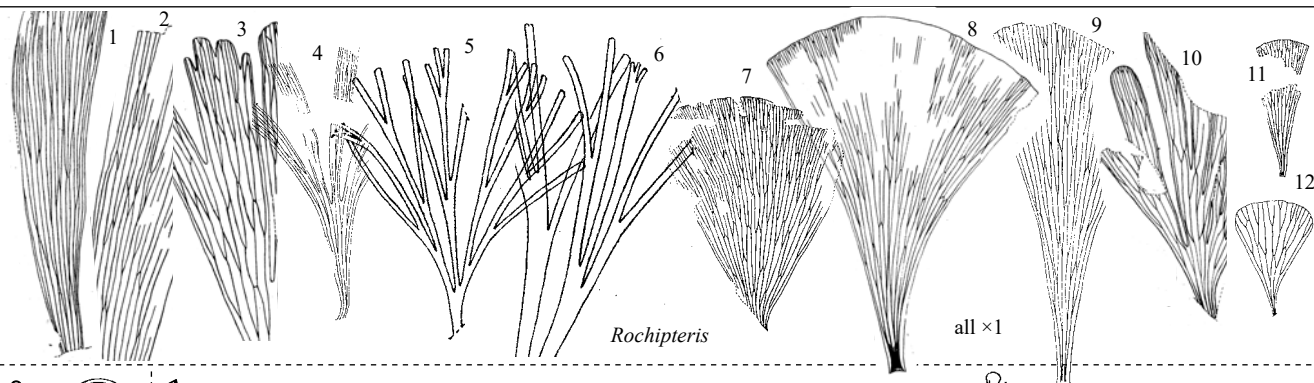
From the global perspective, and based on the above correlations, the Molteno was deposited in the wake of the Carnian Pluvial Episode (CPE), and following the Extinction event midway through the Carnian (separating the Julian and Tuvanian substages). Early in the Tuvanian, “about 232 million years ago, the dinosaurs diversified explosively, so the CPE essentially marks the beginning of the ‘age of dinosaurs’ Further, and perhaps unexpectedly, this time also marks the initial expansion of nearly all modern tetrapod groups, including turtles, crocodiles, lizards and mammals.” (Ruffell *et al.*, 2018). The explosive diversification of plants and of insects as found in the Molteno, would appear to correlate closely with this explosive diversification of the tetrapods!

Fig. 2. Key to the 26 Molteno ‘*Kannaskoppia*’ sites.

1 M5 Cal 211 Hei elo	2 M4 Gre 121 Hei elo	3 Gre 111 Equ sp	4 Boe 112 Dic cor	5 Cyp 111 Dic cra
6 M3 Kan 112 Hei elo	7 Kan 111 Ast spA	8 Tel 111 Hei elo	9 Kom 111 Sph/Dic	10 Vin 111 Dic odo
11 Lut 311 Hei elo	12 Kon 211 Ast 2 spp	13 Pen 311 Hei elo	14 Pen 411 Hei elo	15 Kap 111 Dic/Ris
16 Nuw 111 Dic zub	17 Win 111 Hei elo	18 Hla 213 Dic elo	19 Umk 111 Dic 2 spp	20 San 111 Dic cra
21 Mat 111 Dic dub	22 Lit 111 Dic/Hei	23 Aas 111 Hei elo	24 Aas 211 Hei elo	25 Aas 311 Hei elo
26 Aas 411 Dic/Sph	Here are shown the primary affiliation between ♂ and strobili at each of the 26 sites 1 <i>Dicroidium</i> riparian forest, type 1 2 <i>Dicroidium</i> riparian forest, type 2 3 <i>Dicroidium</i> woodland 4 <i>Sphenobaiera</i> woodland 5 <i>Heidiphyllum</i> thicket 6 Equisetophyte marsh 7 Fern/<i>Kannaskoppia</i> meadow			

Chart 6. *ROCHIPTERIS* & AFFILIATES – MOLTENO OCCURRENCE.

		Foliage species (1–12)												Male species (1–8)													
TCS	assemblages (taphocoenosis)	Members	<i>Rochepteris</i> (Ref. pal)	<i>R. vincularis</i> (Kan 111)	<i>“ telefolia</i> (Tel 111)	<i>“ distivena</i> (Kan 112)	<i>“ rollerii</i> (Aas 111)	<i>“ switzifolia</i> (Lit 111)	<i>“ matatifolia</i> (Mat 111)	<i>“ komifolia</i> (Kom 111)	<i>“ lutifolia</i> (Lut 311)	<i>“ obtriangulata</i> (Umk 111)	<i>“ cf. sinuosa</i> (Umk 111)	<i>“ penensis</i> (Pen 411)	<i>“ pusilla</i> (Pen 311)	<i>“ sp</i>	+O <i>Kannaskoppla</i>	♂ <i>Kannaskopplanthus</i> microsporangia	<i>K. telemagnus</i> (Tel 111)	<i>“ irregularis</i> (Kan 112)	<i>“ aasvoelensis</i> (Aas 111)	<i>“ switzianthus</i> (Lit 111)	<i>“ matatiparvus</i> (Mat 111)	<i>“ komanthus</i> (Kom 111)	<i>“ lutinumerus</i> (Lut 311)	<i>“ telepentatus</i> (Tel 111)	attached organs
1	Cal 211 Hei elo	Qiba	5	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	Gre 121 Hei elo		4	22	–	–	–	22	–	–	–	–	–	–	–	–	–	–	2	1	–	–	2	–	–	–	–
3	“ 111 Equ sp			1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
4	Boe 112 Dic cor			1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
5	Cyp 111 Dic cra	Mayaputi	83	2	–	–	–	1	–	–	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
6	Kan 112 Hei elo		3	19	–	2	4	10	–	–	–	–	–	–	2	1	–	–	5	1	–	5	–	–	–	–	–
7	“ 111 Ast spA			5	5	–	–	–	–	–	–	–	–	–	–	–	–	–	50	–	–	–	–	–	–	–	–
8	Tel 111 Hei elo			33	–	30	–	–	–	–	–	–	–	–	–	2	1	–	–	4	1	2	–	–	–	–	2
9	Kom 111 Sph/Dic			30	–	–	–	–	1	–	29	–	–	–	–	–	–	–	–	2	1	–	–	–	2	–	–
10	Vin 111 Dic odo			2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	Lut 311 Hei elo	66	–	–	–	–	–	–	–	66	–	–	–	–	–	–	–	16	–	–	–	–	–	16	–		
12	Kon 211 Ast 2spp	Indwe	f	5	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	Pen 311 Hei elo		41	–	–	–	34	–	–	–	–	–	–	–	5	2	–	–	–	–	–	–	–	–	–	–	
14	“ 411 “ “		80	–	–	–	70	–	–	–	–	–	–	–	10	–	–	–	4	–	–	4	–	–	–	–	
15	Kap 111 Dic/Ris		e	6	–	–	2	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
16	Nuw 111 Dic zub		d	3	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
17	Win 111 Hei elo		2	5	–	–	–	3	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	
18	Hla 213 Dic elo		b	8	–	–	–	4	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
19	Umk 111 Dic 2spp		50	–	–	–	21	–	–	–	–	1	19	9	–	–	–	–	–	–	–	–	–	–	–	–	
20	San 111 Dic cra		3	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
21	Mat 111 Dic dub		a	2	–	2	–	–	–	17	–	–	–	–	–	–	–	–	3	–	–	–	3	–	–	–	
22	Lit 111 Dic/Hei	Bamboesberg	56	1	–	–	–	55	–	–	–	–	–	–	–	–	–	9	2	–	–	9	–	–	–	–	
23	Aas 111 Hei elo		1	2	–	–	–	2	–	–	–	–	–	–	–	–	–	–	21	5	–	21	–	–	–	–	
24	“ 211 Hei elo		19	1	–	–	18	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	
25	“ 311 Hei elo		26	1	–	–	25	–	–	–	–	–	–	–	–	–	–	–	4	1	–	4	–	–	–	–	
26	“ 411 Dic/Sph	150	–	–	–	150	–	–	–	–	–	–	–	–	–	–	–	21	4	–	21	–	–	–	–	–	
	Total TCS		26	7	3	2	14	4	1	1	5	1	2	4	4	1	1	12	8	1	1	6	1	1	1	1	
	Total individuals		%	%	%	6	%	61	17	29	151	19	10	19	5	1	50	92	16	2	5	53	9	3	2	16	



Dominants

Dicroidium

Sphenobaiera

Heidiphyllum

Horsetails

Ferns

varied scales

Key

Key
Abundance
***5 (bold)** – %
22 (mild) – individuals
* number of *Rochipteris*
indivs. indicated under
descriptions for each
species.

 *Kannaskoppia* – 1TC
 *Kannaskoppianthus* – 12TCs

In a subsequent volume on the insects and other fauna (spiders, Conchostraca, fish impressions, etc., but no tetrapod bones, see And. & And. (2018, chart 7, pp 14, 15)) found in the Molteno series, a full account of the insect fauna and the plant–insect interactions will be given. Conrad Labandeira, who has spent a considerable amount of time on this research (see Acknowledgements, p. vii, and Bibliography, p.318), will play a key role in the latter. (See Labandeira, 2006; Labandeira *et al.*, 2007; Labandeira, And. & And., 2018).

Chart 7. THE 26 MOLTENO PETRIELLACEAE SITES.

27°40.68'E; 31°21.81'S

Heidiphyllum thicket



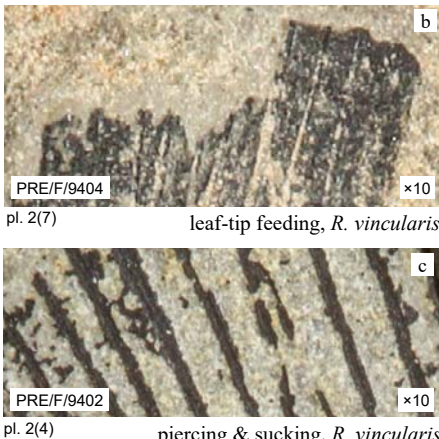
Fig. 1. Cala Road (Cal 211 Hei elo), Cala Bolders.

Habitat: *Heidiphyllum* thicket
Collection: 21 slabs, 2 man-hrs cleaving;
impressions in thickly laminated, medium grey shale,
good cleavage.
Dominants: *Heidiphyllum* 75%, ferns 20%
Biodiversity: vegetative total, 3 spp
Non-gymnosperms: 1 sp
Gymnosperms: 2 spp
Petriellaceae:
Rochipteris vincularis 5%
(8 slabs, 8 indivs, no clusters)

Ref. pal
Kan 111 Ast spA

Taphonomy – parautochthonous

Insects	indivs
nil in 2 man-hrs	
Blattodea (cockroaches)	– 0
Coleoptera (beetles) <i>et alii</i>	– 0
	nil
Plant–insect interaction	
• leaf-margin feeding – ✓	
• leaf-tip feeding – ✓	
• piercing & sucking – ✓	
• leaf mining – •	
• oviposition – •	
✓ – 1 indiv.	
• – nil	
(see glossary, p. 323)	



27°08.94'E; 31°23.62'S

Heidiphyllum thicket

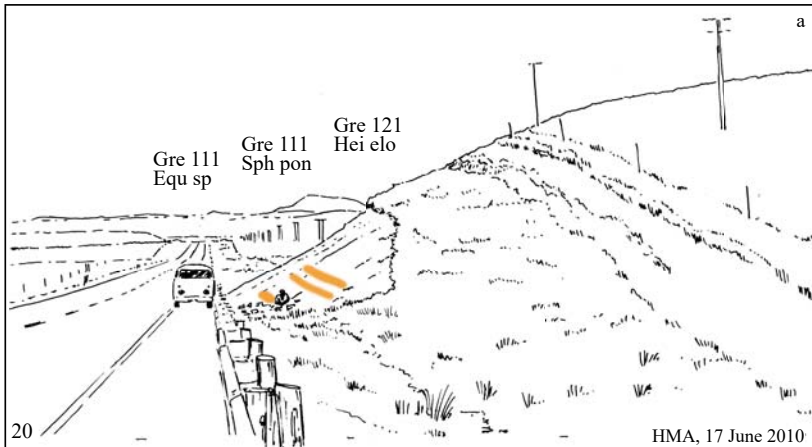
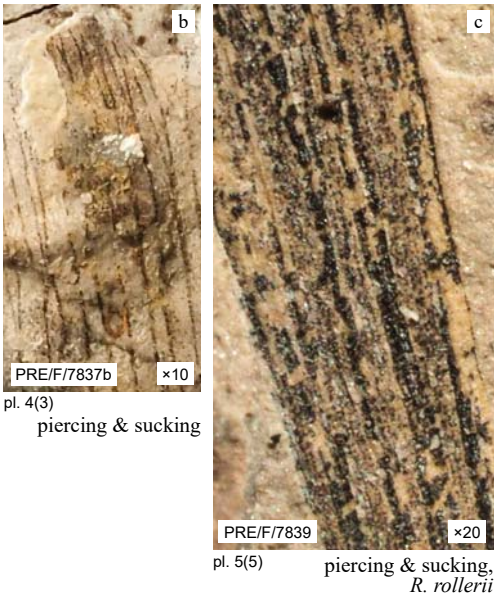


Fig. 2. Greenvale (Gre 121 Hei elo), *Telemachus* Shale.

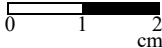
Habitat: *Heidiphyllum* thicket
Collection: 141 slabs, 10 man-hrs cleaving;
impressions in thickly laminated, medium grey shale, good cleavage.
Dominants: *Heidiphyllum* 98%
Biodiversity: vegetative total, 7 spp
Non-gymnosperms: 3 spp
Gymnosperms: 4 spp
Petriellaceae:
Rochipteris rollerii (22 indivs)*
Kannaskoppianthus aasvoelensis (2 indivs)*
– microsporangia (1 indiv.)

Ref. pal
Aas 111 Hei elo
Aas 111 Hei elo

***Affiliation** ♂♂ (grade 4)
– the same affiliation occurs at five other sites (four also being *Heidiphyllum* thicket):
Pen 411 Hei elo, Aas 111 Hei elo, Aas 211 Hei elo, Aas 311 Hei elo, Aas 411 Dic/Sph
Taphonomy – parautochthonous

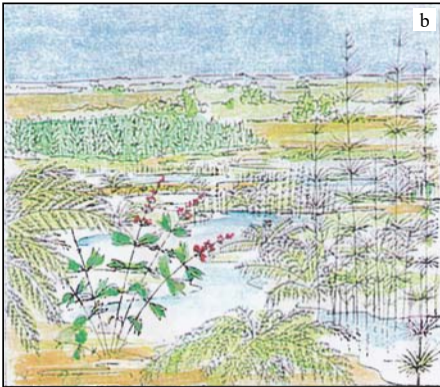
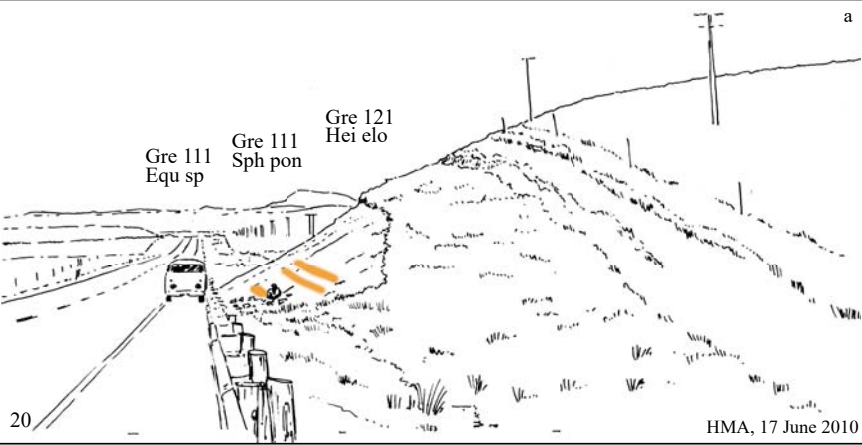


Insects	indivs
nil in 10 man-hrs	
Blattodea (cockroaches)	– 0
Coleoptera (beetles) <i>et alii</i>	– 0
	nil
Plant–insect interaction	
• leaf-margin feeding – •	
• leaf-tip feeding – ✓	
• piercing & sucking – ✓	
• leaf mining – •	
• oviposition – •	



27°09.6'E; 31°23.70'S

Equisetophyte marsh



Gontriglossa/Nataligma



pl. 7(6) leaf-tip feeding, *R. sp indet.*

Fig. 3. Greenvale (Gre 111 Equ sp), *Equisetum* Cutting.

Habitat: Equisetophyte marsh

Collection: 213 slabs, 25 man-hrs cleaving; impressions in thickly laminated, medium grey shale, good cleavage.

Dominants: horsetails 97%, *Dicroidium* 2%

Biodiversity: vegetative total, 10 spp

Non-gymnosperms: 5 spp

Gymnosperms: 5 spp

Petriellaceae:

Rochipteris sp (1 indiv.)

Taphonomy – allochthonous

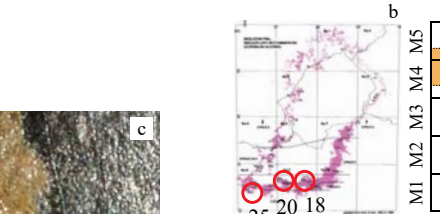
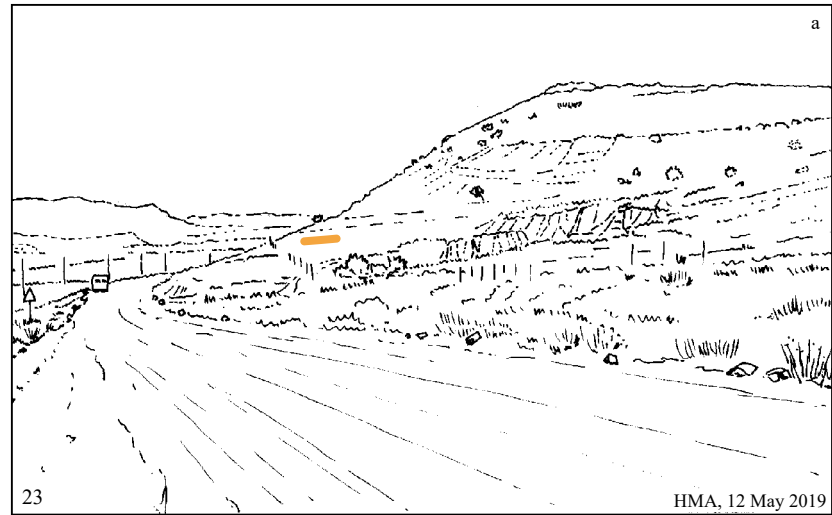
Insects	indivs
1 per 5 man-hrs (rare)	
Homoptera (bugs)	– 2
Mecoptera (scorpionflies)	– 1
Coleoptera (beetles)	– 2
	5

Plant–insect interaction

- leaf-margin feeding – •
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – •

26°08.44'E; 31°29.38'S

Dicroidium open woodland



18 Cal 211
20 Gre 111, 121
25 Boe 112



pl. 8(6) leaf-margin feeding, *R. pusilla*

Fig. 4. Boesmanshoek Pass (Boe 112 Dic cor), *Coriaceum* flats.

Habitat: *Dicroidium* open woodland

Collection: 179 slabs, 6 man-hrs cleaving; impressions in thinly laminated, buff-grey shale with moderate cleavage.

Dominants: *Dicroidium* 99%

Biodiversity: vegetative total, 12 spp

Non-gymnosperms: 1 sp

Gymnosperms: 11 spp

Petriellaceae:

Rochipteris pusilla (1 indiv.)

Ref. pal.

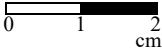
Pen 311 Hei elo

Taphonomy – allochthonous

Insects	indivs
nil in 6 man-hrs	
Blattodea (cockroaches)	– 0
Coleoptera (beetles) <i>et alii</i>	– 0
	nil

Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – •
- piercing & sucking – •
- leaf mining – •
- oviposition – •



26°25.88'E; 31°27.14'S

Dicroidium open woodland

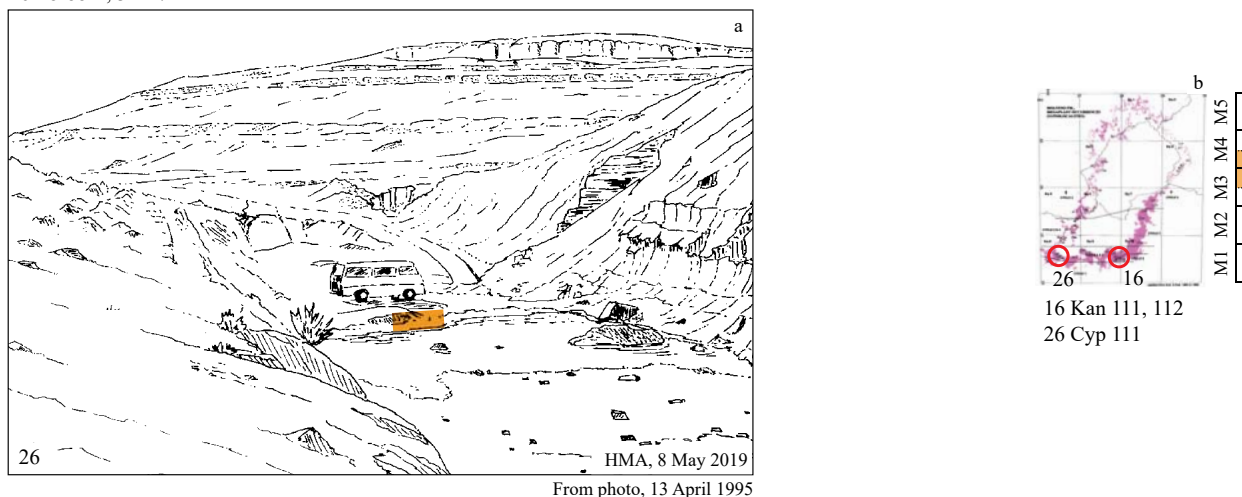


Fig. 5. Cyphergat (Cyp 111 Dic cra), Open cast.

Habitat: *Dicroidium* open woodland

Collection: 362 slabs, 100 man-hrs cleaving; impressions in thickly laminated dark-grey shale with moderate cleavage.

Dominants: *Dicroidium* 75%, *Heidiphyllum* 24%

Biodiversity: vegetative total: 12 spp

Non-gymnosperms: 4 spp

Gymnosperms: 8 spp

Petriellaceae:

Rochipteris 3 spp (83 indivs)
 “ *vincularis* (2 indivs)
 “ *switzifolia* (1 indiv.)
 “ *lutifolia* (80 indivs)*

Ref. pal.

Kan 111 Ast spA
 Lit 111 Dic/Hei
 Lut 111 Dic cra

***Attachment** 011

K. lutifolia – attached to shoot, ?1 indiv.
 – clusters of 2–10 indivs, >10 slabs
 – cluster of 12 indivs, 1 slab

Taphonomy

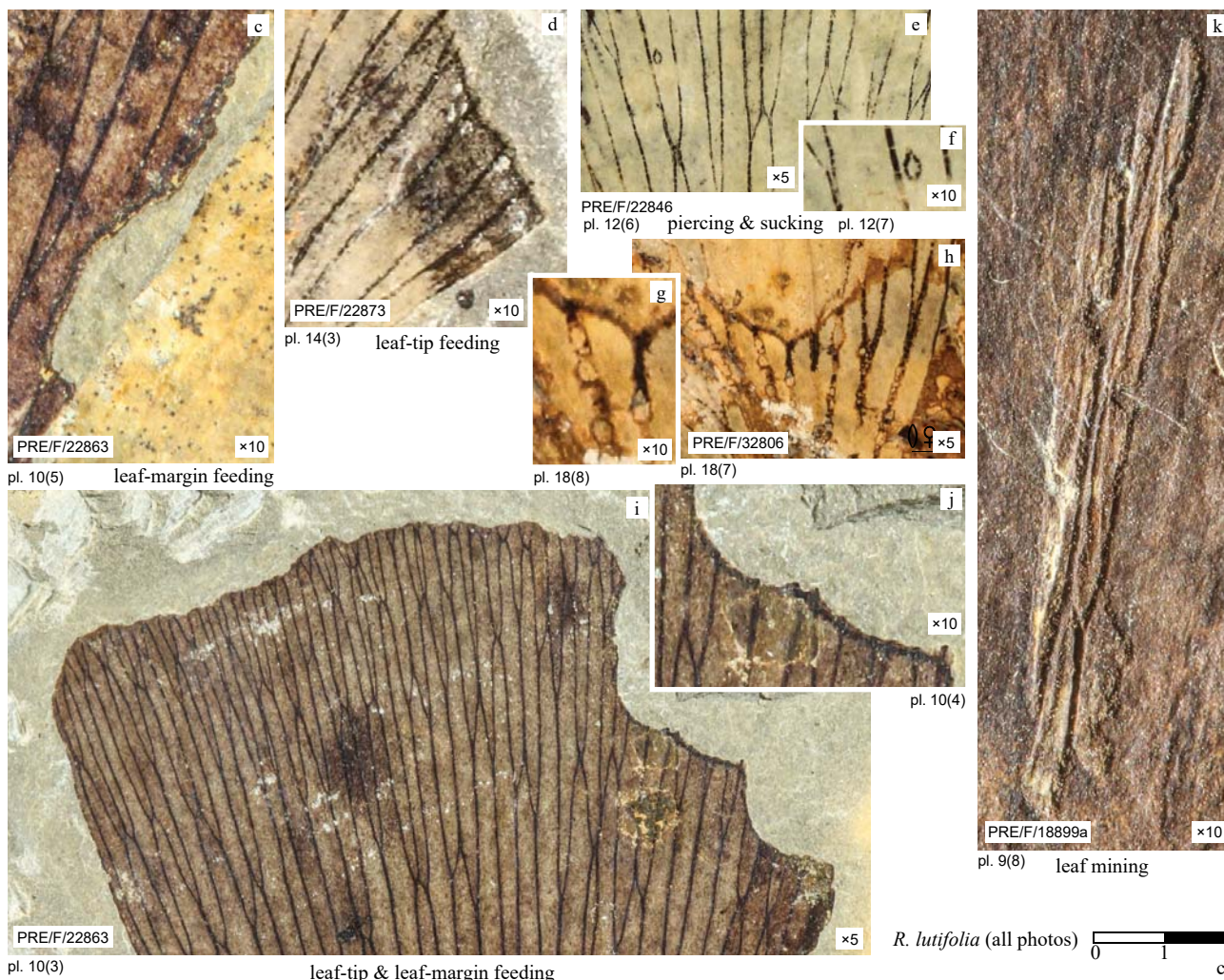
**K. lutifolia* – parautochthonous
 other 2 spp – allochthonous

Insects **indivs**

1 per 3 man-hrs (rare)
 Blattodea (cockroaches) – 5
 Orthoptera (crickets *et alii*) – 2
 Homoptera (bugs) – 9
 Coleoptera (beetles) – 11
 Incertae – 3
 30

Plant–insect interaction

• leaf-margin feeding – ✓✓✓✓
 • leaf-tip feeding – ✓✓✓
 • leaf mining – ✓
 • piercing & sucking – ✓✓✓
 • oviposition – •



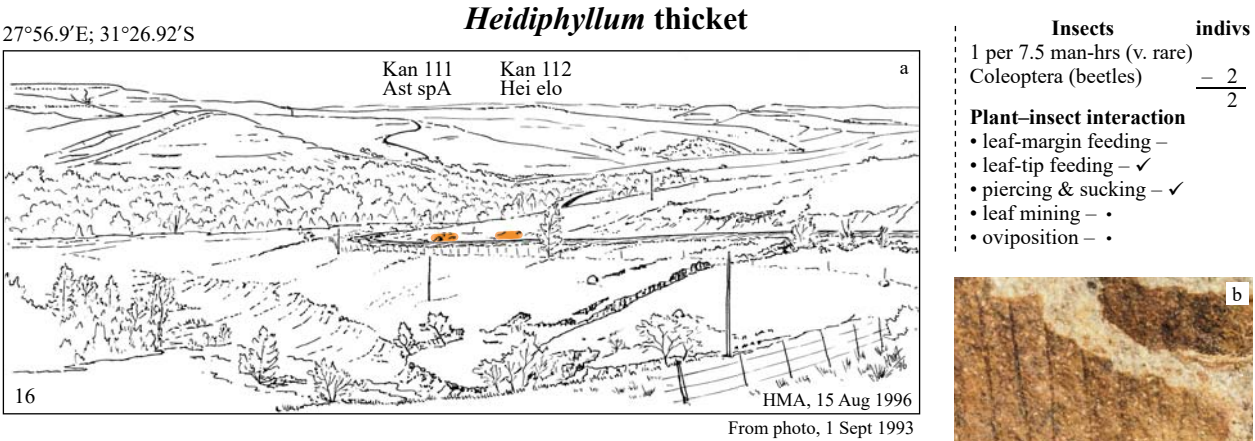


Fig. 6. Kannaskop (Kan 112 Hei elo), Upper End.

Habitat: *Heidiphyllum* thicket
Collection: 145 slabs, 15 man-hrs cleaving; impressions in very thinly bedded, moderately baked, medium-grey shale with poor cleavage.

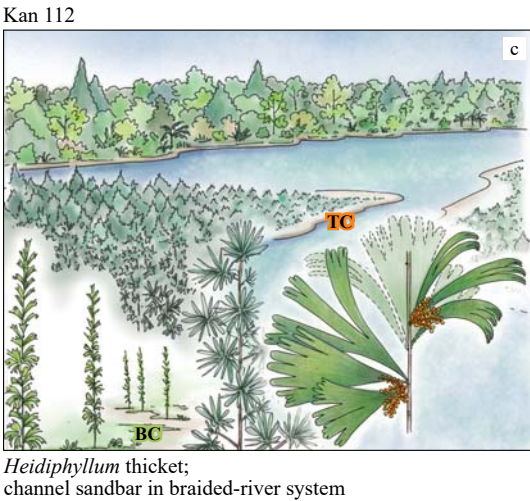
Dominants: *Heidiphyllum* 98%
Biodiversity: vegetative total, 13 spp
Non-gymnosperms: 4 spp
Gymnosperms: 9 spp

Petriellaceae:
Rochipteris 5 spp (19 indivs)
“ *telefolia* (2 indivs)
“ *distivena* (4 indivs)*
“ *rollerii* (10 indivs)
“ *penensis* (2 indivs)
“ *pusilla* (1 indiv.)
Kannaskoppianthus irregularis (5 indivs)*
– microsporangia (1 indiv.)

Ref. pal.
Tel 111 Hei elo
Kan 112 Hei elo
Aas 111 Hei elo
Pen 411 Hei elo
Pen 311 Hei elo
Kan 112 Hei elo

***Affiliation** ♂ (grade 3)
R. distivena/*K. irregularis*

Taphonomy
**K. distivena* – parautochthonous
other 4 spp – allochthonous



Fern/*Kannaskoppia* meadow

Fig. 7. Kannaskop (Kan 111 Ast spA), *Kannaskoppia* Siltstone.

Habitat: Fern/*Kannaskoppia* meadow
Collection: 365 slabs, 30 man-hrs cleaving; impressions in thickly bedded, moderately baked, greenish grey, silty mudstone, with very poor cleavage.

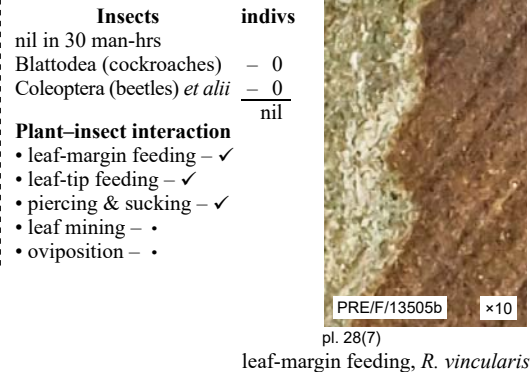
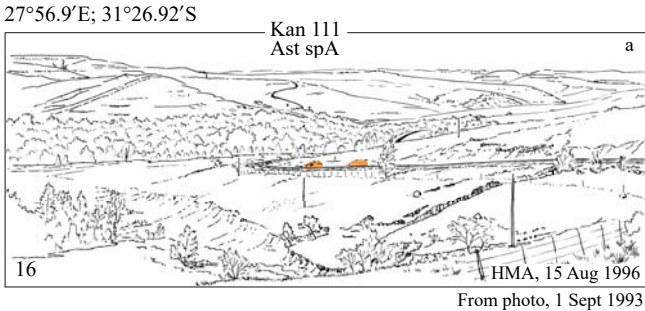
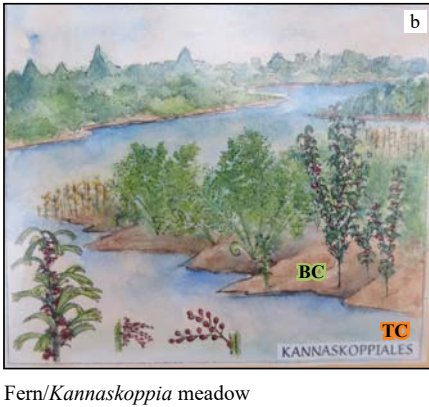
Dominants: ferns 63%, horsetails 22%, *Heidiphyllum* 10%
Biodiversity: vegetative total, 7 spp
Non-gymnosperms: 4 spp
Gymnosperms: 3 spp

Petriellaceae:
Rochipteris vincularis 5%*
Kannaskoppia vincularis (50 indivs)*

Ref. pal.
Kan 111 Ast spA
Kan 111 Ast spA

Attachment ♀ (grade 5 affiliation)
R. vincularis/*K. vincularis*
– mutual attachment, 4 indivs (3 slabs)

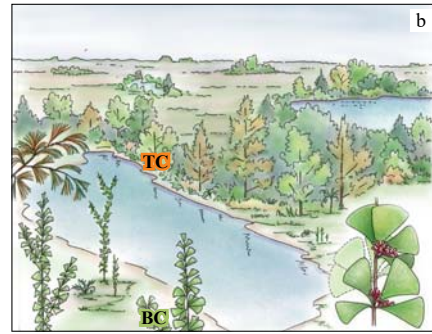
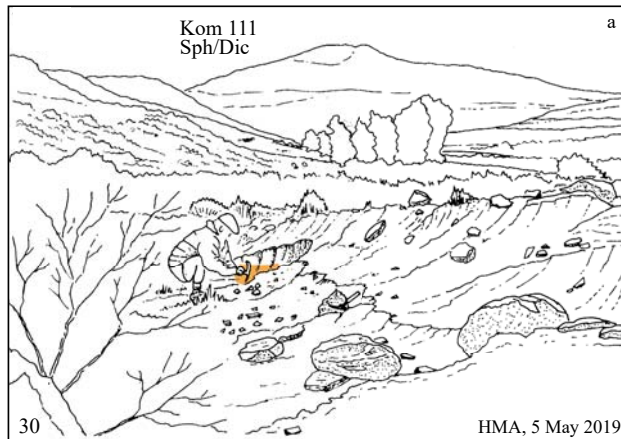
***Taphonomy** – autochthonous



***Dicroidium* open woodland**

26°33.13'E; 31°03.35'S

Kom 111

*Sphenobaiera* woodland (lake in floodplain)**Fig. 9. Kommandantskop (Kom 111 Sph/Dic).****Habitat:** *Sphenobaiera* woodland (lake in floodplain)**Collection:** 168 slabs, 10 man-hrs cleaving;

impressions in thickly laminated buff-grey shale with poor cleavage.

Dominants: *Sphenobaiera* 60%, *Dicroidium* 39%, ferns 1%**Biodiversity:** vegetative total: 7 spp

Non-gymnosperms: 3 spp

Gymnosperms: 4 spp

Petriellaceae:*Rochipteris* 2 spp (30 indivs)" *switzifolia* (1 indiv.)" *komifolia* (29 indivs)**Kannaskoppianthus komanthus* (2 indivs)*

– microsporangia (1 indiv.)

Ref. pal.

Lit 111 Dic/Hei

Kom 111 Sph/Dic

Kom 111 Sph/Dic

***Attachment** ♂ (affiliation grade 5)*K. komanthus*/*R. komifolia*

– mut.att. to shoot (2 slabs)

– clusters (several slabs)

Taphonomy – parautochthonous – autochthonous
allochthonous (*K. switzifolia*)

Insects	indivs
1 per 5 man-hrs (rare)	
Blattodea (cockroaches)	– 1
Coleoptera (beetles)	– 1
	– 2

Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – ✓
- leaf mining – •
- oviposition – •

***Dicroidium* open woodland**

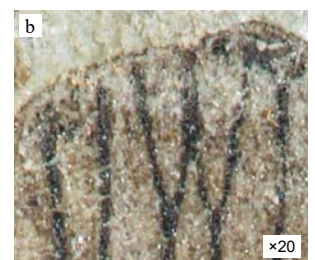
26°46.34'E; 30°56.41'S



Insects	indivs
nil in 10 man-hrs	
Blattodea (cockroaches)	– 0
Coleoptera (beetles) <i>et alii</i>	– 0
	– nil

Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – •

**Fig. 10. Vineyard (Vin 111 Dic odo), Homestead.****Habitat:** *Dicroidium* open woodland**Collection:** 166 slabs, 10 man-hrs cleaving;

impressions in thinly laminated grey shale with good cleavage.

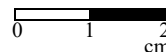
Dominants: *Dicroidium* 70%, *Heidiphyllum* 28%**Biodiversity:** vegetative total, 10 spp

Non-gymnosperms: 2 spp

Gymnosperms: 8 spp

Petriellaceae:*Rochipteris vincularis* (2 indivs)**Ref. pal.**

Kan 111 Ast spA

Taphonomy – allochthonous

Heidiphyllum thicket

26°56.84'E; 30°40.57'S

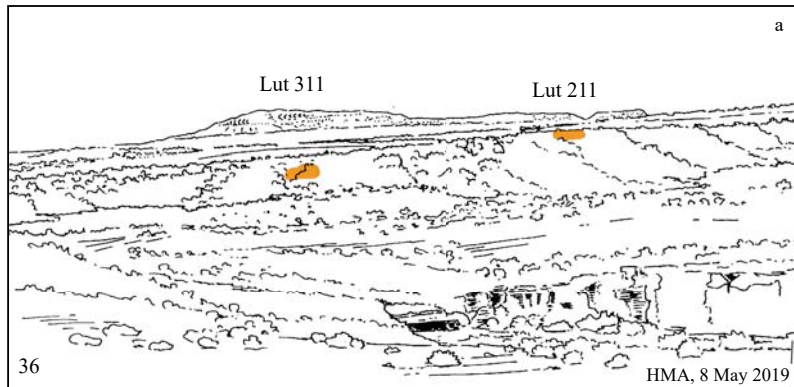


Fig. 11. Lutherskop (Lut 311 Hei elo), Oom Piet's campsite.

Habitat: *Heidiphyllum* thicket

Collection: 589 slabs, 50 man-hrs cleaving; impressions in thickly laminated, medium-grey shale with moderate cleavage.

Dominants: *Heidiphyllum* 99%

Biodiversity: vegetative total, 18 spp

Non-gymnosperms: 4 spp

Gymnosperms: 14 spp

Petriellaceae:

Rochipteris lutifolia (66 indivs)*

Kannaskoppianthus lutinumerus (16 indivs)*

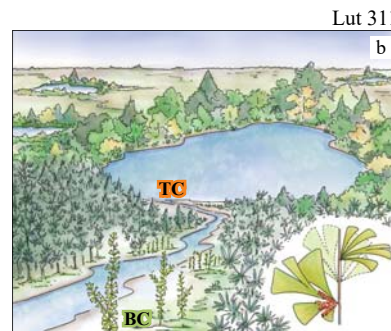
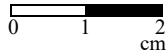
Ref. pal.

Lut 311 Hei elo

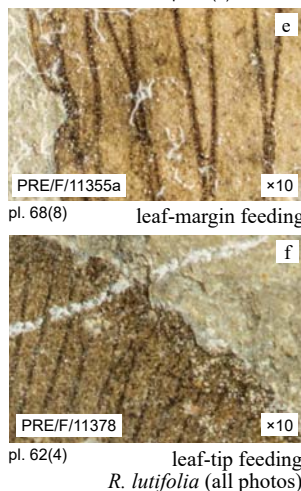
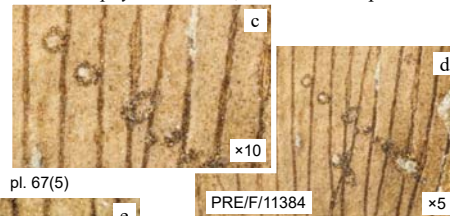
Lut 311 Hei elo

*Affiliation ♂ (grade 4; exclusive)

Taphonomy – parautochthonous



Heidiphyllum thicket, marsh in floodplain



pl. 67(4) piercing & sucking

Insects indivs

c. 1 per 2 man-hrs (rare)	
Paraplecoptera (extinct)	– 2
Blattodea (cockroaches)	– 6
Mantodea (mantids)	– 4
Orthoptera (crickets <i>et alii</i>)	– 2
Homoptera (bugs)	– 1
Mecoptera (scorpionflies)	– 1
Coleoptera (beetles)	– 2
	18

Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – ✓
- leaf mining – •
- oviposition – •

Fern/Kannaskoppia meadow

28°00.87'E; 31°29.32'S

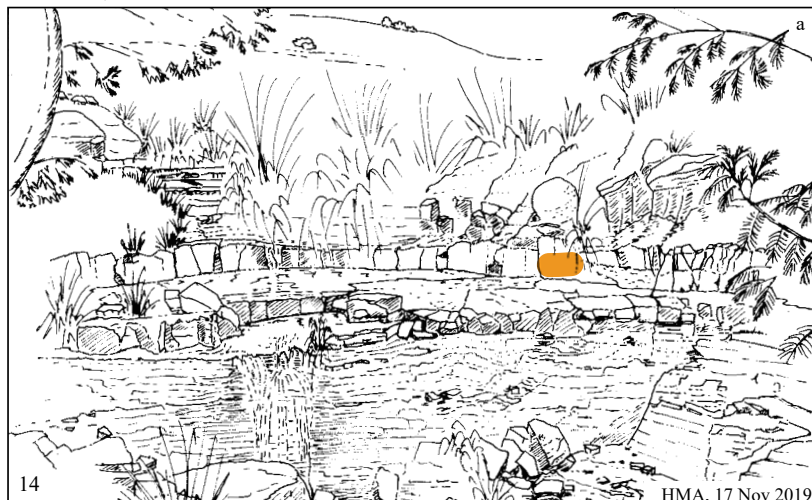


Fig. 12. Koningskroon (Kon 211 Ast 2spp), Rooipoort Donga.

Habitat: Fern/*Kannaskoppia* meadow

Collection: 393 slabs, 14 man-hrs cleaving; impressions in massive light-grey shale with poor cleavage.

Dominants: ferns 52%, horsetails 20%

Biodiversity: Vegetative total: 11 spp

Non-gymnosperms: 6 spp

Gymnosperms: 5 spp

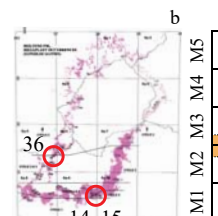
Petriellaceae:

Rochipteris rollerii (5 indivs)

Ref. pal.

Aas 111 Hei elo

Taphonomy – allochthonous



14 Kon 211
15 Pen 311, 411
36 Lut 311



PRE/F/10303a
pl. 70(2) leaf-tip feeding



pl. 70(9) *R. rollerii* (both photos)

Insects indivs

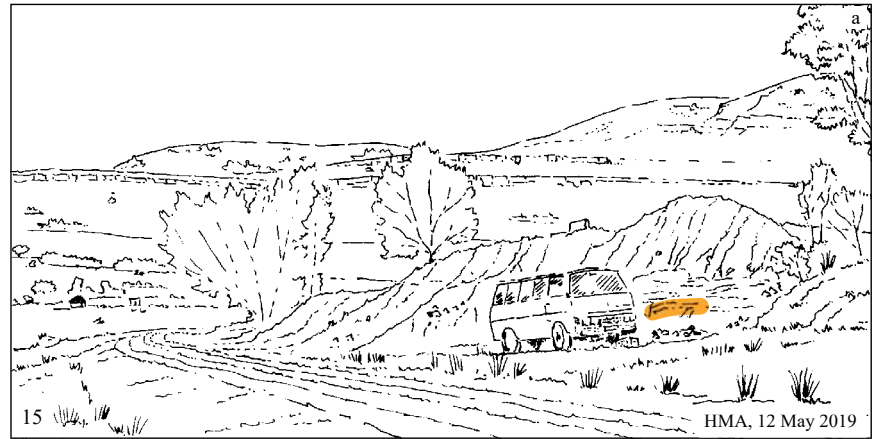
nil in 14 man-hrs	
Blattodea (cockroaches)	– 0
Coleoptera (beetles) <i>et alii</i>	– 0
	nil

Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – •

Heidiphyllum thicket

27°56.84'E; 31°29.59'S

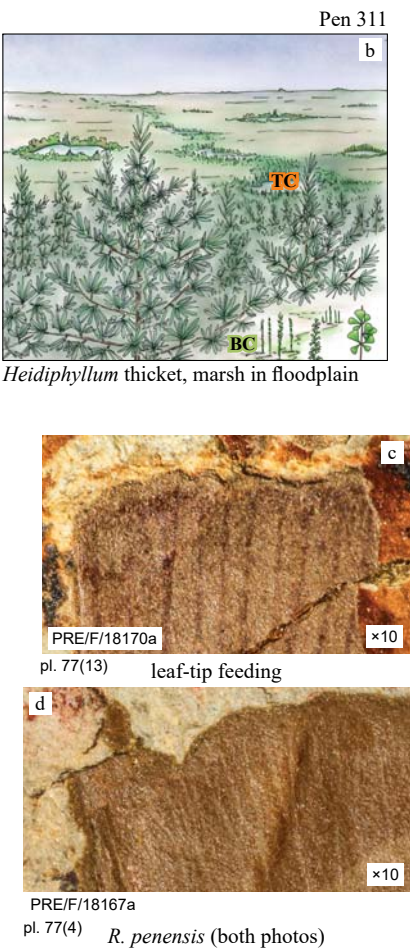


From photo, June 1992

Fig. 13. Peninsula (Pen 311 Hei elo), Campsite Quarry.

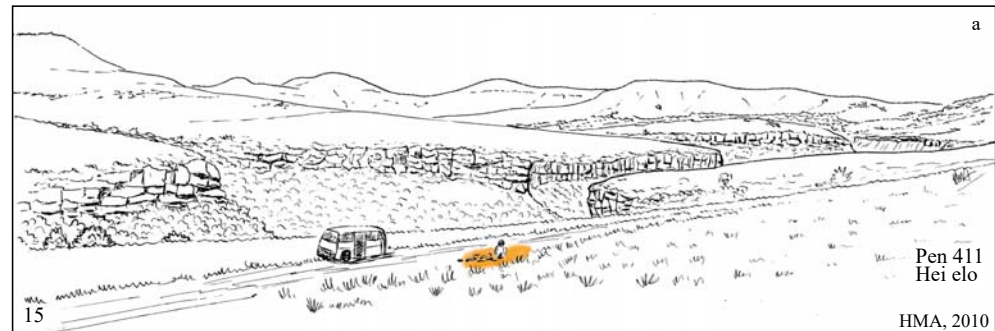
Habitat: *Heidiphyllum* thicket
Collection: 155 slabs, 35 man-hrs cleaving; impressions in thinly laminated buff shale.
Dominants: *Heidiphyllum* 75%, *Dicroidium* 25%
Biodiversity: vegetative total: 11 spp
Non-gymnosperms: 5 spp
Gymnosperms: 6 spp
Petriellaceae:
Rochipteris 3 spp (41 indivs)
 " *rollerii* (34 indivs)
 " *penensis* (5 indivs)
 " *pusilla* (2 indivs)
Ref. pal.
Aas 111 Hei elo
Pen 411 Hei elo
Pen 311 Hei elo
Taphonomy – *R. rollerii*, parautochthonous
 – other 2 spp, allochthonous

Insects	indivs
1 per 5 man-hrs (rare)	
Blattodea (cockroaches)	– 4
Coleoptera (beetles)	– 3
	7
Plant–insect interaction	
• leaf-margin feeding – •	
• leaf-tip feeding – ✓	
• piercing & sucking – •	
• leaf mining – •	
• oviposition – •	



27°56.78'E; 31°30.35'S

Heidiphyllum thicket



From photo, 13 Aug 1996

Fig. 14. Peninsula (Pen 411 Hei elo), Lunchspot.

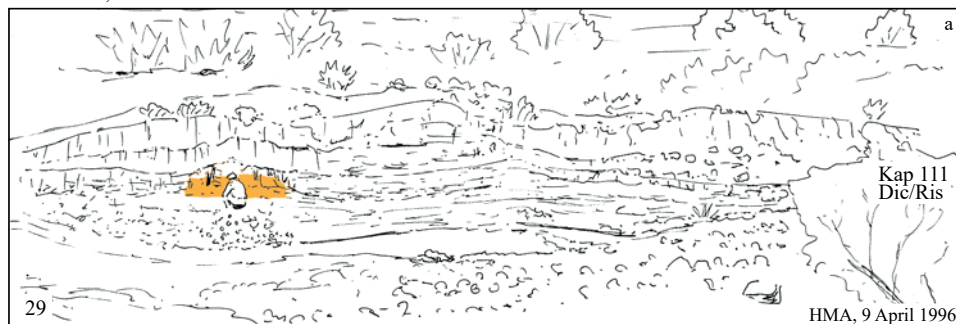
Habitat: *Heidiphyllum* thicket
Collection: 204 slabs, 70 man-hrs cleaving; impressions in thickly laminated, greenish grey shale, moderate cleavage.
Dominants: *Heidiphyllum* 94%, ferns 3%, horsetails 2%
Biodiversity: vegetative total: 11 spp
Non-gymnosperms: 6 spp
Gymnosperms: 5 spp
Petriellaceae:
Rochipteris 2 spp (80 indivs)
 " *rollerii* (70 indivs)*
 " *penensis* (10 indivs)
Kannaskoppianthus aasvoelensis (4 indivs)*
Ref. pal.
Aas 111 Hei elo
Pen 411 Hei elo
Aas 111 Hei elo

*Affiliation ♂ (as for the 4 Aasvoëlberg TCs)
Taphonomy – *R. rollerii*, parautochthonous
 – other spp, parautochthonous – allochthonous

Insects	indivs
c. 1 per 10 man-hrs (v. rare)	
Plecoptera (stoneflies)	– 1
Blattodea (cockroaches)	– 3
Mantodea (mantids)	– 2
Homoptera (bugs)	– 1
Coleoptera (beetles)	– 1
	8
Plant–insect interaction	
• leaf-margin feeding – •	
• leaf-tip feeding – ✓	
• piercing & sucking – •	
• leaf mining – •	
• oviposition – •	

pl. 82(3)

26°29.63'E; 31°05.81'S

Dicroidium* riparian forest (type 2)****Fig. 15. Kapokkraal (Kap 111 Dic/Ris).*Habitat:** *Dicroidium* riparian forest (immature, type 2)**Collection:** 1310 slabs, 65 man-hrs cleaving; impressions in thinly laminated, moderately baked medium dark grey shale, moderate cleavage.**Dominants:** *Dicroidium* 50%, horsetails 10%, *Heidiphyllum* 25 indivs**Biodiversity:** Vegetative total: 19 spp

Non-gymnosperms: 5 spp

Gymnosperms: 14 spp

Petriellaceae:*Rochipteris rollerii* (6 indivs)**Ref. pal.**

Aas 111 Hei elo

Taphonomy – allochthonous**Insects****indivs**

c. 3 per 1 man-hr (not rare)	
Meganisoptera (protodrag.)	– 3
Odonata (dragonflies)	– 8
Paraplecoptera (extinct)	– 4
Plecoptera (stoneflies)	– 1
Blattodea (cockroaches)	– 61
Mantodea (mantids)	– 3
Orthoptera (crickets <i>et alii</i>)	– 5
Homoptera (bugs)	– 12
Mecoptera (scorpionflies)	– 6
Coleoptera (beetles)	– 61
<i>Incertae</i>	– 14
	178

Plant–insect interaction

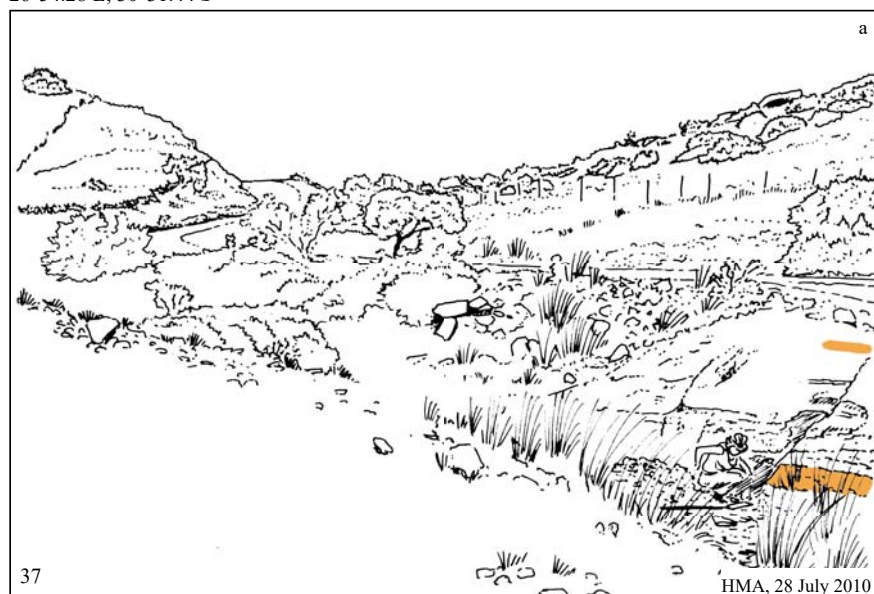
- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – •



pl. 89(8)

leaf-tip feeding, *R. rollerii****Dicroidium* open woodland**

26°54.28'E; 30°31.44'S

**Fig. 16. Nuwejaarspruit (Nuw 111 Dic zub), Clara's Ditch.****Habitat:** *Dicroidium* open woodland**Collection:** 138 slabs, 21 man-hrs cleaving; impressions in thinly laminated grey shale with moderate cleavage.**Dominants:** *Dicroidium* 70%, *Sphenobaiera* 30%**Biodiversity:** vegetative total, 9 spp

Non-gymnosperms: 1 spp

Gymnosperms: 8 spp

Petriellaceae:*Rochipteris lutifolia* (3 indivs)**Ref. pal.**

Lut 311 Hei elo

Taphonomy – allochthonous**Insects****indivs**

c. 1 per 4 man-hrs (rare)	
Blattodea (cockroaches)	– 1
Orthoptera (crickets <i>et alii</i>)	– 2
Coleoptera (beetles)	– 1
<i>Incertae</i>	– 1
	5

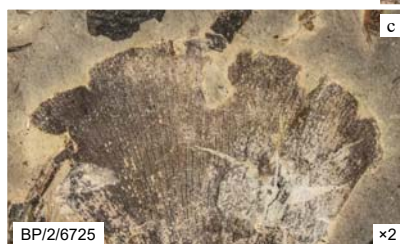
Plant–insect interaction

- leaf-margin feeding – ✓
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – •



pl. 91(7)

leaf-margin feeding



pl. 91(5)

leaf-tip feeding

R. lutifolia (both photos)

0 1 2 cm

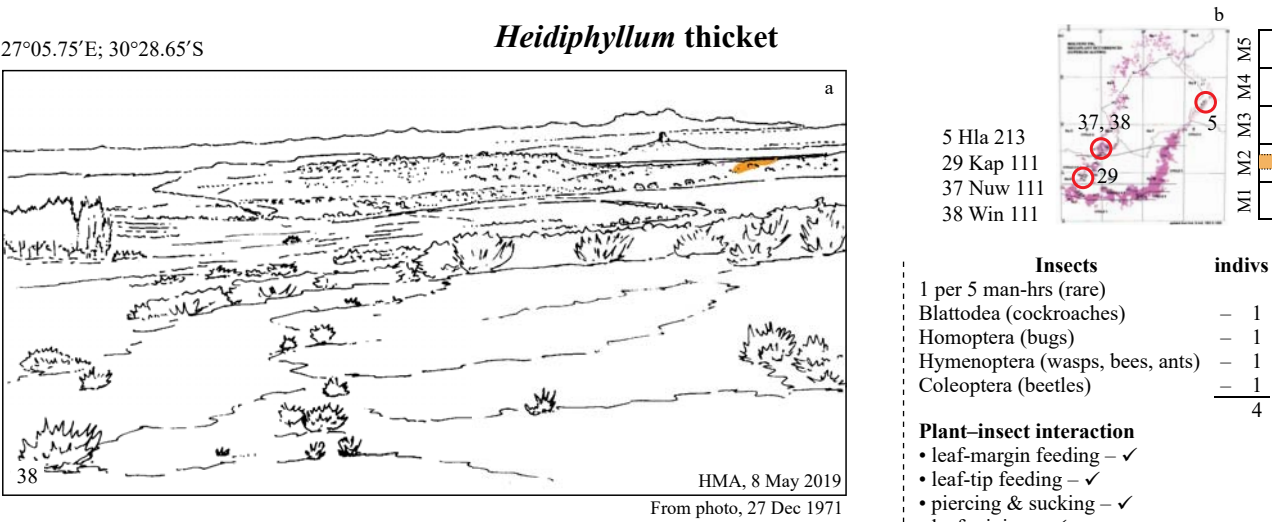


Fig. 17. Winnaarspruit (Win 111 Hei elo).
Habitat: *Heidiphyllum* thicket
Collection: 64 slabs; 20 man-hrs cleaving; impressions in thickly laminated grey shale with poor cleavage.
Dominants: *Heidiphyllum* 79%, *Dicroidium* 10%
Biodiversity: vegetative total, 11 spp
Non-gymnosperms: 5 spp
Gymnosperms: 6 spp
Petriellaceae:
Rochipteris 3 spp (5 indivs)
“ *rollerii* (3 indivs)
“ *lutifolia* (1 indiv.)
“ cf. *sinuosa* (1 indiv.)
Ref. pal
Aas 111 Hei elo
Lut 311 Hei elo
Umk 111 Dic 2 spp
Taphonomy – allochthonous (all 3 spp)

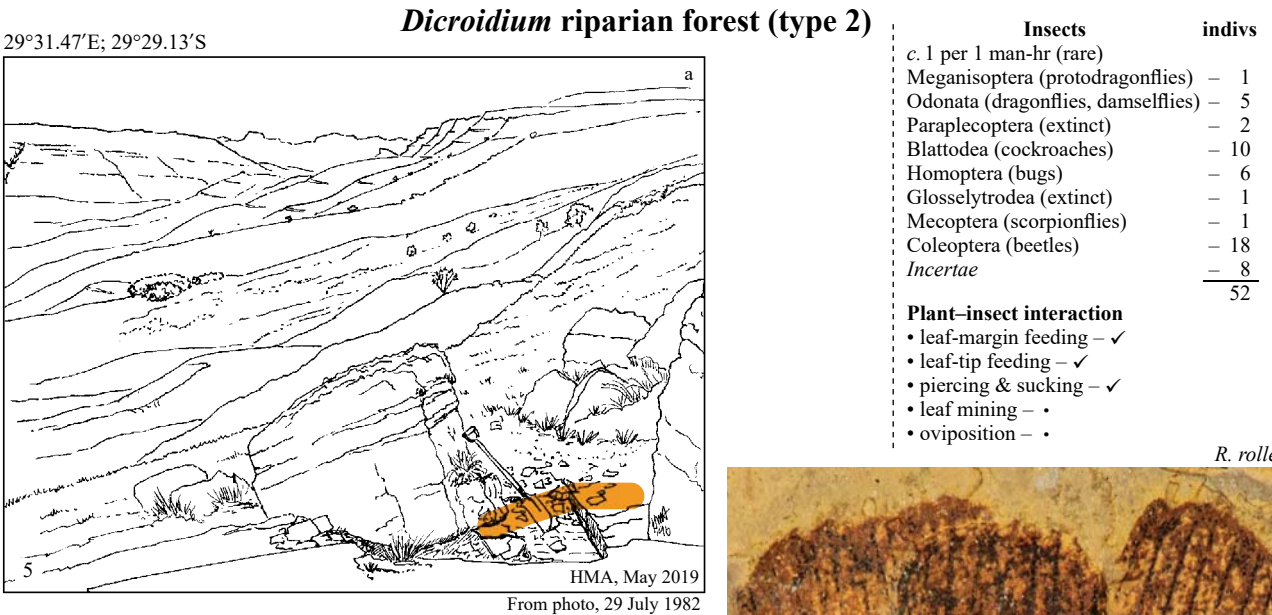


Fig. 18. Hlatimbe (Hla 213 Dic elo), *Batiopteris* Corner.
Habitat: *Dicroidium* riparian forest (immature, type 2)
Collection: 902 slabs, 60 man-hrs cleaving; compression in thinly laminated, carbonaceous (poor cuticle), medium dark-grey shale with good cleavage.
Dominants: *Dicroidium* 89%, *Heidiphyllum* 1%
Biodiversity: vegetative total, 42 spp
Non-gymnosperms: 15 spp
Gymnosperms: 27 spp
Petriellaceae:
Rochipteris 3 spp (8 indivs)
“ *rollerii* (4 indivs)
“ *switzifolia* (4 indivs)
Ref. pal.
Aas 111 Hei elo
Lit 111 Dic/Hei
Taphonomy – allochthonous (all 3 spp)

29°27.3'E; 29°33.54'S

***Dicroidium* riparian forest (type 1)**

From photo, 24 Jan 1979

Fig. 19. Umkomaas (Umk 111 Dic 2 spp), Waterfall Locality.**Habitat:** *Dicroidium* riparian forest (mature, type 1)**Collection:** 3592 slabs, 400 man-hrs cleaving; compressions in thinly laminated, carbonaceous (cuticle), moderately baked, dark-grey shale with good cleavage.**Dominants:** *Dicroidium* 69%, *Heidiphyllum* 7%, *Sphenobaiera* 5%**Biodiversity:** vegetative total, 75 spp

Non-gymnosperms: 29 spp

Gymnosperms: 46 spp

Petriellaceae:*Rochipteris* 4 spp (50 indivs)" *rollerii* (21 indivs)" *lutifolia* (1 indiv.)" *obtriangulata* (19 indivs)" cf. *sinuosa* (9 indivs)**Ref. pal.**

Aas 111 Hei elo

Lut 311 Hei elo

Umk 111 Dic spp

Umk 111 Dic 2 spp

Taphonomy – parautochthonous (*R. rollerii* & *R. lutifolia*)– allochthonous (*R. cf. sinuosa*)– parautochthonous-allochthonous (*R. obtriangulata*)**Insects**

c. 1 per 2 man-hrs (rare)

Odonata (dragonflies, damselflies) – 1

Plecoptera (stoneflies) – 2

Blattodea (cockroaches) – 80

Orthoptera (crickets *et alii*) – 1

Homoptera (bugs) – 12

Megaloptera (alderflies) – 1

Coleoptera (beetles) – 63

Incertae – 6**indivs**

– 1

– 2

– 80

– 1

– 12

– 1

– 63

– 6

166

Plant-insect interaction

• leaf-margin feeding – ✓

• leaf-tip feeding – ✓

• piercing & sucking – •

• leaf mining – ✓

• oviposition – •

R. obtriangulata

(both photos)

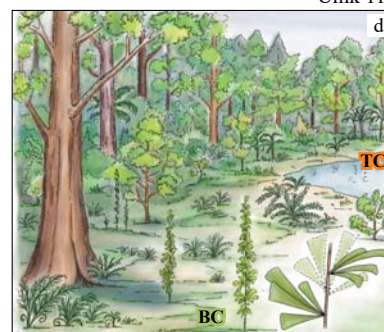
leaf

mining

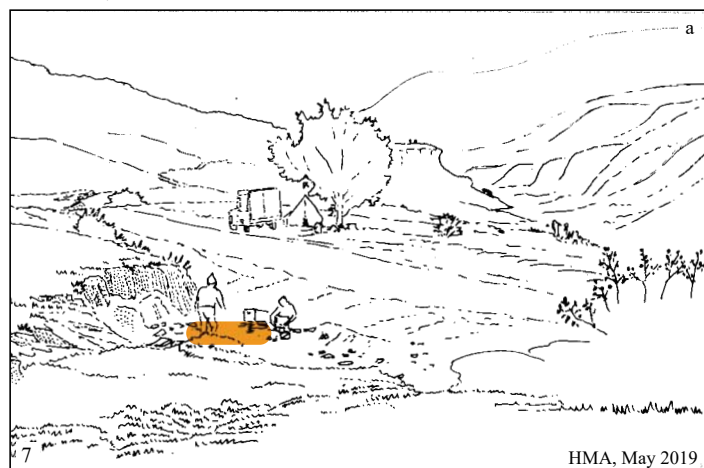
PRE/F/9832

pl. 106(1)

Umk 111

*Dicroidium* riparian forest (mature, type 1)

29°24.62'E; 29°37.73'S

***Dicroidium* riparian forest (type 2)**

HMA, May 2019

From photo, 27 Sept 1971

Fig. 20. Sani Pass (San 111 Dic cra).**Habitat:** *Dicroidium* riparian forest (immature, type 2)**Collection:** 303 slabs, 30 man-hrs cleaving; compressions in thinly laminated, carbonaceous, dark-grey shale with moderate cleavage.**Dominants:** *Dicroidium* 90%, *Heidiphyllum* 5%**Biodiversity:** vegetative total, 19 spp

Non-gymnosperms: 3 spp

Gymnosperms: 16 spp

Petriellaceae:*Rochipteris* 2 spp (3 indivs)" *rollerii* (2 indivs)" *switzifolia* (1 indiv.)**Ref. pal.**

Aas 111 Hei elo

Lit 111 Dic/Hei

Taphonomy – allochthonous (both spp)**Insects**

nil in 30 man-hrs

Blattodea (cockroaches) – 0

Coleoptera (beetles) *et alii* – 0**indivs**

– 0

– 0

nil

Plant-insect interaction

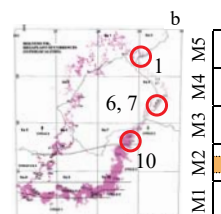
• leaf-margin feeding – ✓

• leaf-tip feeding – ✓

• piercing & sucking – •

• leaf mining – •

• oviposition – •



1 Lit 111

6 Umk 111

7 San 111

10 Mat 111

*R. rollerii*

(both photos)

BP/2/2527

pl. 111(7)



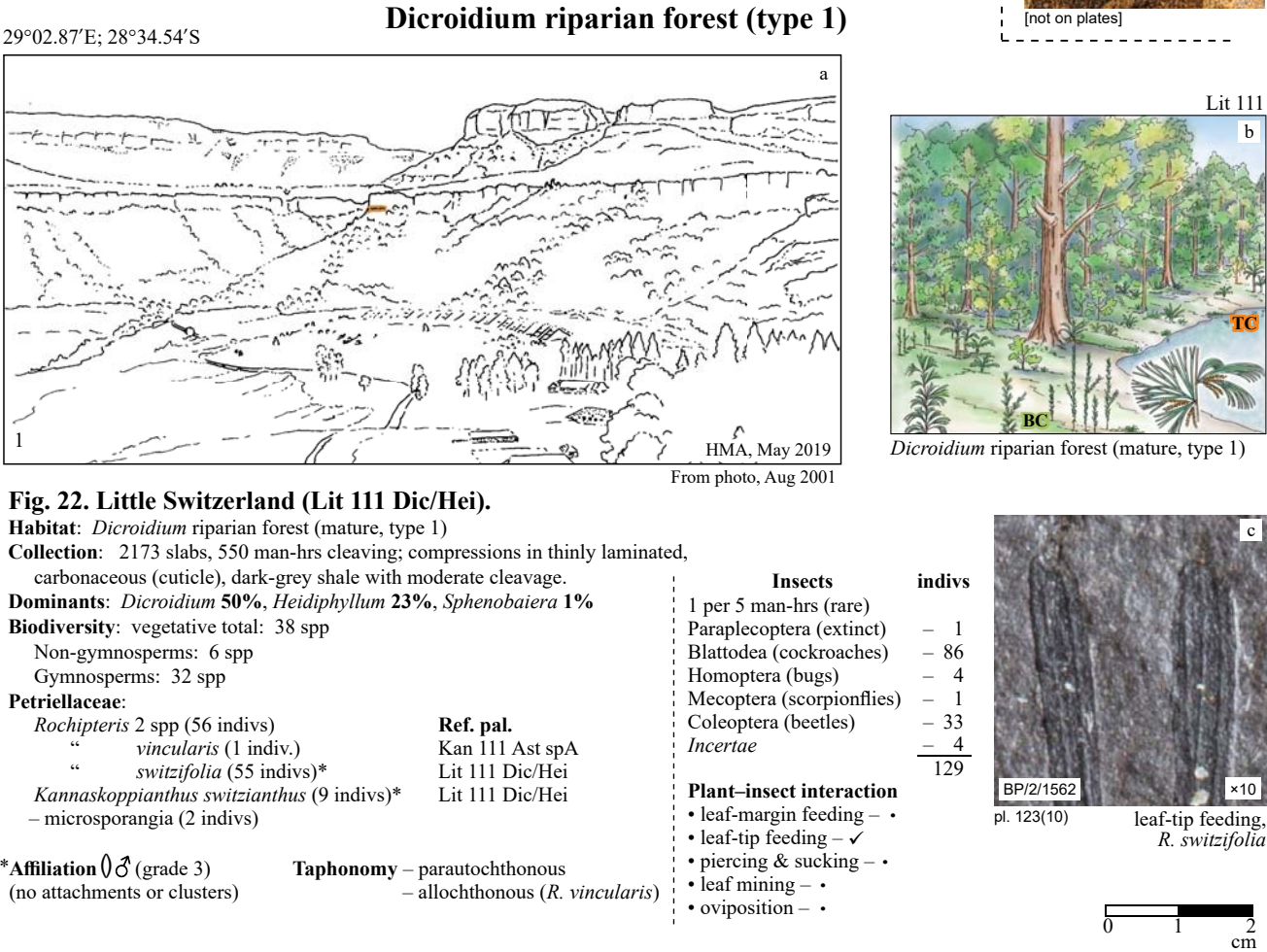
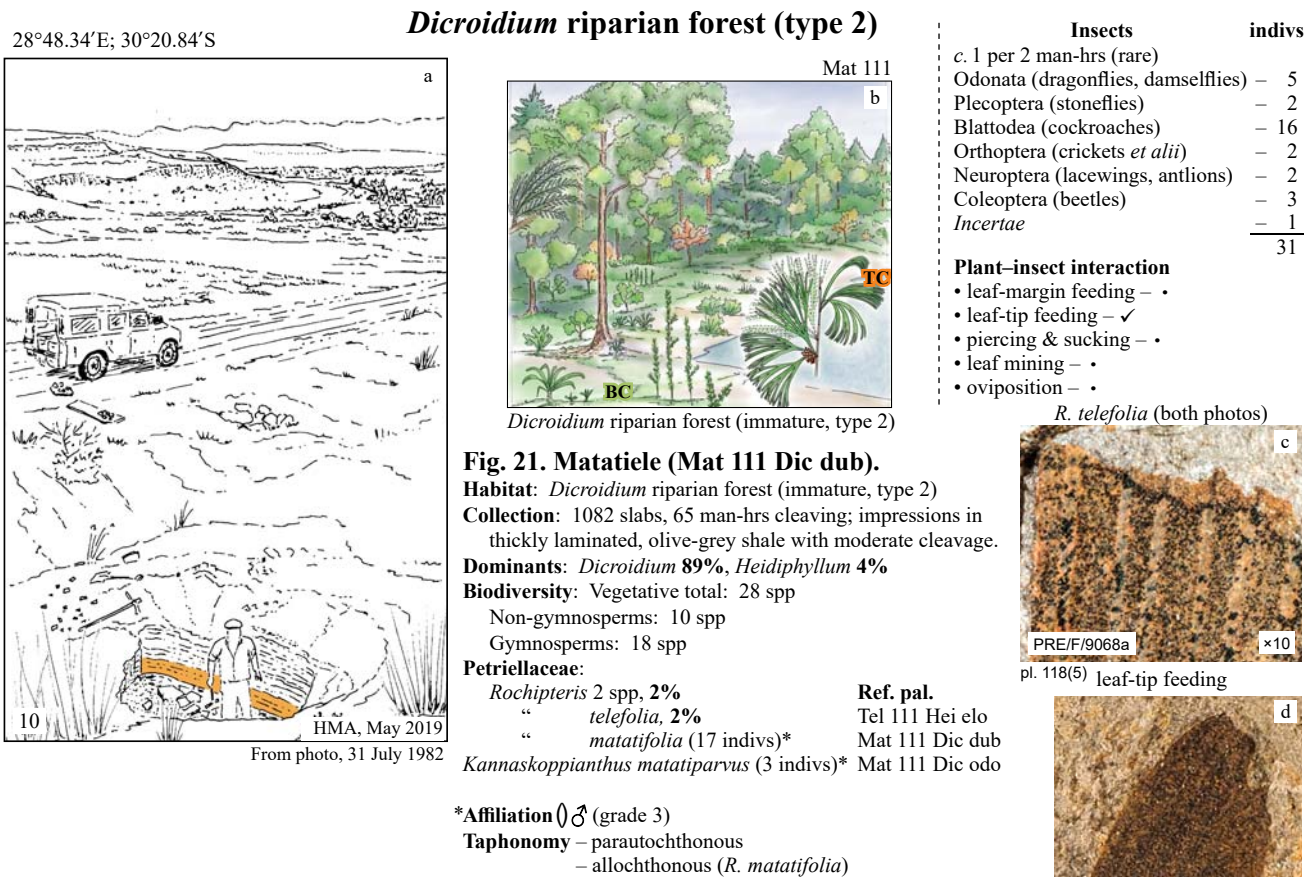
pl. 112(3)

BP/2/2528

leaf-margin

feeding

0 1 2 cm



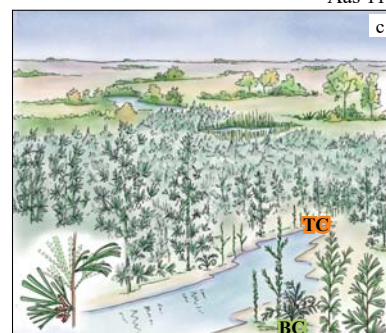
Heidiphyllum thicket

26°16.47'E; 31°33.81'S



HMA, May 2019

From photo, 4 June 1971



Heidiphyllum thicket, marsh in floodplain

R. rollerii



pl. 134(3)

piercing & sucking



pl. 139(3)

Fig. 23. Aasvoëlberg (Aas 111 Hei elo), Turner Shale.

Habitat: *Heidiphyllum* thicket

Collection: 291 slabs; 40 man-hrs cleaving; impressions in thickly laminated, light-grey shale with moderate cleavage.

Dominants: *Heidiphyllum* 77%, ferns 20%

Biodiversity: vegetative total, 13 spp

Non-gymnosperms: 7 spp

Gymnosperms: 6 spp

Petriellaceae:

Rochipteris rollerii, 2%*

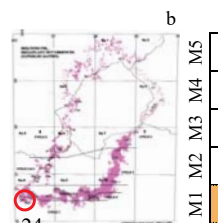
(c.50 slabs, incl. several clusters)

Kannaskoppianthus aasvoelensis (21 indivs)* Aas 111 Hei elo

– microsporangia (5 indivs)

Ref. pal.

Aas 111 Hei elo



24 Aas 111, 211,

“ 311, 411

***Affiliation** ♂ (grade 4)

Taphonomy – parautochthonous

6 clusters (1 of 6 indivs & c. 15 fragments)

(1 of 5 indivs; 4 of 2–3 indivs)

Insects

indivs

c. 1 per 1 man-hr (rare)

Odonata (dragonflies, damselflies) – 1

Blattodea (cockroaches) – 17

Homoptera (bugs) – 33

Coleoptera (beetles) – 8

Incertae – 1

60

Plant–insect interaction

• leaf-margin feeding – •

• leaf-tip feeding – ✓

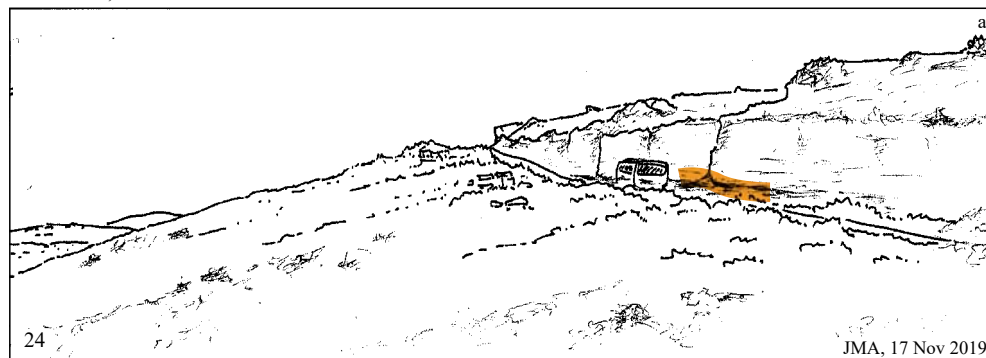
• piercing & sucking – ✓

• leaf mining – •

• oviposition – •

Heidiphyllum thicket

26°13.94'E; 31°33.35'S



JMA, 17 Nov 2019

From photo, 27 March 1989



pl. 144(3) piercing & sucking



pl. 144(5)

R. rollerii

Fig. 24. Aasvoëlberg (Aas 211 Hei elo), Proppie Shale.

Habitat: *Heidiphyllum* thicket

Collection: 154 slabs; 35 man-hrs cleaving; impressions in thickly laminated light-grey shale with moderate cleavage.

Dominants: *Heidiphyllum* 99%,

Biodiversity: vegetative total, 7 spp

Non-gymnosperms: 3 spp

Gymnosperms: 4 spp

Petriellaceae:

Rochipteris 2 spp (19 indivs)

“ *vincularis* (1 indiv.)

“ *rollerii* (18 indivs)*

Kannaskoppianthus aasvoelensis (1 indiv.)* Aas 111 Hei elo

Ref. pal.

Kan 111 Ast spA

Aas 111 Hei elo

Aas 111 Hei elo

Insects

indivs

c. 2 per 1 man-hr (rare)

Odonata (dragonflies, damselflies) – 2

Blattodea (cockroaches) – 44

Mantodea (mantids) – 1

Homoptera (bugs) – 1

Neuroptera (lacewings, antlions) – 1

Coleoptera (beetles) – 6

Incertae – 1

56

Plant–insect interaction

• leaf-margin feeding – •

• leaf-tip feeding – ✓

• piercing & sucking – ✓

• leaf mining – •

• oviposition – •

0 1 2
cm

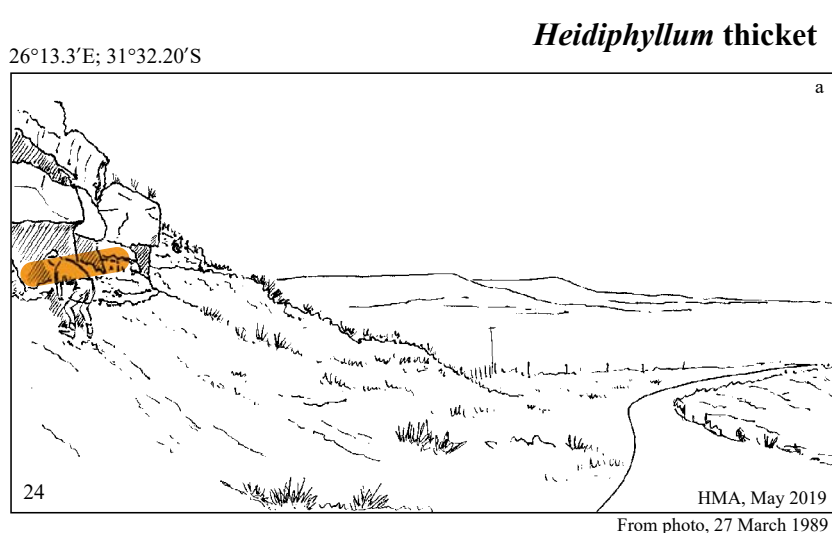


Fig. 25. Aasvoëlberg (Aas 311 Hei elo), Easter-egg Sh.

Habitat: *Heidiphyllum* thicket

Collection: 528 slabs; 140 man-hrs cleaving; impressions in thickly laminated, light-grey shale with moderate cleavage.

Dominants: *Heidiphyllum* 99%

Biodiversity: vegetative total, 11 spp

Non-gymnosperms: 4 spp

Gymnosperms: 7 spp

Petriellaceae:

Rochipteris 2 spp (26 indivs)

“ *vincularis* (1 indiv.)

“ *rollerii* (25 indivs)*

Kannaskoppianthus aasvoelensis (4 indivs)*

Ref. pal.

Kan 111 Ast spA

Aas 111 Hei elo

Aas 111 Hei elo

*Affiliation (♂) (grade 4)

Taphonomy – parautochthonous

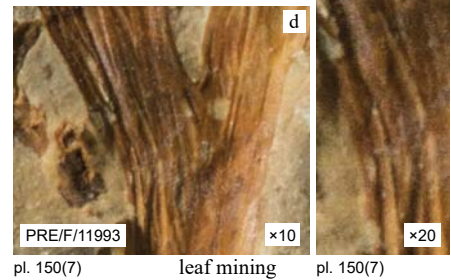
– allochthonous (*K. vincularis*)



Insects	indivs
c. 1 per 1 man-hr (rare)	
Odonata (dragonflies, damselflies)	– 2
Paraplecoptera (extinct)	– 3
Blattodea (cockroaches)	– 77
Mantodea (mantids)	– 5
Orthoptera (crickets <i>et alii</i>)	– 3
Homoptera (bugs)	– 20
Mecoptera (scorpionflies)	– 4
Coleoptera (beetles)	– 23
<i>Incertainae</i>	– 9
	146

Plant–insect interaction

- leaf-margin feeding – •
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – ✓✓
- oviposition – •

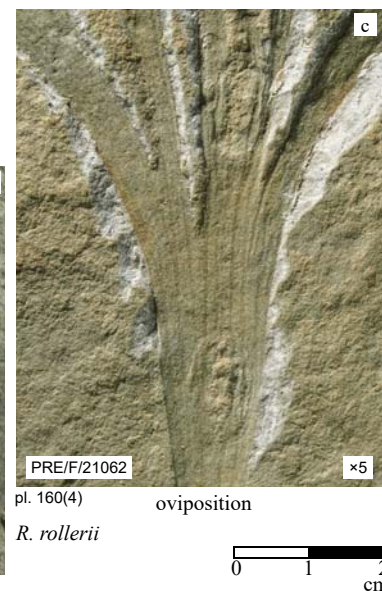


R. rollerii (all photos)

Insects	indivs
c. 1 per 4 man-hrs (rare)	
Meganisoptera (protodragonflies)	– 7
Odonata (dragonflies, damselflies)	– 8
Paraplecoptera (extinct)	– 3
Blattodea (cockroaches)	– 54
Mantodea (mantids)	– 2
Orthoptera (crickets <i>et alii</i>)	– 4
Homoptera (bugs)	– 9
Glosselytrodea (extinct)	– 1
Neuroptera (lacewings, antlions)	– 4
Mecoptera (scorpionflies)	– 1
Trichoptera (caddisflies)	– 1
Lepidoptera (butterflies)	– 2
Coleoptera (beetles)	– 28
<i>Incertainae</i>	– 5
	129

Plant–insect interaction

- leaf-margin feeding – •
- leaf-tip feeding – ✓
- piercing & sucking – •
- leaf mining – •
- oviposition – ✓✓✓



R. rollerii

0 1 2 cm

26°12.16'E; 31°33.43'S

***Sphenobaiera* closed woodland**



Fig. 26. Aasvoëlberg (Aas 411 Dic/Sph), *Fredlindia* Slate.

Habitat: *Sphenobaiera* closed woodland

Collection: 2176 slabs, 512 man-hrs cleaving; impressions in thinly laminated, strongly baked yellowish grey shale, very good cleavage.

Dominants: *Dicroidium* 60%, *Sphenobaiera* 30%, *Heidiphyllum* 1%

Biodiversity: vegetative total, 30 spp

Non-gymnosperms: 8 spp

Gymnosperms: 22 spp

Petriellaceae:

Rochipteris rollerii (150 indivs)*

Kannaskoppianthus aasvoelensis (21 indivs)*

– microsporangia (4 indivs)

Ref. pal.

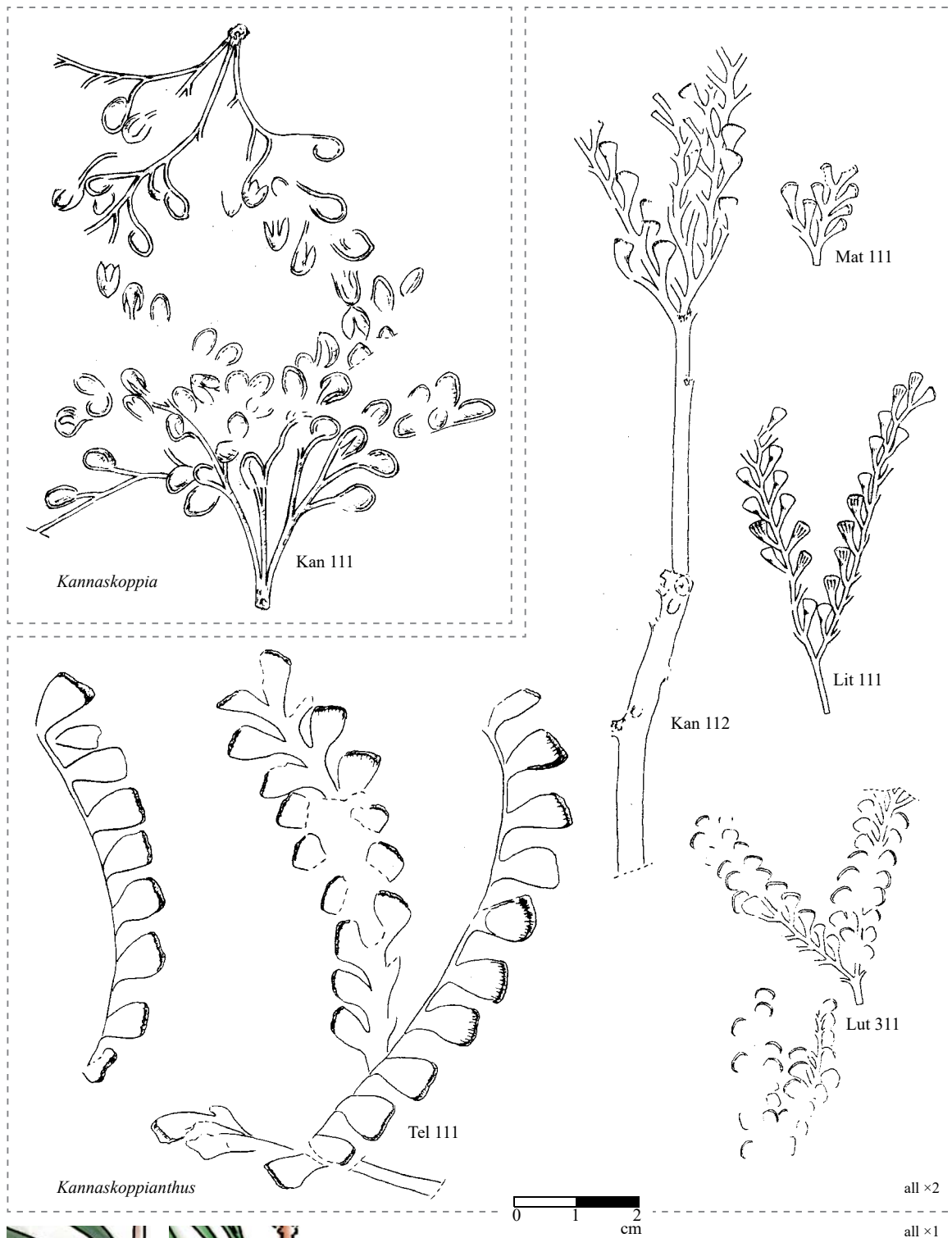
Aas 111 Hei elo

Aas 111 Hei elo

*Affiliation (♂) (grade 4)

Taphonomy – parautochthonous





Kan 112



Aas 111



Lit 111



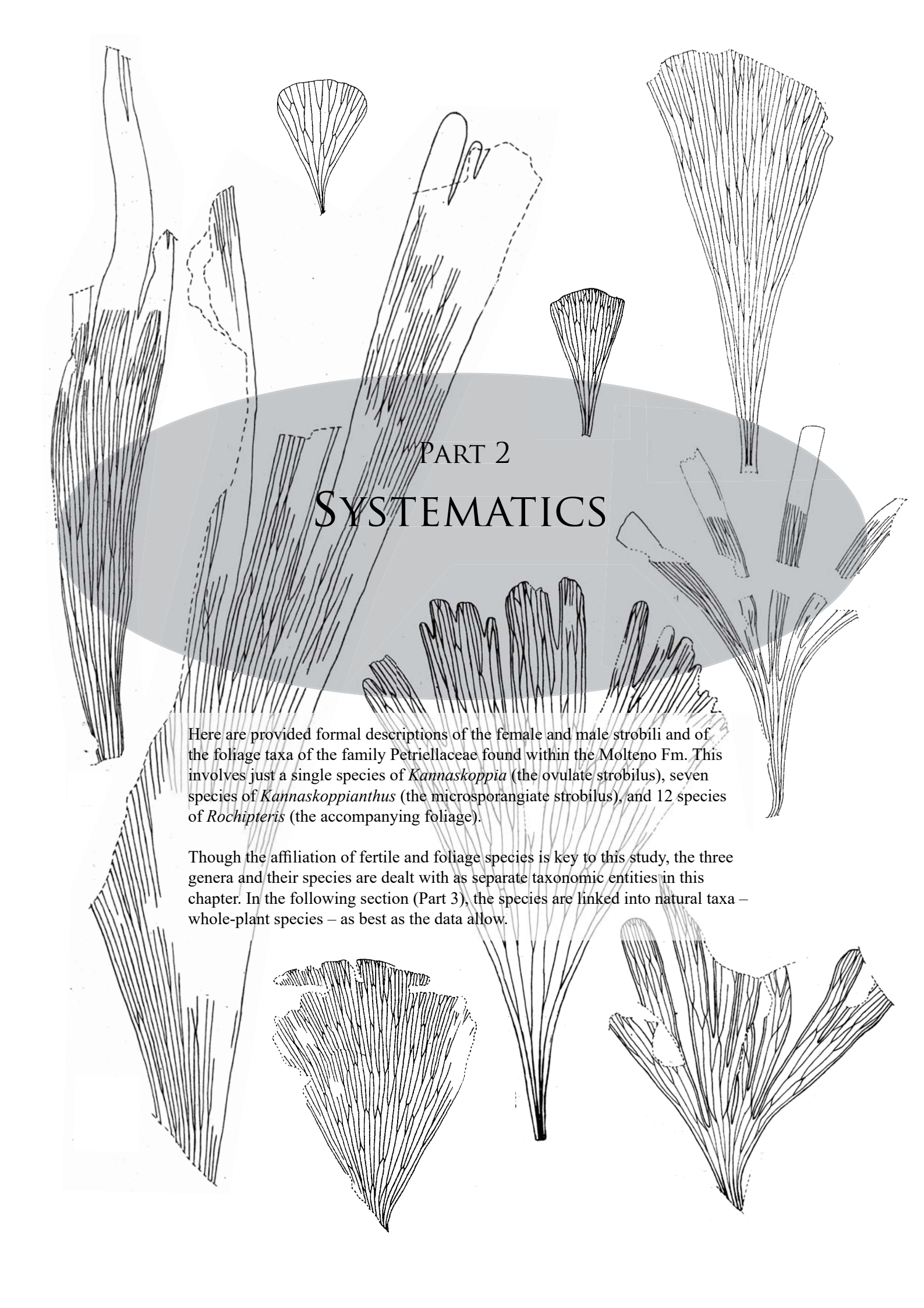
Mat 111



Kom 111



Lut 311



PART 2

SYSTEMATICS

Here are provided formal descriptions of the female and male strobili and of the foliage taxa of the family Petriellaceae found within the Molteno Fm. This involves just a single species of *Kannaskoppia* (the ovulate strobilus), seven species of *Kannaskoppianthus* (the microsporangiate strobilus), and 12 species of *Rochipteris* (the accompanying foliage).

Though the affiliation of fertile and foliage species is key to this study, the three genera and their species are dealt with as separate taxonomic entities in this chapter. In the following section (Part 3), the species are linked into natural taxa – whole-plant species – as best as the data allow.

Chart 1. TAXONOMIC APPROACH.

Recognizing taxa in fossil floras

In describing the fossil flora of the Molteno, our approach has revolved around comprehensive sampling through the formation (geographic, stratigraphic and ecological); and the recognition of varying populations (palaeodemes) of specimens from the different assemblages (taphocoenoses), see p. 66 and glossary p. 320 (And. & And., 1983, 1989, 2003).

Consider the two very different gymnosperm foliage genera, *Dicroidium* and *Rochipteris*, and their affiliates, as sampled in the

Molteno (tabled below). Though both are ubiquitous and diverse across the Gondwana Triassic, *Dicroidium* is regarded as a large shrub to tree, whilst *Rochipteris* is a slender herbaceous pioneering shrub. In their ubiquity and diversity, both offer particular opportunities for exploring approaches to palaeobotanical taxonomy. *Dicroidium*, in being far more abundant and being found in 75 of the 100 Molteno TCs, offers the best opportunity for defining subspecies and forma. *Rochipteris*, with its unique array of attached female and male strobili, allows the best option for focussing on whole-plant taxa.

Dicroidium (Molteno)

Habit & habitat: large shrubs to trees, dominant in riparian forest, and lakeside or open floodplain woodland

Frequency: 75 (of 100) assemblages (TCs)

Abundance: >50% of assemblage (46 TCs); 25–49% of assemblage (6 TCs); 1–24% of assemblage (13 TCs)

Dominance: sole-dominant in 36 TCs; co-dominant in 18 TCs (25% or more of assemblage)

Diversity: 19 foliage species

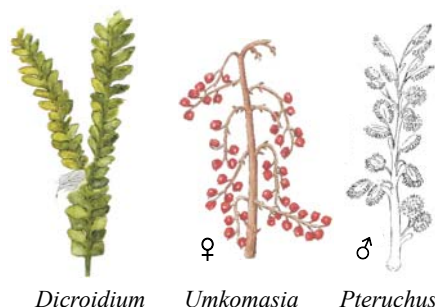
Taphonomy: parautochthonous to mostly allochthonous

Attachment: no accepted cases yet found of *Umkomasia* or *Pteruchus* attached to leafy shoots

Dicroidium (foliage) – 75 (of 100) assemblages; 19 spp

Umkomasia (female) – 22 (of 100) assemblages; 503 indivs; 8 spp

Pteruchus (male) – 22 (of 100) assemblages; 425 indivs; 3 spp



Dicroidium

Umkomasia

Pteruchus

Rochipteris (Molteno)

Fig. 1.

Habit & habitat: Slender herbaceous pioneering shrubs bordering river channels or lakes in floodplain; and on sandbars in braided rivers

Frequency: 26 (of 100) assemblages (TCs)

Abundance: <1% of assemblage (22 TCs); 2% (in 2 TCs); 5% (in 2 TCs)

Dominance: never a dominant element in a TC

Diversity: 12 foliage species

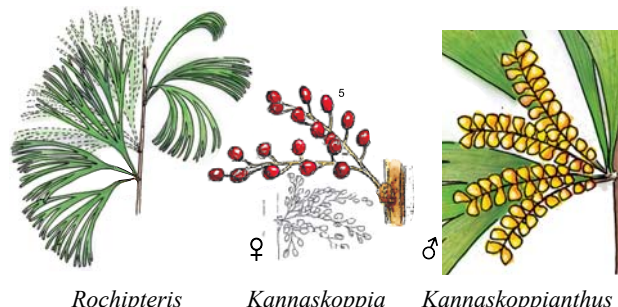
Taphonomy: autochthonous (in cases of attachment) to parautochthonous (often) to allochthonous (less often)

Attachment: specimens are found attached in 5 TCs: foliage in 4 TCs; female with foliage in 1 TC; male in 2 TCs (once with foliage)

Rochipteris (foliage) – 26 (of 100) assemblages; 12 spp

Kannaskoppia (female) – 1 (of 100) assemblages; 50 indivs; 1 spp

Kannaskoppianthus (male) – 12 (of 100) assembl.; 92 indivs; 8 spp



Rochipteris

Kannaskoppia

Kannaskoppianthus

Evolution in the lifespan of a single tree

As the life sciences progress, as the breadth of research spreads and the number of papers increases, so evolution and variation are found to be ever more dynamic and complex. Consider key findings of a recent article on the Sitka spruce. Here paraphrased:

Picea sitchensis (Sitka spruce) – to over 500 years old, and over 70 m (230 ft) in height.

- Modular organisms: plants (as opposed to animals) “grow by producing multiple copies of discrete units”.
- Mutations and genetic diversity in a single tree are common: to “100,000 genetic differences” from the base to the canopy of a single tree.
- Many mutations will be “either neutral or potentially harmful”, but others advantageous in a changing environment over 500 years.
- The “reproductive cells of trees develop from somatic cells” – “the same cells that form stems”.
- Thus mutations in the stem “can be passed on” to the seeds in cones.

Such information adds another dimension to the molecular definition of plant species and the expression in the phenotype. With fossils (even abundant ones such as *Dicroidium*) one is restricted to rather artificial definitions of species based on morphology and associated evidence.



Sitka spruce
Picea sitchensis

Google
images

Ref.: Hanlon et al. (2019a,b); *Surprising genetic diversity in old growth trees* (www.indefenseofplants.com/blog, 23 July 2019)

Chart 2. SIGMA (AS OPPOSED TO ALPHA) TAXONOMY: how to define a species probabilistically without assuming clear boundaries between taxa.

Francis Thackeray, August 2019

One of the greatest problems in biology, whether one is dealing with modern or fossil animals or plants, is how to define a species. It is common enough to employ the Linnaean binomial system of nomenclature whereby a specimen is classified under the assumption that it can be pigeon-holed into a particular genus and species. This works well when one is dealing with the morphology of just a few similar specimens including a holotype, but as the sample sizes increase for one particular species, one detects a certain degree of variation that may eventually overlap with that of another species for which there is a different holotype. How would one go about quantifying the degree of similarity or difference between groups of specimens that may or may not represent the same species? In the context of morphometrics of vertebrate fauna (excluding plants for the moment), the approach recognizes the need to define a species in a probabilistic manner.

Here are two concepts, relating to Alpha and Sigma taxonomy:

Alpha taxonomy – The classification of animals or plants under the assumption that there are distinct boundaries between species.

Sigma taxonomy – The classification of animals or plants in terms of probabilities of conspecificity, without assuming distinct boundaries between species (Thackeray, 2018). Sigma is the Greek letter Σ (S) standing for a ‘spectrum of variation through evolutionary time’ (Thackeray & Schrein, 2017).

One possible morphometric method for Sigma Taxonomy

One method (not necessarily the best one, but a viable one for purposes of sigma taxonomy) makes use of least squares linear regression analysis in pairwise comparisons (initiated by Thackeray *et al.*, 1997). In the case of the examples that follow, the variables under discussion are linear measurements of crania, based on standard landmarks.

Let us assume that two specimens A and B are known to represent the same extant species from a population living in one area at the same time. Linear measurements (let us say at least 25 of them) of the cranium of specimen A are compared against those of specimen B. A pairwise plot of the kind shown in Fig. 1 can be analysed using least squares linear regression analysis.

In this case, the log of the standard error of the m co-efficient (log sem) associated with the regression equation $y = mx + c$ is -1.61 . This relates to a small degree of scatter around the regression line. By

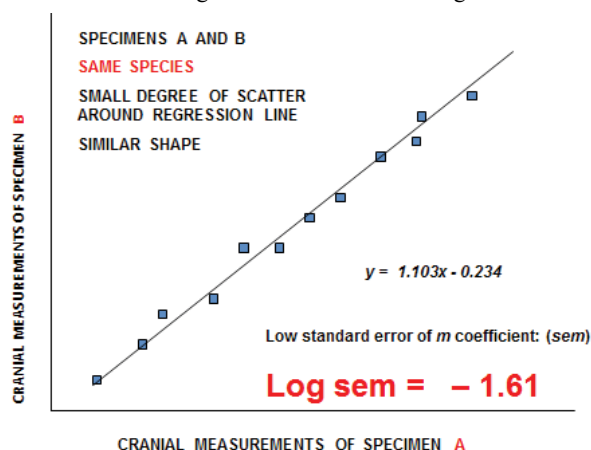


Fig. 1. Measurements of two specimens of the same species are compared. There is a *small* degree of scatter around the regression line, and the log sem value is -1.61 which is a typical value when two specimens of the same species are compared (Thackeray, 2007).

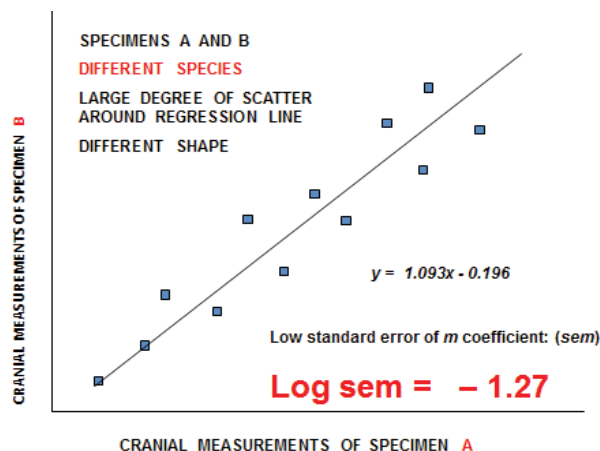


Fig. 2. Measurements of two specimens of *different* species are compared. There is a *high* degree of scatter around the regression line, and the log sem value is also relatively *high* (more positive than -1.61).

contrast (as shown in Fig. 2), log sem is higher (more positive, >-1.61) when two specimens of different species are compared.

Now let us repeat the process for many conspecific pairs, as in the case of Fig. 1, but let us do this for 100 species of vertebrate animals (mammals, birds and reptiles), using at least 25 measurements for each comparison. For any two specimens, let us obtain two log sem values: in the first analysis put specimen A on the x -axis, and conspecific specimen B on the y -axis. In the second analysis put A on the y -axis, and B on the x -axis. What we will find is that the difference between the log sem values (delta log sem) is small for conspecific pairs (*circa* 0.03 as demonstrated by Thackeray & Dykes (2016) for certain vertebrate mammals). Continuing this analysis, let us look at a histogram of log sem values for the pairwise comparisons of conspecifics. On the basis of results obtained from exploratory analyses, we find a normal distribution of log sem values around a mean of -1.61 (Thackeray, 2007). For discussion see Thackeray & Dykes (2016), who indicated that a standard deviation of ± 0.1 may be expected in relation to a mean log sem of -1.61 for many conspecific pairs (idealized in Fig. 3). Recognizing central tendency around -1.61 for the mean log sem value for many conspecific comparisons, whether males or females (Thackeray, 2018), it has been proposed (Thackeray, 2007) that this value is an approximation of a biological species constant ($T = -1.61$), here associated with a typical standard deviation (± 0.1) to reflect the typical degree of variation within a vertebrate species.

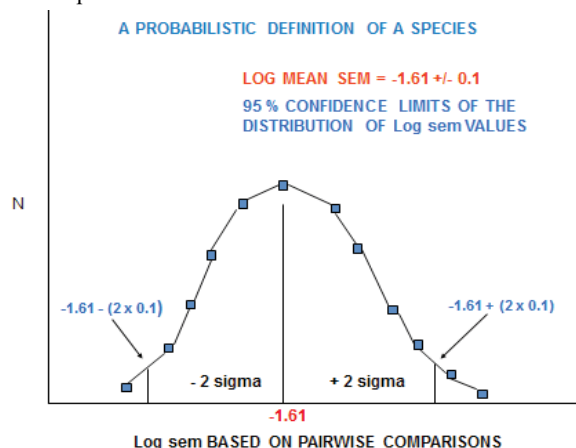


Fig. 3. A normal distribution of log sem values for modern conspecific pairs of specimens.

We are now in a position to propose that -1.61 ± 0.1 is a probabilistic definition of a species, and it has applications in vertebrate palaeontology. If any two fossil crania have a log sem value which is exactly -1.61 , or a value that falls within the 95% confidence limits of -1.61 ± 0.1 (Fig. 4), we could say that there is a high probability of conspecificity for fossil specimens A and B. By contrast, if the log sem value for two other crania (specimens C and D) is outside the upper 95% confidence limit, one could advocate that there is a low probability of them being the same species.

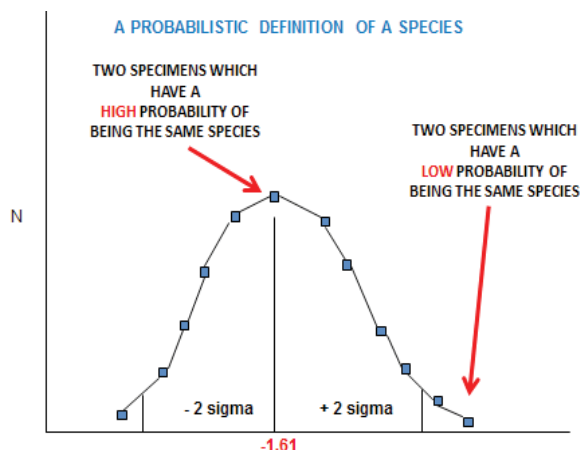


Fig. 4. Log sem values are used to assess probabilities of conspecificity for pairs of specimens.

Applications

This approach has been applied to Plio-Pleistocene hominin fossils. For example, Thackeray & Odes (2013) have demonstrated that there was a spectrum of variation of log sem, ranging from relatively low values (<-1.61) reflecting high probabilities of conspecificity for specimens attributed to the same species, to higher values (>-1.61) reflecting lower probabilities of conspecificity as in the case when specimens of different species were compared. A pertinent observation made by Thackeray (2018) is that certain specimens attributed to *Australopithecus africanus* (e.g. Mrs Ples, Sts 5, from Sterkfontein in South Africa) were not necessarily different (at the level of species) from other specimens attributed to *Homo habilis* (e.g. OH 24 from Olduvai Gorge in Tanzania). There is evidently not a clear boundary between these two genera in the context of evolutionary time (from 2.5 to 1.6 million years).

In the context of geographical space, the same approach has been applied by Thackeray *et al.* (2005) in the case of anatomically modern *Homo sapiens* ('CroMagnon') and *Homo neandertalensis* skulls, again indicating the lack of a clear boundary between taxa. An overlap of data suggested the possibility of interbreeding, a fact

which has subsequently been confirmed on the basis of palaeogenomic analyses.

Similarly, the approach has been applied by Thackeray (2018) in the case of two species of chimpanzees (*Pan paniscus*, the bonobo; and *P. troglodytes*), indicating the lack of a clear boundary between taxa. An overlap of log sem data (Thackeray & Dykes, 2016) is entirely consistent with episodic changes in climate and habitats, coinciding with episodic interbreeding which has been demonstrated genetically. Hybridization occurred twice within the last million years.

The approach has been applied to two Triassic therapsid species, *Lystrosaurus murrayi* and *L. declivis*, postdating the Permo-Triassic extinction at 252 million years ago. Measurements from skulls of specimens attributed to one or other species were compared to obtain log sem values. In an initial exploratory study (Thackeray *et al.*, 1998) it was suggested that only one species might be represented. In a subsequent study (Thackeray, 2019) it was recognized from log sem that the type specimen of *L. declivis* was probably distinct from at least one other individual attributed to *L. murrayi*, suggesting that not all Triassic *Lystrosaurus* should be lumped into one species. However, the possibility remains that near the time of divergence of the two species postdating 252 million years ago, *L. murrayi* and *L. declivis* could have interbred, which would account for the instances when it is necessary to classify certain specimens simply as *L. murrayi/declivis*. Unfortunately the holotype for *L. murrayi* is not well preserved. This creates a problem, but if a neotype is recognized, more can be done with regard to sigma taxonomy, using a probabilistic approach (Thackeray, in prep.).

Conclusion

This approach has the advantage in that it does not assume clear boundaries between taxa, as in the case of alpha taxonomy. Sigma taxonomy relates to the classification of specimens in terms of probabilities of conspecificity, where Sigma is the Greek letter Σ (S) standing for a 'spectrum of variation through evolutionary time' (Thackeray & Schrein, 2017).

Thus far the approach has been applied to vertebrate taxa. It has not as yet been applied to plants, but the potential exists to do this. In this regard, it is appropriate to mention that, as in the case of animal species, boundaries between plant taxa are not necessarily clear. Take roses, for example. Peter Knox-Shaw (pers. comm. to Thackeray, 28 March 2019) says "Nature is promiscuous. *Rosa gigantea*, the emperor of wild roses, produces single flowers the size of saucers and climbs on occasion to 80 feet. This species has sired more hybrids than Genghis Khan. In our garden alone it has crossed with *R. banksia*, with *R. longicuspis*, with *R. rubus* and with a number of other roses impossible to identify. And none of the progeny appear to be infertile".

GINKGOOPSIDA Engler, 1897
PETRIELLALES T.N.Taylor *et al.*, 1994
PETRIELLACEAE T.N.Taylor *et al.*, 1994

Kannaskoppia J.M.And. & H.M.And., 2003

Type species

Kannaskoppia vincularis J.M.And. & H.M.And., 2003

Kannaskop (Kan 111), Karoo Basin, S. Africa; Carnian, Triassic.

Plant fossil names registry number: PFN002287 (for genus)

Generic diagnosis

A ginkgoopsid strobilus with a forked axis bearing rows of several simple megasporophylls consisting of a single, recurved, pedicellate cupule.

Generic characters

Fertile shoot: stem with short shoots in an irregular helical arrangement; leaves (1 or 2) and strobili (2 or 3) borne irregularly on each shoot.

Strobilus: lax, planar; bilaterally symmetrical, small (c. 20 mm long); axis gracile, proximally forked; megasporophylls in 2 adaxial oblique rows (of 4–6 units) along each fork (limb), angle between rows c. 90°.

Megasporophyll: apparently reduced to single pedunculate cupules; ovuliferous cupules recurved; peduncles 2–3 mm long, gracile, sinuously curved.

Cupule: small (c. 2.5 × 2 mm), roundly ovoid, splitting more or less regularly into 3 lobes at maturity.

Ovule/seed: unknown.

Etymology

Kannaskoppia – after the type locality Kannaskop, an Afrikaans name for a hill bearing *Canna* plants (not the monocots of the family Cannaceae).

“In the 17th Century in the Cape of Good Hope, indigenous Khoisan inhabitants were known to chew or smoke a plant which had hallucinogenic properties. It has been spelt “canna” or “kanna”, with the latter in modern usage. The plant is almost certainly *Sceletium* as opposed to anything else”. Francis Thackeray (pers. comm., Jan. 2021).

Global range: 1 sp., Gondwana, Tr. (CRN).

First & last: Molteno Fm.

Gondwana Triassic occurrence

South Africa – Karoo Basin, I TC (50 indivs).

Molteno occurrence (see Tab. 2, p. 40)

Frequency (F): 1 TC (of 100 sampled in the Molteno).

Diversity (D): 1 species.

Abundance (A): 50 indivs; rare.

Kan 111 Ast spA: 50 indivs in 30 man-hrs cleaving (c. 20 per 1 man-day), rare.

Affiliated organs

Male strobilus: *Kannaskoppianthus* – Grade 5 (Mor. corr., Kin. reinf.).

Foliage: *Rochipteris* – Grade 5 (Org. att.).

Evidence for affiliation of organs

Organic attachment

The holotype specimen of *Rochipteris vincularis*, together with the associated specimen on the same slab and additional material, constitutes the most convincing example of affiliated organs in the Molteno flora. Typical strobili and leaves are found attached to short shoots borne on a section of stem. Other specimens in the collection show the male strobilus, *Kannaskoppianthus*, attached in a similar manner to short shoots with *Rochipteris* leaves.

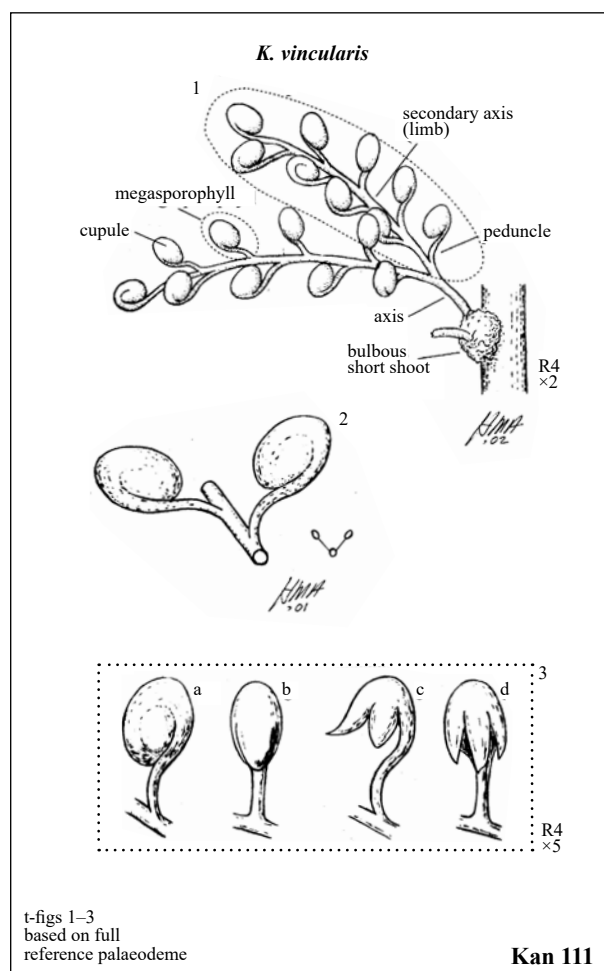
Classification & comparison

Suprageneric classification (Petriellaceae/Petriellales)

Kannaskoppia is considered to be closely allied to *Petriellaea* and thus placed in the order Petriellales and family Petriellaceae (Taylor *et al.*, 1994). We now follow Bomfleur *et al.* (2014) although we previously placed these female cupules in their own family Kannaskoppiaceae (And. & And., 2003).

Intergeneric comparison (Gondwana Triassic)

Petriellaea is known from a single permineralized peat deposit in the Middle Triassic Fremouw Fm. of Antarctica (Taylor *et al.*, 1994). The microscopic anatomy of the ovulate organ is exquisitely preserved revealing five ovules per cupule and many other details, but the overall architecture of the cupule remains uncertain. The reflexed cupules, as well as the size and configuration of the ovulate heads, are reminiscent of *Kannaskoppia*. It is possible that further new finds may show *Petriellaea* and *Kannaskoppia* to be congeneric, but this is not possible to conclude at the present time. What is known of the one genus is mostly unknown of the other.



Reconstructions

Fertile shoot

The reconstructions (t-figs 1–3 above) are based on the comprehensive palaeodeme from Kan 111 Ast spA. The shoot showing attachment of foliage and female cupule (p. 37, t-fig. 1) is largely a combination of PRE/F/13487a'y' and PRE/F/13487b'x' – the two portions of shoot illustrated on pls 23–26. These lie closely adjacent on the part and counterpart of a single cleaved slab. The arrangement of leaves and megasporophylls on the short shoots appears to show no consistent systematic pattern. However, the size and number of megasporophylls probably diminish towards the shoot apex.

Strobilus

The strobili, occurring in twos or threes, are found attached to bulbous short shoots which usually bear one or two leaves. Simplified reconstructions, with leaves removed, include a group of three strobili at natural size (p. 37, t-fig. 2), and a single strobilus showing characteristic fork and double row of megasporophylls at ×2 magnification (t-fig. 1 above).

Megasporophyll

The megasporophyll is taken to consist of a single cupulate unit borne on a long gracile, slightly recurved peduncle. Cupule details (t-figs 3a–d above) are based largely on three specimens, PRE/F/13489a,b, PRE/F/13508a,b and PRE/F/13518a,b; see pls 29, 33, 35, which show the cupules preserved at various angles. Due to the 3D nature of the preservation of the material shown in pls 23–26, it is possible to observe the curved peduncle with its tendency to flex downwards, and to estimate the angle of c. 90° between the cupule rows as shown in our reconstructions (t-figs 1, 2 above). The cupule is roundly ovoid and at maturity splits into three more or less regular lobes (t-figs 3c–d above).

Ovule/seed

While much is known about the gross morphology of the megasporophylls and their mode of attachment, nothing is known of the interior organization of the cupules or of the ovules. Nowhere on the many slabs bearing the cupule is there any indication that either cupules or seeds are individually dispersed.

Ref.: text & figs (4-page spread) updated from And. & And. (2003, pp 286–289)

Tab. 1. *Kannaskoppia/Kannaskoppianthus/Rochipteris*, Molteno occurrence.

TCs	assemblages (taphocoenosis)		<i>Rochipteris</i> ○	<i>Kannaskoppia</i> +○	<i>Kannaskopplanthus</i> ○	attached organs	fern/Kannask. meadow	Dominants				
								<i>Dicroidium</i>	<i>Sphenobolera</i>	<i>Heidiphyllum</i>	horsetails	ferns
1	Cal 211	Hei elo	5	–	–	–	–	–	–	75	–	20
2	Gre 121	Hei elo	22	–	2	–	–	3	–	98	20	2
3	" 111	Equ sp	1	–	–	–	–	2	–		97	1
4	Boe 112	Dic cor	1	–	–	–	–	99	–	14	4	–
5	Cyp 111	Dic cra	83	–	–	○	–	75	–	24	–	4
6	Kan 112	Hei elo	19	–	5	♂	–	1	–	98	6	7
7	" 111	Ast spA	5	50	–	○♀	✓	–	–	10	22	63
8	Tel 111	Hei elo	33	–	4	○	–	6	–	89	48	58
9	Kom 111	Sph/Dic	30	–	2	○♂	–	39	60	–	15	1
10	Vin 111	Dic odo	2	–	–	–	–	70	4	28	–	2
11	Lut 311	Hei elo	66	–	16	–	–	58	29	99	30	3
12	Kon 211	Ast 2spp	4	–	–	–	–	–	–	–	20	52
13	Pen 311	Hei elo	41	–	–	–	–	25	–	75	5	11
14	" 411	" "	80	–	4	–	–	13	–	94	2	3
15	Kap 111	Dic/Ris	6	–	–	–	–	50	20	25	10	4
16	Nuw 111	Dic zub	1	–	–	–	–	70	30	–	–	4
17	Win 111	Hei elo	4	–	–	–	–	10	–	79	2	3
18	Hla 213	Dic elo	7	–	–	–	–	89	49	1	11	32
19	Umk 111	Dic 2spp	50	–	–	–	–	69	5	7	2	1
20	San 111	Dic cra	3	–	–	–	–	90	–	5	2	1
21	Mat 111	Dic dub	2	–	3	–	–	89	18	4	20	7
22	Lit 111	Dic/Hei	56	–	9	–	–	50	1	23	10	10
23	Aas 111	Hei elo	2	–	21	–	–	7	1	77	10	20
24	" 211	Hei elo	19	–	1	–	–	–	–	99	–	2
25	" 311	Hei elo	26	–	4	–	–	15	9	99	–	2
26	" 411	Dic/Sph	150	–	21	–	–	60	30	1	75	24
	Total TCs		26	1	12		2					
	Total individuals		%	50	92							

Comparisons beyond Gondwana Triassic

Apart from *Petriellaea*, the Mesozoic ovulate structure most comparable with *Kannaskoppia* is *Caytonia* (Jurassic, Eurasia) – in its size and form with lateral rows of dorsally reflexed cupules on short peduncles. In both genera the cupules fully enclose the ovule(s), but in *Kannaskoppia* their nature remains unknown. *Kannaskoppia* differs most evidently in the strobilus being forked and in the pedunculate cupules not abscising.

***Caytonia* (Jurassic/Eurasia)**

Geographic & stratigraphic distribution: The ovulate organ, *Caytonia*, is now known as a widespread element of the lower half of the Jurassic of Eurasia: Yorkshire (>9 localities, M. Jurassic, Bajocian to Bathonian); Greenland (2 localities, basal Liassic, Hettangian); Poland (1 locality, U. Liassic); Sardinia and the USSR. Foliage identified as *Sagenopteris* has been reported from the U. Triassic to U. Cretaceous. The first report of *Caytonia* made from Gondwana was by Clifford & Camilleri (1998) who described *C. tierneyi* affiliated with *Sagenopteris* leaves from the Lower Jurassic Marburg Fm., Queensland, Australia. A possible *Caytonia* cupule was described by Elgorriaga *et al.* (2019) from the Lower Jurassic of Patagonia and they reviewed the other possible Gondwana finds.

Affiliation of organs: The *Caytonia* plant, the basis of the order Caytoniales, is one of around 20 fossil and extant gymnospermous 'orders' (or approximate ordinal groupings) on which cladistic analyses of the gymnosperms are based (Crane, 1985, 1986, 1988). It is one of the few fossil gymnosperm genera where most organs are known through well-established affiliations (Grade 4) from a good number of localities. The organs include *Caytonia* (female strobilus), *Caytonanthus* (male strobilus) and *Sagenopteris* (foliage).

Preservation: Adding value to *Caytonia* (and affiliated organs) is that it is often found as well-preserved compressions.

Megasporophylls (morphology): 'Cupules' on short peduncles, spherical, reflexed dorsally with distinctive lip, apparently fleshy and berrylike at maturity, abscising at base of pedicel, with 8–30 tiny ovules.

Abundance: Explicit abundance and frequency data on fossil taxa are rarely given and this holds generally true for the *Caytonia* plant. In the Yorkshire Jurassic sites where it is best known, Harris (1964, p. 3) writes that it is "by no means common".

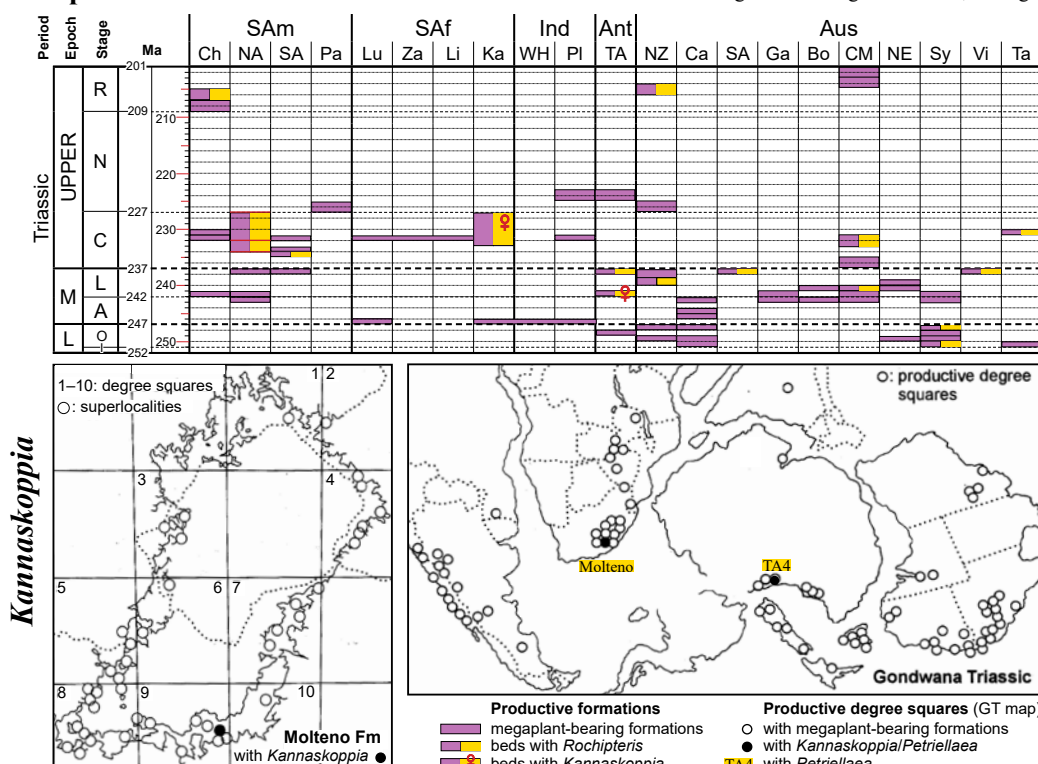
Diversity: No recent taxonomic revision of the *Caytonia* plant has been attempted, so any real sense of specific diversity is very difficult to gather. Five named species of the genus *Caytonia* appear to be currently valid from Eurasia.

References: Harris (1933, 1940, 1958, 1964); Reymanówna (1973); Crane (1985); Krassilov (1977).

***Polyspermophyllum* (Permian/Argentina)**

Kannaskoppia cupules are remarkably similar to the ovuliferous component of *Polyspermophyllum sergii*. Archangelsky & Cuneo (1990) from the Permian of Argentina. These are described as "distally placed curved ovuliferous units (cupules?) bearing a single ovule." However, the ?cupules are borne on repeatedly dichotomizing trusses and occur with attached leaves bearing a single medial vein and two longitudinal marginal furrows, setting them far apart from *Kannaskoppia*.

Polyspermophyllum is included in the Dicranophyllales. Archangelsky & Cuneo also discuss the possible links of their genus to the Ginkgoales and other orders.

Map 1.

Kannaskoppia vincularis J.M.And. & H.M.And., 2003**Holotype**

Specimen: PRE/F/13487 a'y'; tf. 2 below; pls 23, 24

Assemblage: Kan 111 Ast spA, Kannaskop.

Preservation: a shoot 90 mm long with clusters of foliage and megasporophylls attached; compressed 3D mould and cast (no cuticle or carbonized material); on the counterpart slab there is an additional isotype specimen, PRE/F/13487b'x', from which a piece of matrix (flake) can be lifted to reveal foliage and fruit at a different level; impression in thick-bedded, moderately baked, greenish grey silty mudstone with very poor cleavage.

Isotype: tf. 1 below; see notes on p. 67; pls 25, 26

Plant fossil names registry number: PFN002288

Reference palaeodeme

Assemblage: as for holotype.

Specimens: c. 50 indivs, pls 23–34 (includes further foliage as indicated);

5 torn sections of shoot with foliage and strobili attached;

>50 detached strobili or clusters of strobili;

12 torn sections of shoot with foliage only;

>25 detached leaves, generally torn or twisted.

Sister palaeodemes – nil.

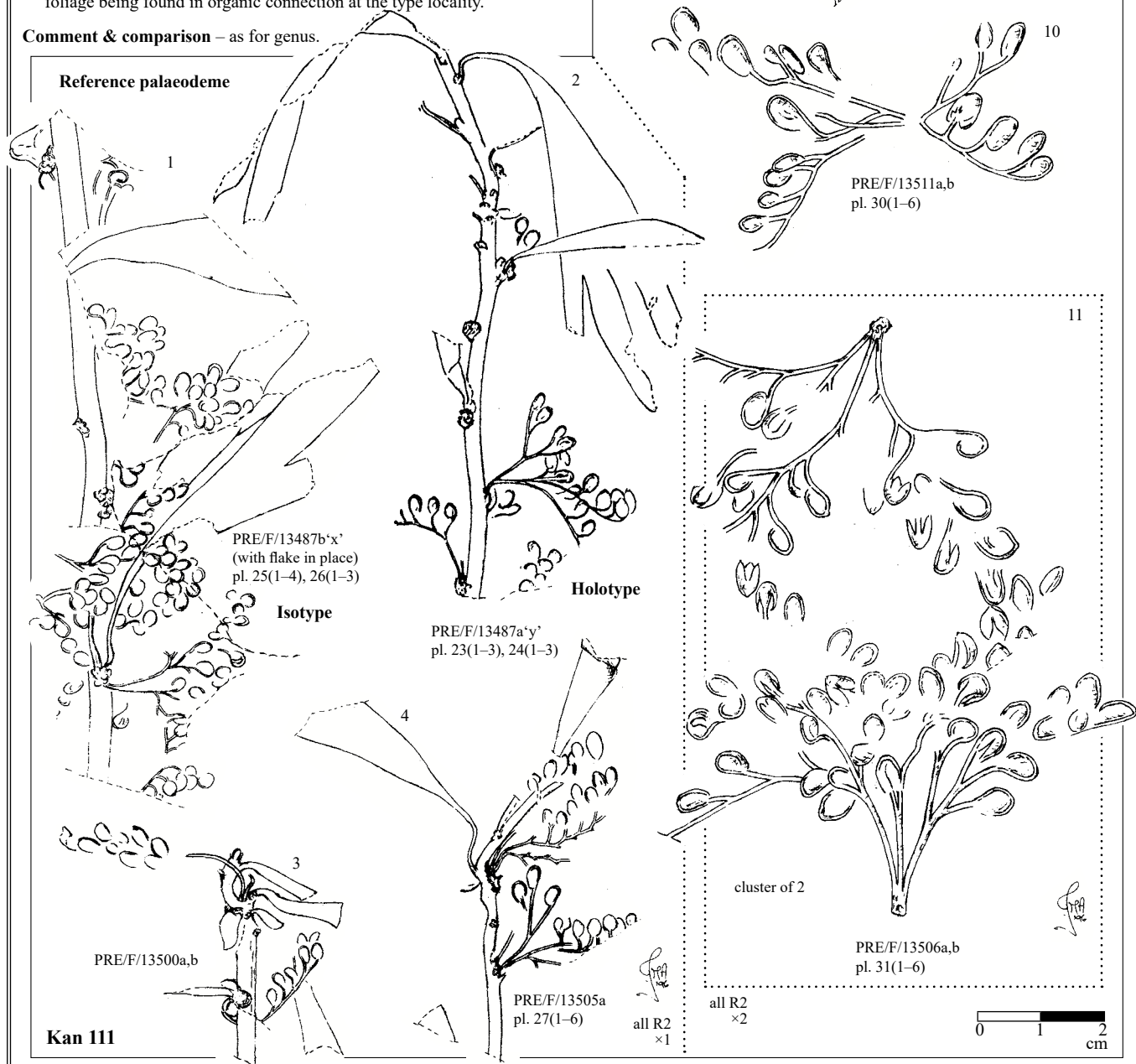
Specific diagnosis – as for genus.

Specific characters – as for genus.

Etymology

vincularis – *vinculum* (Lat.), link, bond, with reference to the fruit and foliage being found in organic connection at the type locality.

Comment & comparison – as for genus.

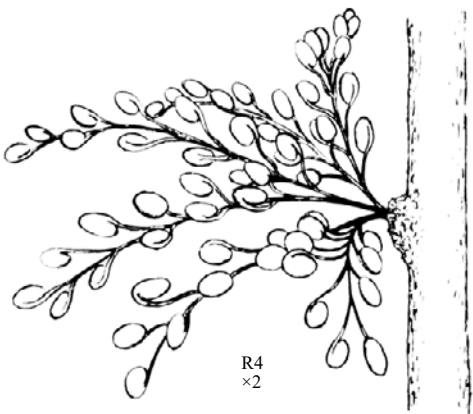


Kannaskoppia vincularis

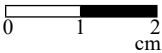


R4
×1

t-figs 1, 2 based on
full reference palaeodeme,
but largely on
PRE/F/13487a'y' & PRE/F/13487b'x'



R4
×2



Kan 111

H. H. H.
1996

Kannaskoppianthus J.M.And. & H.M.And., 2003**Type species**

Kannaskoppianthus luterus J.M.And. & H.M.And., 2003,
Lutherskop (Lut 311), Karoo Basin, S. Africa; Carnian, Triassic.

Plant fossil names registry number: PFN002296 (for genus)

Generic diagnosis

A ginkgoopsid strobilus comprising a forked axis bearing 2 rows of several adaxial microsporophylls with 5–10 longitudinal microsporangia in a concavity protected by an operculum.

Generic characters

Fertile shoot: strobili attached in fascicle with leaf cluster along shoot or at end of shoot.

Strobilus: lax, planar, bilaterally symmetrical, small (8–25 mm long) to rarely medium (up to 45 mm); axis gracile, proximally forked; microsporophylls in 2 adaxial oblique rows (of 4–10 units) along each fork (limb), angle between rows *c.* 90°.

Microsporophyll: spatulate, dorsoventrally flattened, bilaterally symmetrical; microsporangia 5–10 per unit, longitudinally aligned in distinctive concavity, attached distally to apical arcuate scale cap, protected by a dehiscent operculum.

Microsporangia: elongate-elliptic (1.5 × 0.5 mm), with fine linear ornamentation.

Pollen: unknown.

Etymology

Kannaskoppianthus – after the type locality and acknowledging certain affiliation with the female strobilus *Kannaskoppia*.

Global range: 8 spp., Gondwana, Tr. (CRN–RHA).

First: Molteno Fm. (233–227 myrs)

Last: Chile, Ternera Fm. (207 Ma)

Gondwana Triassic occurrence

South Africa – Karoo Basin, 12 TCs (92 indivs).

Molteno occurrence

Frequency (F): 12 TCs (of 100 sampled in Molteno).

Diversity (D): 8 species.

Abundance (A): 92 indivs total; rare to extremely rare in top 8 TCs.

Aas 111 Hei elo:	21 indivs in	40 man-hrs	(5 per 1 man-day)	rare
Lut 311 Hei elo:	16 “ “	50 “	(3 “ 1 “)	“
Kan 112 Hei elo:	5 “ “	15 “	(3 “ 1 “)	“
Kom 111 Sph/Dic:	2 “ “	10 “	(2 “ 1 “)	“
Aas 411 Dic/Sph:	21 “ “	512 “	(1 “ 2 “)	very rare
Mat 111 Dic dub:	3 “ “	65 “	(1 “ 2 “)	“ “
Tel 111 Hei elo:	4 “ “	90 “	(1 “ 2 “)	“ “
Lit 111 Dic/Hei:	9 “ “	550 “	(1 “ 6 “)	extr. rare

The abundance figures reflected here for the eight TCs with the highest *Kannaskoppianthus* yield, account for every specimen found, no matter how fragmentary or poorly preserved. All were retained and curated. At the four further sites not listed above, *Kannaskoppianthus* is even rarer (Tab. 2, p. 40).

Although very rare, the *Kannaskoppianthus* male occurs in 12 of the 26 TCs yielding *Rochipteris* foliage. This frequency ratio of 1:2 (male to foliage) is high for the Molteno. In the 12 TCs it ranges in abundance from 1 individual in 7 man-days cleaving to 5 in 1 day, with a norm at around 1 found every 2 days. There appears to be no particular pattern of abundance based on habitat.

Affiliated organs

Female strobilus: *Kannaskoppia* – Grade 5 (Mor. corr.).

Foliage: *Rochipteris* – Grade 5 (Org. att.).

From Kommandantskop (Kom 111 Sph/Dic), PRE/F3231a,b (t.fig.5 adjacent) shows two strobili of *Kannaskoppianthus* attached to an axis with a whorl of four *Rochipteris* leaves (see also pl. 47(1–8)). From Kannaskop (Kan 112 Hei elo), PRE/F/20114a,b (pls 19–20) shows a strobilus attached to a stem with leaf/branch scars. This is similar to the stems bearing leaves and female strobili (*Kannaskoppia*) from Kan 111 Ast spA.

Classification & comparison

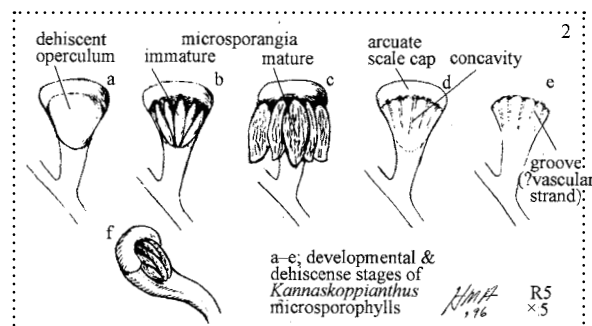
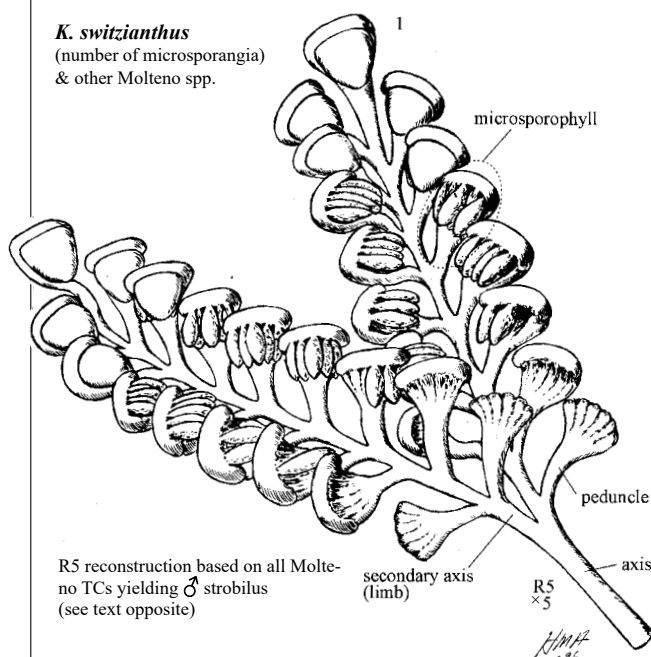
Suprageneric classification

See under *Kannaskoppia*.

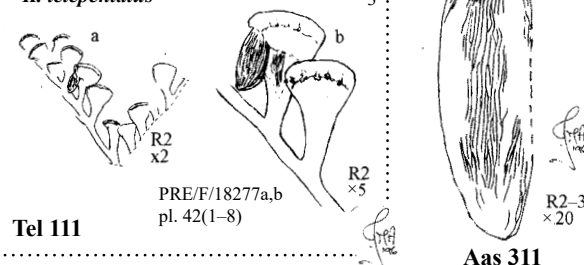
Intergeneric comparison (Gondwana Triassic)

Kannaskoppianthus is unique among known ginkgoopsid microsporangiate genera. In their size, diagnostic forking and paired erect rows of fertile units, the micro- and megasporophylls (*Kannaskoppia*) are remarkably alike. The latter are noticeably more gracile.

K. switzianthus
(number of microsporangia)
& other Molteno spp.

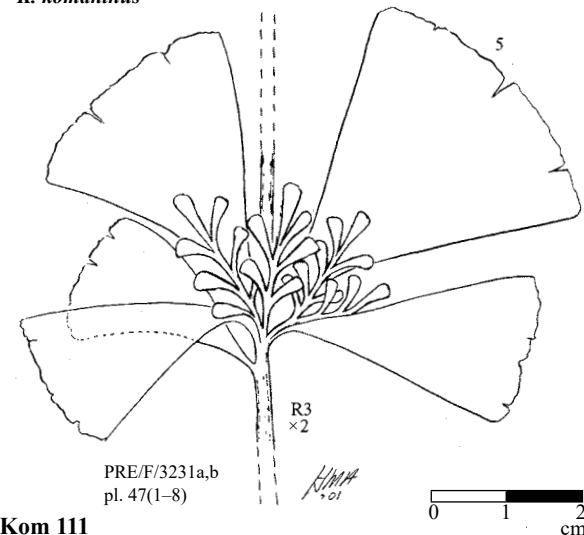


K. telepentatus



Aas 311
PRE/F/12001a,b
pl. 147(7–10)

K. komanthus



Reconstructions

The R5 reconstructions (t-figs 1, 2 opposite) of *Kannaskoppianthus* are based on the full set of Molteno specimens at hand, but primarily on:

- Lut 311: PRE/F/11433, pl. 53(1–8): architecture of strobilus, nature of protective operculum
 Aas 211: PRE/F/15280, pl. 143(1–11): angle of microsporophyll
 Tel 111: PRE/F/18277a,b, pl. 42(1–8): structure of microsporophyll, attachment and number of microsporangia
 Aas 411: several indivs, pls. 153–156: attachment of microsporangia
 Aas 311: PRE/F/12001, pl. 147(8,9): morphology of microsporangia
 Tel 111: PRE/F/7711, pl. 41(1–6): nature of protective operculum
 Lit 111: PRE/F/21497, pl. 119(1–6): number of microsporangia, groove
 Gre 121: PRE/F/7856, pl. 3(1–6): number of microsporangia, groove

Number of microsporangia

No specimens in the collection show microsporophylls with the full complement of microsporangia attached. A specimen from Tel 111, PRE/F/18277a,b, clearly shows two attached microsporangia, pl. 42(1–8). The size and shape of these microsporangia suggest a full complement of five pollen sacs in the undehiscent original. Furthermore, five grooves or vascular strands are seen where the microsporangia were probably attached (t-figs 2d, 3b opposite). In three species, 10 grooves or attachment scars are evident, e.g. PRE/F/7711, pl. 41(1–6).

Microsporophyll developmental & dehiscence stages (t-figs 2a–e opposite):

- microsporophyll with protective operculum covering the microsporangia;
- operculum dehiscent revealing the five closely packed immature microsporangia;
- mature microsporangia ready to release pollen;
- microsporophyll with the microsporangia detached exposing five grooves or vascular strands;
- the woody arcuate scale cap is now detached; most specimens in the collection show this stage of preservation;
- microsporophyll at stage (b) in oblique view at characteristic angle (as if on intact strobilus).

Gondwana Triassic occurrence (elaborated)

From South America (Hypodigm, Chart 1, pp 106, 107), Solms-Laubach (1899) named and illustrated a fertile structure as *Acrocarpus ternerae* which is here regarded as a *Kannaskoppianthus* sp. The genus *Acrocarpus* does not have priority as it is an extant genus in the family Fabaceae. Artabe *et al.* (1998) reported fertile structures associated with these leaves but did not describe them. They are probably male and need to be described.

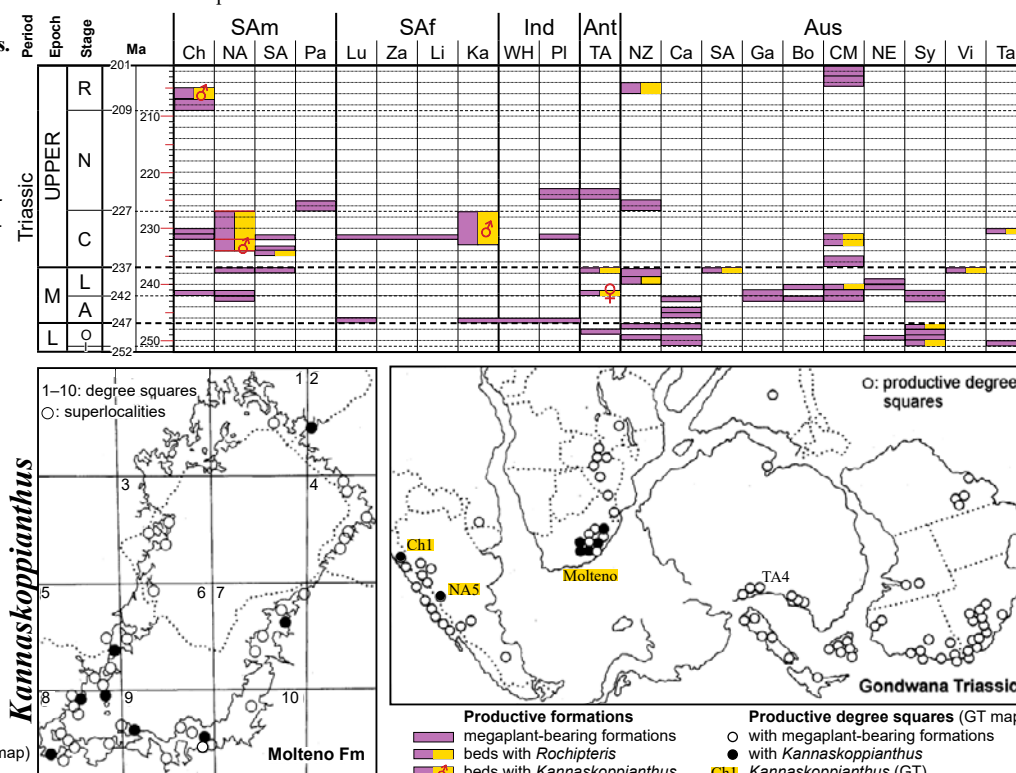
A doubtful record of a sporophyll was reported by Jones & De Jersey (1947, t-fig. 59) from the Ipswich Basin in Australia. Although thought to bear seeds, in size and shape the specimen comes close to *Kannaskoppianthus*. However, poor preservation does not allow closer comparison.

Comparisons beyond Gondw. Trias.

The only pollen-bearing structures that show some similarity to *Kannaskoppianthus* occur in the Carboniferous of Euramerica. The class Lagenostomopsida includes the genera *Crossothea* and *Feraxotheca*, both of which have numerous microsporangia attached at the end of modified ultimate pinnae. *Paracalathiops* shows a similarity in the basic architecture of a bifurcating axis and pedunculate microsporophylls (see Taylor & Taylor, 2009).

While the megasporophyll *Kannaskoppia* shows some similarities to *Caytonia*, the microsporophyll *Kannaskoppianthus* differs greatly from *Caytonianthus*, which has a pinnate structure bearing lateral ‘branches’ and a few pedicellate microsporangia consisting of usually ‘four locules’ which dehisce towards their inner side (Crane, 1985).

Productive superlocalities (Molteno map)
 ● with *Kannaskoppianthus*



Intactness & preservation (Molteno)

Microsporangia (see Tab. 2, p. 40)

The male strobilus has been found in 12 of the 26 *Rochipteris*-bearing TCs. Although microsporangia have been recognized from eight of these 12 TCs they remain notably rare, probably because the microsporangia are shed before or during fossilization. Of the strobili preserved with associated microsporangia, only a small proportion are seen with sacs clearly attached: Tel 111 (PRE/F/18277a,b); Aas 411 (PRE/F/12050a,b, PRE/F/20558a,b, PRE/F/21339a,b, PRE/F/21720a,b). The best preserved of the individual microsporangia have been illustrated: pl. 147 from Aas 311, and pl. 42 from Tel 111.

Pollen

Of all the *Kannaskoppianthus* microsporophyll sites, only the Lit 111 Dic/Hei TC yields carbonized compression material with the potential for extracting *in situ* pollen. And only two of the nine available strobili (PRE/F/5939 & PRE/F/5734) from this site appear to bear a few microsporangia that could possibly yield pollen.

Cuticles

Potential sample: Lit 111, 9 indivs.

Macerated (And. & And., 2003): 2 indivs.

Preservation grade: Grade 3 (fair), a few features available, small pieces mainly from stalk area.

Diagnostic characters: cells oblong to narrowly oblong, walls straight to gently curved; stomata absent; trichome bases apparently indicated by circular marks, distribution random but towards the end of cells, on both surfaces.

Significance:

Classification – The cuticular features do not indicate any particular plant group, but also do not dispute placement in the Ginkgoopsida and family Petriellaceae.

Affiliations – The diagnostic stomata and characteristic (?) glands found in the leaf (*Rochipteris*) cuticle have not been found in that of the affiliated male strobilus. The cell outlines and walls, however, correspond well with those characterizing the foliage.

Adaptive radiation (Molteno diversity)

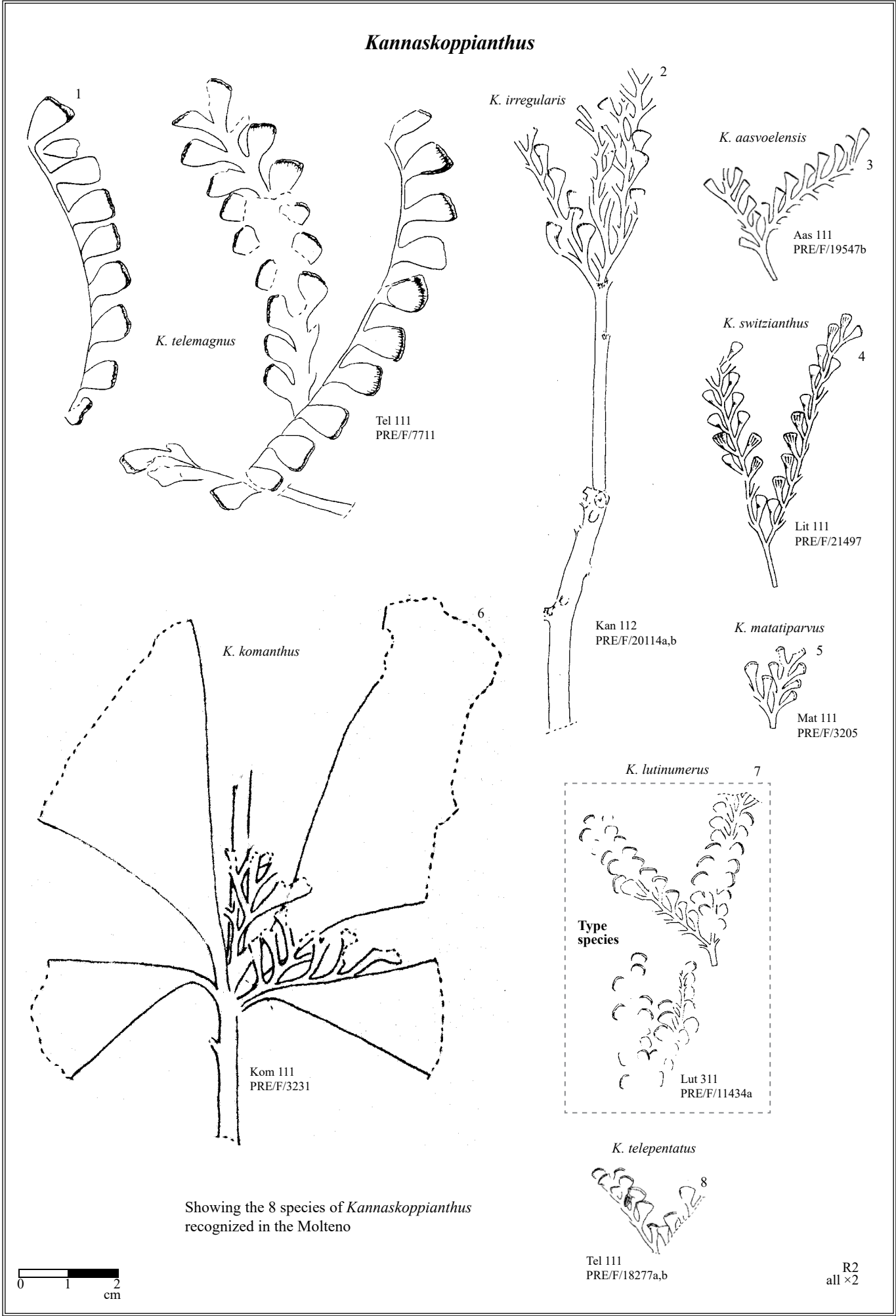
Previously four species of *Kannaskoppianthus* were recognized (And. & And., 2003), but a closer examination has led to eight species being recognized here. The diversity in the male fruit is less than in the foliage where 12 species are recognized. (The female fruit is represented by only one species from one TC.) The diagnostic characters of the eight male species lie in the size and forking of the strobilus and in the number of microsporophyll pairs per limb, and the number of microsporangia per head.

Tab. 2. *Kannaskoppianthus* – Molteno occurrence.

		Kannaskoppianthus														Habitat							Dominants					
TCs	assemblages (taphocoenosis)		Members	<i>Rochipteris</i>	<i>Kannaskoppia</i>	<i>Kannaskoppianthus</i>	microsporangia	<i>K. telemagnus</i> (Tel 111)	<i>K. irregularis</i> (Kan 112)	<i>K. aasvoelensis</i> (Aas 111)	<i>K. switzianthus</i> (Lit 111)	<i>K. mataiparvus</i> (Mat 111)	<i>K. komanthus</i> (Kom 111)	<i>K. lutinumerus</i> (Lut 311)	<i>K. telepentatus</i> (Tel 111)	attached organs	<i>Dicr. rip. forest</i> (t.1)	<i>Dicr. rip. forest</i> (t.2)	<i>Dicr. woodland</i>	<i>Sphenobaiera</i> woodl.	<i>Heidiphyllum</i> thicket	<i>Equisetophyte</i> marsh	fern/Kannask. meadow	<i>Dicroidium</i>	<i>Sphenobaiera</i>	<i>Heidiphyllum</i>	horsetails	ferns
1	Cal 211	Hei elo	T 5	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	75	–	20
2	Gre 121	Hei elo	Obba 4	22	–	2	1	–	–	2	–	–	–	–	–	–	–	–	–	–	✓	–	–	3	–	98	20	2
3	" 111	Equ sp		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	97	1	
4	Boe 112	Dic cor		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	99	–	14	4	–
5	Cyp 111	Dic cra		83	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	75	–	24	–	4
6	Kan 112	Hei elo	Mayaputi 3	19	–	5	1	–	5	–	–	–	–	–	–	♂	–	–	–	✓	–	–	1	–	98	6	7	
7	" 111	Ast spA		5	50	–	–	–	–	–	–	–	–	–	–	0♀	–	–	–	–	–	–	–	–	–	10	22	63
8	Tel 111	Hei elo		33	–	4	1	2	–	–	–	–	–	–	2	0	–	–	–	✓	–	–	6	–	89	48	58	
9	Kom 111	Sph/Dic		30	–	2	1	–	–	–	–	–	–	2	–	0♂	–	–	–	✓	–	–	39	60	–	15	1	
10	Vin 111	Dic odo	Indwe 2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	70	4	28	–	2	
11	Lut 311	Hei elo		66	–	16	–	–	–	–	–	–	–	16	–	–	–	–	–	✓	–	–	58	29	99	30	3	
12	Kon 211	Ast 2spp		4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	52	
13	Pen 311	Hei elo		f	41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	25	–	75	5	11	
14	" 411	" "	Bamboesberg 1	80	–	4	–	–	–	4	–	–	–	–	–	–	–	–	–	✓	–	–	13	–	94	2	3	
15	Kap 111	Dic/Ris		e	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50	20	25	10	4	
16	Nuw 111	Dic zub		d	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	70	30	–	–	4	
17	Win 111	Hei elo		4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	79	2	3	
18	Hla 213	Dic elo	a	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	89	49	1	11	32		
19	Umk 111	Dic 2spp		50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	69	5	7	2	1		
20	San 111	Dic cra		b	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	90	–	5	2	1	
21	Mat 111	Dic dub		2	–	3	–	–	–	–	–	3	–	–	–	–	–	✓	–	–	–	–	89	18	4	20	7	
22	Lit 111	Dic/Hei	a	56	–	9	2	–	–	–	9	–	–	–	–	–	✓	–	–	–	–	50	1	23	10	10		
23	Aas 111	Hei elo	1	2	–	21	5	–	–	21	–	–	–	–	–	–	–	–	–	✓	–	–	7	1	77	10	20	
24	" 211	Hei elo		19	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	✓	–	–	–	–	99	–	2
25	" 311	Hei elo		26	–	4	1	–	–	–	4	–	–	–	–	–	–	–	–	–	✓	–	15	9	99	–	2	
26	" 411	Dic/Sph		150	–	21	4	–	–	–	21	–	–	–	–	–	–	–	–	–	✓	–	–	60	30	1	75	24
	Total TCs			26	1	12	8	1	1	6	1	1	1	1	1		1	1	–	2	8	–						
	Total individuals			%	50	92	16	2	5	53	9	3	2	16	2													

Kannaskoppianthus* occurrence in the Molteno Fm.*Taphocoenoses:** occurs in 12 of the 100 sampled TCs**Members:** occurs in the lower 4 of the 6 Molteno Members;
but most frequently in the Bamboesberg & Mayaputi Members**Diversity:** 8 species of *Kannaskoppianthus* recognized.**Habitat:** the genus has been found in 4 of the 7 habitats identified;
but by far most frequently in the *Heidiphyllum* thicket (8 of 12 TCs)**Dominants:** *Heidiphyllum* & *Dicroidium* are clearly the most
abundant associates of *Kannaskoppianthus***Abundance:** bold – %
regular – indivs

1. *K. telemagnus* And. & And., 2003
2. *K. irregularis* And. & And., 2003
3. *K. aasvoelensis* And. & And., sp. nov.
4. *K. switzianthus* And. & And., sp. nov.
5. *K. matatiparvus* And. & And., 2003
6. *K. komanthus* And. & And., sp. nov.
7. *K. lutiinumerus* (And. & And., 2003)
emended
8. *K. telepentatus* And. & And., sp. nov.



Kannaskoppianthus telemagnus J.M.And. & H.M.And., 2003**Holotype**

Specimen: PRE/F/7711; And. & And., 2003, pl. 118(1,2,4–6).

Assemblage (TC): Tel 111 Hei elo, Telemachus Spruit.

Preservation: cluster of 4 detached strobilus limbs, without counterpart; impression in thickly laminated, light olive-grey shale with poor cleavage.

Plant fossil names registry number: PFN002301

Reference palaeodeme

Assemblage (TC): as for holotype.

Specimens: 2 indivs (1 cluster, 1 fragment); this vol., pl. 41(1–7).

Sister palaeodemes – nil.

Specific diagnosis

A *Kannaskoppianthus* species with large strobili with limbs bearing 9 or 10 microsporophylls per row and c. 10 microsporangia per unit.

Specific characters

Attachment: unknown.

Strobilus: large (>40 mm long), fork unknown; microsporophylls 9 or 10 per row.

Microsporophyll: broadly convexly conate (c. 3 mm wide distally), with c. 10 microsporangial attachment scars per unit.

Etymology

telemagnus – *tele*, for the type locality Telemachus Spruit; *magnus* (Lat.), with reference to the large size of the strobilus.

Affiliation ♂ (foliage)

Rochipteris telefolia (30 indivs); Grade 4 (virtually exclusive)

The strobilis is clearly affiliated with the distinctive large-leaved *Rochipteris telefolia* which, with 30 individuals (from Tel 111), is relatively common. Two specimens of *K. telepentatus* have also been collected from the Tel 111 TC.

Comment & comparison

Molteno species

K. telemagnus differs clearly from the other seven *Kannaskoppianthus* species in the far larger size of its strobili and microsporophylls. The holotype is reconstructed here (p. 126, fig. 1) as a pair of forked strobili attached to a single node.

Gondwana species

The fertile structure *Acrocarpus ternerae* described by Solms-Laubach (1899) (Hypodigm, Chart 1, p. 106) is closest to this species in size and shape but does not show enough details to make a closer comparison. It is affiliated with the leaves *Rochipteris copiapensis* described from the same locality and regarded as a distinct species of *Kannaskoppianthus* (see p. 49 for ‘Proposed new combination’).

Petriellaceae in Tel 111 Hei elo TC

Kannaskoppianthus telemagnus (2 indivs)

“ *telepentatus* (2 indivs)

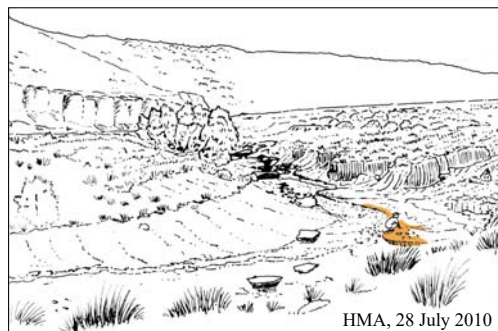
Rochipteris telefolia (30 indivs)

“ *penensis* (2 indivs)

“ *pusilla* (1 indiv.)

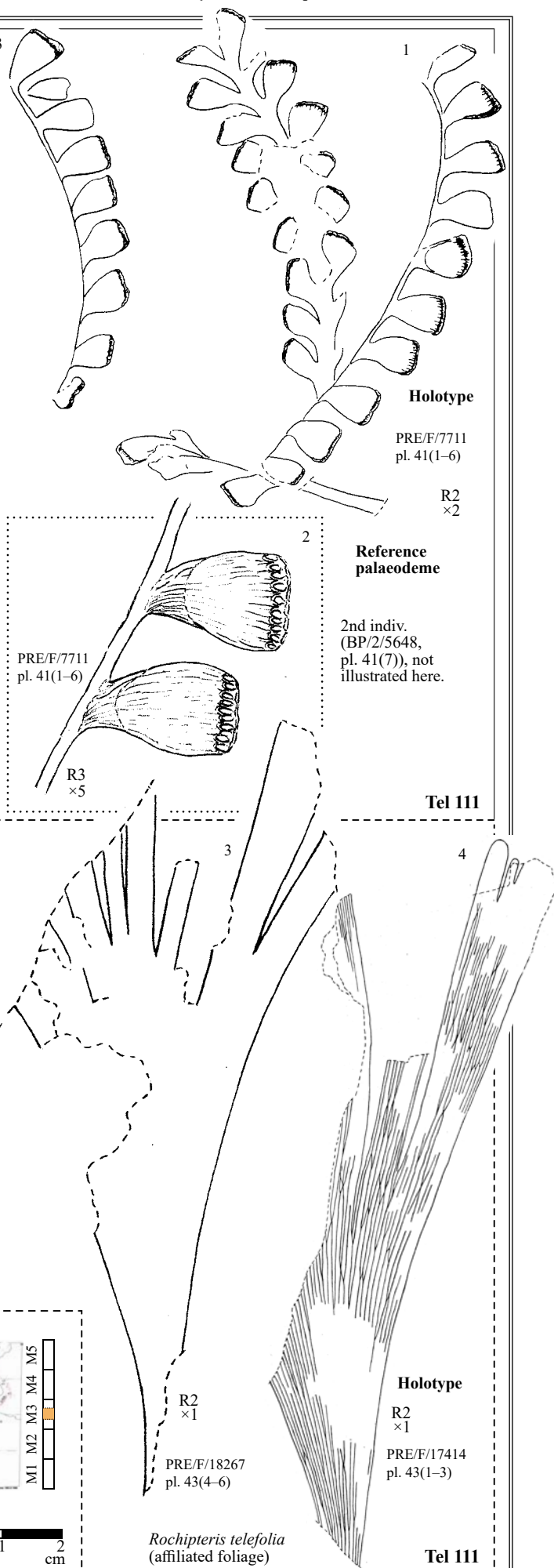
Rarity of *K. telemagnus* at Tel 111

2 indivs in 90 man-hrs (1 per 4 man-days), very rare

**Telemachus Spruit (Tel 111 Hei elo)**

Habitat: *Heidiphyllum* thicket

Collection: 581 slabs, 90 man-hrs cleaving



Kannaskoppianthus irregularis J.M.And. & H.M.And., 2003**Holotype**

Specimen: PRE/F/20114a,b; And. & And., 2003, pl. 117(1–6).

Assemblage (TC): Kan 112 Hei elo, Kannaskop.

Preservation: intact strobilus attached to an axis, part & counterpart; impression in very thin-bedded, moderately baked, medium grey shale with poor cleavage.

Plant fossil names registry number: PFN002302

Reference palaeodeme

Assemblage (TC): as for holotype.

Specimens: 5 indivs (1 attached intact, 4 partial); this vol., pl. 19(1–6), 20(1–6).

Sister palaeodemes – nil.

Specific diagnosis

A *Kannaskoppianthus* species with medium irregularly forked strobili whose limbs bear 5 or 6 microsporophylls per row.

Specific characters

Attachment: strobili attached terminally to a stem (?long shoot).

Strobilus: medium (>26 mm long), irregularly forked; microsporophylls 5 or 6 per row.

Microsporophyll: broadly concavely conate (c. 2 mm wide distally), with unknown number of microsporangial attachment scars per unit.

Etymology

irregularis – (Lat.), referring to the irregular branching of the strobilus.

Affiliation ♂ (foliage)

Rochipteris distivena (4 indivs); Grade 3.5 (very probable)

Amongst the 5 species of *Rochipteris* identified at Kan 112, aside from *R. brumensis* (1 indiv), the other 3 foliage species are all preoccupied as regards affiliation.

Comment & comparison

Molteno species

K. irregularis differs from the other *Kannaskoppianthus* species in the irregularly branching strobili. In the holotype, PRE/F/20114a,b, the stem shows leaf scars but no intact leaves and the strobili are attached seemingly terminally on the shoot.

The only other attached *Kannaskoppianthus* strobilus found in the Molteno to date is PRE/F/3231 from Kom 111, previously (And. & And., 2003) included in *K. irregularis*, but is described here as a new species, *K. komanthus*. It differs from *K. irregularis* in the shape of the microsporophylls and in their lesser number per row. It consists of a stem with four attached leaves and two strobili, but their actual point of attachment is not clear.

Petriellaceae in Kan 112 Hei elo TC

Kannaskoppianthus irregularis (5 indivs)

Rochipteris telefolia (2 indivs)

“ *distivena* (4 indivs)

“ *rollerii* (10 indivs)

“ *penensis* (2 indivs)

“ *pusilla* (1 indiv.)

Rarity of *K. irregularis* at Kan 112

5 indivs in 15 man-hrs (3 per 1 man-day), rare

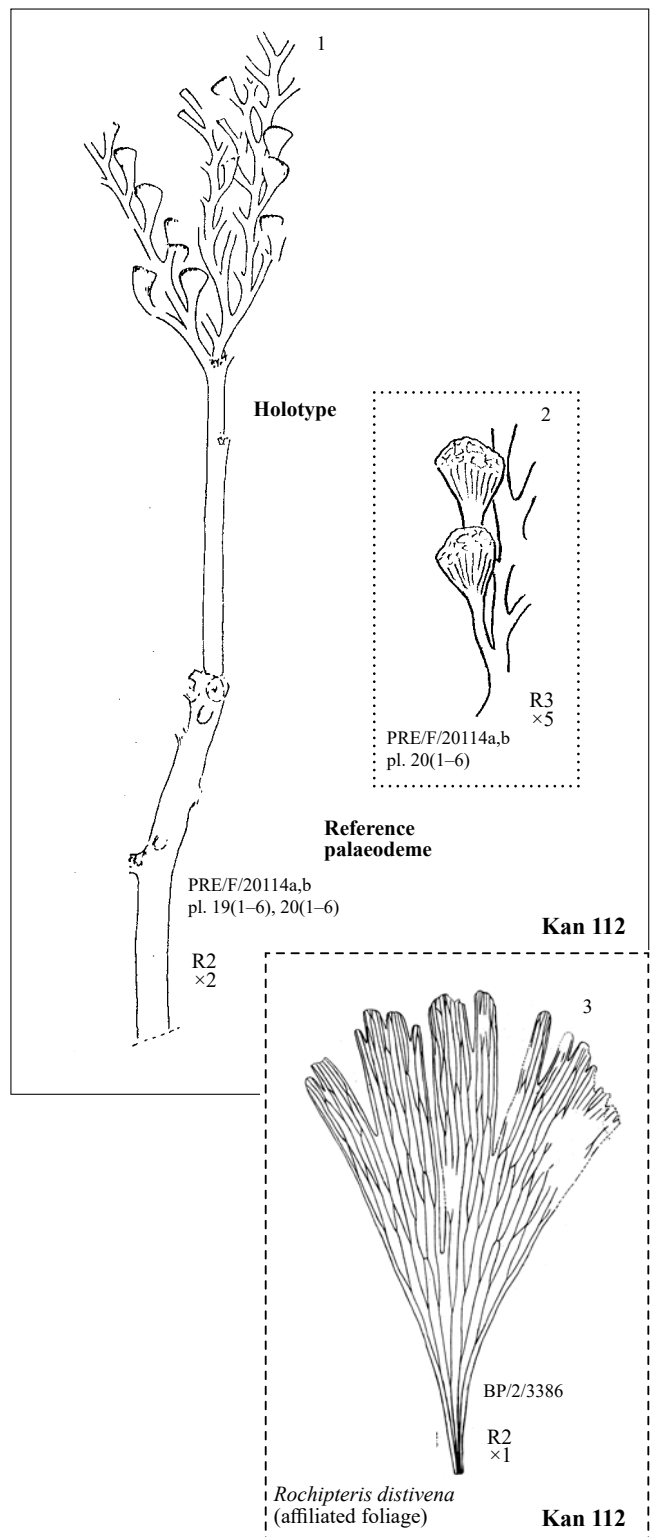


From photo, 1 Sept 1993

Kannaskop (Kan 112 Hei elo), Upper End

Habitat: *Heidiphyllum* thicket

Collection: 145 slabs, 15 man-hrs cleaving



16. Kan 112

Kannaskoppianthus aasvoelensis J.M.And. & H.M.And., sp. nov.**Holotype**

Specimen: PRE/F/19547a,b, pl. 125(1–9).

Assemblage (TC): Aas 111 Hei elo, Aasvoëlberg.

Preservation: mostly intact strobilus (part & counterpart); impressions in thickly laminated, light-grey shale with moderate cleavage.

Plant fossil names registry number: PFN002303

Reference palaeodeme

Assemblage (TC): as for holotype

Specimens: 21 indivs (6 intact, 15 partial); this vol., pls 125–130, 131(1–4).

Sister palaeodemes – 5

Gre 121 Hei elo: 2 indivs.

Pen 411 Hei elo: 4 indivs (2 of these have opercula attached).

Aas 211 Hei elo: 1 indiv. (intact).

Aas 311 Hei elo: 4 indivs (1 intact, 3 partial), microsporangia present.

Aas 411 Dic/Sph: 21 indivs (10 intact, 11 partial), microsporangia present.

Gre 121, p. 81, fig. 12, pl. 3(1–6); Pen 411, pl. 79–80;

Aas 211, p. 83, fig. 6, pl. 143(1–11); Aas 311, pl. 145–147;

Aas 411, p. 87, figs 1–5, pl. 153–156.

Specific diagnosis

A *Kannaskoppianthus* species with small regularly forked strobili whose limbs bear 5–8 microsporophylls per row and c. 10 microsporangia per unit.

Specific characters

Attachment: unknown.

Strobilus: small to medium (c. 13–20 mm long), regularly forked; microsporophylls 5–8 per row

Microsporophyll: narrowly concavely conate, convex to end (c. 1 mm wide distally); with c. 10 microsporangial attachment scars per unit.

Etymology

aasvoelensis – aasvoel, for the type locality Aasvoëlberg.

Affiliation ♂ (foliage)

Rochipteris rollerii (2% of TC); Grade 4 (mutually exclusive occurrence)

R. rollerii, being the only *Rochipteris* species recognized at Aas 111, is considered the almost certain affiliate of *K. aasvoelensis* (with 21 indivs), the sole male-strobilus species found at the site.

Comment & comparison

Molteno species

K. aasvoelensis is most like *K. lutinumerus* (p. 48) in the number of microsporophylls per row (and the number of microsporangia per unit); but graphs (Chart 3, p. 77) show the latter species to have a distinctly greater spread. From Aas 411 derives a good collection (21 indivs) which are very similar to the reference population; and show a few unclearly preserved microsporangia (pl. 156, figs 7, 9).

Petriellaceae in Aas 111 Hei elo TC

Kannaskoppianthus aasvoelensis (21 indivs)

Rochipteris rollerii (2%)

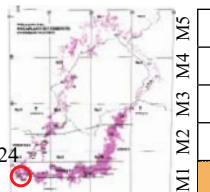
Rarity of *K. aasvoelensis* at Aas 111

21 indivs in 40 man-hrs (5 per 1 man-day), rare

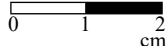


HMA, May 2019

From photo, 4 June 1971

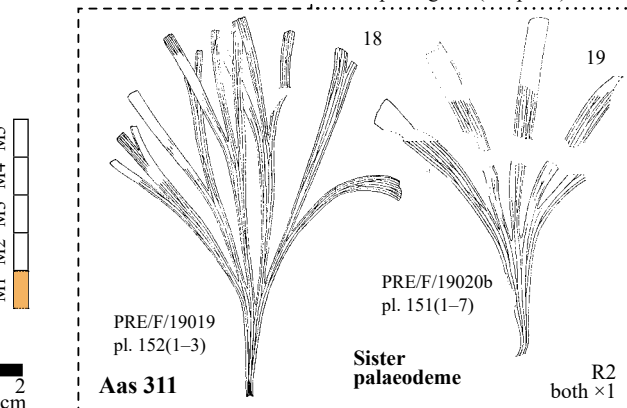
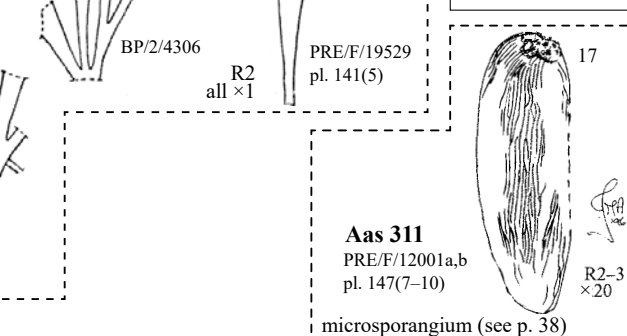
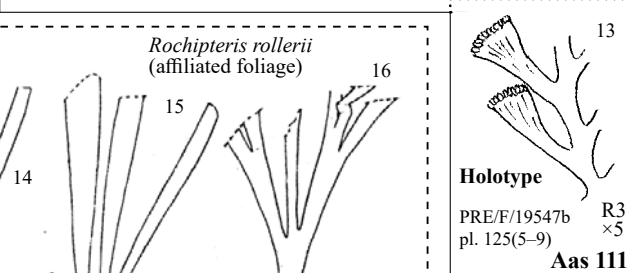
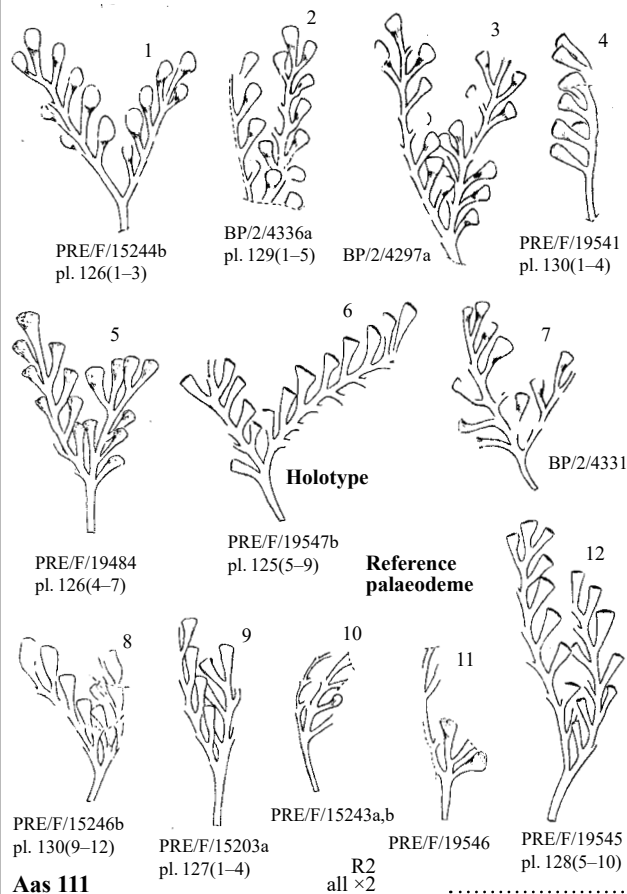


24. Aas 111

**Aasvoëlberg (Aas 111 Hei elo), Turner Shale**

Habitat: *Heidiphyllum* thicket

Collection: 291 slabs, 40 man-hrs cleaving



Kannaskoppianthus switzianthus J.M.And. & H.M.And., sp. nov.**Holotype**

Specimen: PRE/F/21497a,b; pl. 119(1–6).

Assemblage (TC): Lit 111 Dic/Hei, Little Switzerland.

Preservation: intact strobilus (past & counterpart); compressions in thinly laminated, carbonaceous (with cuticle), dark-grey shale with moderate cleavage.

Plant fossil names registry number: PFN002304

Reference palaeodeme

Assemblage (TC): as for holotype.

Specimens: 9 indivs (6 intact, 3 partial), cuticle, microsporangia present; this vol., pls 119–120.

Sister palaeodemes – nil.

Specific diagnosis

A *Kannaskoppianthus* species with small regularly forked strobili whose limbs bear 6–10 microsporophylls per row and c. 4–5 microsporangia per unit.

Specific characters

Attachment: unknown.

Strobilus: small to medium (c. 14–25 mm long), regularly forked, microsporophylls 6–10 per row.

Microsporophyll: concavely elongate, convex to end (c. 1–1.5 mm wide distally), with c. 4–5 robust elongate microsporangial attachment scars per unit.

Etymology

switzianthus – *switzi*, for the type locality Little Switzerland; *anthus* (Lat.), male.

Affiliation ♂ (foliage)

Rochipteris switzifolia (55 indivs); Grade 4 (virtually exclusive)

With the only other *Rochipteris* species at Lit 111, *R. vincularis* (with 1 indiv.), being so rare, *R. switzifolia* is clearly the most likely affiliate of *Kannaskoppianthus switzianthus*.

Comment & comparison

Molteno species

In And. & And. (2003), *K. switzianthus* was included in *K. lutinumerus*, but it is here recognized as distinct in having c. 5 microsporangia per microsporophyll – while *K. lutinumerus* and *K. aasvoelensis* have c. 10 microsporangia; and *K. matatiparvus* and *K. telepentatus* are distinguished by having fewer microsporophylls per row.

Petriellaceae in Lit 111 Dic/Hei TC

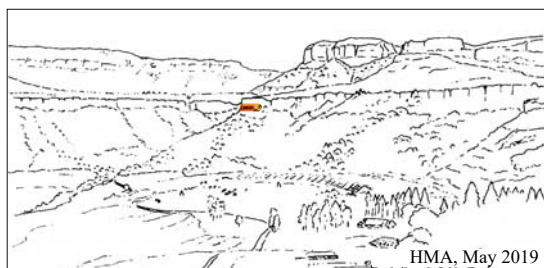
Kannaskoppianthus switzianthus (9 indivs)

Rochipteris vincularis (1 indiv.)

“ *switzifolia* (55 indivs)

Rarity of *K. switzianthus* at Lit 111

9 indivs in 550 man-hrs (1 per 6 man-days), extr. rare



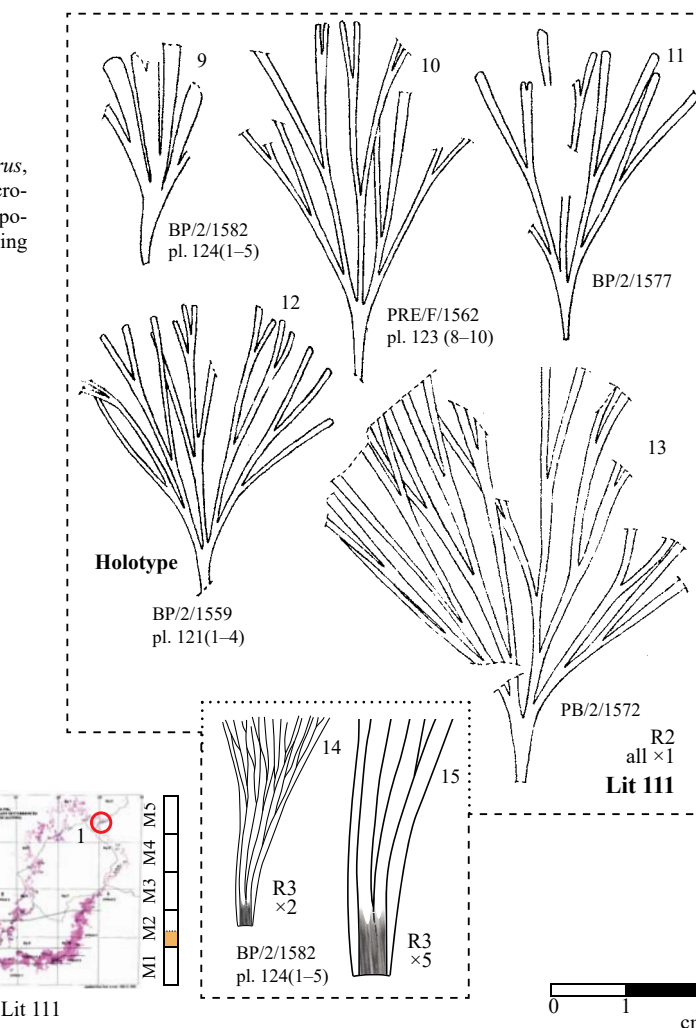
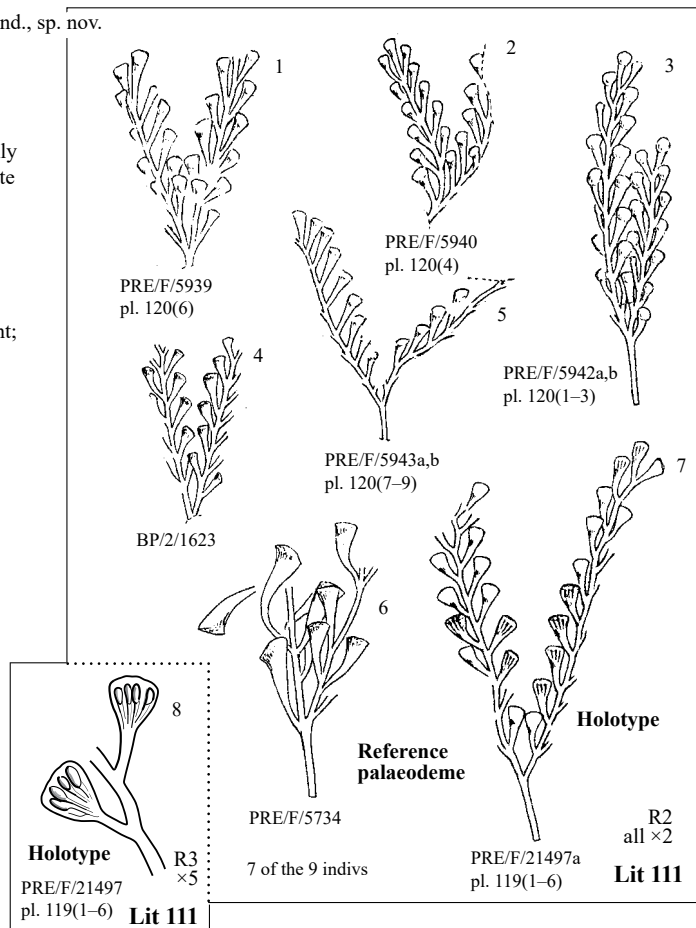
HMA, May 2019

From photo, Aug 2001

Little Switzerland (Lit 111 Dic/Hei)

Habitat: *Dicroidium* riparian forest (mature, type 1)

Collection: 2173 slabs, 550 man-hrs cleaving



Kannaskoppianthus matatiparvus J.M.And. & H.M.And., 2003**Holotype**

Specimen: PRE/F/3205; this vol., pl. 113(1–4).

Assemblage (TC): Mat 111 Dic dub, Matatiele.

Preservation: intact strobilus, without counterpart; impression in thickly laminated, olive-grey shale with moderate cleavage.

Plant fossil names registry number: PFN002305

Reference palaeodeme

Assemblage (TC): as for holotype.

Specimens: 3 indivs (2 intact, 1 partial); this vol., pls 113–114.

Sister palaeodemes – nil.

Specific diagnosis

A *Kannaskoppianthus* species with small regularly forked strobili whose limbs bear 4–6 microsporophylls per row and c. 4–5 microsporangia per unit.

Specific characters

Attachment: unknown.

Strobilus: small (c. 8–10 mm long), regularly forked; microsporophylls 4–6 per row.

Microsporophyll: narrowly concavely conate (c. 1–1.5 mm wide distally); with c. 5 microsporangial attachment scars per unit.

Etymology

matatiparvus – *matati*, for the type locality Matatiele; *parvus* (Lat.), small.

Affiliation ♂ (foliage)

Rochipteris matatifolia (17 indivs); Grade 3 (most probable)

R. matatifolia is the most likely affiliate of *K. matatiparvus* (with 3 indivs) – *R. telefolia* (with 2% of the flora; rated Grade 3.5 affiliate of *K. telemagnus*), being the only other *Rochipteris* species identified at Mat 111.

Comment & comparison

Molteno species

K. matatiparvus is particularly rare (3 indivs) and infrequent (1 TC) and is differentiated from *K. switzianthus*, the most similar species in the reduced number of microsporophyll units per limb. It is also similar to *K. telepentatus* which is affiliated with a very different leaf species, namely *R. penensis*.

Petriellaceae in Mat 111 Dic dub TC

Kannaskoppianthus matatiparvus (3 indivs)

Rochipteris telefolia (2%)

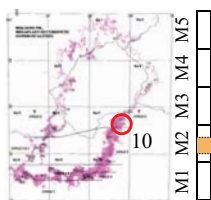
“ *matatifolia* (17 indivs)

Rarity of *K. matatiparvus* at Mat 111

3 indivs in 65 man-hrs (1 per 2 man-days), very rare



From photo, 31 July 1982

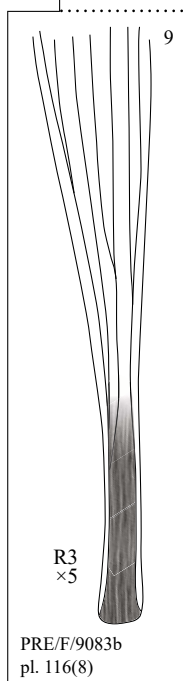
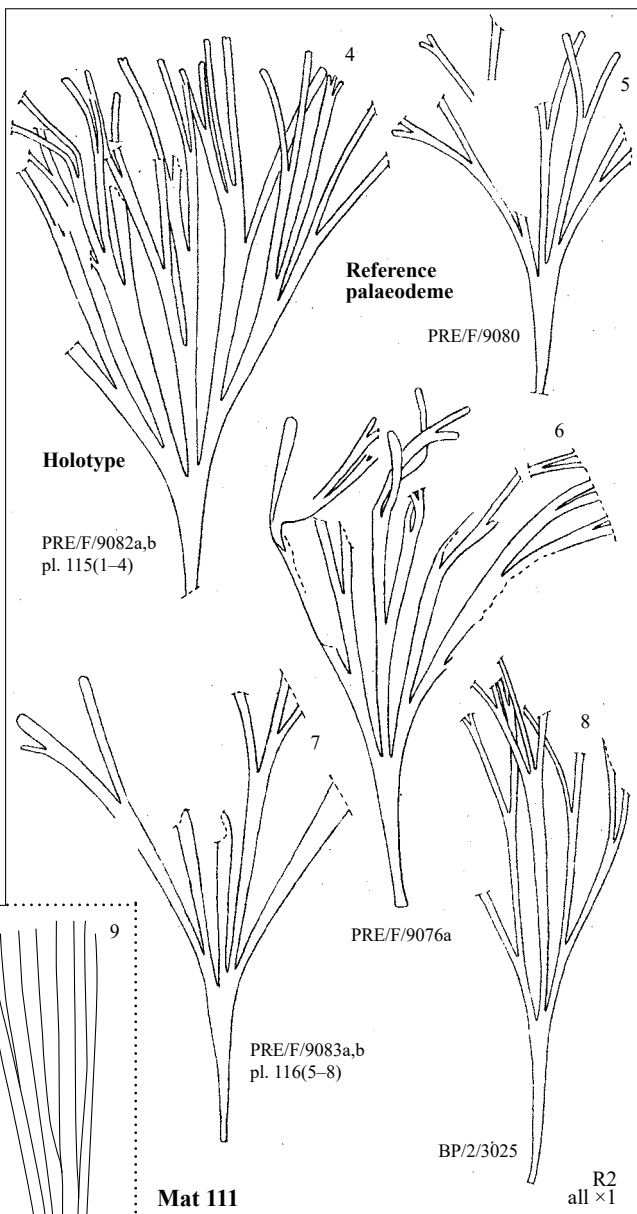
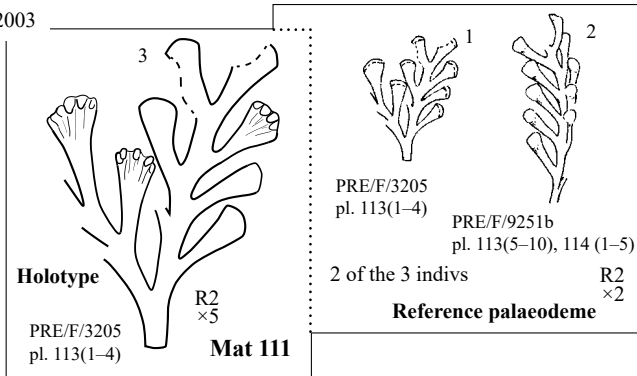


10. Mat 111

Matatiele (Mat 111 Dic dub)

Habitat: *Dicroidium* riparian forest (immature, type 2)

Collection: 1082 slabs, 65 man-hrs cleaving



Kannaskoppianthus komanthus J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/3231a,b; this vol., pl. 47(1–8)*Assemblage* (TC): Kom 111 Sph/Dic, Kommandantskop*Preservation*: almost complete strobilus, attached with foliage, part & counterpart; impressions in thickly laminated buff-grey shale with poor cleavage.**Plant fossil names registry number**: PFN002306**Reference palaeodeme***Assemblage*: as for holotype.*Specimens*: 2 indivs (1 fairly complete attached, 1 fragmentary); this vol., pls 47(1–8), 48(1–3).**Sister palaeodemes** – nil.**Specific diagnosis***A Kannaskoppianthus species with medium irregular strobili, with c. 4 microsporophylls per row and c. 5 microsporangia per unit.***Specific characters***Attachment*: strobili attached in fascicle with leaf cluster along shoot.*Strobilus*: medium (c. 20 mm long), irregularly forked; microsporophylls c. 4 per row.*Microsporophyll*: narrowly concavely cuneate (unknown width distally), with apparently c. 5 microsporangia per unit.**Etymology***komanthus* – *kom*, for the type locality Kommandantskop; *anthus* (Lat.), male**Affiliation** ♂ (foliage)*Rochipteris komifolia* (29 indivs); Grade 5 (certain)

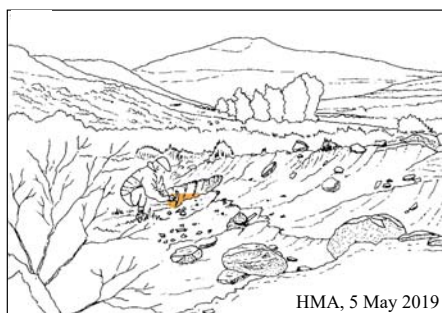
This is the only attached foliage/male-strobilus pairing yet found for the Petriellales.

Comment & comparison*Molteno species*In And. & And. (2003), *K. komanthus* was included with *K. irregularis*, but is now considered a distinct species as the strobilus has less microsporophylls and the shape is cuneate. The affiliated foliage – found attached in this case – is a different species, namely *R. komifolia*.

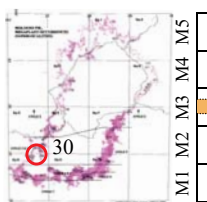
The leaves and strobili clearly derive from a common point of origin, but the actual point of attachment is not clear. A second specimen, PRE/F/3227, occurs closely associated with an attached cluster of leaves.

Although the tips of these attached leaves are incomplete, they compare closely in size and venation to the more complete leaves occurring at this TC, and are clearly affiliated to *R. komifolia*. The only other leaf is one specimen placed in *R. switzifolia*, with many segments.**Petriellaceae in Kom 111 Sph/Dic TC***Kannaskoppianthus komanthus* (2 indivs)*Rochipteris switzifolia* (1 indiv.)“ *komifolia* (29 indivs)**Rarity of *K. komanthus* at Kom 111**

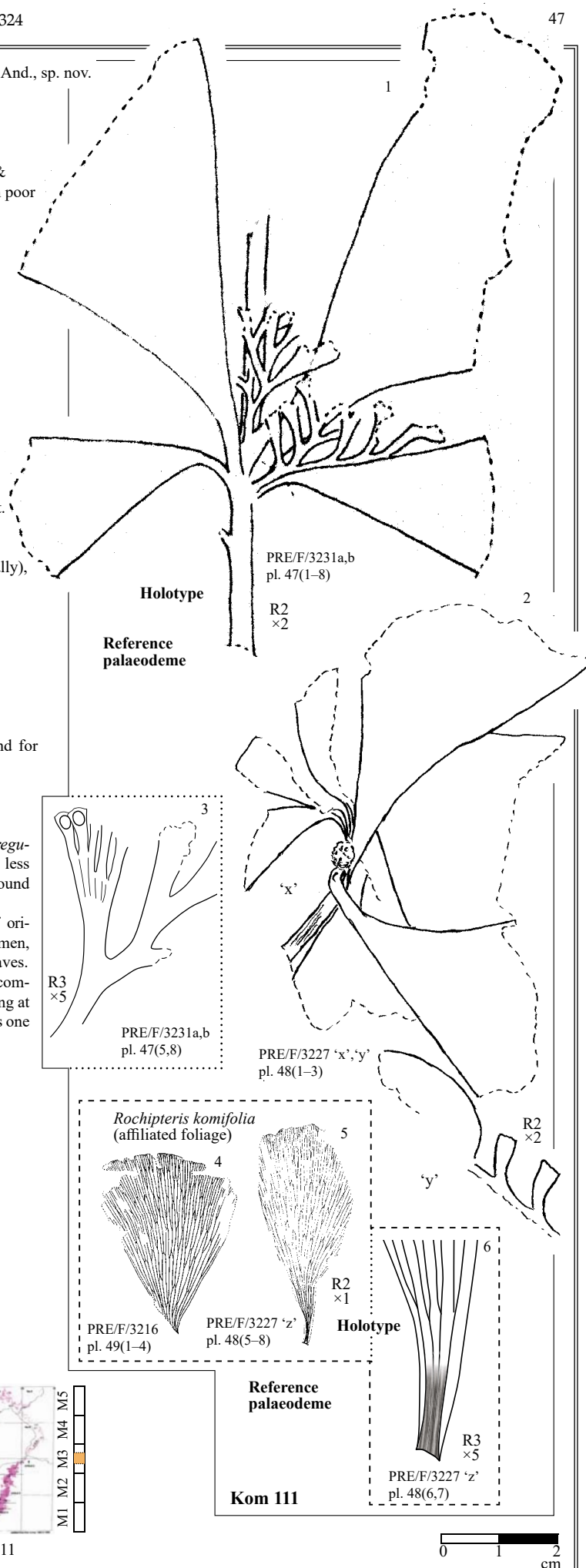
2 indivs in 10 man-hrs (2 per 1 man-day), rare



From photo, MM, 10 Oct 1989

Kommandantskop (Kom 111 Sph/Dic),**Habitat**: *Dicroidium* open woodland**Collection**: 168 slabs, 10 man-hrs cleaving

30. Kom 111



Kannaskoppianthus lutinumerus (J.M.And. & H.M.And., 2003) emend. nov.**Holotype**

Specimen: PRE/F/11433 a,b; And. & And., 2003, pl. 110(3,7,9).

Assemblage (TC): Lut 311 Hei elo, Lutherskop.

Preservation: complete very clearly preserved strobilus, part & counterpart; impression in thickly laminated, medium-grey shale with moderate cleavage.

Plant fossil names registry number: PFN002300

Reference palaeodeme

Assemblage (TC): as for holotype.

Specimens: 16 indivs (mostly intact, 1 cluster of 2); this vol., pls 53–60.

Sister palaeodemes – nil.

Specific diagnosis emended

A *Kannaskoppianthus* species with small regularly forked strobili whose limbs bear 5–11 microsporophylls per row and c. 10 microsporangia per unit.

Specific characters

Attachment: unknown.

Strobilus: small (c. 16–18 mm long), regularly forked; microsporophylls 5–11 per row.

Microsporophyll: narrowly concavely conate (c. 1–1.5 mm wide distally); with c. 10 very fine microsporangial attachment scars per unit.

Etymology

lutinumerus – *luti*, for the type locality Lutherskop; *numerus* (Lat.), with reference to the large number of microsporophylls per row.

Affiliation ♂ (foliage)

Rochipteris lutifolia (66 indivs); Grade 4 (exclusive)

At the type locality, the affiliation of *K. lutinumerus* (with 16 indivs), and *Rochipteris lutifolia* (with 66 indivs) is exclusive, there being no other species of either the strobilus or foliage present.

Comment & comparison

Molteno species

K. lutinumerus was previously recorded as including seven sister palaeodemes (And. & And., 2003), but with closer examination these are now placed in three newly described species, *K. aasvoelensis*, *K. switzianthus* and *K. telepentatus*. *K. lutinumerus* is similar to *K. aasvoelensis* in the number of microsporophylls per limb (and number of microsporangia per unit). However, graphs showing the number of microsporophylls per limb for the two species plot out quite differently (Chart 3, p. 77) – with *K. lutinumerus* having the greater range. In detail, the best-preserved heads are distinctive (in being more obtuse and spread out than those of *K. aasvoelensis*) and the affiliated foliage (Grade 4, exclusive in both cases) is of a very different morphology to *R. rollerii*.

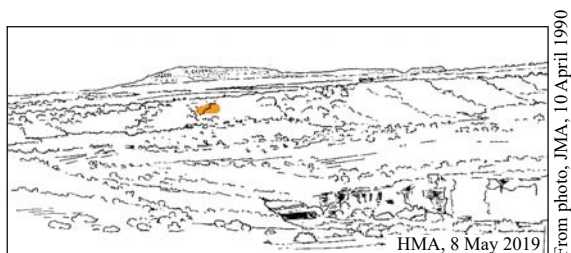
Petriellaceae in Lut 311 Hei elo TC

Kannaskoppianthus lutinumerus (16 indivs)

Rochipteris lutifolia (66 indivs)

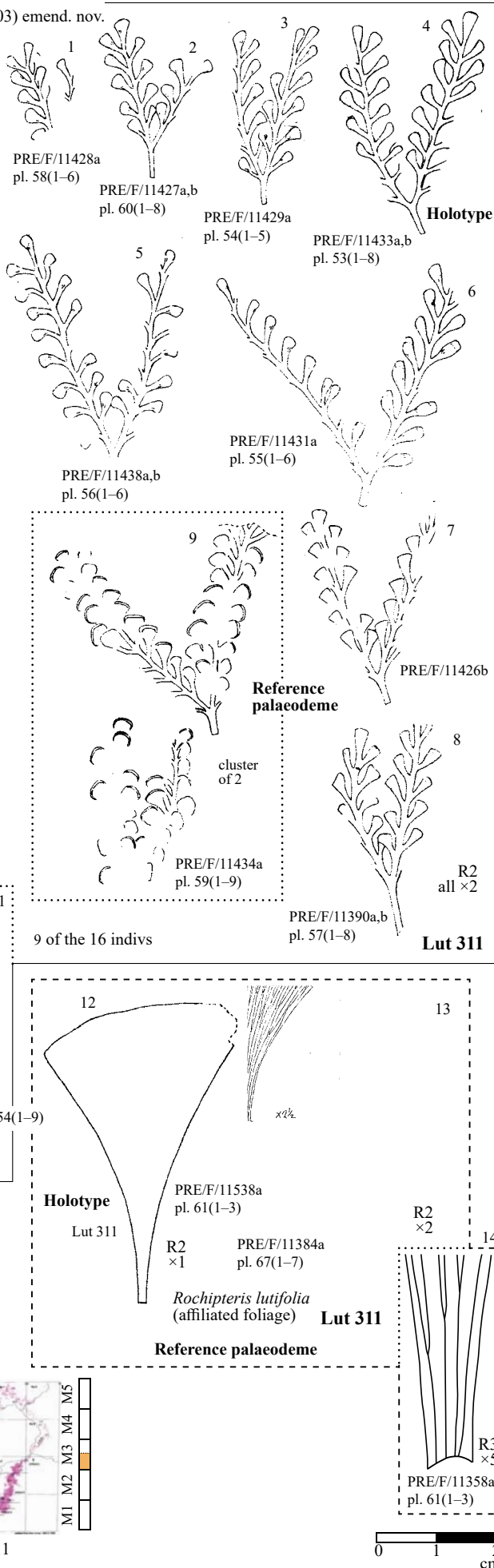
Rarity of *K. lutinumerus* at Lut 311

16 indivs in 50 man-hrs (3 per 1 man-day), rare

**Lutherskop (Lut 311 Hei elo), Oom Piet's campsite**

Habitat: *Heidiphyllum* thicket

Collection: 589 slabs, 50 man-hrs cleaving



36. Lut 311

Kannaskoppianthus telepentatus J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/18277a,b, pl. 42(1–8).*Assemblage* (TC): Tel 111 Hei elo, Telemachus Spruit.*Preservation*: intact, fairly complete strobilus (part & counterpart); impression in thickly laminated, light olive-grey shale with poor cleavage.**Plant fossil names registry number**: PFN002307**Reference palaeodeme***Assemblage* (TC): as for holotype.*Specimens*: 2 indivs (1 intact, 1 isolated), microsporangia attached; this vol., pl. 42(1–8).**Sister palaeodemes** – nil.**Specific diagnosis**

A *Kannaskoppianthus* species with small regularly forked strobili whose limbs bear c. 5 microsporophylls per row and c. 5 microsporangia per unit.

Specific characters*Attachment*: unknown.*Strobilus*: small (c. 12–13 mm long), regularly forked; microsporophylls c. 5 per row.*Microsporophyll*: short, concavely conate (c. 1.5 mm wide distally), with c. 5 microsporangial attachment scars per unit.**Etymology**

telepentatus – *tel*, for the type locality Telemachus Spruit; *pentatus* (Lat.), referring to the 5 microsporangia.

Affiliation ♂ (foliage)*Rochipteris penensis* (2 indivs); Grade 3 (probable)

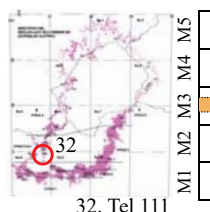
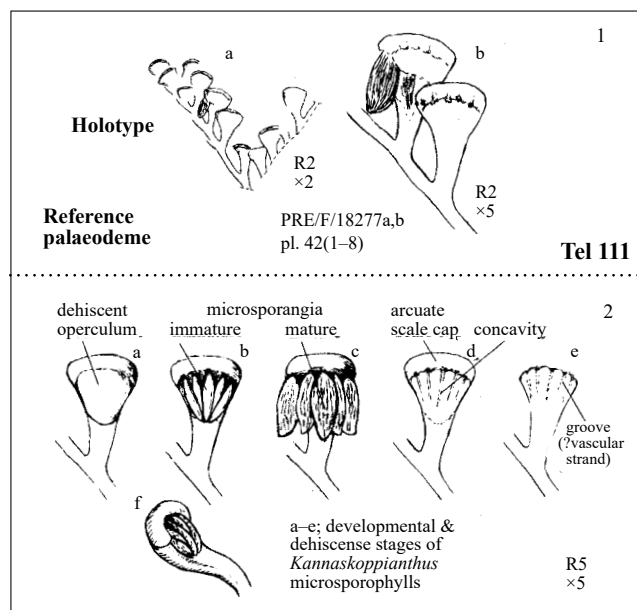
Tel 111 is the only TC from which 2 species of *Kannaskoppianthus* have been collected (see below); it has also yielded 3 species of foliage. Given that the affiliation between *K. telemagnus* and *R. telefolia* is Graded 4 (virtually exclusive), it is most probable that *K. telepentatus* (with 2 indivs) and *R. penensis* (with 2 indivs) are affiliated. The less likely foliage affiliate, would be *R. pusilla* (with 1 indiv).

Comment & comparison*Molteno species*

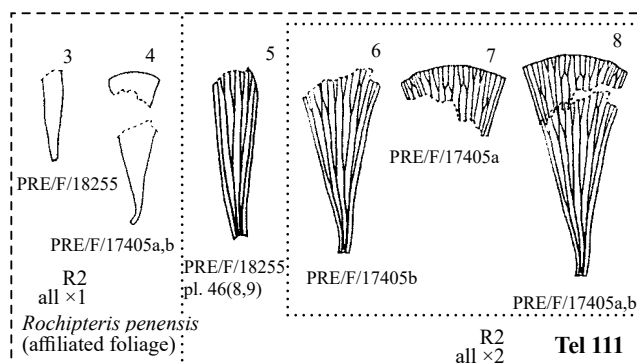
Like *Kannaskoppianthus switzianthus* (Lit 111) and *K. aasvoelensis* (Aas 111), this species was included within *K. lutienerus* (Lut 311) in And. & And. (2003). However, in the detail of the microsporophylls bearing c. 5 microsporangia, it is recognized as distinct from the latter species and from *K. switzianthus*, in being larger than most of the nine individuals from the Lit 111 TC. It is also affiliated with a different *Rochipteris* species to the other three

Petriellaceae in Tel 111 Hei elo TC*Kannaskoppianthus telemagnus* (2 indivs)“ *telepentatus* (2 indivs)*Rochipteris telefolia* (30 indivs)“ *penensis* (2 indivs)“ *pusilla* (1 indiv.)**Rarity of *K. telepentatus* at Tel 111**

2 indivs in 90 man-hrs (1 per 4 man-days), very rare

**Telemachus Spruit (Tel 111 Hei elo)****Habitat**: *Heidiphyllum* thicket**Collection**: 581 slabs, 90 man-hrs cleaving

And. & And. (2003, p. 290)

**Proposed new combination*****Kannaskoppianthus ternerae*** (Solms-Laubach 1899)

J.M.And. & H.M.And., comb. nov.

Basionym

Acrocarpus ternerae Solms-Laubach, 1899, pp 601–602, pl. 14(5), Q. de la Ternera, Copiapo, Chile.

Plant fossil names registry number

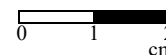
PFN 002310

Diagnosis/description

See Solms-Laubach (1899, pp 601, 602).

Remarks

The genus *Acrocarpus* belongs in the family Fabaceae and the specimen was incorrectly named. It clearly belongs to *Kannaskoppianthus* as described from the Molteno, but we were previously not aware of this reference (see comment, p. 42).



Rochipteris (Herbst *et al.*, 2001) emend. J.M.And. & H.M.And.

Synonymy

Kannaskoppifolia J.M.And. & H.M.And., 2003, p. 294

Kannaskop (Kan 111), Karoo Basin, S. Africa; Carnian, Triassic.

Type species

Chiropteris lacerata sp. nov. Arber 1917, p. 27, pl. 3(8); Tank Gully, Mt Potts, New Zealand; Tank Gully Coal Measures; housed in Natural History Museum, London, catalogue number NHMUK v15671.

Plant fossil names registry number: PFN002311 (for genus)

Generic diagnosis, emended

A ginkgoopsid leaf with apetiolate to partially petiolate, entire to trifidly divided cuneate to flabellate lamina with numerous segments, and subparallel, anastomosing veins with density increasing distally.

Generic characters

Attachment: several leaves borne on bulbous short shoots or spirally on slender stem.

Leaf: lamina narrowly to broadly cuneate to flabellate, apetiolate to partially petiolate, entire to trifidly deeply segmented with few to numerous segments; veins fine, forking, radiating, subparallel and anastomosing to form a variously elongated mesh, density increasing distally.

Cuticle: as described by And. & And. (2003); repeated here, p. 51.

Etymology

Rochipteris – named by Herbst *et al.* (2001), inverting the spelling to replace the genus name *Chiropteris* previously in use for some of these leaves.

Global range – 24 spp., Gondwana, Tr. (LAD–RHA).

First: *Rochipteris* (*Ginkgoites* sp.), (Walkom, 1925a); L. Newport Fm., Turrismetta Head, Sydney, Australia.

Last: *Rochipteris* (*Chiropteris copiapensis*), (Solms-Laub. & Steinm., 1899); Ternera Fm., Quebr. La Ternera, Copiapo, Chile.

Gondwana Triassic occurrence

Frequency (F): 22 degree squares (of the 84 across Gondwana).

Ubiquity (U): 4 continents (of 5 comprising Gondwana).

Diversity (D): 24 foliage species.

Abundance (A): <1% (the norm in Molteno TCs).

Longevity (L): 44 myrs (Olenekian to Rhaetian).

Colonization success: FUDAL rating 22/4/24/–/44 = 94. Intermediate success (Grade 3); *Rochipteris* was the 4th most prominent gymnosperm foliage genus in the Gondwana Triassic (And. & And., 2003, tab. 27); it was ubiquitous, diverse, long-enduring and relatively frequent, but generally lacking in abundance.

FUDAL ratings of the top 5 gymnosperm foliage genera in the GT:

1. *Dicroidium* – 188
2. *Heidiphyllum* – 147
3. *Sphenobaiera* – 99
4. *Rochipteris* – 94
5. *Taeniopteris* – 69

Endemism: one species occurs widely distributed on three continents, while at the other end of the scale, four species from the Molteno are single-assembly endemics.

Molteno occurrence

Frequency (F): 26 TCs (of 100 sampled in the Molteno).

Diversity (D): 12 species.

Abundance (A): common (3–5%) in 1 TC; occasional (2%) in 2 TCs; and <1% in the other 23 TCs.

Habit: slender, erect, woody shrubs (see Part 3).

Preferred habitat: occupied a wide range of habitats, but principally *Dicroidium* riparian forest, *Heidiphyllum* thicket and fern meadows of riverine sandbanks and floodplain wetlands.

Adaptive radiation (Molteno species, see Tab. 3, p. 52).

We currently recognize 12 species of *Rochipteris*, as described here. Very interestingly, the species in many instances coincide with different habitats, suggesting that they are biologically and ecologically distinct entities.

Affiliated organs

Female strobilus: *Kannaskoppia* – Grade 5 (Org. att.).

Male strobilus: *Kannaskoppianthus* – Grade 5 (Org. att.).

Classification & comparison

Suprageneric classification

As *Rochipteris* is known attached to both male and female affiliates, the classification is based on the ovulate strobilus *Kannaskoppia* (p. 34).

Intergeneric comparison

Such leaves were frequently classified as *Chiropteris* or *Ginkgoites* prior to Retallack (1980a) placing them in Ginkgophytopsis. Herbst *et al.* (2001) placed these leaves in a new genus *Rochipteris*. Concurrently And. & And. (1997, 2003) studied similar leaves from the Molteno and in view of the proven affiliation of attached leaves with male and female strobili erected the genus *Kannaskoppifolia* (And. & And., 2003). Holmes & Anderson (2005) later proposed that *Kannaskoppifolia* be used for attached leaves and *Rochipteris* for isolated leaves. Bomfleur *et al.* (2014) objected to this proposal and made *Kannaskoppifolia* a junior synonym of *Rochipteris* which is followed in this study. And. & And. (2003) suggested that *Ginkgophytopsis* be restricted to Devonian and Carboniferous leaves as dealt with by Høeg (1967), who included the genus in the order Palaeophyllales and placed the Gondwana *Chiropteris* leaves with a distinct petiole in a new genus *Batiopteris*. From the Early Permian of China a *Chiropteris* has been described in organic connection with the oviferous organs of *Nystroemia* by Wang *et al.* (2003). These bear bicornute platyspermic seeds which show no resemblance to the cupules of *Kannaskoppia*. Holmes & Anderson (2005) from the Nymboida Flora, described leaves somewhat similar to *Rochipteris* (also attached in whorls to a gracile axis) but with dichotomizing venation as *Walkomiopteris*.

Other reticulate leaves from the Molteno, such as *Gontriglossa*, *Graciliglossa* and *Cetiglossa*, all have a distinct midrib similar to that in *Glossopteris* (Permian) and *Sagenopteris* (Jurassic) leaves.

Eoginkgoites Bock from the Upper Triassic Newark Group and the Chinle Fm., U.S.A. (Ash, 1976, 1977) has anastomosing venation and syndetocheilic stomata, but differs in the finer venation, a marginal vein, pinnate form 'and its papillate cuticle'. Ash (1976, p. 1329) suggested a relationship with the Bennettiales rather than the Ginkgoales.

Gondwana Triassic (elaborated)

Herbst *et al.* (2001) erected the new genus *Rochipteris* for some Gondwanic leaf species previously assigned to *Chiropteris* Kurr ex Bronn. They describe five species of *Rochipteris*, two being new, from the Upper Triassic of Argentina and Chile. *Kannaskoppifolia* (And. & And., 2003) was considered a junior synonym of *Rochipteris* by Bomfleur *et al.* (2014) and this is accepted here. However, the South American foliage apparently yields no cuticle and there is no mention of female or male fruit affiliates.

Barone-Nugent *et al.* (2003) adopted the name *Rochipteris* for two new species and a third unnamed species from the Ipswich Coal Measures, the Leigh Creek Coal Measures and the Springfield Basin of the Upper Triassic of eastern Australia. As for the South American material, there occurs no affiliated fruit such as described here from the Molteno, but cuticle is illustrated and described for the Leigh Creek species. This cuticle is, in many respects, very different from that which we find characterizing the Molteno species. In particular, the stomata appear not to be transverse and the cells are isodiametric (almost square over the veins), not oblong. Furthermore, there are six subsidiary cells and these are clearly lappetate. The Molteno stomata are paracytic and nonlappetate. However, certain specialized cells (trichomes or glands) are remarkably similar. The leaf morphology, with its markedly expanded clasping base, is likewise rather different from the Molteno *Rochipteris* species.

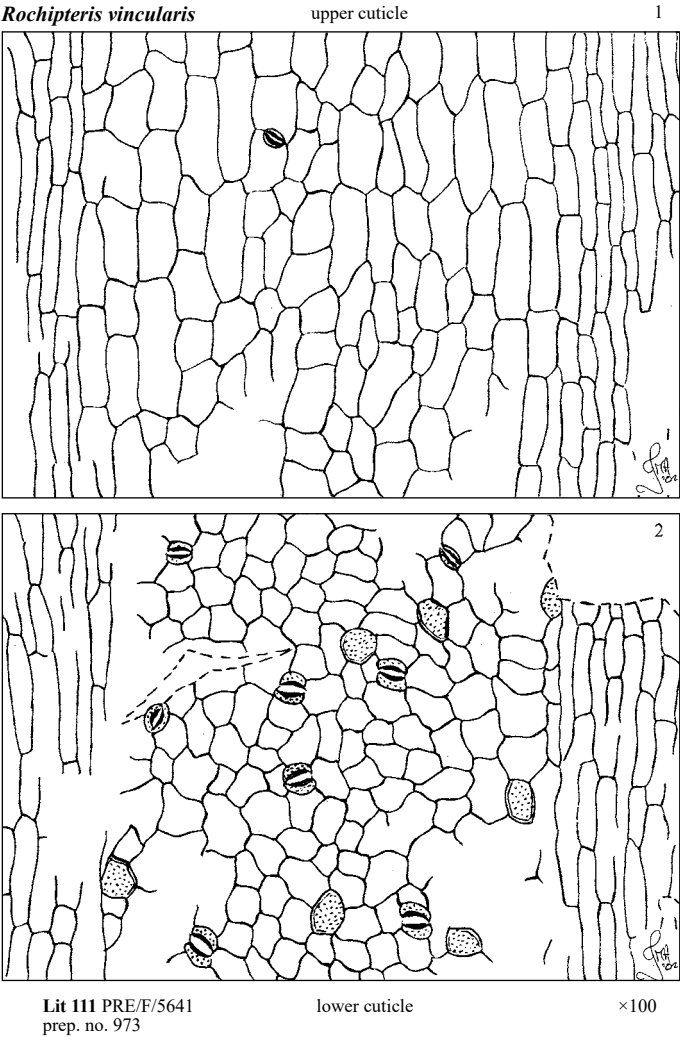
Rochipteris is a widespread element throughout the Gondwana Triassic. It is recorded in the literature from eight 'localities' (c. 88 indivs illustrated) in S. America (Chile, N. Argentina, S. Argentina), 15 'localities' in Australasia (Queensland, NSW, Victoria, South Australia and New Zealand) and two localities from Antarctica. Some of the published illustrations are insufficiently clear to show whether the venation anastomoses or not. In such instances one might be confusing this genus with *Sphenobaiera*, which can appear superficially similar (especially where specimens tend towards a bifurcating rather than trifurcating division of the lamina). The abundance of *Rochipteris* is rarely, if ever, clearly stated in the literature. The general impression is that it is uncommon, as in the Molteno.

Cuticles

Potential sample: Lit 111, 51 indivs; Umk 111, 42 indivs.
Macerated (And. & And., 2003): Lit 111, 35 indivs; Umk 111, 30 indivs; only a few indivs yielded good cuticle.
Preservation grade: Grade 4, features clear, fair-sized pieces.
Diagnostic characters: cells isodiametric to oblong (linear over vein areas), walls gently curved; stomata hypostomatic, nonpapillate, interveinal, transversely orientated; subsidiary cells paracytic, noncutinized, nonlappetate, guard cells narrowly elliptic; specialized cells isodiametric to circular, strongly cutinized.
Comment: The specialized cells may be trichome bases or, in appearing strongly cutinized, glands. They occur scattered on the upper and lower cuticle. Such cells have not previously been recorded from the Molteno.

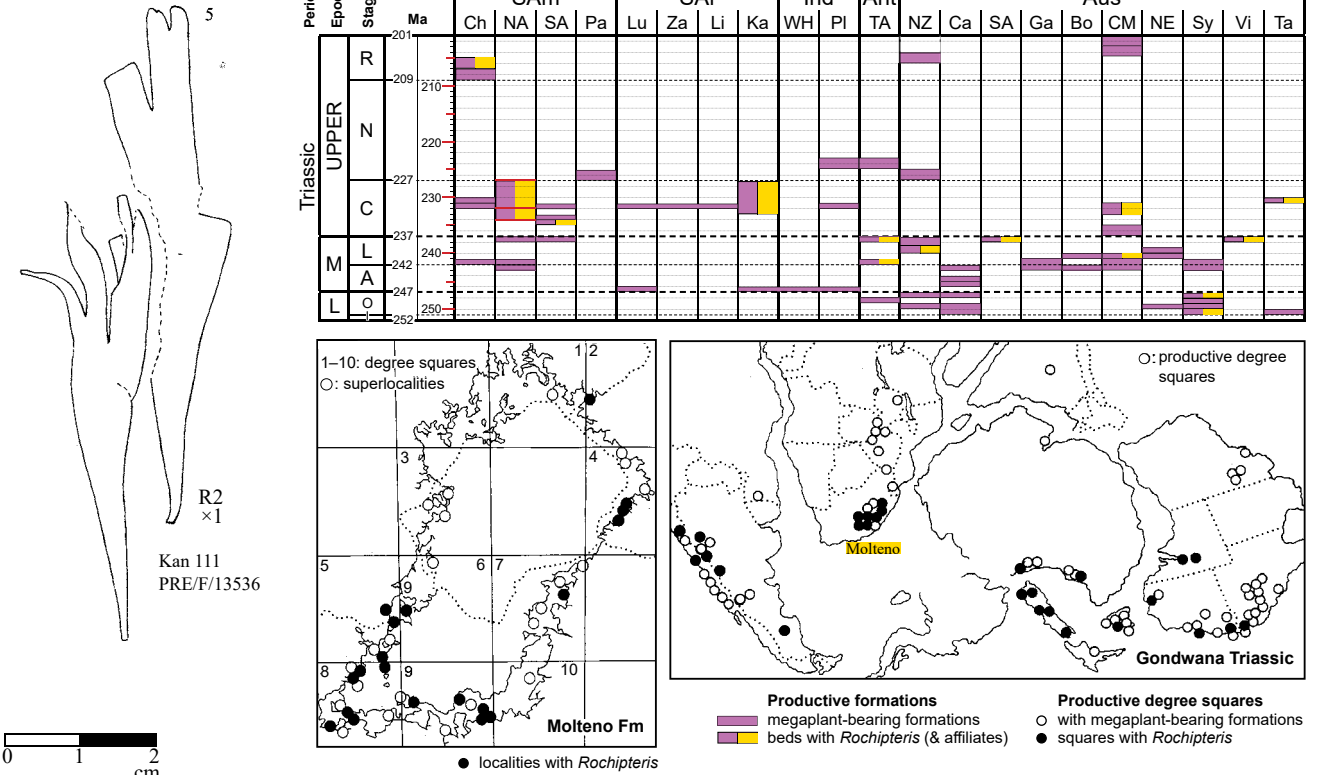
Significance

Classification – The transversely orientated, paracytic stomata make the cuticle of *Rochipteris* quite unique amongst the Ginkgoopsida. The only other taxon with clear paracytic stomata in the Molteno is *Gontriglossa verticillata* placed in the Gnetopsida. The latter has digitate amorphous cells and the stomata are orientated randomly in the interveinal areas.
The different species of *Rochipteris* from Lit 111 and Umk 111 all exhibit distinctive cuticles. That from the single specimen of *R. vincularis* from Lit 111 is used here to illustrate the generic characteristics. The second species, *R. switzifolia* from Lit 111, and *R. rollerii* from Umk 111 both show papillate epidermal cells. While the other common species from Umk 111, *R. obtriangulata* has yielded only poorly preserved cuticle, it does show the diagnostic stomata and specialized cells. The remaining two species (each represented by one individual) yield potential cuticle but have not been macerated or studied.
Affiliations – Cuticular correspondence between the leaf and male strobilus is not clear on present evidence and affiliation is based on direct attachment.



Rochipteris

Map 3.

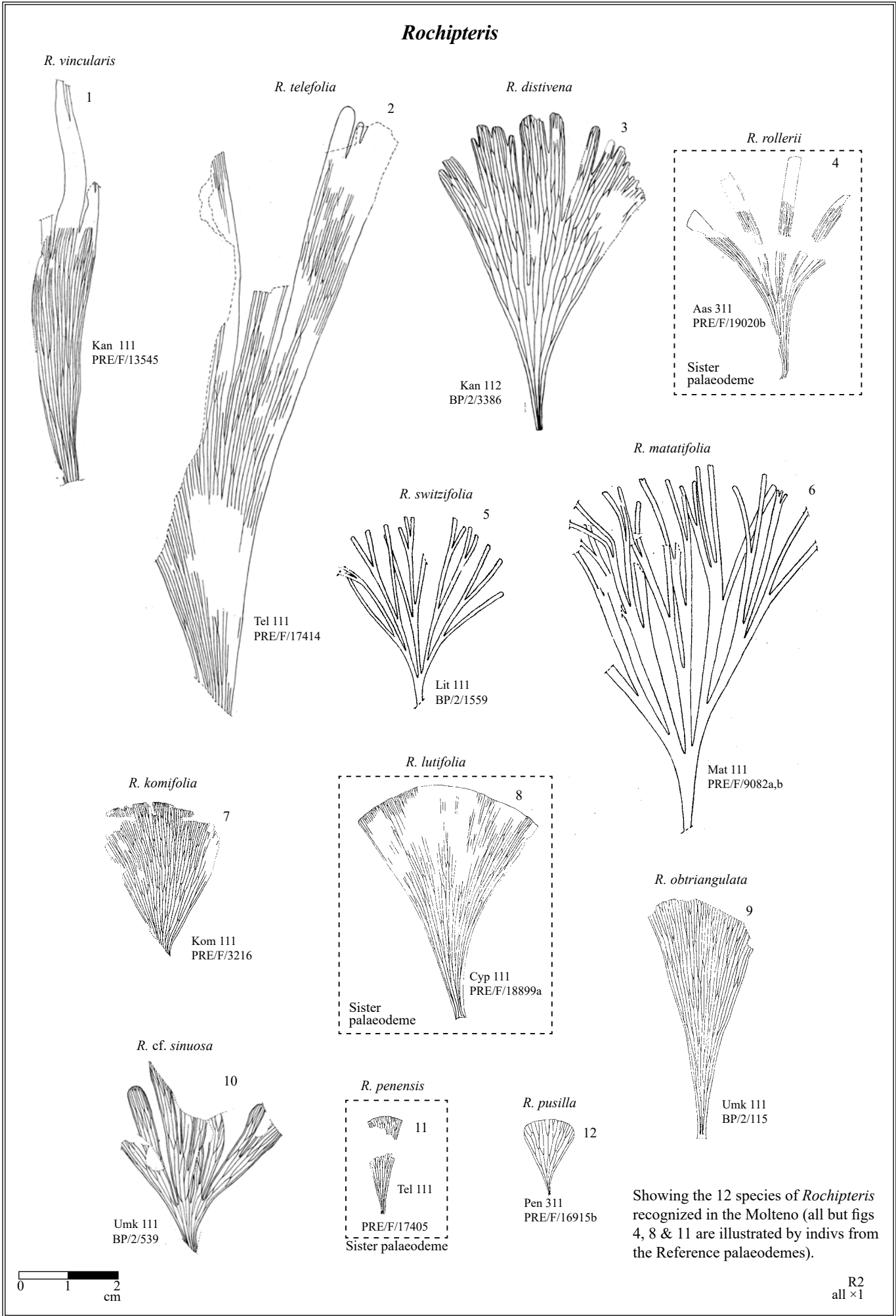


Tab. 3. *Rochipteris* – Molteno occurrence.

TCs		assemblages (taphocoenosis)		Members	Foliage species															Habitat							Dominants				
					<i>Rochipteris</i> ()	<i>R. vicularis</i> (Kan 111) 1	<i>telefolia</i> (Tel 111) 2	<i>distivena</i> (Kan 112) 3	<i>rollerii</i> (Aas 111) 4	<i>switzifolia</i> (Lit 111) 5	<i>matatifolia</i> (Mat 111) 6	<i>komifolia</i> (Kom 111) 7	<i>lutifolia</i> (Lut 311) 8	<i>obtriangulata</i> (Umk 111) 9	<i>cf. sinuosa</i> (Umk 111) 10	<i>penensis</i> (Pen 411) 11	<i>pusilla</i> (Pen 311) 12	<i>sp.</i> 13	<i>Dicr. rip. forest</i> (t.1) 1	<i>Dicr. rip. forest</i> (t.2) 2	<i>Dicr. woodland</i> 3	<i>Sphenobalera</i> woodl. 4	<i>Heidiphyllum</i> thicket 5	<i>Equisetophyte</i> marsh 6	<i>fern/Kannask. meadow</i> 7	<i>Dicroidium</i> 1	<i>Sphenobalera</i> 2	<i>Heidiphyllum</i> 3	horsetails 4	ferns 5	
1	Cal 211	Hei elo	T	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	75	-	20		
2	Gre 121	Hei elo	Qiba	4	22	-	-	-	22	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	3	-	98	20	2		
3	" 111	Equ sp			1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	✓	-	-	2	-	-	97	1	
4	Boe 112	Dic cor			1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	✓	-	-	-	-	99	-	14	4	-	
5	Cyp 111	Dic cra	Mayaputi	3	83	2	-	-	-	1	-	-	80	-	-	-	-	-	-	✓	-	-	-	-	75	-	24	-	4		
6	Kan 112	Hei elo			19	-	2	4	10	-	-	-	-	-	-	-	2	1	-	-	-	-	✓	-	-	1	-	98	6	7	
7	" 111	Ast spA			5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	10	22	63	
8	Tel 111	Hei elo			33	-	30	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	✓	-	-	6	-	89	48	58	
9	Kom 111	Sph/Dic			30	-	-	-	-	1	-	29	-	-	-	-	-	-	-	-	-	✓	-	-	-	39	60	-	15	1	
10	Vin 111	Dic odo			2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	70	4	28	-	2	
11	Lut 311	Hei elo			66	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	-	-	✓	-	-	58	29	99	30	3	
12	Kon 211	Ast 2spp			Indwe	2	5	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	20	52	
13	Pen 311	Hei elo					f	41	-	-	-	34	-	-	-	-	-	5	2	-	-	-	-	✓	-	-	-	25	-	75	5
14	" 411	" "	e	80			-	-	-	70	-	-	-	-	-	-	10	-	-	-	-	✓	-	-	-	13	-	94	2	3	
15	Kap 111	Dic/Ris	d	6			-	-	-	2	6	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	50	20	25	10	4	
16	Nuw 111	Dic zub	b	3			-	-	-	-	-	-	3	-	-	-	-	-	-	-	✓	-	-	-	-	70	30	-	-	4	
17	Win 111	Hei elo	a	5			-	-	-	3	-	-	1	-	1	-	-	-	-	-	-	✓	-	-	-	-	10	-	79	2	3
18	Hla 213	Dic elo	b	8			-	-	-	4	4	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	89	49	1	11	32	
19	Umk 111	Dic 2spp	a	50			-	-	-	21	-	-	-	1	19	9	-	-	-	✓	-	-	-	-	-	69	5	7	2	1	
20	San 111	Dic cra	3	-			-	-	3	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	90	-	5	2	1	
21	Mat 111	Dic dub	2	-			2	-	-	-	17	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	89	18	4	20	7	
22	Lit 111	Dic/Hei	Bamboesberg	1	56	1	-	-	-	55	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	50	1	23	10	10		
23	Aas 111	Hei elo			2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	7	1	77	10	20	
24	" 211	Hei elo			19	1	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	99	-	2	
25	" 311	Hei elo			26	1	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	15	9	99	-	2	
26	" 411	Dic/Sph	150	-	-	-	150	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	60	30	1	75	24			
	Total TCs				26	7	3	2	14	4	1	1	5	1	2	4	4	1	2	4	4	2	11	1	2						
	Total individuals				%	%	%	6	%	61	17	29	151	19	10	19	5	1													

Rochipteris* occurrence in the Molteno Fm.*Taphocoenoses:** occurs in 26 of the 100 sampled TCs.**Members:** occurs in the 1st 5 of the 6 Molteno Members; but most frequently in the Indwe Member (2).**Diversity:** 12 species of *Rochipteris* recognized.**Habitat:** the genus occurs in all 7 habitats identified; but most frequently in the *Heidiphyllum* thicket (11 of 26 TCs).**Dominants:** *Heidiphyllum* & *Dicroidium* are clearly the most abundant associates of *Rochipteris*.**Abundance:** bold – %
mild – indivs

1. *R. vicularis* And. & And., 2003
2. *R. telefolia* And. & And., sp. nov.
3. *R. distivena* And. & And., sp. nov.
4. *R. rollerii* (Frenguelli 1946) Bodnar *et al.*, 2020
5. *R. switzifolia* And. & And., sp. nov.
6. *R. matatifolia* And. & And., sp. nov.
7. *R. komifolia* And. & And., sp. nov.
8. *R. lutifolia* And. & And., sp. nov.
9. *R. obtriangulata* Holmes & H.M.And., 2005
10. *R. cf. sinuosa* Holmes & H.M.And., 2005
11. *R. penensis* And. & And., sp. nov.
12. *R. pusilla* Holmes & H.M.And., 2005



Rochipteris telefolia J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/17414; pl. 43(1–3)*Assemblage* (TC): Tel 111 Hei elo, Telemachus Spruit*Preservation*: fairly complete, clear venation, without counterpart; impression in thickly laminated, light olive-grey shale with poor cleavage.**Plant fossil names registry number**: PFN002316**Reference palaeodeme***Assemblage* (TC): as for holotype (pls 43–46; figs pp 69–71)*Specimens*: 30 slabs (27 isolated leaves, 2 attached, 1 cluster)

attached (foliage only) – 1 slab; 5 leaves (3 att., 2 in clear orientation)

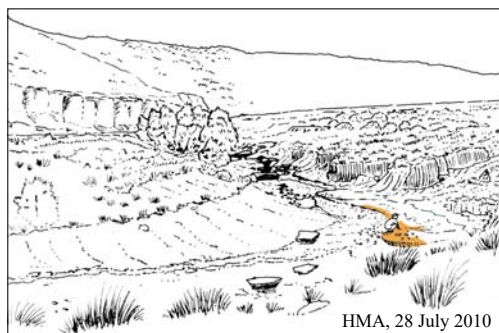
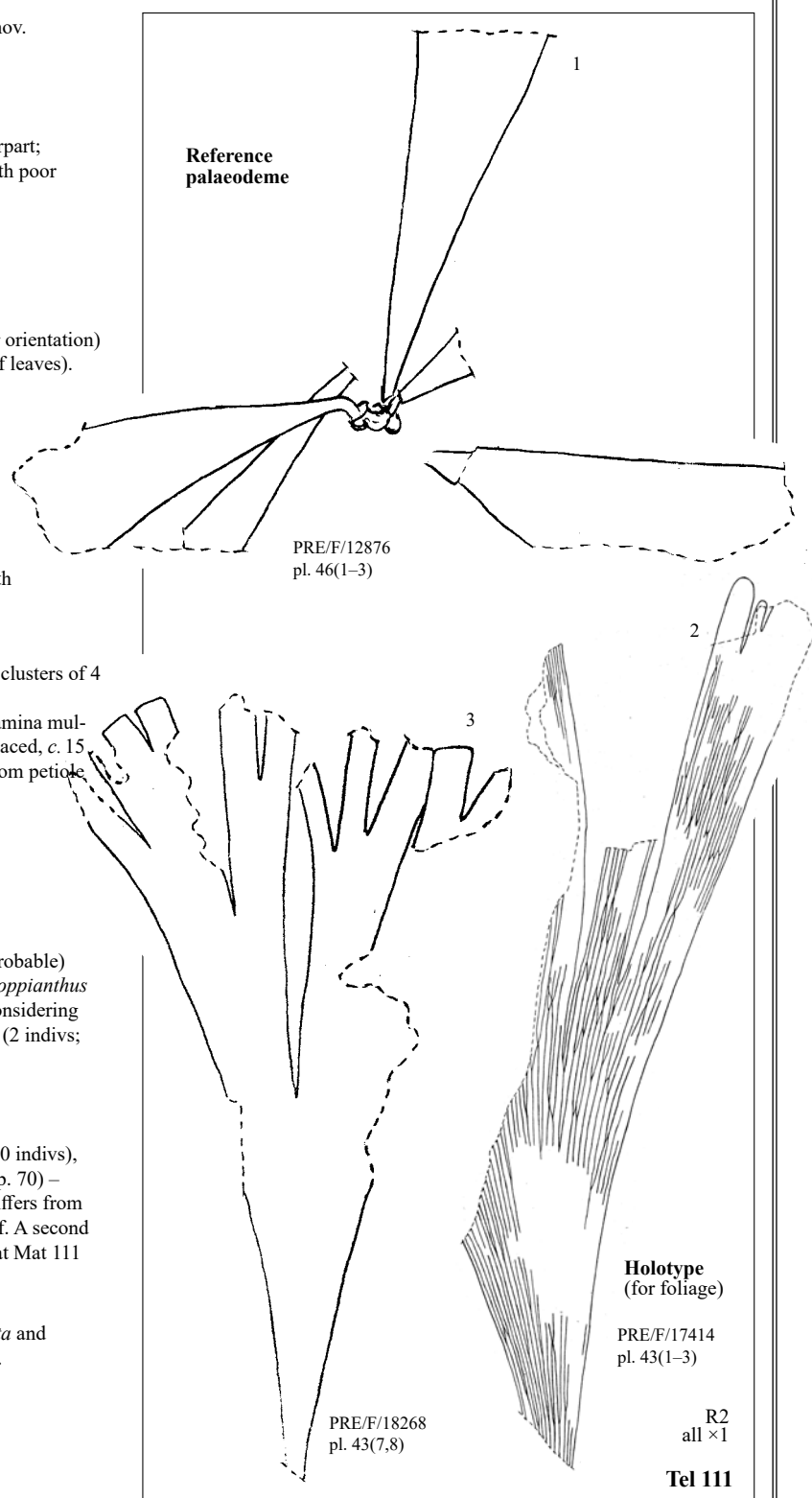
1 slab; c. 8 leaves (undoubted, based on orientation of leaves).

clusters – 1 slab; 3 leaves.

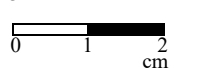
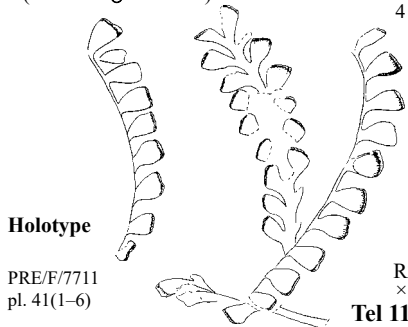
Sister palaeodemes – 2

Kan 112 Hei elo: 2 indivs

Mat 111 Dic dub: 2% (pls 117, 118)

Specific diagnosis*A Rochipteris* species of large size with broadly obtriangulate lamina irregularly divided to mid-depth, and with closely spaced anastomosing venation.**Specific characters***Attachment*: leaves interpreted as being generally attached in clusters of 4 to bulbous leaf cushions (Chart 2, pp 126, 127).*Leaf*: obtriangulate, of large size (up to >130 by c. 70 mm); lamina multiply and variously divided to mid-depth; veins closely spaced, c. 15 per cm midway, with anastomoses frequent throughout from petiole to distal margin.**Etymology***telefolia* – *tele*, for the type locality Telemachus Spruit; *folia* (Lat.), foliage.**Affiliated organs** (♂ (male strobilus))*Kannaskoppianthus telemagnus* (2 indivs); Grade 3.5 (most probable)Though 3 species of *Rochipteris* and 2 species of *Kannaskoppianthus* occur at Tel 111, this affiliation is considered very probable considering the large size of each, and the exclusiveness of *K. telemagnus* (2 indivs; 1 intact, 1 partial) to Tel 111.**Comment & comparison***Molteno species*Given the excellently represented Ref. pal. from Tel 111 (30 indivs), including three specimens showing attachment or clustering (p. 70) – there is no doubt about the distinctiveness of this species. It differs from *R. vincularis* by the deeper divisions and larger size of the leaf. A second good palaeodeme derives from a *Dicroidium* riparian habitat at Mat 111 Dic dub (pls 117, 118; pp 72, 73).*Gondwana Triassic species* (non-Molteno)For a discussion of the somewhat similar leaves, *R. lacerata* and *R. incisa*, consult introduction to the Hypodigm (pp 102, 103).**Telemachus Spruit (Tel 111 Hei elo)****Habitat**: *Heidiphyllum* thicket**Collection**: 581 slabs, 90 man-hrs cleaving

32. Tel 111

***Kannaskoppianthus telemagnus***
(affiliated ♂ strobilus)

Rochipteris distivena J.M.And. & H.M.And., sp. nov.**Holotype**

Specimen: BP/2/3386; pl. 21

Assemblage (TC): Kan 112 Hei elo, Kannaskop (Upper end).

Preservation: complete leaf with clean venation, without counterpart; impression, in very thinly bedded, moderately baked, medium-grey shale, with poor cleavage.

Plant fossil names registry number: PFN002317

Reference palaeodeme

Assemblage (TC): as for holotype (pls 21, 22; figs p. 74)

Specimens: 4 indivs; attached and clusters nil.

Sister palaeodemes – 1

Kap 111 Dic/Ris: 2 indivs (pl. 89)

Specific diagnosis

A *Rochipteris* species of intermediate size with cuneate irregularly divided lamina to mid-depth, and with widely spaced anastomosing venation.

Specific characters

Attachment: unknown (for foliage); male strobili known attached to a narrow stem.

Leaf: broadly obtriangulate, of intermediate to large size (up to c. 90 by 55–75 mm); upper half of lamina divided 2–3 times into irregular segments; veins widely spaced, c. 10 veins per cm at midway, to more closely spaced at tip with c. 18 veins per cm.

Etymology

distivena – (Lat.), widely spaced veins.

Affiliated organs ♂ (male strobilus)

Kannaskoppianthus irregularis (5 indivs); Grade 3.5 (very probable)

Both *R. distivena* (4 indivs) and *K. irregularis* (5 indivs) are unique to Kan 112, and although both are uncommon, the affiliation is very probable.

Comment & comparison*Molteno species*

The leaves of this species have widely spaced veins to more closely spaced distally, fining markedly to the tips. The only other species with widely spaced veins and divided lamina is *R. cf. sinuosa* from Umk 111 which differs in the lamina being flabellate and deeply divided to around one-third from the base. In overall shape, it is similar to leaves with multiple segments in the upper part of the lamina such as *R. telefolia* and *R. vincularis* which have much finer venation. From Kap 111 Dic/Ris, two fragmentary leaves are provisionally compared to this species as they show widely spaced venation (pl. 89). A leaf collected by Du Toit from Umk 111 and originally described as *Chiropteris copiapensis* (Du Toit, 1927, t-fig. 3B) possibly belongs to this species since, although incomplete, the base is cuneate and the venation similarly widely spaced.

The single indiv. from Gre 111 Equ sp (p. 101, pl. 7(1–7)), referred to as *Rochipteris* sp., is closest to *R. distivena*, in having similar divided tips and open venation, but lacks the characteristic deep division of the leaf and is of much smaller size, which suggests it may represent a distinct species.

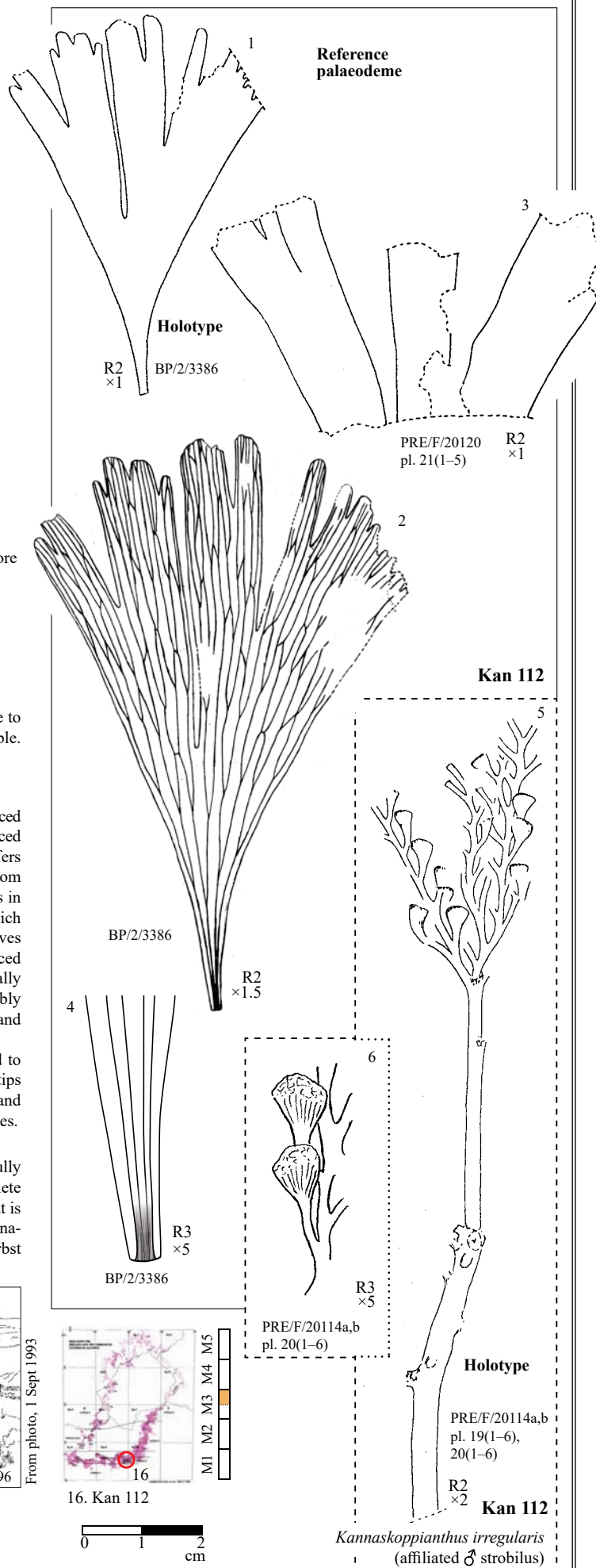
Gondwana Triassic species (non-Molteno)

Chiropteris lacerata Arber 1917 (p. 27, pl. 3(8)), from the Tank Gully Coal Measures, Mt Potts, New Zealand, is based on a single incomplete specimen. It has lacerate tips and is similar in overall shape and size, but is missing the lower third to the diagnostic base, and has distinctly finer venation in the upper third. See also *Rochipteris lacerata* (Arber, 1917) Herbst *et al.* (2001), S. Argentina. Consult introduction to Hypodigm (p. 102).

**Kannaskop (Kan 112 Hei elo), Upper End**

Habitat: *Heidiphyllum* thicket

Collection: 145 slabs, 15 man-hrs cleaving



Rochipteris rollerii (Frenguelli, 1946) Bodnar *et al.*, 2020**Lectotype**

Specimen: LPPB 20770a, Bodnar *et al.*, 2020, p. 9, fig. 5A.

Assemblage (TC): Puesto Miguez, Cacheuta Hill, Mendoza Province, Argentina.

Preservation: compression in fine-grained shale.

Plant fossil names registry number: PFN002344

Plant fossil names registry number: PFN002345 (Lectotype)

Reference palaeodeme

Assemblage (TC): Aas 111 Hei elo, Aasvoëlberg (Turner shale) (pls 131–142; figs p. 84); impressions in thickly laminated, light-grey shale with moderate cleavage.

Specimens: 2% of assemblage (c. 50 slabs; c. 75 indivs).

attached – nil

clusters – 6 slabs; c. 20 indivs (×1), 5 indivs (×1), 2–3 indivs (×4)

Sister palaeodemes – 13

Gre 121 Hei elo: 22 indivs (pls 4–6), 4 clusters; ♂ affil., 2 indivs (pl. 3)

Kan 112 Hei elo: 10 indivs

Kon 211 Ast 2spp: 5 indivs (pls 69–72), 4 clusters

Pen 311 Hei elo: 34 indivs (pls 73–76), 1 cluster

Pen 411 Hei elo: 70 indivs (pls 81–86); ♂ affil., 4 indivs (pls 79, 80)

Kap 111 Dic/Ris: 6 indivs (pl. 90)

Win 111 Hei elo: 3 indivs (pl. 92)

Hla 213 Dic elo: 4 indivs (pls 95, 96)

Umk 111 Dic 2spp: 21 indivs (pls 97–102)

San 111 Dic cra: 3 indivs (pls 111, 112)

Aas 211 Hei elo: 18 indivs (pl. 144); ♂ affil., 1 indiv. (pl. 143)

Aas 311 Hei elo: 25 indivs (pls 148–152); ♂ affil., 4 indivs (pls 145–147)

Aas 411 Dic/Sph: 150 indivs (pls 157–162); ♂ affil., 21 indivs (pls 153–156)

Specific concept

A *Rochipteris* species of small to intermediate size with flabellate lamina deeply divided mainly 1–2 times, and with closely spaced anastomosing venation.

Specific characters

Attachment: unknown.

Leaf: flabellate, of small to intermediate size (up to c. 45–50 × 35 mm);

lamina deeply divided mainly 1–2 times, ranging from 2–13 segments;

veins closely spaced, c. 25 per cm midway.

Etymology

rollerii – named by Frenguelli (1946, p. 103) in honour of the collector Roller.

Affiliated organs (♂ (male strobilus))

Kannaskoppianthus aasvoelensis (21 indivs); Grade 4 (mutual occurrence)

At Aas 111 there occurs just the one species of *Rochipteris* (2%) and one species of the male strobilis (21 indivs) – both in significant numbers – providing good evidence for affiliation. The same affiliation also occurs at another 5 TCs (Gre 121, Pen 411, Aas 211, Aas 311, Aas 411, Chart 6, p. 12).

Comment & comparison***Molteno species***

R. rollerii, recognized in 14 of our Molteno TCs yielding specimens of the genus, is the most frequent and abundant of the 12 *Rochipteris* species in the formation. The leaves show a wide range of variation, as evident from the set of line drawings representing nine of the palaeodemes, and from the histograms plotting the degree of division of the laminae.

R. switzifolia, from 5 Molteno TCs, is closely similar, but the histogram for its Ref. pal., Lit 111 Dic/Hei (with 55 indivs), plots quite differently with many leaves far more divided. There occurs some overlap in morphology involving the smaller less-divided leaves (pp 76, 77).

***Gondwana Triassic species* (non-Molteno)**

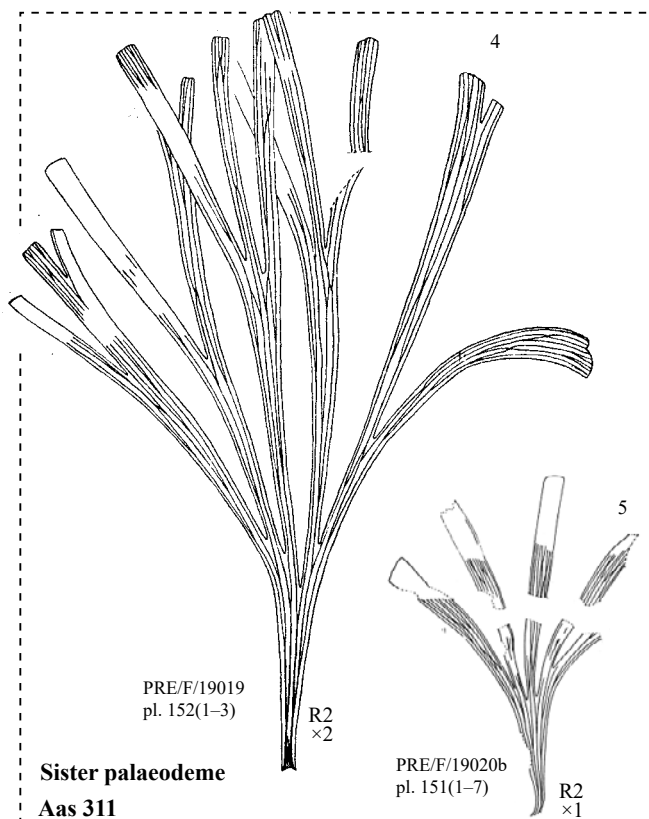
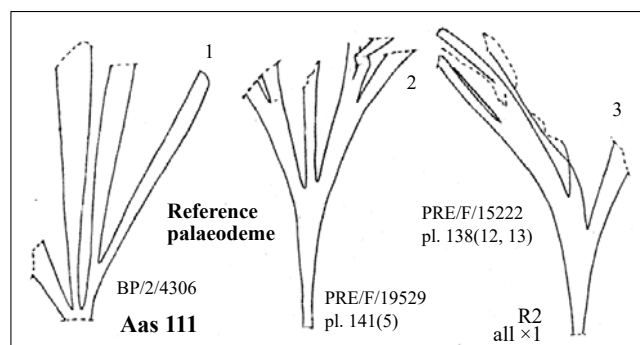
R. rollerii is common at the type locality in Argentina and the Molteno palaeodemes compare well with the original and subsequent collections of leaves in shape and size. As yet no fertile affiliates are known at the type locality. Consult introduction to Hypodigm (p. 103) for further discussion on this species and the similar *R. alexandriana*.



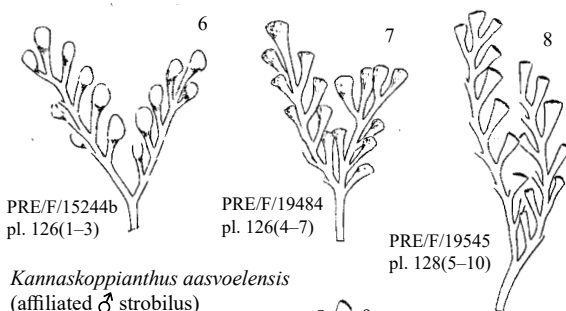
Aasvoëlberg (Aas 111 Hei elo), Turner Shale

Habitat: *Heidiphyllum* thicket

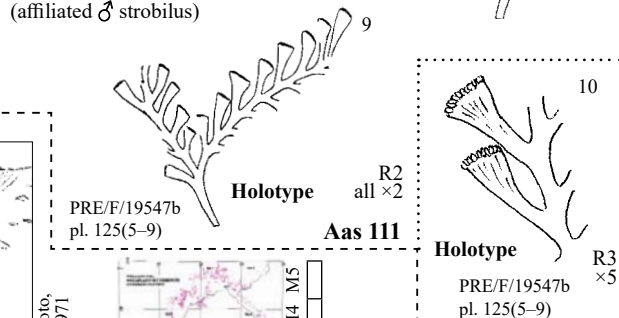
Collection: 291 slabs, 40 man-hrs cleaving

**Sister palaeodeme**

Aas 311



Kannaskoppianthus aasvoelensis
(affiliated ♂ strobilus)



Holotype
PRE/F/19547b
pl. 125(5–9)

Aas 111

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

Holotype
PRE/F/19547b
pl. 125(5–9)

SYSTEMATICS

Rochipteris matatifolia J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/9082a,b, pl. 115(1–4).*Assemblage* (TC): Mat 111 Dic dub, Matatiele.*Preservation*: almost complete leaf, proximal end of ‘petiole’ missing, part & counterpart; impression in thickly laminated, olive-grey shale with moderate cleavage.**Plant fossil names registry number**: PFN002319**Reference palaeodeme***Assemblage* (TC): as for holotype (pls 115, 116; figs pp 90, 91)*Specimens*: 17 indivs; attached and clusters nil.**Sister palaeodemes** – nil.**Specific diagnosis**

A *Rochipteris* species of small to intermediate size with flabellate lamina deeply divided mainly 2–4 times, and with closely spaced anastomosing venation that conjoins towards base in a distinct petiole.

Specific characters*Attachment*: unknown

Leaf: flabellate, small to intermediate in size (up to 50–60 mm in length and width); lamina deeply divided mainly 2–4 times, ranging from 6–33 segments; veins closely spaced, c. 20 per cm midway, conjoining for c. 4 mm at base in a distinct petiole.

Etymology

matatifolia – *matati*, for the type locality Matatiele;
folia (Lat.), foliage.

Affiliated organs (♂) (male strobilus)*Kannaskoppianthus matatiparvus* (3 indivs); Grade 3 (most probable)

This well-sampled foliage palaeodeme of 17 individuals (mostly complete) can most probably be affiliated with the only male strobilus occurring in the TC. However, the other common foliage species at this site, *R. telefolia* (2% of TC), cannot be ruled out as a possible contender. At Tel 111, *R. telefolia* is most clearly affiliated with the male *K. telemagnus*.

Comment & comparison*Molteno species*

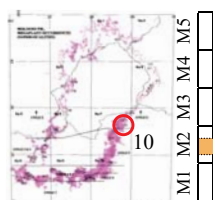
As with *R. switzifolia*, the smaller less divided leaves of the palaeodeme show a variable overlap with the *R. rollerii* palaeodemes in the Molteno, while the larger more divided leaves are distinct. These larger leaves are similar to those in the palaeodeme from Lit 111 (*R. switzifolia*) and are separated by their distinctly longer section of conjoined veins in the petiole.

Gondwana Triassic species (non-Molteno)

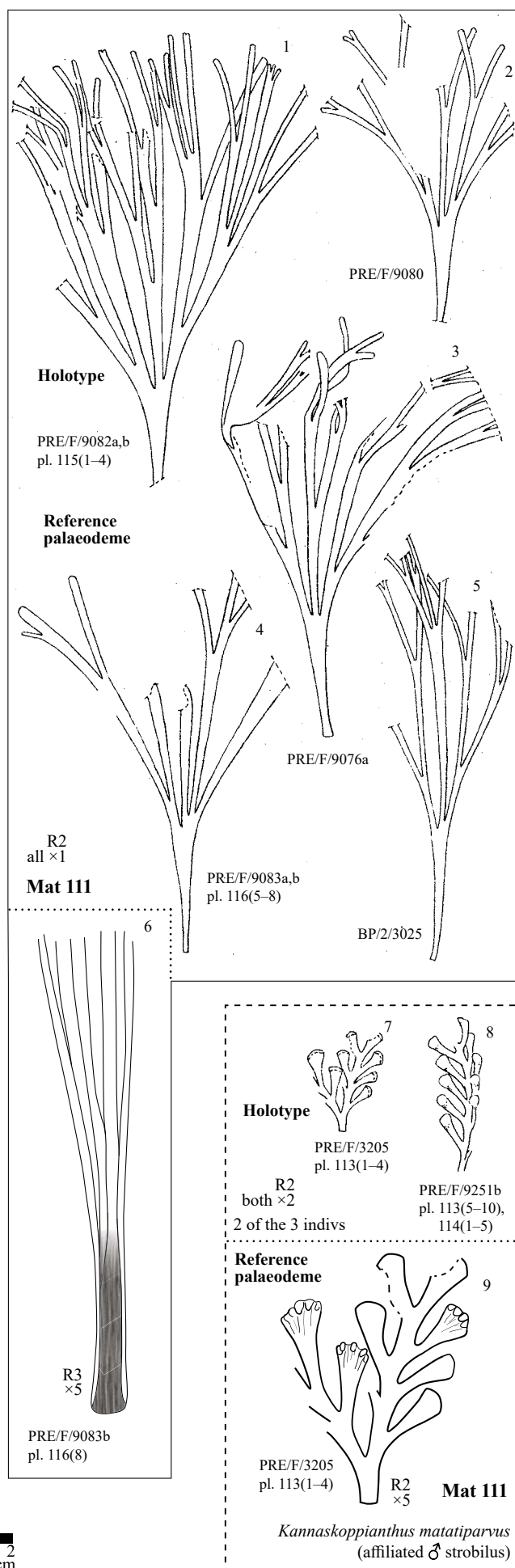
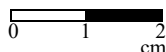
The only similar species are *R. rollerii* and *R. alexandriana* from Argentina, as discussed under *R. switzifolia* and in introduction to Hypodigm (p. 103).



From photo, 31 July 1982



10. Mat 111

Matatiele (Mat 111 Dic dub)**Habitat**: *Dicroidium* riparian forest (immature, type 2)**Collection**: 1082 slabs, 65 man-hrs cleaving

Rochipteris komifolia J.M.And. & H.M.And., sp. nov.**Holotype**

Specimen: PRE/F/3227 'z'; pl. 48(4–8)

Assemblage (TC): Kom 111 Sph/Dic, Kommandantskop.

Preservation: almost complete leaf including petiole, clear venation, no counterpart; impression in thickly laminated buff-grey shale with poor cleavage. The holotype occurs on the reverse side of the slab PRE/F/3227 'x', 'y', which shows an attached leaf cluster 'x', and a separate partial male strobilus 'y'.

Plant fossil names registry number: PFN002320

Reference palaeodeme

Assemblage (TC): as for holotype (pls 47–50; figs pp 92, 93)

Specimens: 29 slabs (8 isolated leaves, 14 attached, 7 clusters);

attached (foliage & ♂) – 3 slabs

attached (foliage only) – 11 slabs (almost certain based on orientation of leaves, nil definite)

clusters – 7 slabs (of 2–5 leaves)

Sister palaeodemes – nil**Specific diagnosis**

A *Rochipteris* species of small to intermediate size with cuneate usually entire lamina with slightly undulating convex distal margin and straight to slightly concave lateral margins, and with closely spaced anastomosing veins that conjoin toward base into a short distinctive petiole.

Specific characters

Attachment: foliage and male strobili mutually attached, with 4 leaves and 2 strobili at node.

Leaf: cuneate, small to intermediate in size (up to 60 × 45 mm); lamina usually entire, very rarely once divided to c. ½ length of leaf; veins closely spaced, c. 20 per cm midway, conjoining to form a distinct short petiole.

Etymology

komifolia – *komi*, for the type locality Kommandantskop; *folia* (Lat.), foliage.

Affiliated organs (♂) (male strobilus)

Kannaskoppianthus komanthus (2 indivs); Grade 5 (attached)

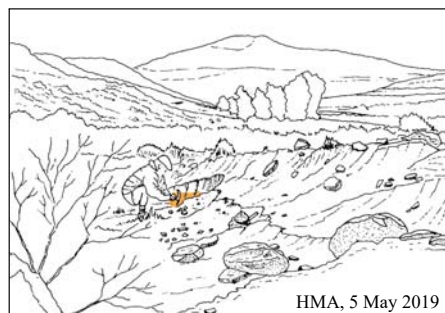
Considering the 26 Molteno TCs yielding *Rochipteris*, Kom 111 is the only one with foliage and male strobilus attached to the same stem. Of the two specimens, the one shows mutual attachment, the other a clear association, or possible attachment, of leaves and a fragment of a male strobilus.

Comment & comparison***Molteno species***

With its broadly spreading cuneate lamina, the species is similar to *R. luti-folia*, but the latter is more cuneate and lacks the section of conjoined veins at the base. In the Kom 111 palaeodeme, characterized by a high proportion of attached or clustered leaves (pl. 50(6–9); p. 92 (7–9)) there is only one leaf showing two divisions, and it is not clear whether it belongs to the whorl or not (PRE/F/3216, p. 92). *R. luti-folia*, Lut 311, includes occasional leaves with a single cleft in the lamina; three are illustrated on p. 94.

***Gondwana Triassic species* (non-Molteno)**

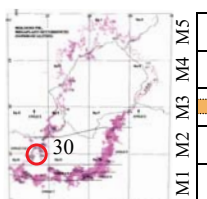
For species that are morphologically similar see comments under *R. luti-folia*.

**Kommandantskop (Kom 111 Sph/Dic),**

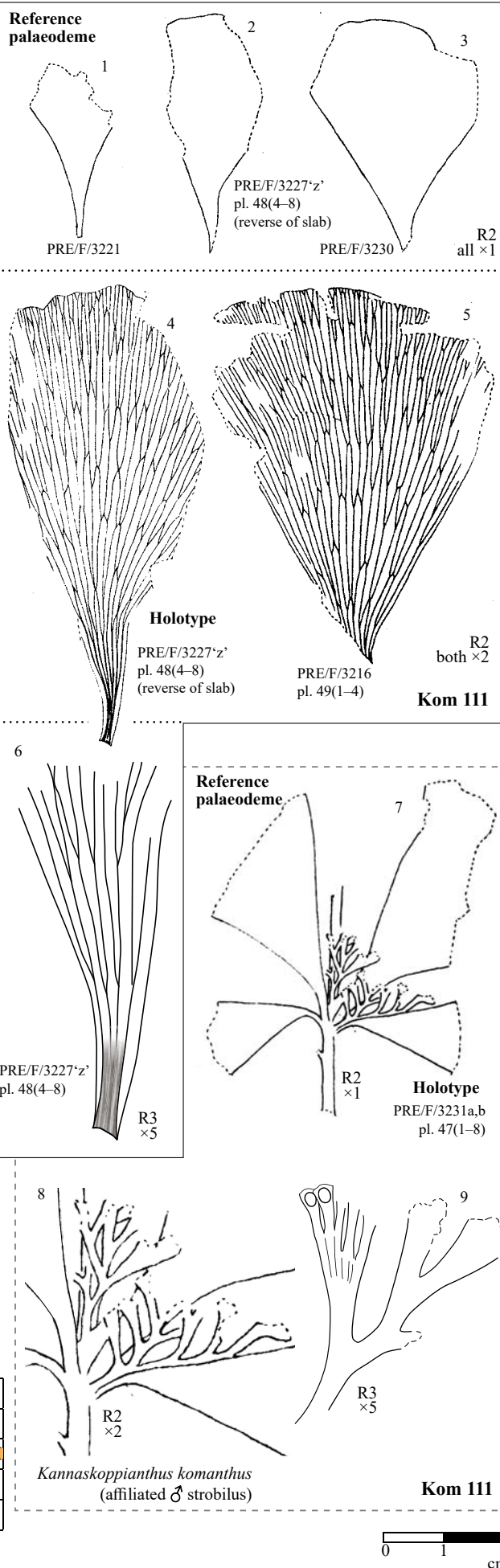
Habitat: *Dicroidium* open woodland

Collection: 168 slabs, 10 man-hrs cleaving

From photo, MM, 10 Oct 1989



30. Kom 111



Rochipteris lutifolia J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/11358a, pl. 61(1–3)*Assemblage* (TC): Lut 311 Hei elo, Lutherskop*Preservation*: complete leaf with good base and clear venation, with counterpart; impressions in thickly laminated medium-grey shale with moderate cleavage.**Plant fossil names registry number**: PFN002321**Reference palaeodeme***Assemblage* (TC): as for holotype (pls 61–68; figs pp 94, 95)*Specimens*: 66 indivs; attached and clusters nil.**Sister palaeodemes – 4**

Cyp 111 Dic cra: 80 indivs (pls 9–18); attachment (1 indiv.), clusters (>10)

Nuw 111 Dic zub: 3 indivs (pl. 91)

Win 111 Hei elo: 1 indiv. (pl. 93)

Umk 111 Dic 2spp: 1 indiv.

Specific diagnosis

A *Rochipteris* species of small to intermediate size with cuneate entire to once-divided lamina with slightly undulating convex distal margin and concave lateral margins, and with closely spaced anastomosing venation not conjoining toward base.

Specific characters*Attachment*: with 3–4 leaves attached in a whorl.

Leaf: small to intermediate in size (up to 60 × 45 mm), lamina cuneate, usually entire, or once divided to c. ½ length; veins closely spaced, c. 20 per cm midway, not conjoining at base.

Etymology*lutifolia* – *luti*, for the type locality Lutherskop; *folia* (Lat.), foliage.**Affiliated organs** (♂ (male strobilus))*Kannaskoppianthus lutinumerus* (16 indivs); Grade 4 (exclusive)

With only one species of *Rochipteris* (66 indivs) and one of the male strobilus (16 indivs), the affiliation is virtually exclusive. The leaves are common at Cyp 111, which has not yielded any male strobili to date.

Comment & comparison*Molteno species*

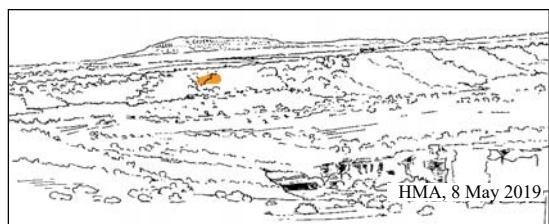
The species name, *Chiropteris cuneata* (a species from Australia), was previously applied to a leaf from Cyphergat (equivalent to our Cyp 111) by Seward (1903) and Du Toit (1927). Our amply sampled palaeodemes from Cyp 111 and Lut 111 reveal leaves markedly more cuneate with a narrow base (petiole), and are smaller than the original type specimen. The Molteno leaves are thus considered distinct. Consult further discussion in introduction to Hypodigm (p. 103).

R. lutifolia is similar to *R. komifolia*, but differs in being more cuneate in shape with the veins showing no fusion at the base.

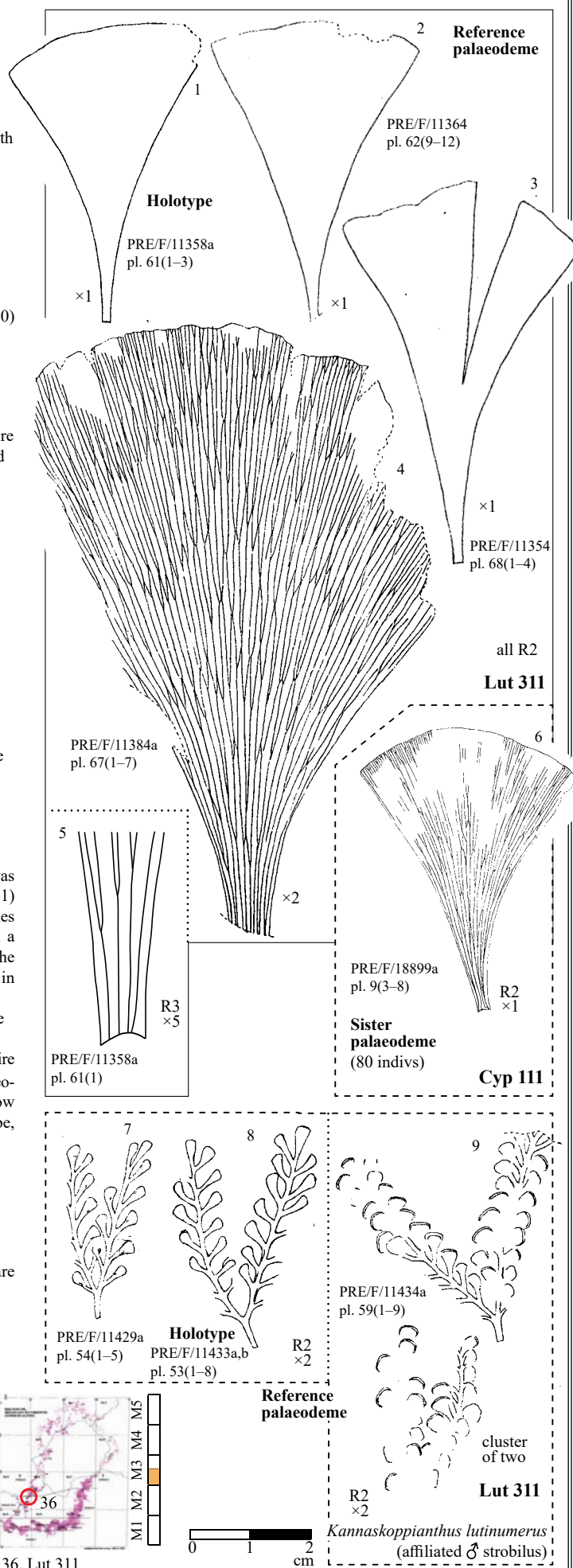
The population at Lut 311, furthermore shows a range from simple entire leaves to larger ones with a distinct cleft – as seen in three specimens (palaeodeme, p. 94, pls 65(7), 68). The population at Cyp 111 (p. 96) does not show any notched leaves and is classified here on the basis of the cuneate shape, though the ‘petiole’ is somewhat intermediate between the two species.

Gondwana Triassic species (non-Molteno)*R. tasmanica* (Walkom, 1926) Herbst *et al.*, 2001, Tasmania.*R. nymboidensis* Holmes & H.M.And., 2000, Australia.*R. turbata* Holmes & H.M.And., 2005, Australia.*R. cuneata* (Carruthers, 1872) Herbst *et al.*, 2001, Australia.

These four species show some similarity to *R. lutifolia*; their differences are discussed in introduction to Hypodigm (pp 103, 104).



From photo, JMA, 10 April 1990

Lutherskop (Lut 311 Hei elo), Oom Piet's campsite**Habitat**: *Heidiphyllum* thicket**Collection**: 589 slabs, 50 man-hrs cleaving

Rochipteris obtriangulata Holmes & H.M.And., 2005**Holotype**

Specimen: AMF 126840; Holmes & H.M.And., p. 46, fig. 18 A,B.

Assemblage (TC): Coalmine quarry, Basin Creek Fm., Nymboida, Clarence/Moreton Basin, Australia.

Preservation: carbonaceous, no cuticle, grey coarse mudstone.

Plant fossil names registry number: PFN002322

Reference palaeodeme

Assemblage (TC): Umk 111 Dic 2spp, Umkomaas (pls 103–106; figs p. 98)

Specimens: 19 indivs; attached and clusters nil.

Sister palaeodemes – nil**Specific concept**

A *Rochipteris* species of small to intermediate size with obtriangulate entire lamina with truncate distal margin, and with closely spaced anastomosing venation.

Specific characters

Attachment: close spirals or whorls of leaves.

Leaf: narrowly obtriangulate, small to intermediate in size (up to 65 × 15–23 mm); lamina entire with truncate distal margin; veins closely spaced, c. 20 per cm midway, anastomoses frequent along distal 2/3 of leaf.

Etymology

obtriangulata – (Lat.), obtriangular, referring to the reversed triangular leaf form; as named by Holmes & H.M.And. (2005, p. 46).

Affiliated organs ♂ – nil**Comment & comparison***Molteno species*

R. obtriangulata, recognized exclusively from Umk 111 (with 19 individual leaves), is a distinctive species based on the narrow elongated wedge shape. It can be separated from the similar species *R. penensis*, by the much larger size of the leaf and elongated base. Leaves belonging to this palaeodeme were first collected by Du Toit and originally described as *Chiropteris copiapensis* (Du Toit, 1927, t-fig. 3C). He noted that there were two practically identical leaves set at an angle of 70° as in a whorl.

Gondwana Triassic species (non-Molteno)

R. obtriangulata Holmes & H.M.And., 2005; Australia.

This species was based on a remarkable slab from Nymboida, Australia, bearing a nearly complete whorl of leaves and portions of another two whorls and isolated leaves. The foliage is arranged in a close spiral or in a terminal whorl of 8–10 leaves on a narrow stem. The leaf bases are obscured by the matrix and it is not possible to observe the actual point of attachment. The wedge-shaped leaves compare closely in size and shape with the isolated leaves from the Molteno. These latter may appear to have a longer base but this is due to the Nymboida leaves being foreshortened as they curve down into the sediment.

R. copiapensis (Solms-Laubach, 1899) Herbst *et al.*, 2001, Chile.

R. truncata (Frenguelli, 1946) Morel *et al.*, 2011, N. Argentina.

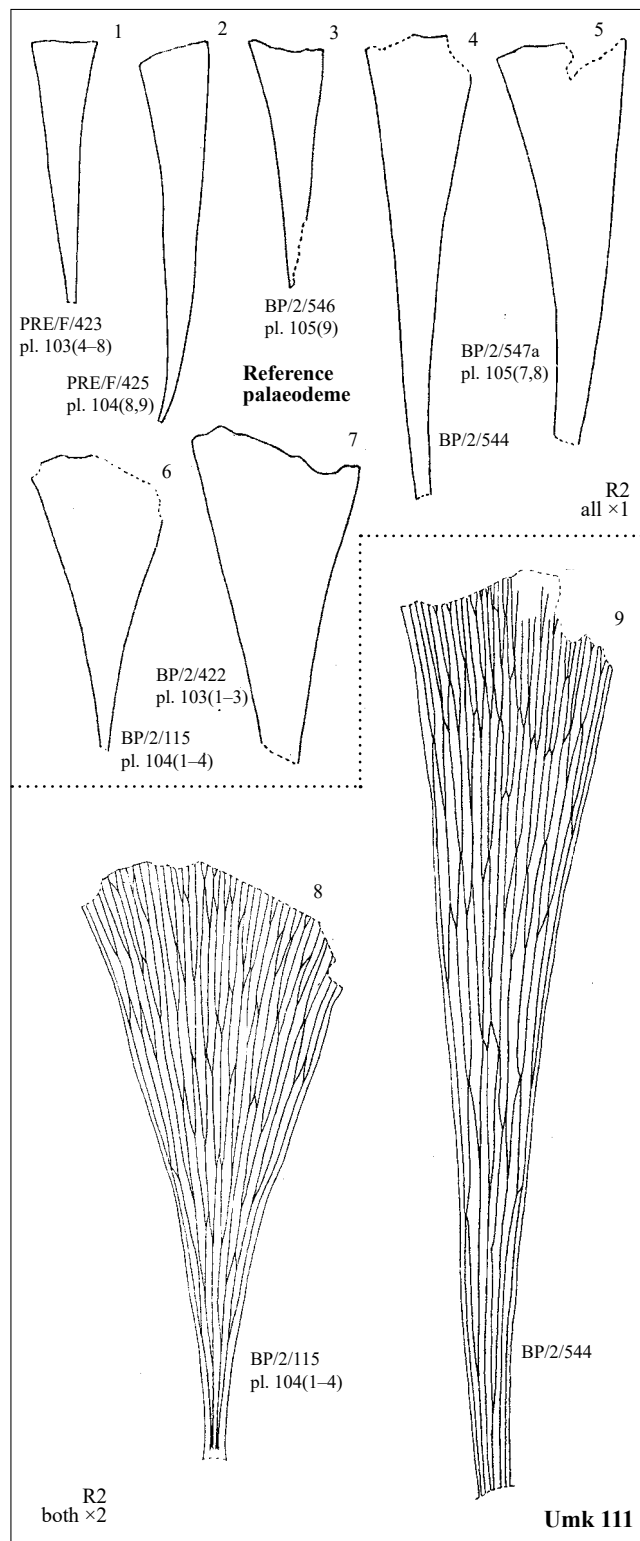
R. turbata Holmes & H.M.And., 2005, Australia.

These three species show some similarity to *R. obtriangulata*; their differences are discussed in introduction to Hypdigm (p. 104).

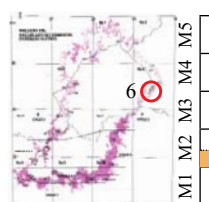
**Umkomaas (Umk 111 Dic 2spp), Waterfall Locality**

Habitat: *Dicroidium* riparian forest (mature, type 1)

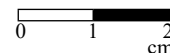
Collection: 3592 slabs, 400 man-hrs cleaving



Without male affiliate



6. Umk 111



Rochipteris cf. sinuosa* Holmes & H.M.And., 2005*Holotype**

Specimen: AMF126845; Holmes & H.M.And., 2005, p. 48, fig. 23 A–C.

Assemblage (TC): Coalmine Quarry, Basin Creek Fm., Nymboida, Clarence/Moreton Basin, Australia.

Preservation: carbonaceous, no cuticle, grey coarse mudstone.

Plant fossil names registry number: PFN002323

Reference palaeodeme

Assemblage (TC): Umk 111 Dic 2 spp, Umkomaas (pls 107–110(1–3); fig. p. 99).

Specimens: 9 indivs; attached and clusters nil.

Preservation: fairly complete isolated leaves; with clear venation; compressions in thinly laminated, carbonaceous (cuticle), moderately baked, dark-grey shale, with good cleavage.

Sister palaeodemes – 1

Win 111 Hei elo: 1 indiv. (pl. 93)

Specific concept

A *Rochipteris* species of small to intermediate size with flabellate deeply irregularly divided lamina, and with widely spaced anastomosing venation.

Specific characters

Attachment: unknown

Leaf: flabellate, intermediate in size (c. 85 × 75 mm); lamina deeply divided 3 times into irregular segments (up to 2/3 length of leaf); veins widely spaced, c. 10 per cm midway, anastomoses more frequent distally.

Etymology

sinuosa – (Lat.), sinuous, referring to the venation; as named by Holmes & H.M.And. (2005, p. 48).

Affiliated organs ♂ – nil**Comment & comparison*****Molteno species***

R. cf. sinuosa, based on several leaves from Umk 111, is one of the more unusual of the 12 *Rochipteris* species recognized in the Molteno. Specimen BP/2/539, in particular, is well-preserved and almost complete, and quite unlike the other species of foliage from Umk 111, or the Molteno in general. *R. distivena* from Kan 112 (with four individual leaves) is the nearest in having broad venation, but this is more open towards the base of the leaf. Further differences are the larger leaves, the lamina not so deeply divided and the overall shape being cuneate. Two leaves (BP/2/549, 553), of similar open anastomosing venation but with crenulate margins, were previously placed in *Batiopteris* sp. indet. by And. & And. (2003, p. 324) and are now included here. Similarly, another leaf from Win 111 (And. & And., 2003, fig. 3, p. 325) is now considered to belong here (pl. 93).

***Gondwana Triassic species* (non-Molteno)**

Rochipteris sinuosa Holmes & H.M.And., 2005, Australia.

The Molteno leaf is provisionally placed in this species as it is similar in size, the deeply divided lamina and in venation. However, as the bases are incomplete, it is not possible to ascertain whether the Umk 111 leaves also have the diagnostic clasping base.

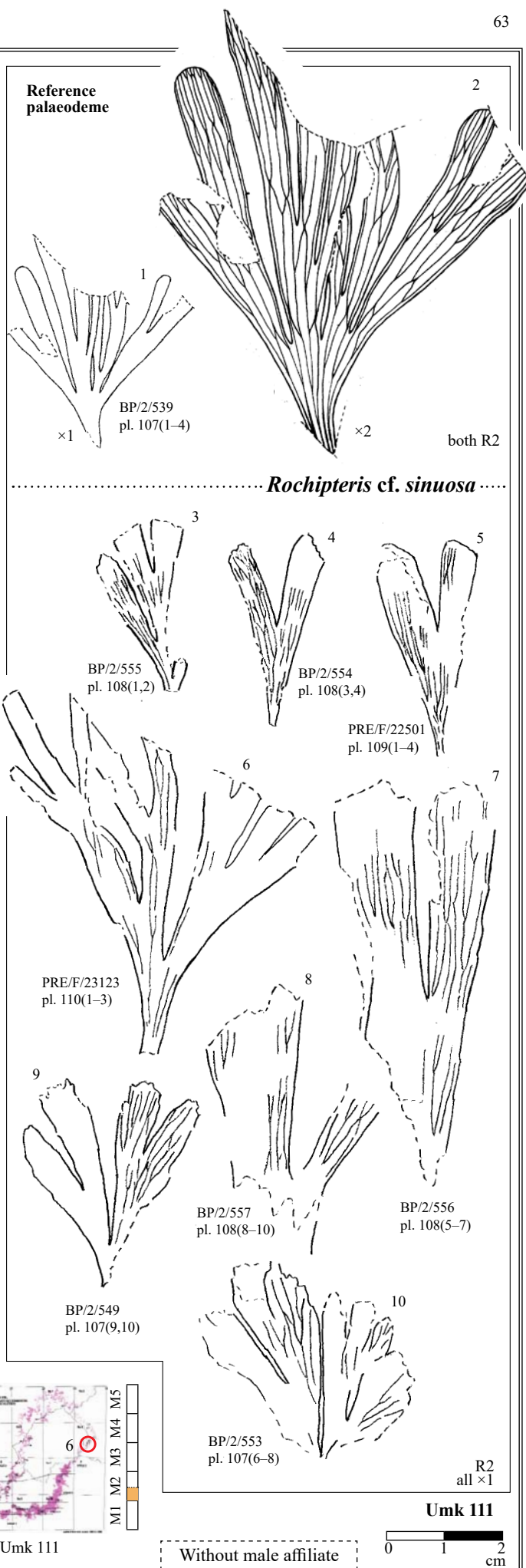


From photo, 24 Jan 1979
HMA, 9 April 1996

Umkomaas (Umk 111 Dic 2 spp), Waterfall Locality

Habitat: *Dicroidium* riparian forest (mature, type 1)

Collection: 3592 slabs, 400 man-hrs cleaving



Rochipteris penensis J.M.And. & H.M.And., sp. nov.**Holotype***Specimen*: PRE/F/17943a,b pls 87(8, 14), 88(5)*Assemblage* (TC): Pen 411 Hei elo, Peninsula*Preservation*: almost complete leaf, impression in thickly laminated, greenish grey shale, moderate cleavage.**Plant fossil names registry number**: PFN002324**Reference palaeodeme***Assemblage* (TC): as for holotype (pls 87, 88; figs p. 100)*Specimens*: 10 indivs; attached and clusters nil.**Sister palaeodemes – 3**

Kan 112 Hei elo: 2 indivs

Tel 111 Hei elo: 2 indivs (pl. 46(6–9)); ♂ affil. (2 indivs, pl. 42)

Pen 311 Hei elo: 5 indivs (pls 77, 78(1–7))

Specific diagnosis

A *Rochipteris* species of small size with obtriangulate entire lamina and truncate to convex distal margin, and with closely spaced anastomosing venation.

Specific characters*Attachment*: unknown.

Leaf: broadly obtriangulate, of small size (up to 35 × 11 mm); lamina entire, with truncate to convex distal margin; veins closely spaced, c. 20 per cm midway, anastomoses more frequent distally.

Etymology*penensis* – (Lat.), after the type locality, Peninsula.**Affiliated organs** (♂) (male strobilus)

Sister palaeodeme: Tel 111 Hei elo

Kannaskoppianthus telepentatus (2 indivs); Grade 3 (probable)

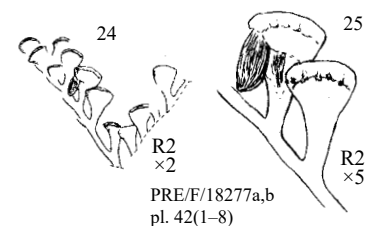
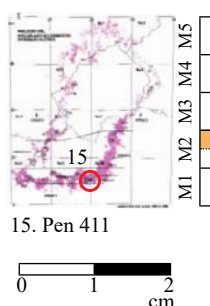
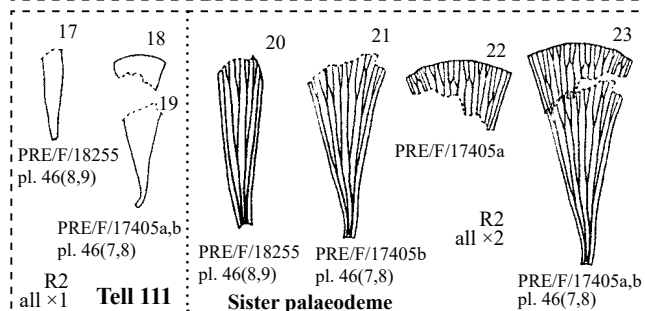
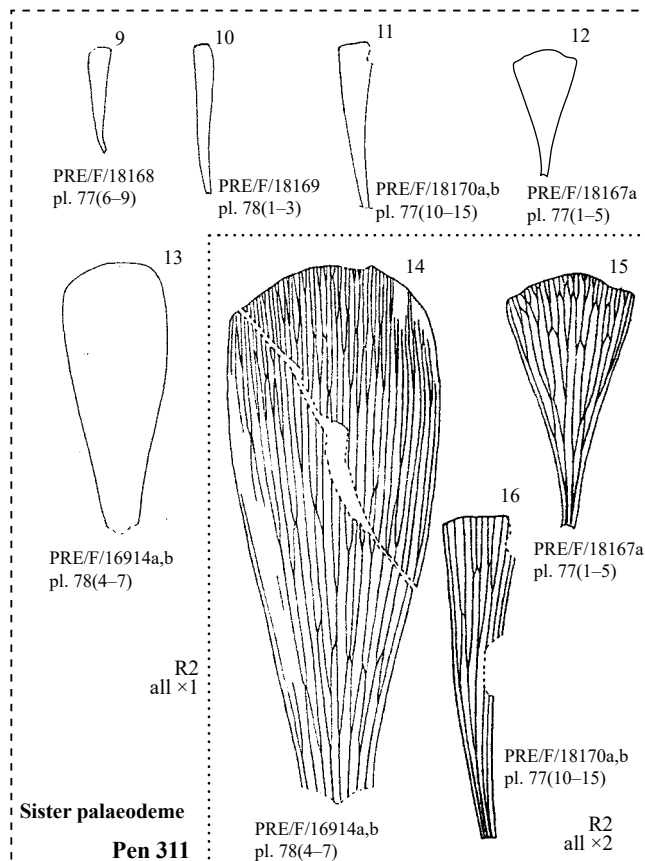
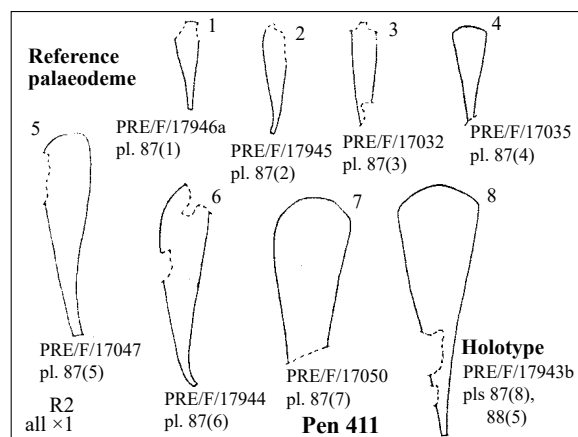
In the Pen 411 Ref. pal., there occur no affiliated strobili; but the sister palaeodeme from Tel 111 has yielded a probable male affiliate, *Kannaskoppianthus telepentatus*.

Comment & comparison (Molteno)*Molteno species*

R. penensis can be separated from the similarly shaped species *R. obtriangulata* by the smaller size of the leaf and the shorter base. *R. pusilla* and *R. penensis*, based on Ref. Pals from Pen 311 and Pen 411 respectively, are most similar amongst the Molteno species in view of their small size. However, in shape, *R. pusilla* is cuneate and the venation is widely spaced, making them quite distinctive. Note that at Pen 311, both these species occur in low numbers. Interestingly at both Pen 311 and Pen 411, the dominant *Rochipteris* species is *R. rolleri*.

Gondwana Triassic species (non-Molteno)

Rochipteris truncata (Frenguelli, 1946) Morel *et al.*, 2011, N. Argentina. The obtriangulate shape and truncate tip of this leaf is similar to *R. penensis*, but it is a consistently larger leaf and is broader at the base. *R. truncata* is considered a separate species and distinct from the Molteno populations of both *R. obtriangulata* and *R. penensis*. Consult further discussion in introduction to Hypodigm (p. 104).

**Peninsula (Pen 411 Hei elo), Lunchspot***Habitat*: *Heidiphyllum* thicket*Collection*: 204 slabs, 70 man-hrs cleaving

Kannaskoppianthus telepentatus Tel 111
(affiliated ♂ strobilus, as at sister TC)

Rochipteris pusilla Holmes & H.M.And., 2005**Holotype**

Specimen: AMF126854; p. 49, Fig. 25A–C.

Assemblage (TC): Coalmine Quarry, Basin Creek Fm., Nymboida, Clarence/Moreton Basin, Australia.

Preservation: carbonaceous, no cuticle, grey coarse mudstone.

Plant fossil names registry number: PFN002325

Reference palaeodeme

Assemblage (TC): Pen 311 Hei elo, Peninsula (pl. 78(8–15); figs p. 101)

Specimens: 2 indivs; attached and clusters nil.

Sister palaeodemes – 3

Boe 112 Dic cor: 1 indiv. (pl. 8)

Kan 112 Hei elo: 1 indiv.

Tel 111 Hei elo: 1 indiv.

Specific concept

A *Rochipteris* species of small size with cuneate entire lamina and convex distal margin, and with widely spaced anastomosing venation.

Specific characters

Attachment: unknown

Leaf: cuneate, of very small size (up to 20 × 14 mm); lamina entire, with convex distal margin; veins widely spaced, c. 10 per cm midway.

Etymology

pusilla – (Lat.), very small, this being the smallest species described by Holmes & H.M.And. (2005).

Affiliated organs ♂ – nil**Comment & comparison** (Molteno)*Molteno species*

The palaeodemes of *R. penensis* and *R. pusilla*, from Pen 311 and Pen 411 are, in view of their small leaf size, most similar amongst the Molteno species. However, in shape *R. penensis* is broadly obtriangulate and it has closely spaced venation making them quite distinctive.

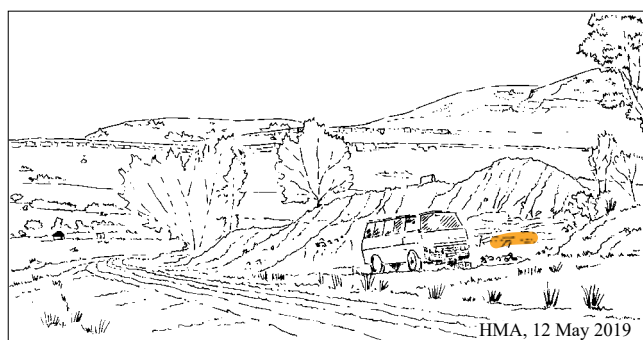
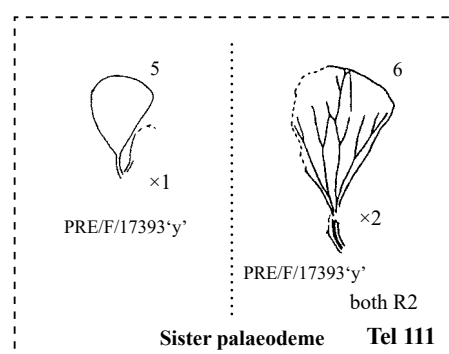
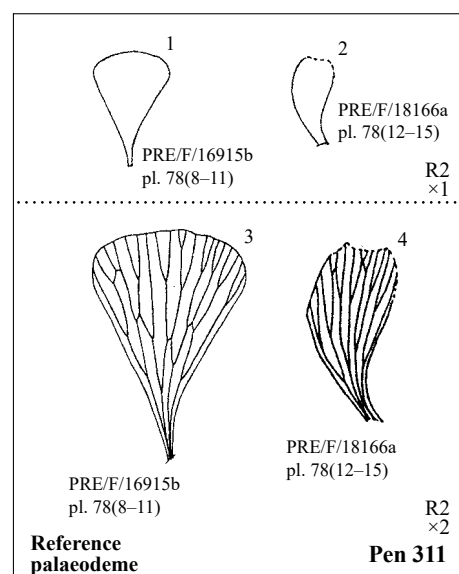
Gondwana Triassic species (non-Molteno)

Rochipteris pusilla Holmes & H.M.And., 2005, Australia.

Due to the small size, similar shape, and open venation, the Molteno specimens have been placed in this species based on a single specimen (with a slightly undulate upper margin) from Nymboida. As so few specimens occur from the four assemblages in the Molteno, the specific identity is somewhat uncertain.

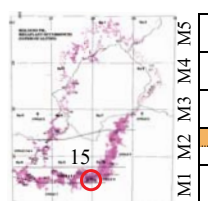
Rochipteris tasmanica (Walkom, 1926) Herbst *et al.*, 2001, Tasmania.

The specimen described by Walkom (1926) has finer venation, is twice as large as the Molteno Pen 311 specimens, and is more than a third larger than the type specimen of *R. pusilla* from Nymboida.

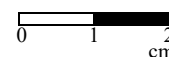
**Peninsula (Pen 311 Hei elo), Campsite Quarry**

Habitat: *Heidiphyllum* thicket

Collection: 155 slabs, 35 man-hrs cleaving



15. Pen 311



PALAEODEME SKETCHES

Introduction

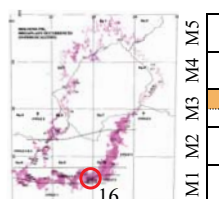
Central to our taxonomic approach – introduced in our volume on *Dicroidium* (And. & And., 1983) – is the palaeodeme (fossil population, see Glossary, p. 319). The focus is on the comparison of populations of specimens from particular assemblages (taphocoenoses) through the geographic, stratigraphic and ecological extent of the Molteno Fm., rather than on individual specimens.

In the following section are presented sketches of all the palaeodemes representing *Rochipteris* and affiliates from the Molteno. These follow the same sequence dealt with for the species descriptions and similarly for the Whole-plant species in Part 3.

What becomes very evident – especially for *Rochipteris rollerii*, which occurs in 14 of the 26 assemblages – is that the spread of variation in each palaeodeme is different. These differences become more apparent by compiling a series of histograms plotting the number of segments/leaflets for foliage specimens within the palaeodeme (pp 76, 77). This has been undertaken for numerous *R. rollerii* palaeodemes and the morphologically overlapping species, *R. switzifolia* and *R. matatifolia*. Similarly, graphs showing microsporophyll counts for the *Kannaskoppianthus* species have been compiled (p. 77).

What becomes apparent is evolution in action and the variations resulting from differing habitats. Taxonomy is a complex endeavour when assemblages are scattered through time (millions of years) and different habitats (riverine forest to open woodland).

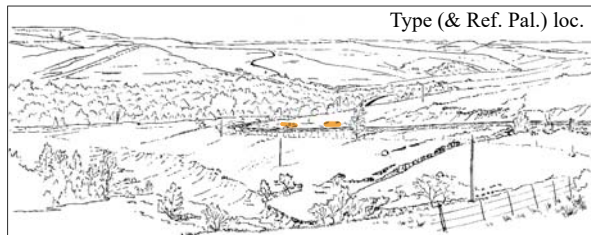
The graphs (pp 76, 77) plotting leaflet numbers for *R. rollerii*, *R. switzifolia* and *R. matatifolia*, and microsporophyll numbers for *Kannaskoppianthus*, clearly show the significant variability between palaeodemes from different TCs.



16. Kan 111

27°56.9'E; 31°26.92'S

Type (& Ref. Pal.) loc.



Kannaskop (Kan 111 Ast sp A), *Kannaskoppia* siltstone

Habitat: Fern/*Kannaskoppia* meadow

Collection: 365 slabs, 30 man-hrs cleaving

Rochipteris vincularis (5% of assemblage, c. 45 slabs)

attached to shoots (leaves & ♀) – 4 slabs

attached (leaves only) – 12 slabs

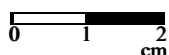
clusters of leaves – 1 slab

detached/isolated leaves – >25 slabs

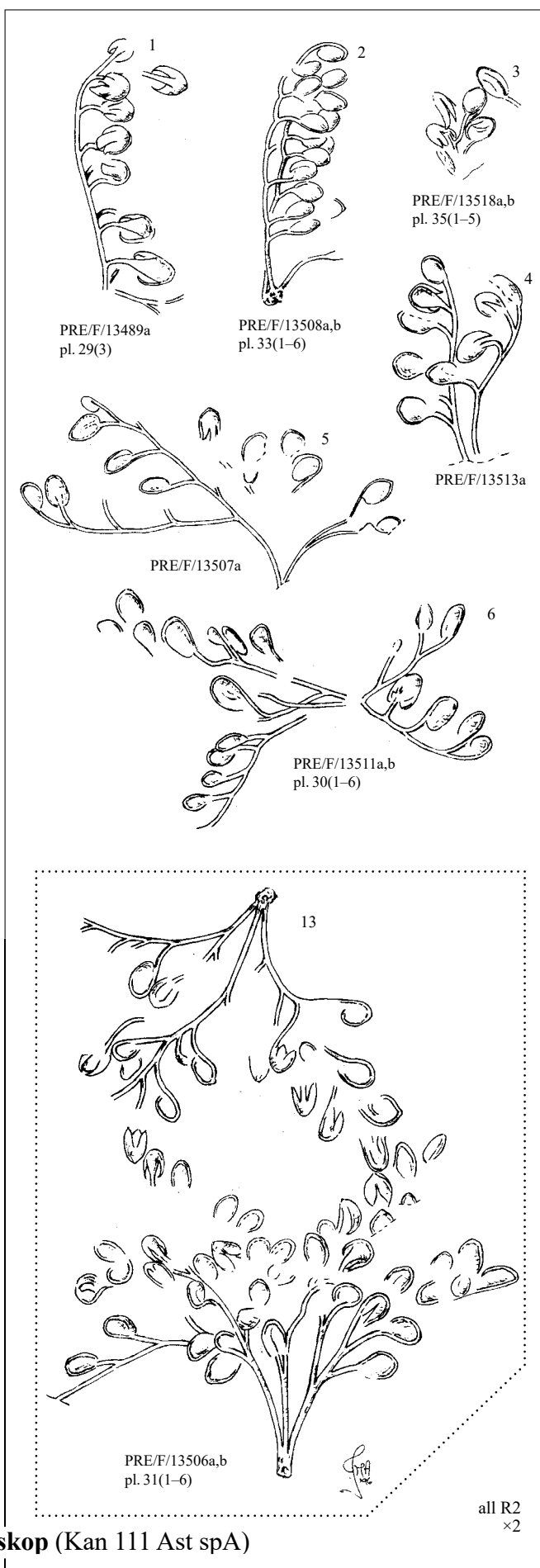
***Kannaskoppia* ♀** – 50 indivs (attached, Grade 5 affil.)

***Kannaskoppianthus* ♂** – nil

Taphonomy (*R. vincularis*) – autochthonous

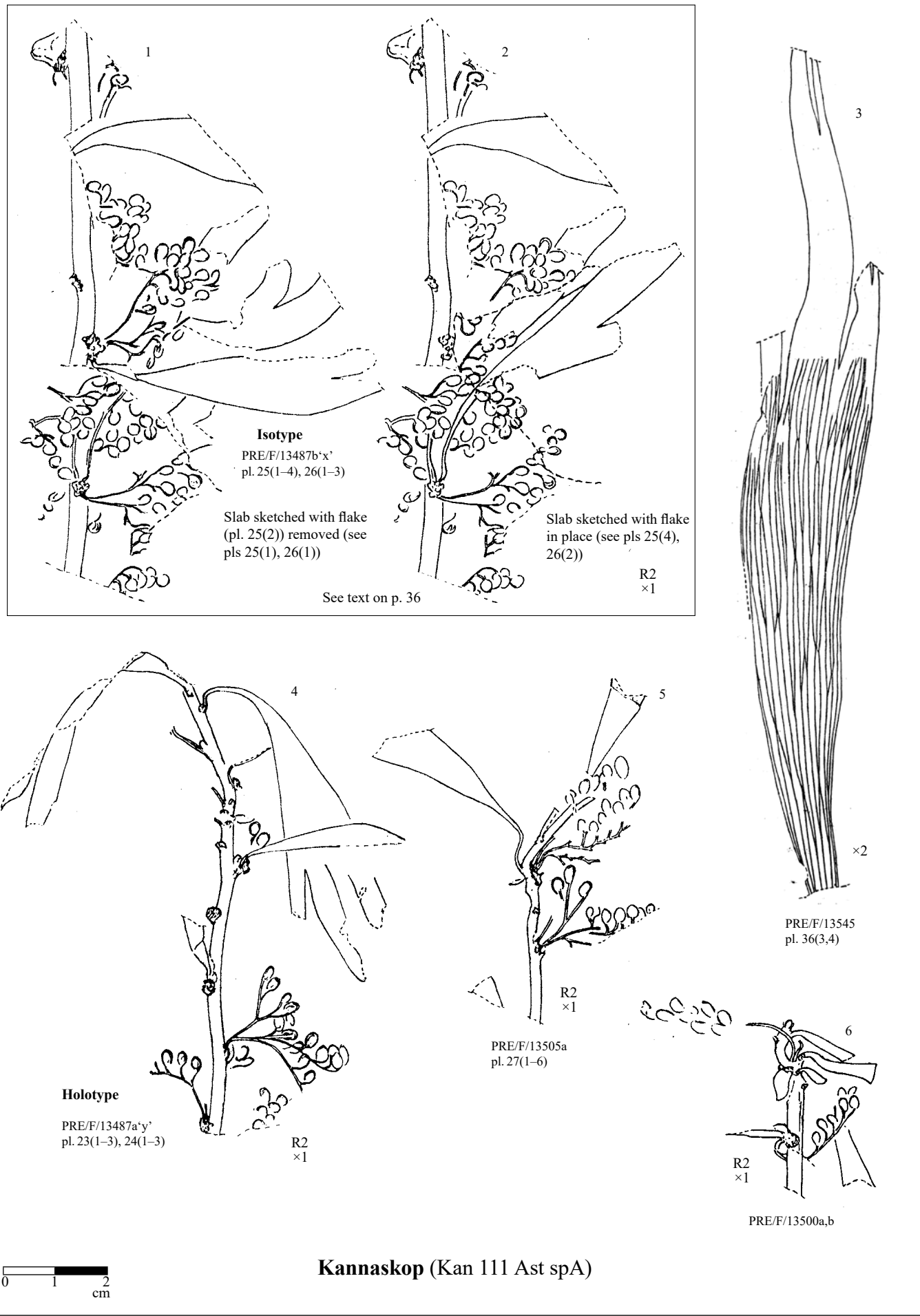


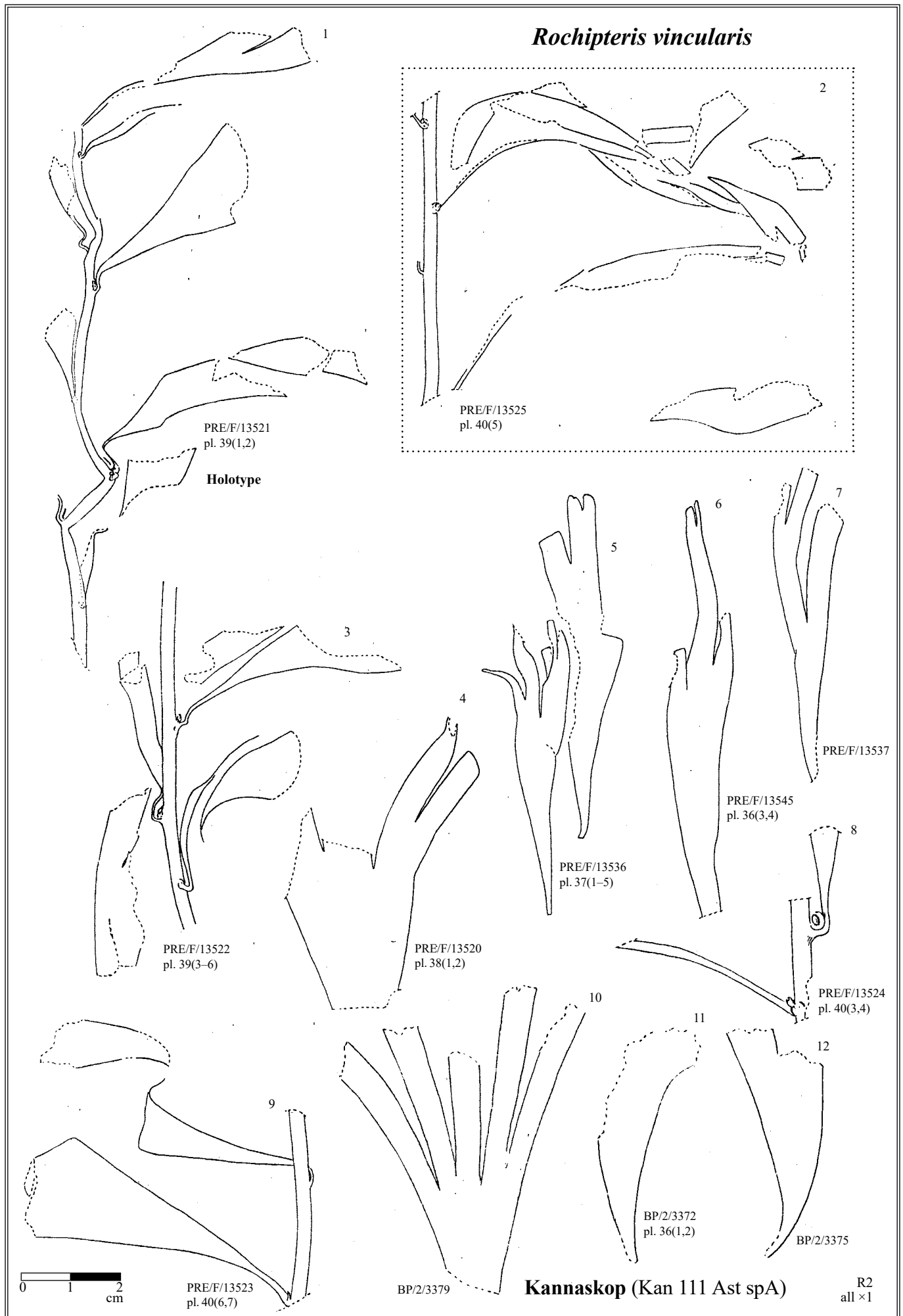
Kannaskoppia vincularis



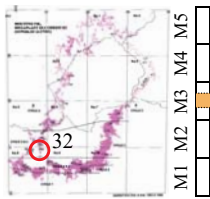
Kannaskop (Kan 111 Ast spA)

Kannaskoppia vincularis / *Rochipteris vincularis*



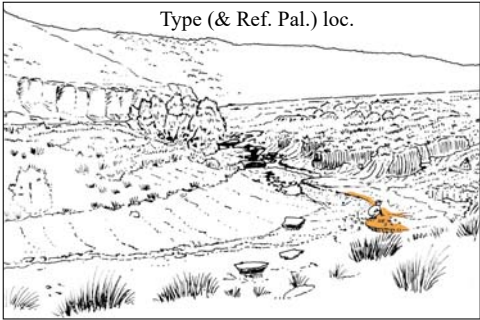


Rochipteris telefolia



32. Tel 111

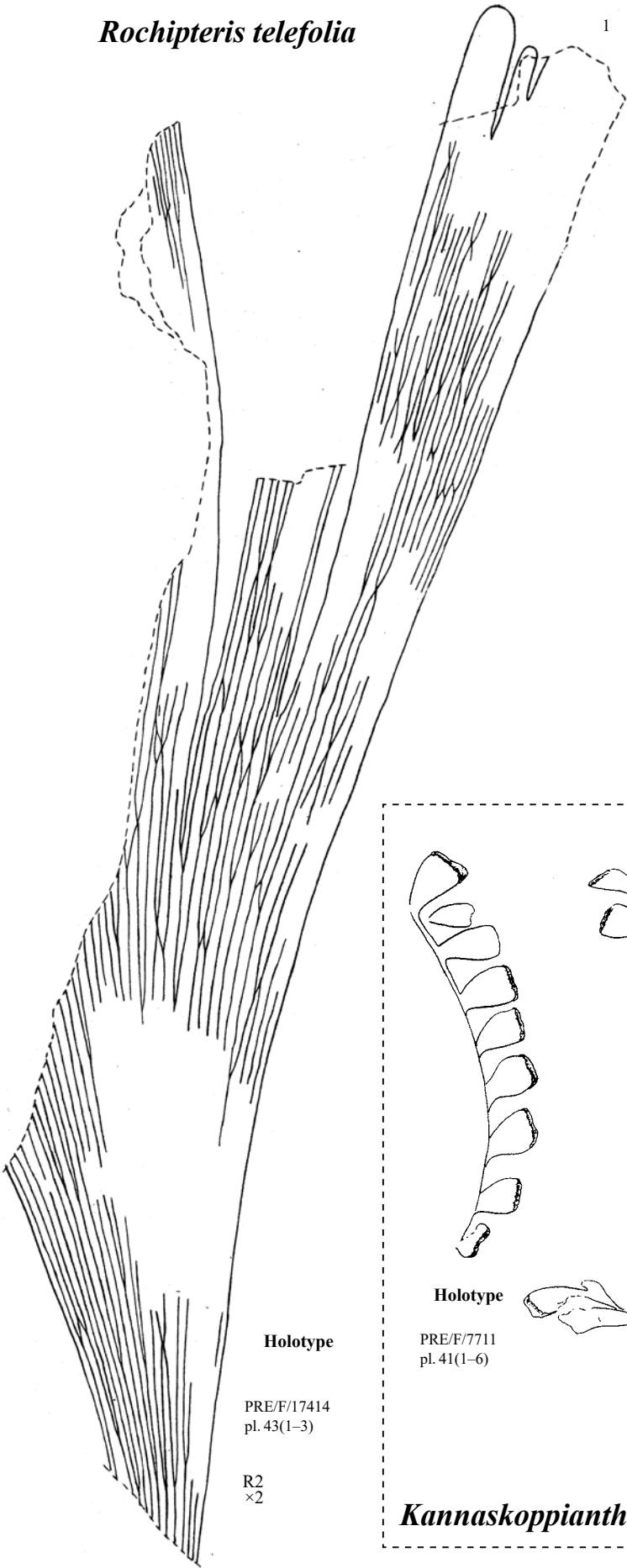
26°47.78'E; 31°02.86'S



Type (& Ref. Pal.) loc.

Telemachus Spruit (Tel 111 Hei elo)

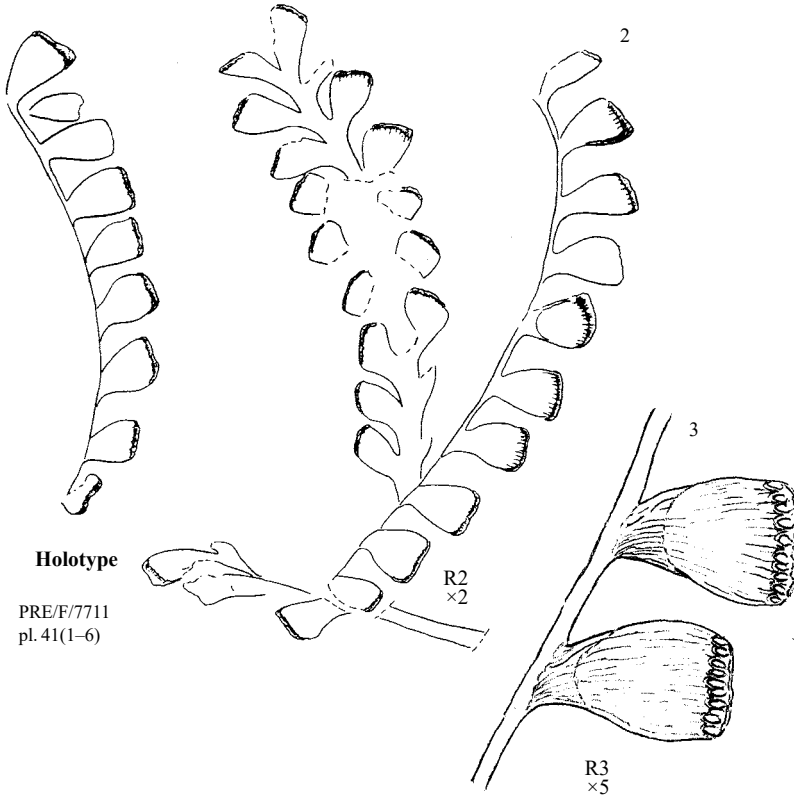
Habitat: *Heidiphyllum* thicket
Collection: 581 slabs, 90 man-hrs cleaving
Rochipteris telefolia (30 indivs)
attached to shoots – 2 slabs (5 leaves, 8 leaves)
clusters – 1 slab (3 leaves)
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – 2 spp (4 indivs)
K. telemagnus (2 indivs); Grade 4 affil. to *R. telefolia*
Taphonomy (*R. telefolia*) – parautochthonous



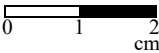
Holotype

PRE/F/17414
pl. 43(1–3)

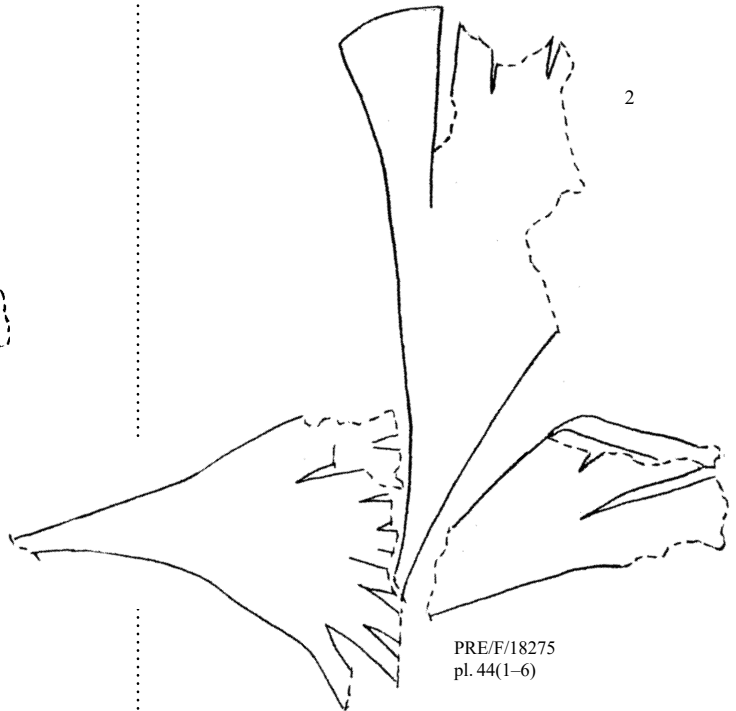
R2
×2



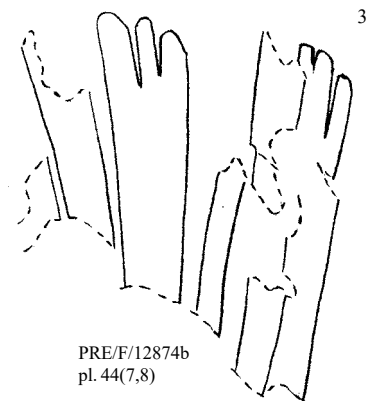
Kannaskoppianthus telemagnus



Telemachus Spruit (Tel 111 Hei elo)

Rochipteris telefolia

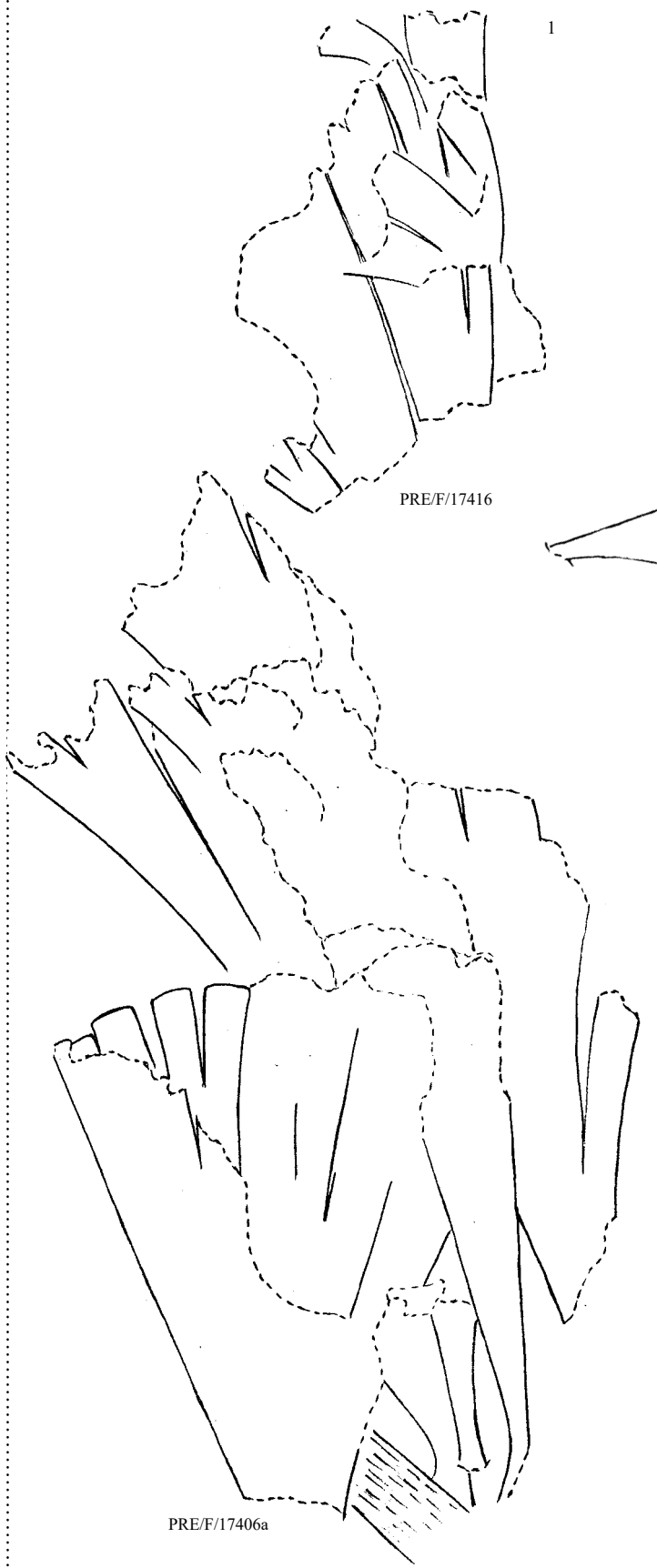
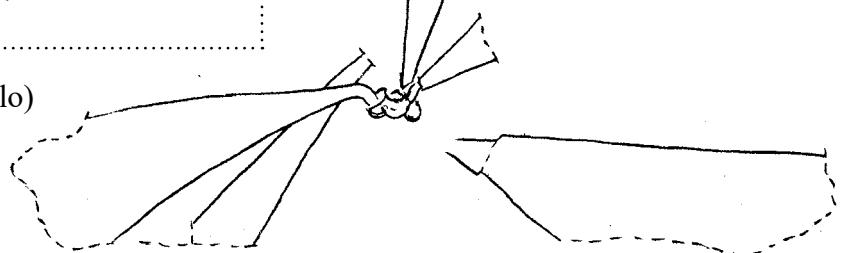
PRE/F/18275
pl. 44(1–6)



PRE/F/12874b
pl. 44(7,8)

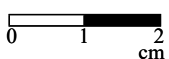
4

PRE/F/12876
pl. 46(1–3)

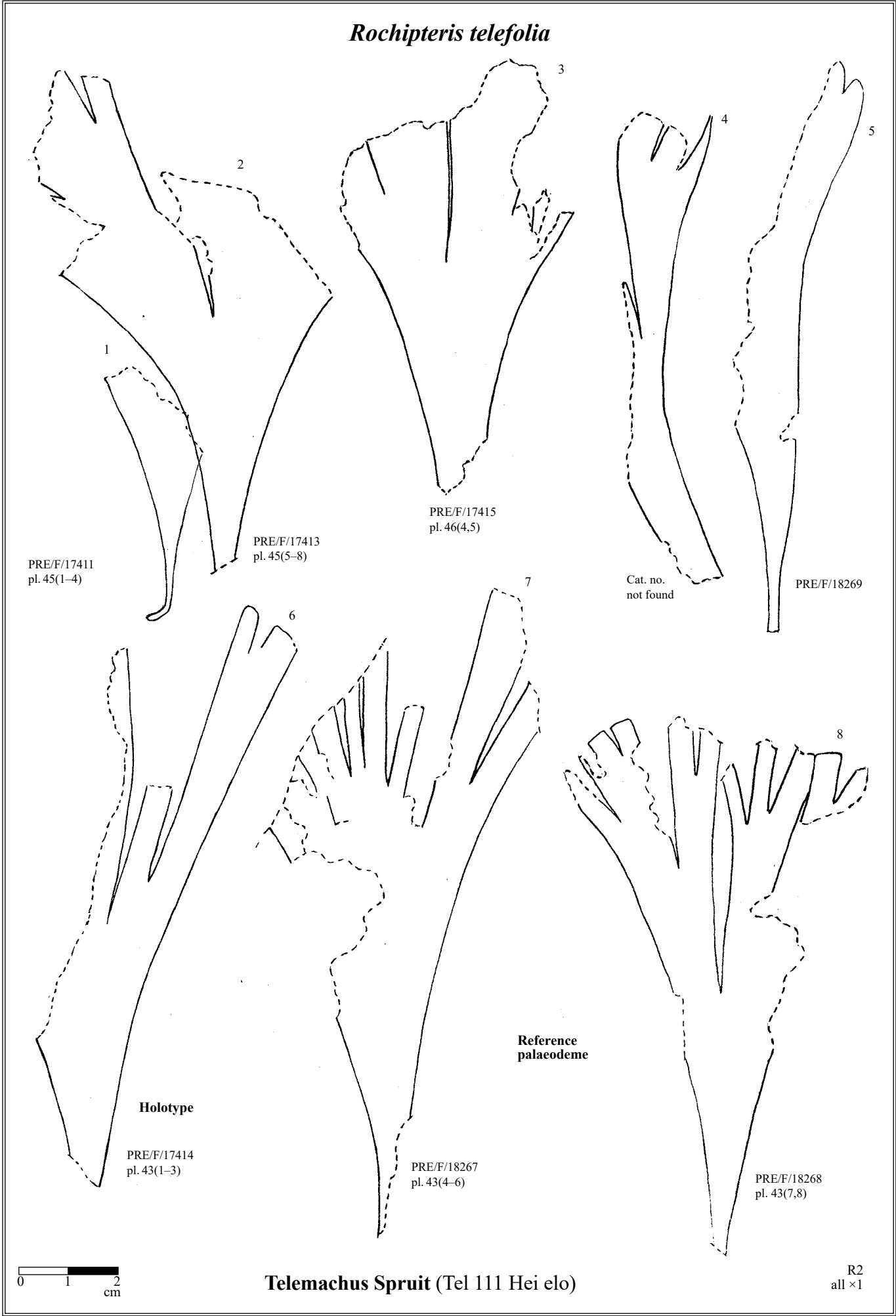


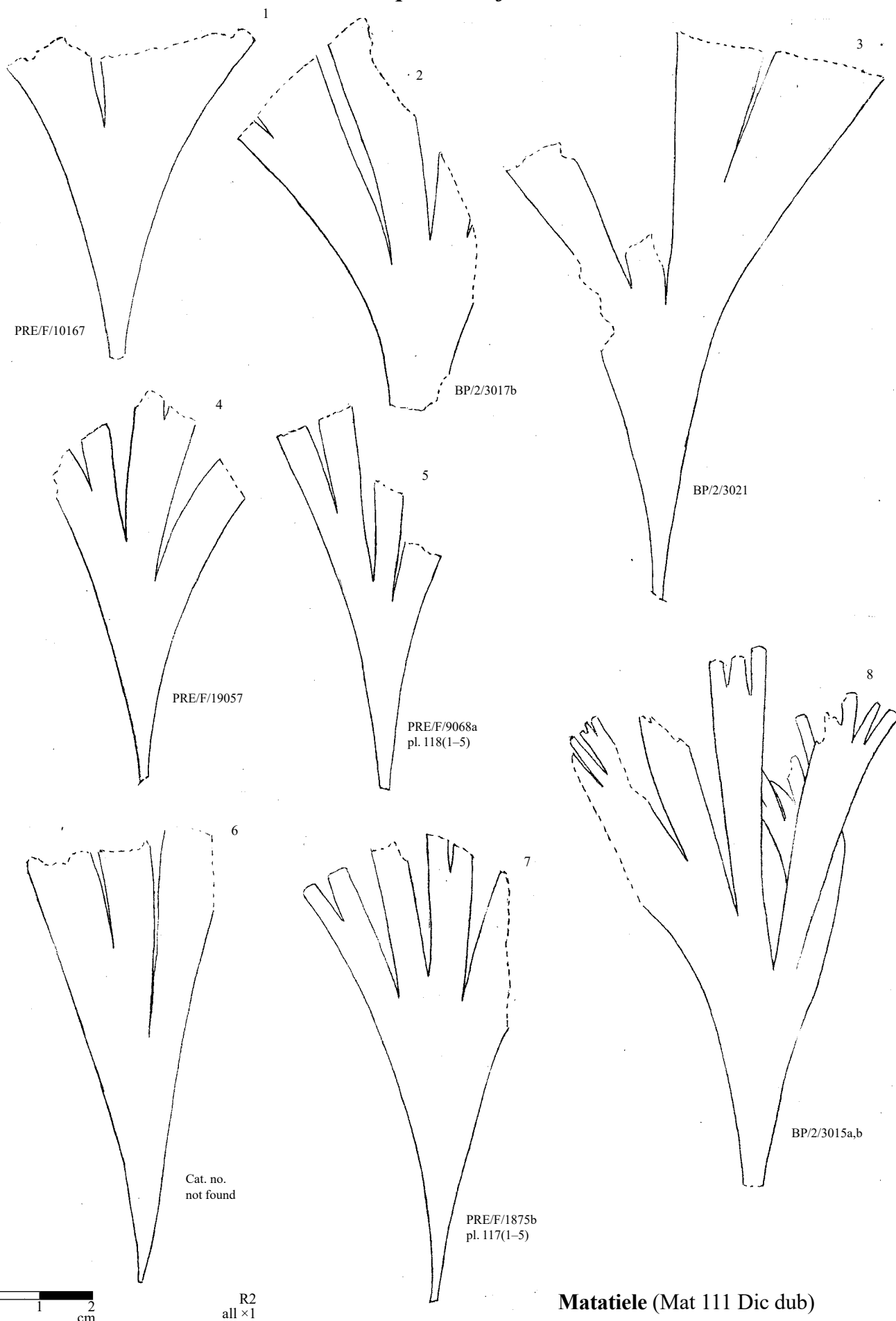
PRE/F/17416

PRE/F/17406a

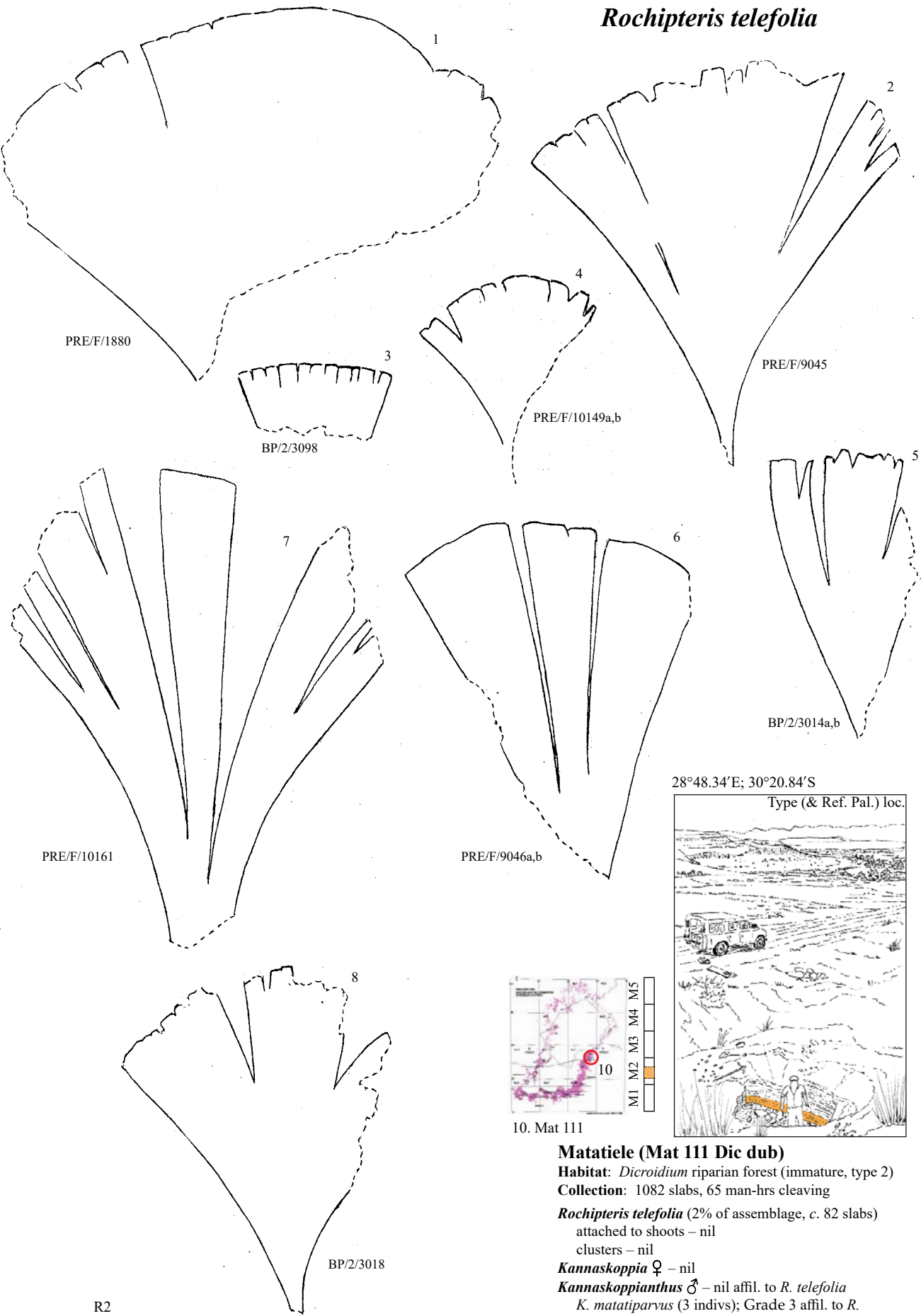
Telemachus Spruit (Tel 111 Hei elo)

R2
all ×1

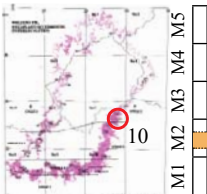


Rochipteris telefolia

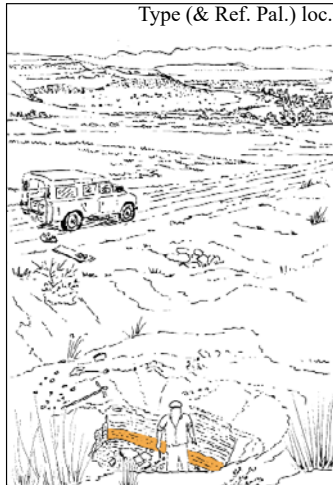
Rochipteris telefolia



28°48.34'E; 30°20.84'S
Type (& Ref. Pal.) loc.

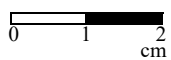
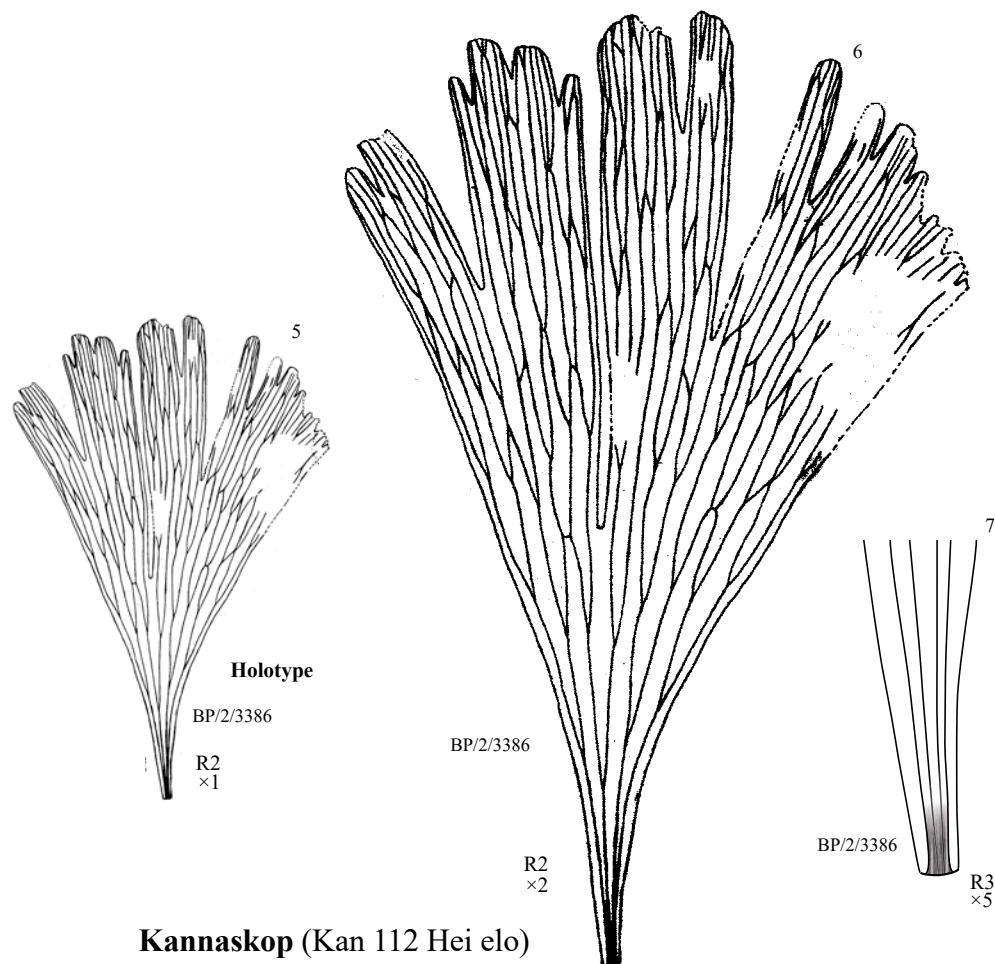
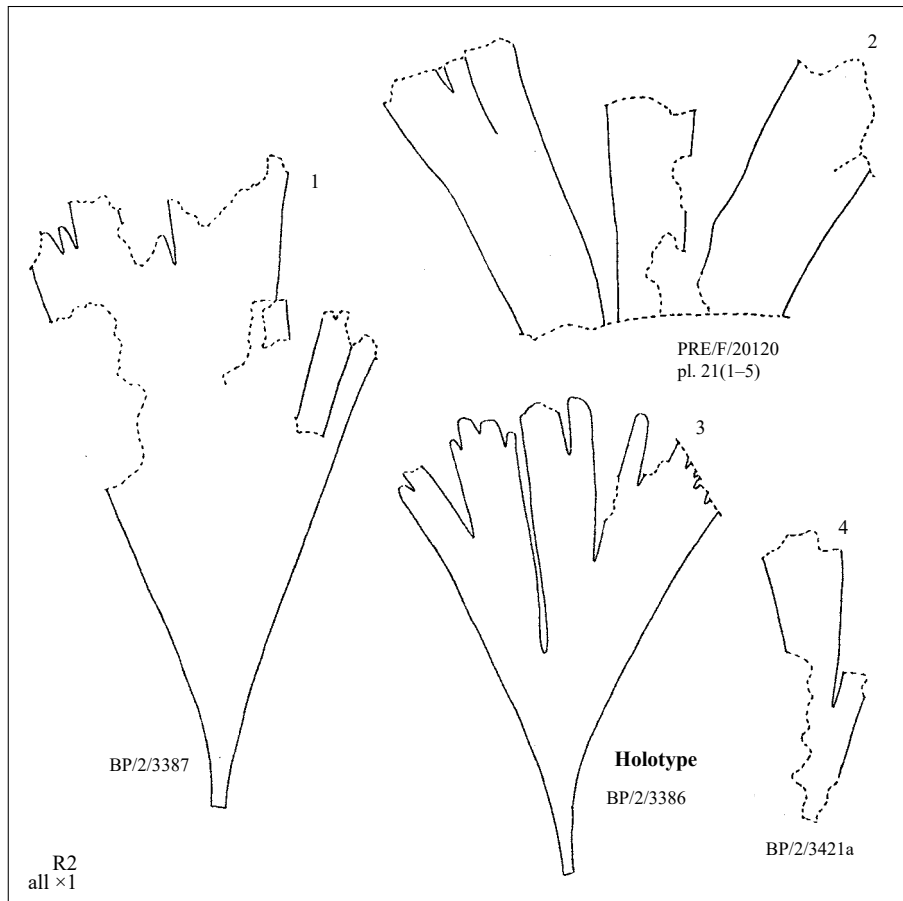


10. Mat 111



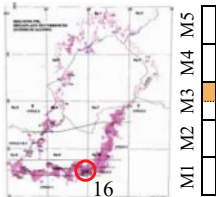
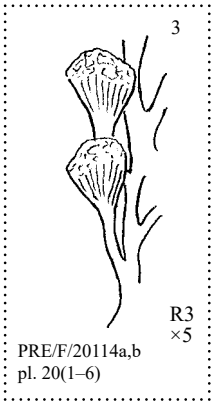
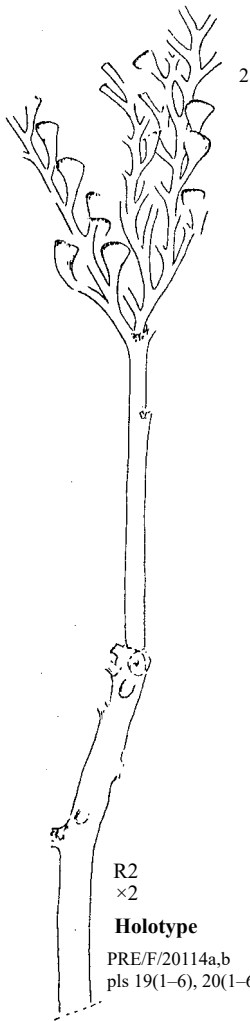
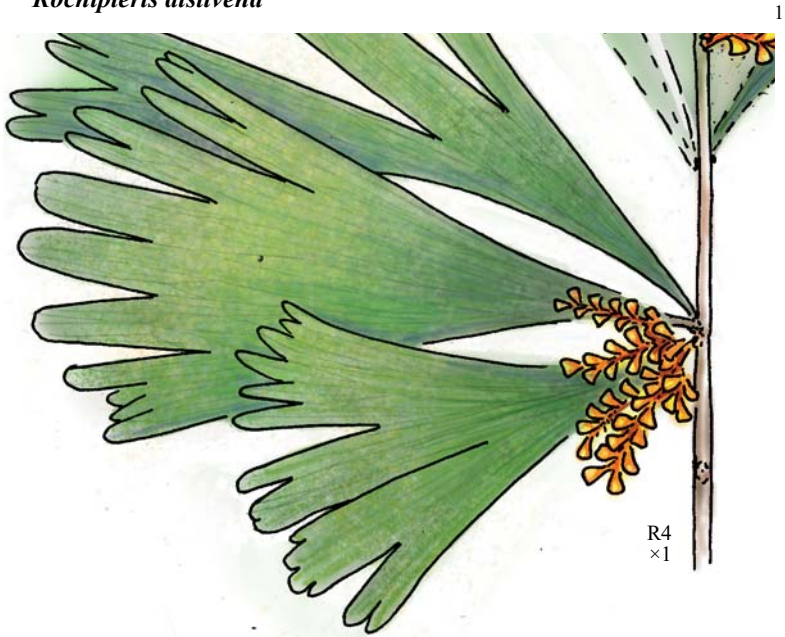
Matatiele (Mat 111 Dic dub)
Habitat: *Dicrodium* riparian forest (immature, type 2)
Collection: 1082 slabs, 65 man-hrs cleaving
Rochipteris telefolia (2% of assemblage, c. 82 slabs)
attached to shoots – nil
clusters – nil
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – nil affil. to *R. telefolia*
K. matatiparvus (3 indivs); Grade 3 affil. to *R. gracilis*
Taphonomy (*R. telefolia*) – parautochthonous

Matatiele (Mat 111 Dic dub)

Rochipteris distivena**Kannaskop (Kan 112 Hei elo)**

Rochipteris distivena

Kannaskoppianthus irregularis /
Rochipteris distivena



16. Kan 112

27°56.9'E; 31°26.92'S

Type (& Ref. Pal.) loc.



Kannaskop (Kan 112 Hei elo), Upper End

Habitat: *Heidiphyllum* thicket
Collection: 145 slabs, 15 man-hrs cleaving

Rochipteris distivena (4 indivs)
attached to shoots – nil
clusters – nil

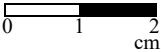
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – 5 indivs (affil., Grade 3)

Taphonomy (*R. distivena*) – parautochthonous

Affiliated male strobilus

Kannaskoppianthus
irregularis

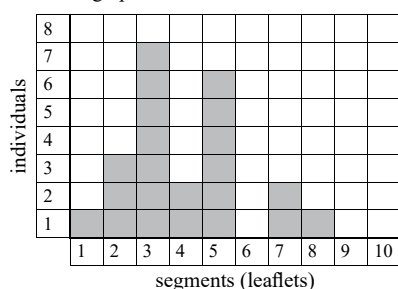
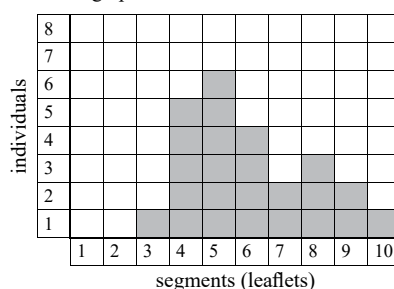
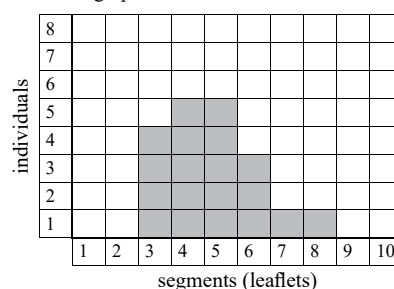
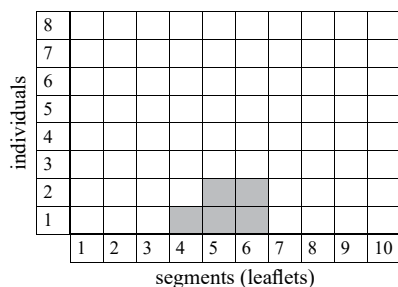
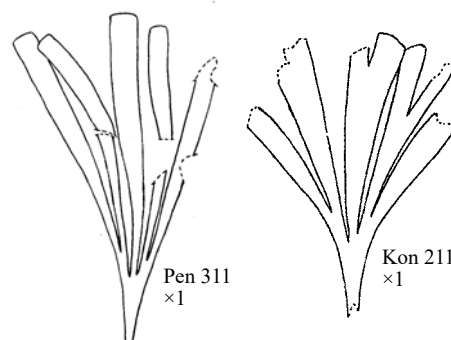
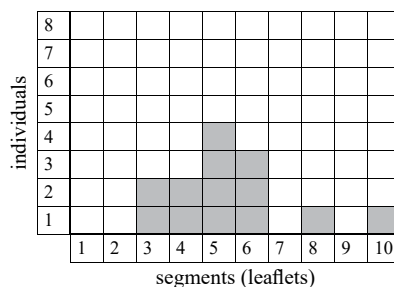
Holotype
PRE/F/20114a,b
pls 19(1–6), 20(1–6)



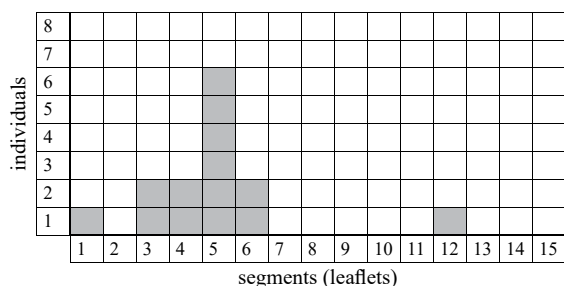
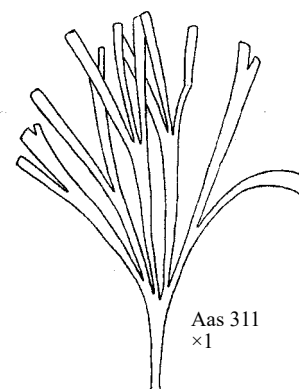
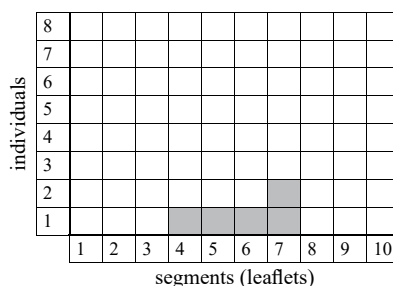
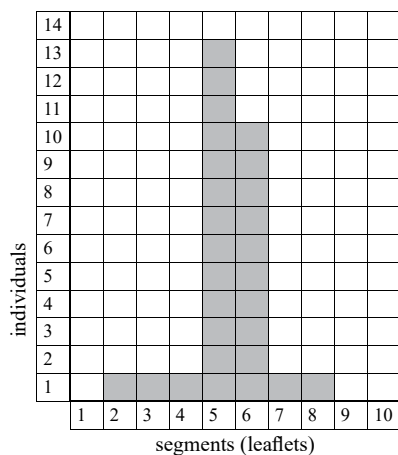
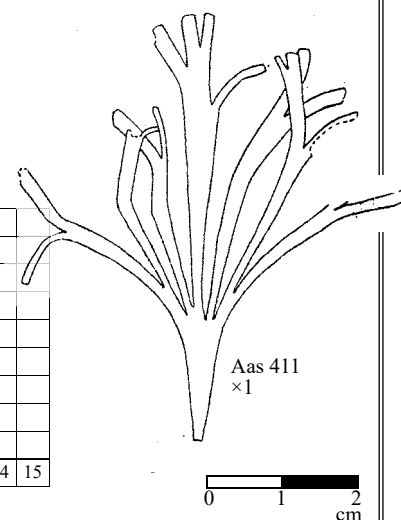
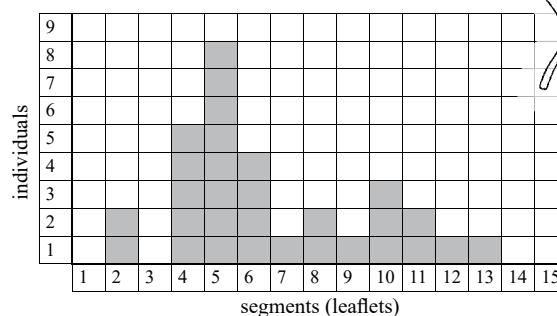
Kannaskop (Kan 112 Hei elo)

Chart 3. Foliage (9 TCs)

With histograms showing variability between palaeodemes

Rochipteris rollerii**Pen 311 Hei elo**34 indivs total
22 indivs drawn
all 22 graphed**Pen 411 Hei elo**70 indivs total
24 indivs drawn
all 24 graphed**Umk 111 Dic 2spp**21 indivs total
19 individuals drawn
all 19 graphed**Kon 211 Ast 2spp**5 indivs total
5 indivs drawn
all 5 graphed**Gre 121 Hei elo**22 indivs total
20 indivs drawn
13 indivs graphed**Segment counts**

Leaflets counted if divided to clearly >25% of the distance to the primary cleft in the lamina.

Aas 311 Hei elo25 indivs total
14 indivs drawn
all 14 graphed**Aas 211 Hei elo**18 indivs total
5 indivs drawn
all 5 graphed**Aas 111 Hei elo**2% of assemblage (c. 50 slabs, incl. several clusters)
39 indivs drawn
28 indivs graphed**Aas 411 Dic/Sph**150 indivs total
31 indivs drawn
30 indivs graphed

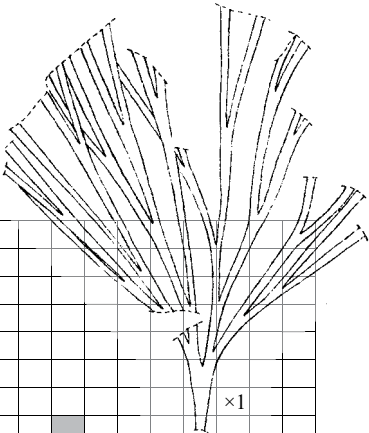
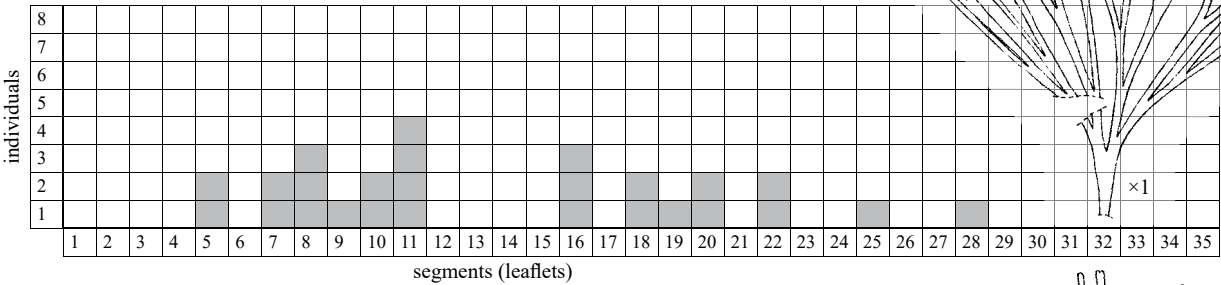
0 1 2 cm

Foliage (2 TCs)

Lit 111 Dic/Hei

55 indivs total
26 indivs drawn
26 indivs graphed

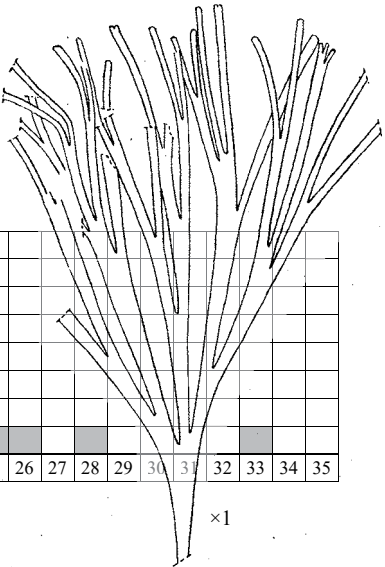
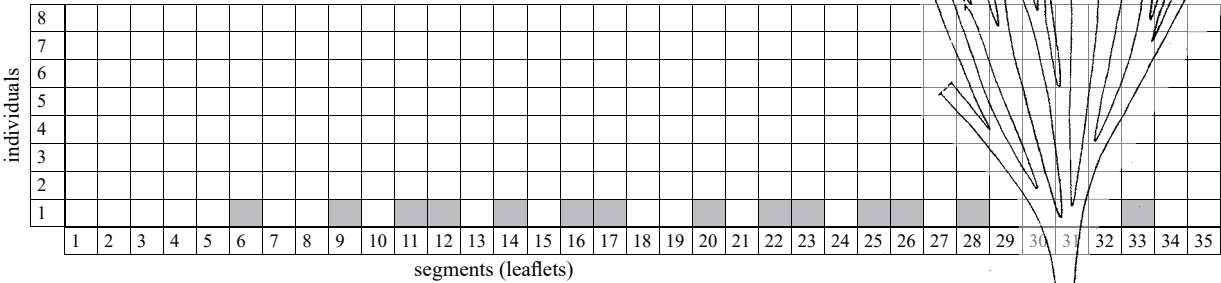
Rochipteris switzifolia



Mat 111 Dic dub

17 indivs total
14 indivs drawn
14 indivs graphed

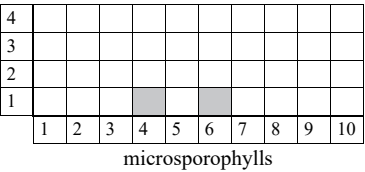
Rochipteris matatifolia



Male strobili (4 TCs)

Mat 111 Dic dub

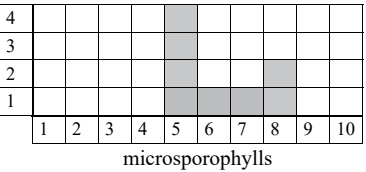
3 indivs total
2 indivs drawn
2 indivs graphed



K. matatiparvus

Aas 111 Hei elo

21 indivs total
12 indivs drawn
8 indivs graphed

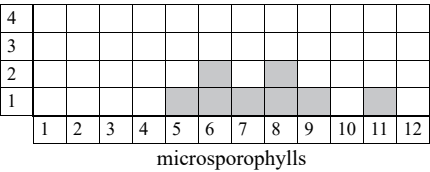


K. aasvoelanthus

Kannaskoppianthus

Lut 311 Hei elo

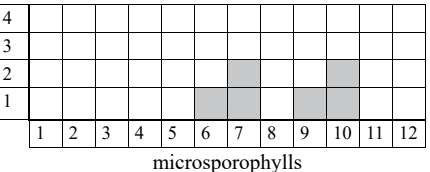
16 indivs total
10 indivs drawn
8 indivs graphed



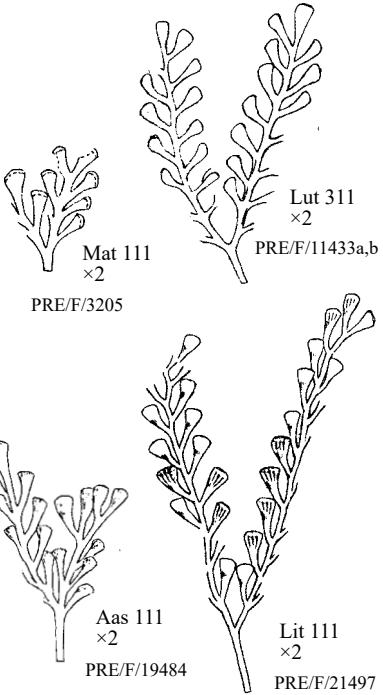
K. lutinumerus

Lit 111 Dic/Hei

9 indivs total
7 indivs drawn
6 indivs graphed

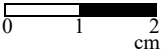


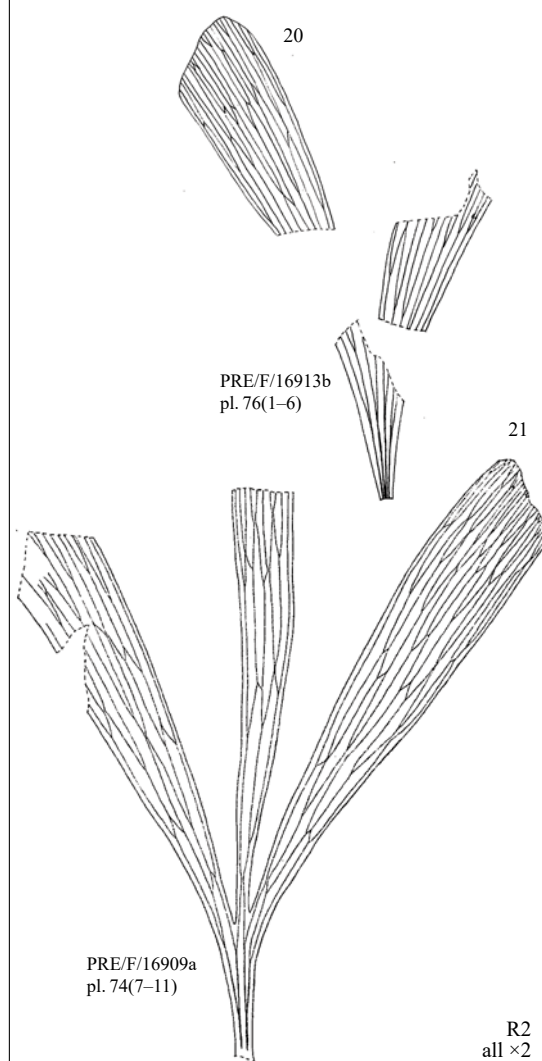
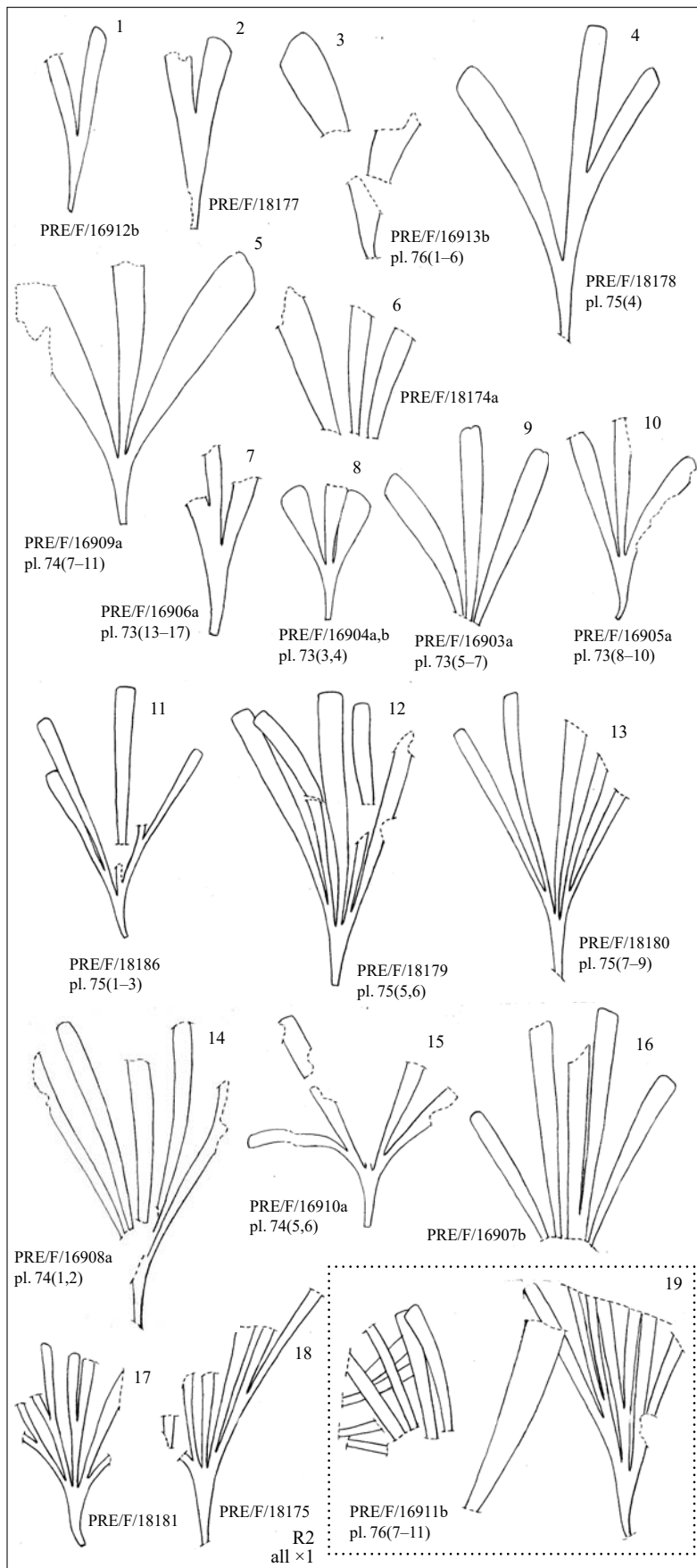
K. switzianthus



Microsporophyll counts

Maximum counts made along inner or outer margin of strobilus limb.



Rochipteris rollerii

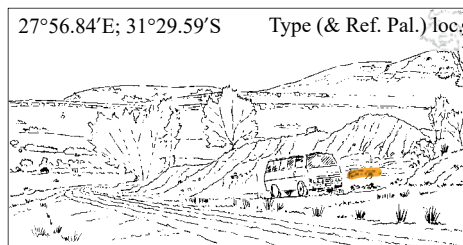
Pen 311 Hei elo

8										34 indivs total
7										22 indivs drawn
6										all 22 graphed
5										
4										
3										
2										
1										
	1	2	3	4	5	6	7	8	9	10

segments (leaflets)

27°56.84'E; 31°29.59'S

Type (& Ref. Pal.) loc.



Peninsula (Pen 311 Hei elo), Campsite Quarry

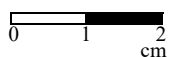
Habitat: *Heidiphyllum* thicket

Collection: 155 slabs, 35 man-hrs cleaving

Rochipteris rollerii (34 indivs)

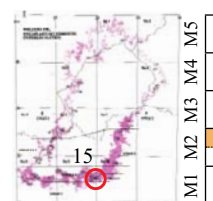
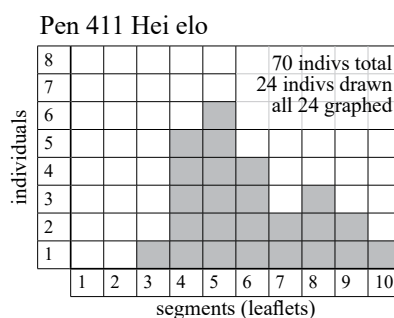
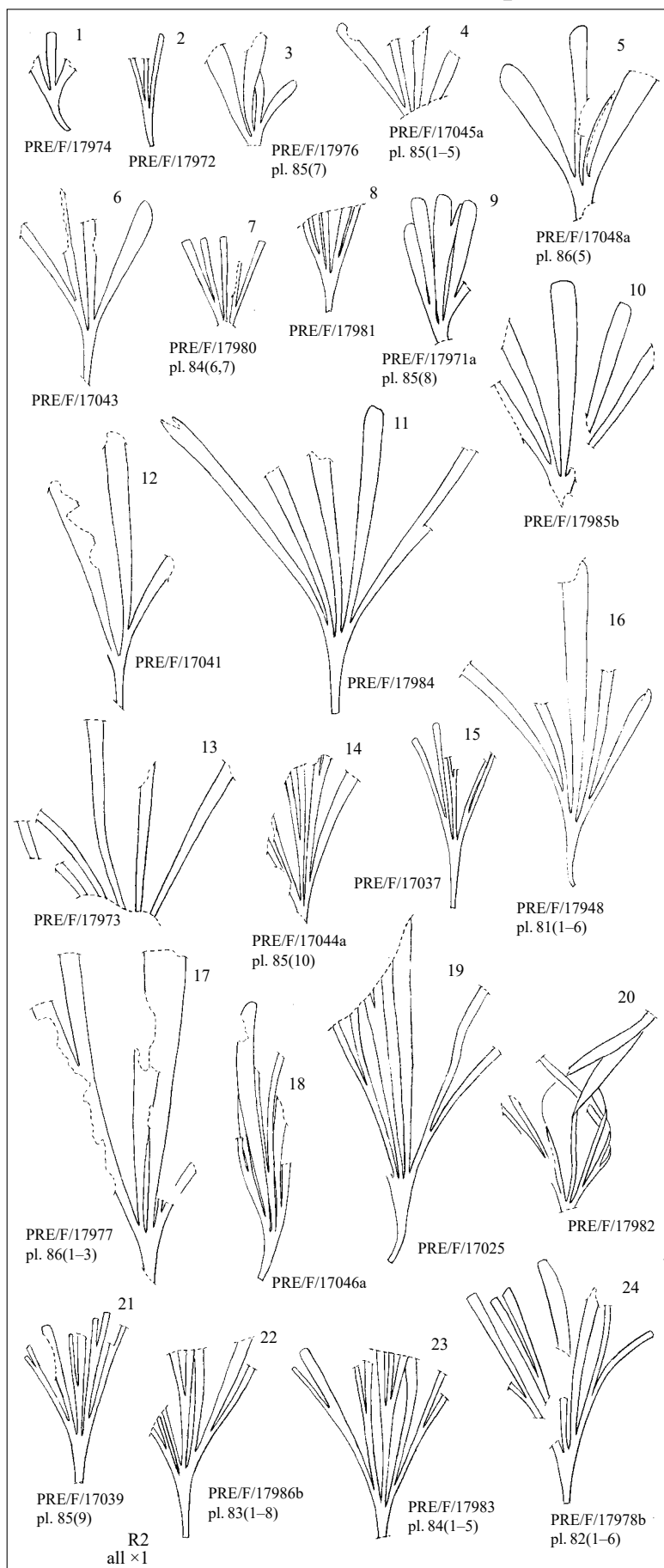
attached to shoots – nil

clusters – 1 slab (3 leaves)

Kannaskoppia ♀ – nil*Kannaskoppianthus* ♂ – nilTaphonomy (*R. rollerii*) – parautochthonous

Peninsula (Pen 311 Hei elo)

Rochipteris rollerii



15. Pen 311, 411

27°56.78'E; 31°30.35'S

Type (& Ref. Pal.) loc.



Peninsula (Pen 411 Hei elo), Lunchspot

Habitat: *Heidiphyllum* thicket

Collection: 204 slabs, 70 man-hrs cleaving

Rochipteris rollerii (70 indivs)

attached to shoots – nil

```
clusters – nil
```

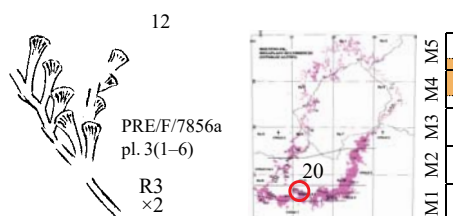
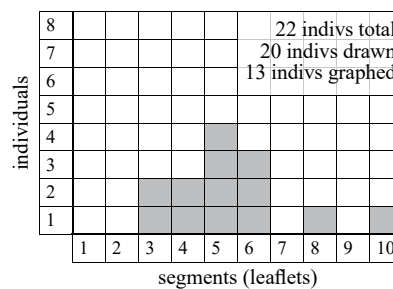
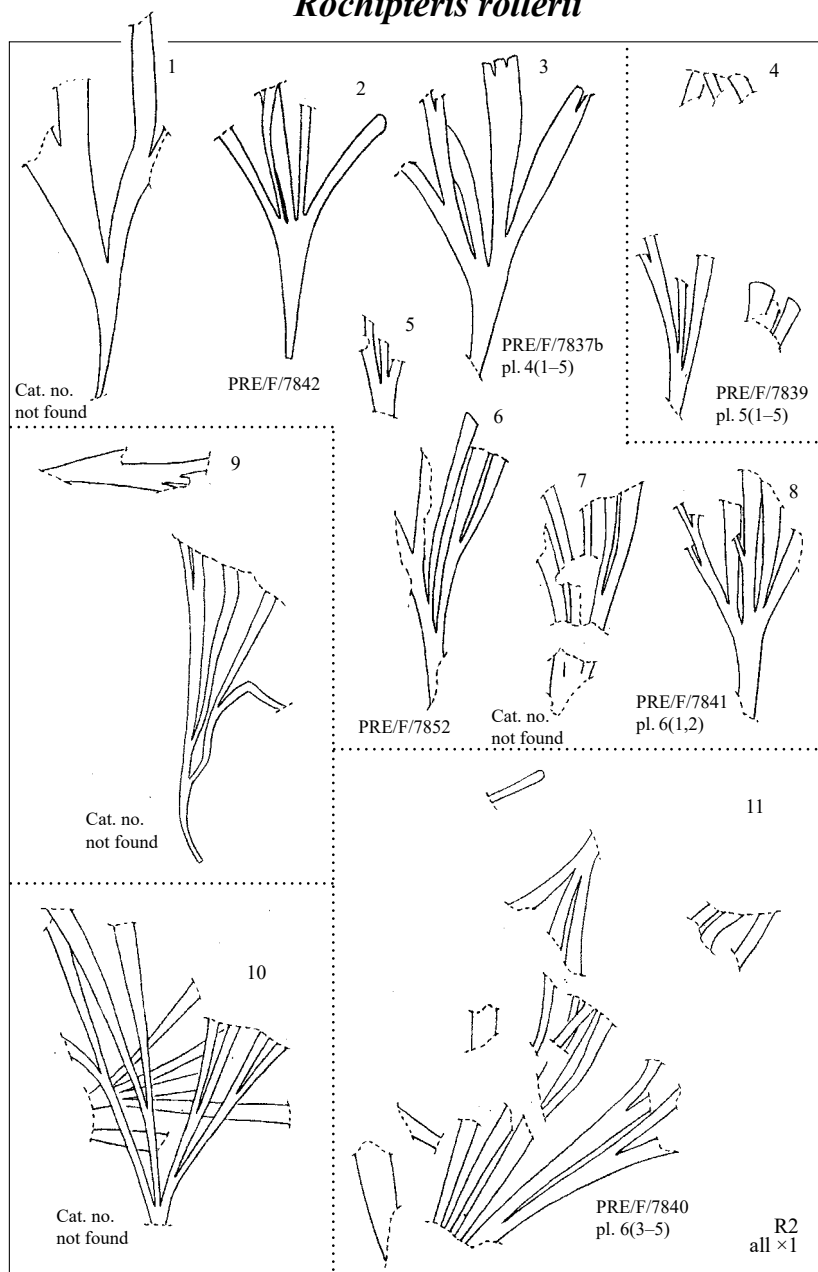
Kannaskoppia ♀ – nil

Kannaskoppianthus ♂ – 4 indivs (affil., Grade 4)

Taphonomy (*R. rollerii*) – parautochthonous

Peninsula (Pen 411 Hei elo)

Gre 121 Hei elo



K. aasvoelensis

20 Gre 111, 121

27°08.94'E; 31°23.62'S Type (& Ref. Pal.) loc.



Greenvale (Gre 121 Hei elo)

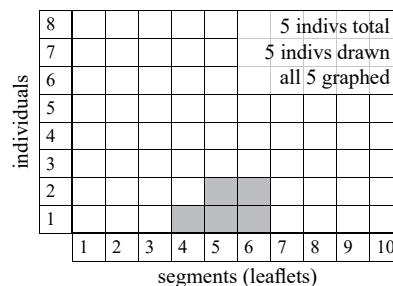
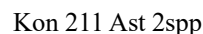
Rochipteris rollerii (22 indivs)

clusters – 4 slabs (2 – c. 7 leaves)

Kannaskoppia ♀—nil

Kannaskoppianthus ♂ – 2 indivs (Grade 4 affil.)

Taphonomy (*R. rollerii*) – parautochthonous



28°00.87'E; 31°29.32'S Type (& Ref. Pal.) loc.



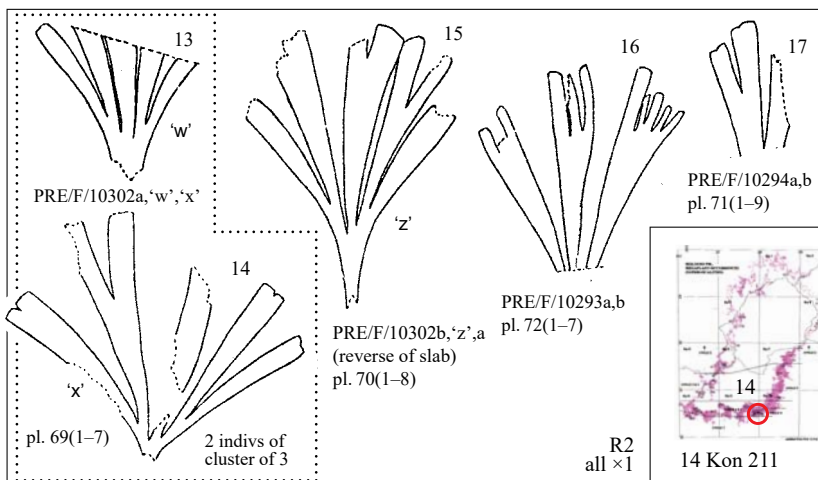
Koningskroon (Kon 211 Ast 2spp)

Habitat: Fern/*Kannaskoppia* meadow

Collection: 393 slabs, 14 man-hrs cleaving

Rochipteris rollerii (5 indivs; nil clusters, ♀ or ♂)

Taphonomy (*R. rollerii*) – allochthonous



Konings Kroon (Kon 211 Ast 2spp)

1
PRE/F/19021a,b
pl. 150(1-4)

2
PRE/F/19022

3
PRE/F/11987

4
PRE/F/11986

5
PRE/F/19347a

6
PRE/F/19346
pl. 149(4)

7
PRE/F/19348b
pl. 149(1-3)

8
Cat. no.
not found

9
PRE/F/11993
pl. 150(5-7)

10

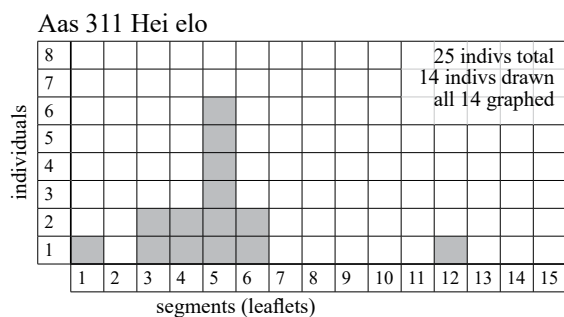
11
PRE/F/11991

12
PRE/F/12002a,b
pl. 148(1-6)

13
PRE/F/11988
pl. 149(5-9)

14
PRE/F/19019
pl. 152(1-3)

R2
all $\times$



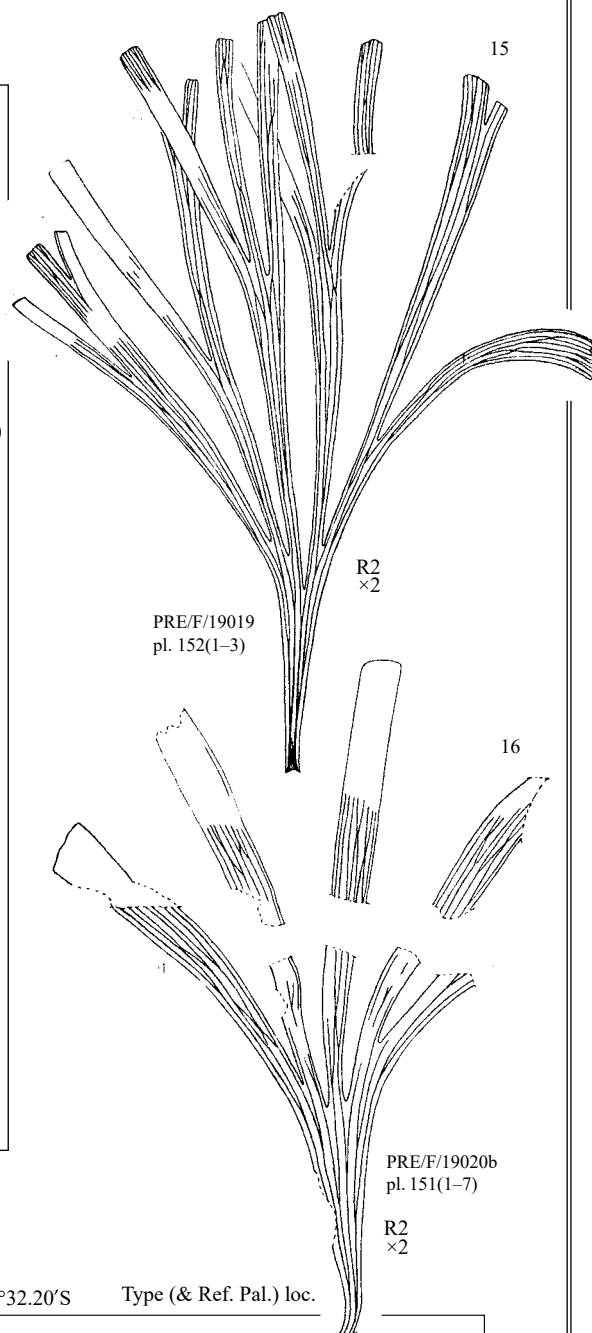
17
PRE/F/19407a,b
pls 145, 146(1-6)
Aas 311

18
PRE/F/19343b
pl. 146(7)

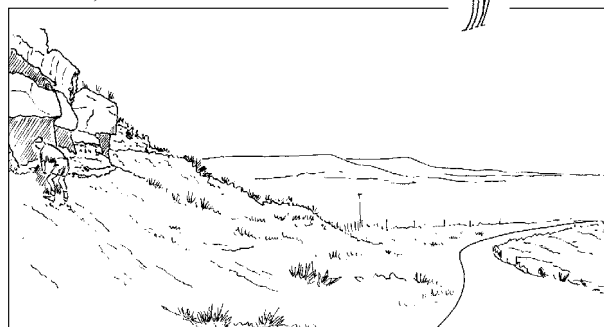
19
PRE/F/12001a,b
pl. 147(1-6)
R2
all $\times 2$

20
PRE/F/12001a,b
pl. 147(7-10)
microsporangium
R2-3
 $\times 20$

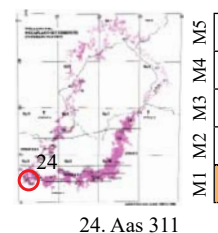
0 1 2
cm



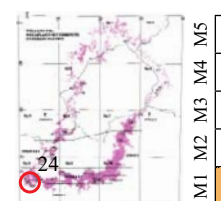
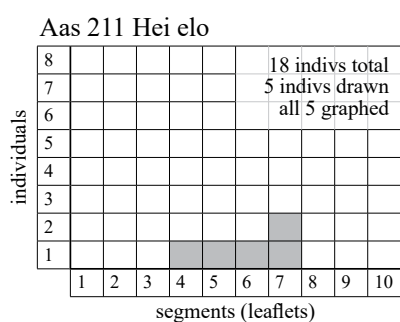
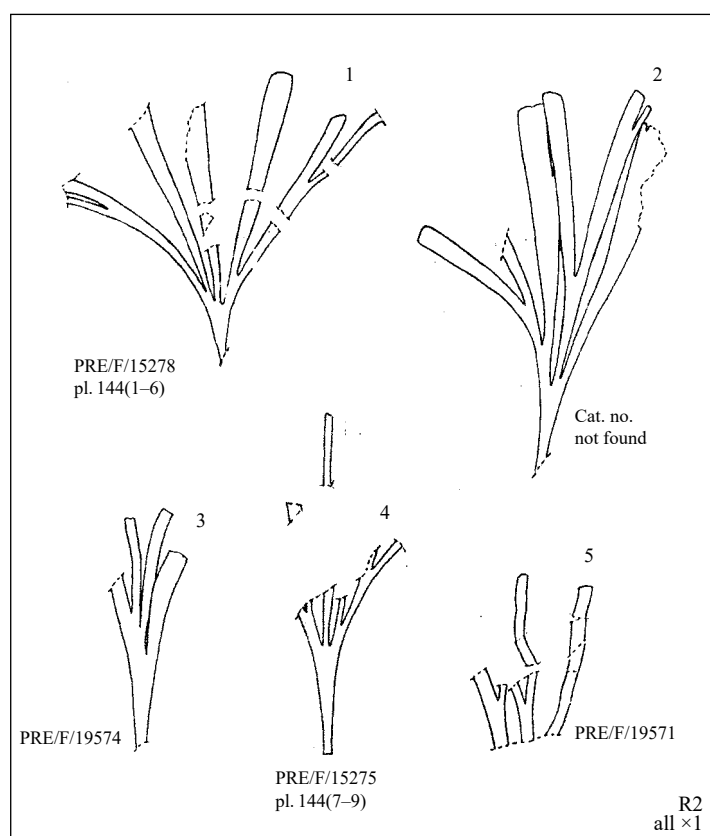
26°13.3'E; 31°32.20'S Type (& Ref. Pal.) loc.



Aasvoëlberg (Aas 311 Hei elo)



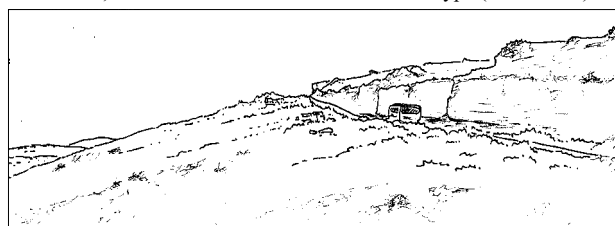
Rochipteris rollerii



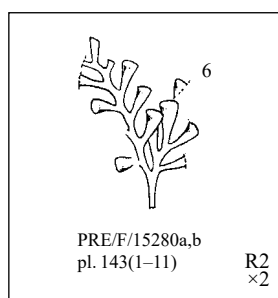
24. Aas 211

26°13.94'E; 31°33.35'S

Type (& Ref. Pal.) loc.



Kannaskoppianthus aasvoelensis



Aas 211

Aasvoëlberg (Aas 211 Hei elo)

Habitat: *Heidiphyllum* thicket

Collection: 154 slabs; 35 man-hrs cleaving

Rochipteris rollerii (18 indivs)

attached to shoots – nil

clusters – nil

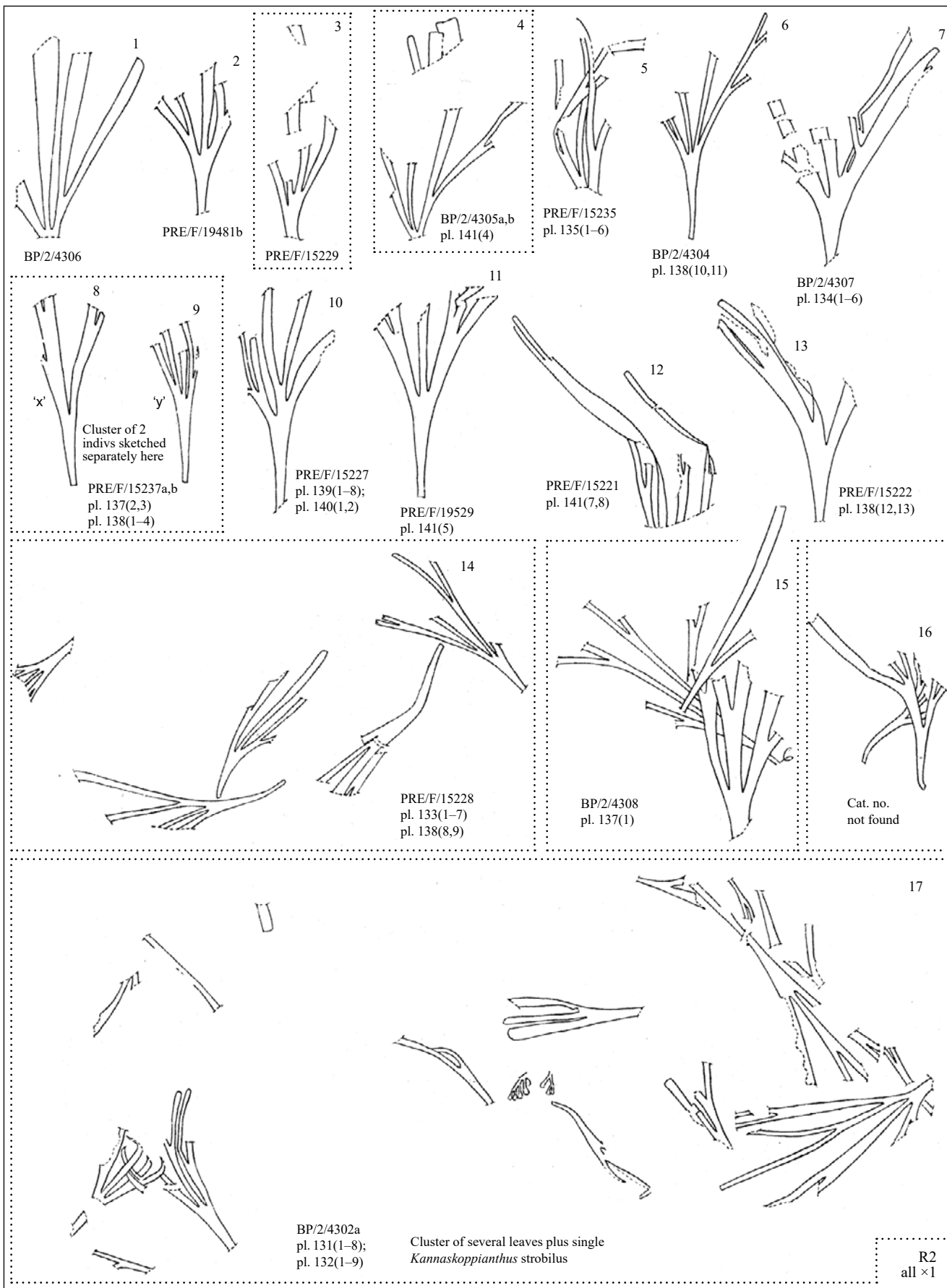
Kannaskoppia ♀—nil

Kannaskoppianthus ♂ – 1 indiv. (affil., Grade 4)

Taphonomy (*R. rollerii*) – parautochthonous



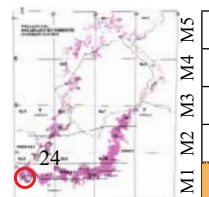
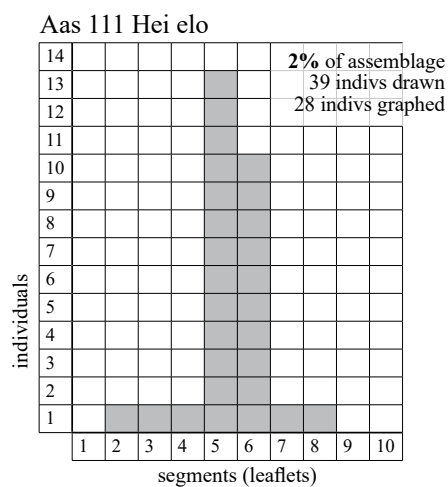
Aasvoëlberg (Aas 211 Hei elo)

Rochipteris rollerii

0 1 2
cm

Aasvoëlberg (Aas 111 Hei elo)

Rochipteris rollerii



26°16.47'E; 31°33.81'S

Type (& Ref. Pal.) loc.



Aasvoëlberg (Aas 111 Hei elo)

Habitat: *Heidiphyllum* thicket

Collection: 291 slabs, 40 man-hrs cleaving

Rochipteris rollerii (2% of assemblage)

attached to shoots – nil

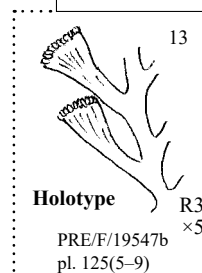
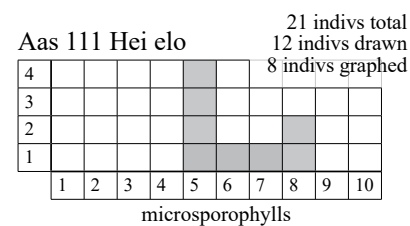
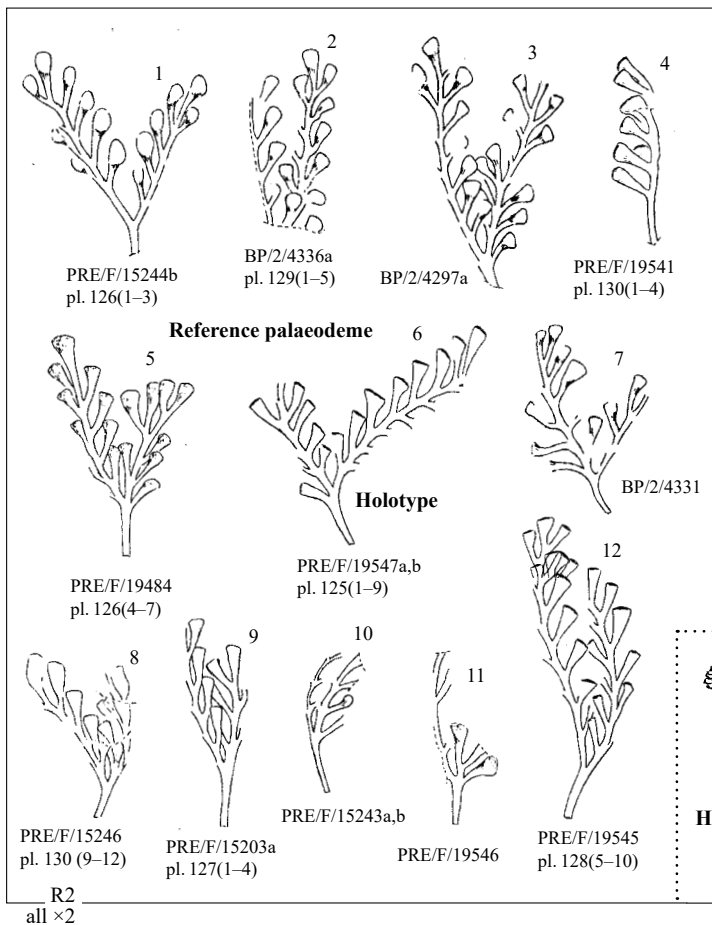
clusters – 6 slabs (2 – c.20 leaves)

Kannaskoppia ♀ – nil

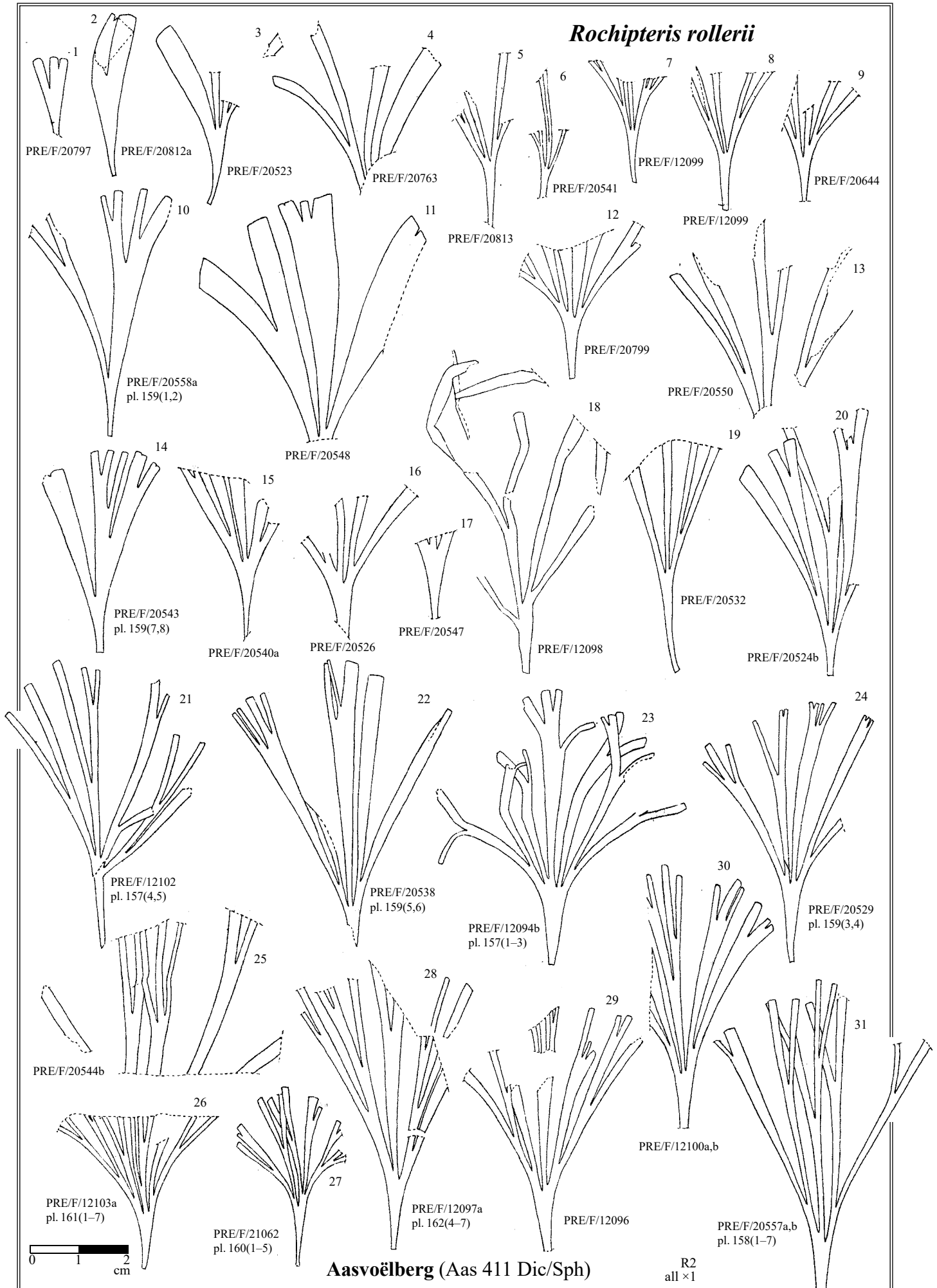
***Kannaskoppianthus* ♂ – 21 indivs (affil., Grade 4)**

Taphonomy (*R. rollerii*) – parautochthonous

Kannaskoppianthus aasvoelensis

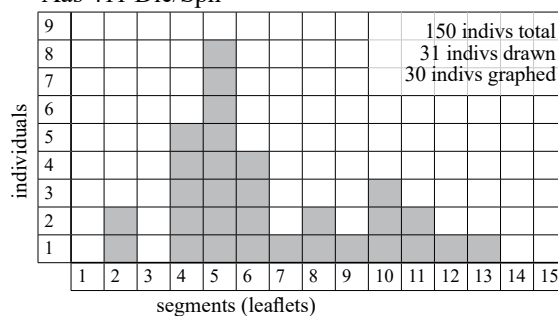


Aasvoëlberg (Aas 111 Hei elo)

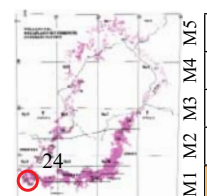
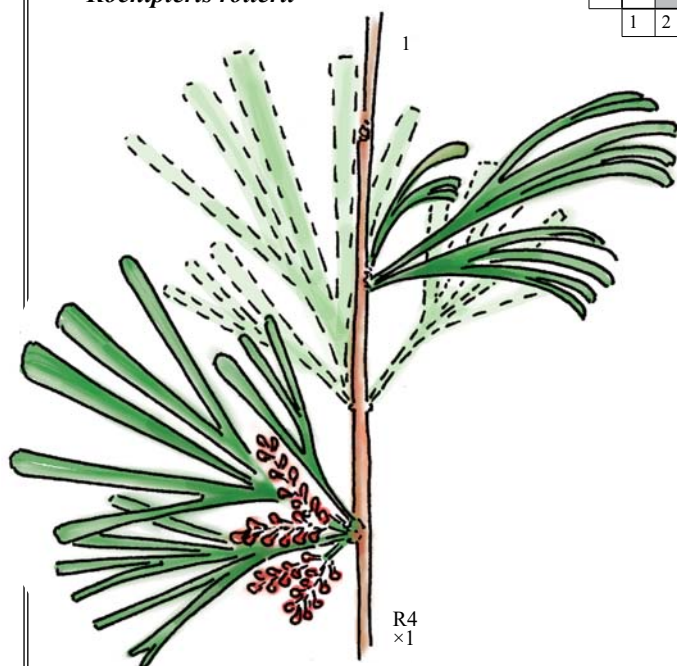


Rochipteris rollerii

Aas 411 Dic/Sph

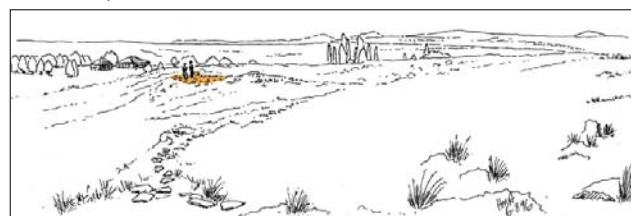


Kannaskoppianthus aasvoelensis /
Rochipteris rollerii



24. Aas 411

26°12.16'E; 31°33.43'S



Aasvoëlberg (Aas 411 Dic/Sph)

Habitat: *Sphenobairea* closed woodland

Collection: 2176 slabs, 512 man-hrs cleaving

Rochipteris rollerii (150 indivs)

attached to shoots – nil

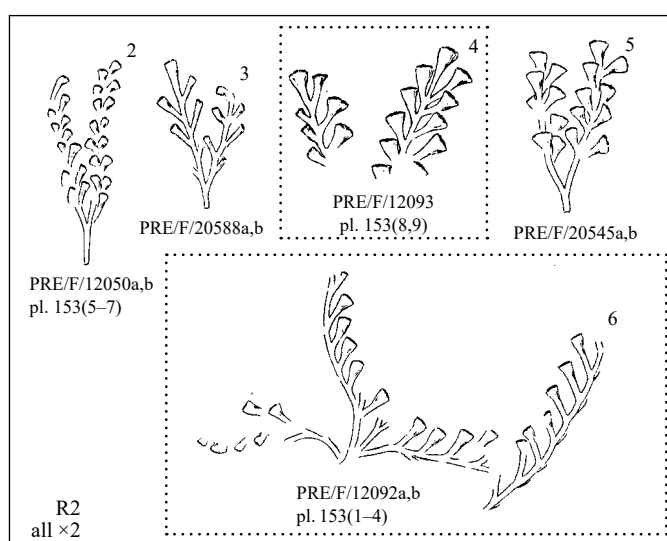
clusters – nil

Kannaskoppia ♀ – nil

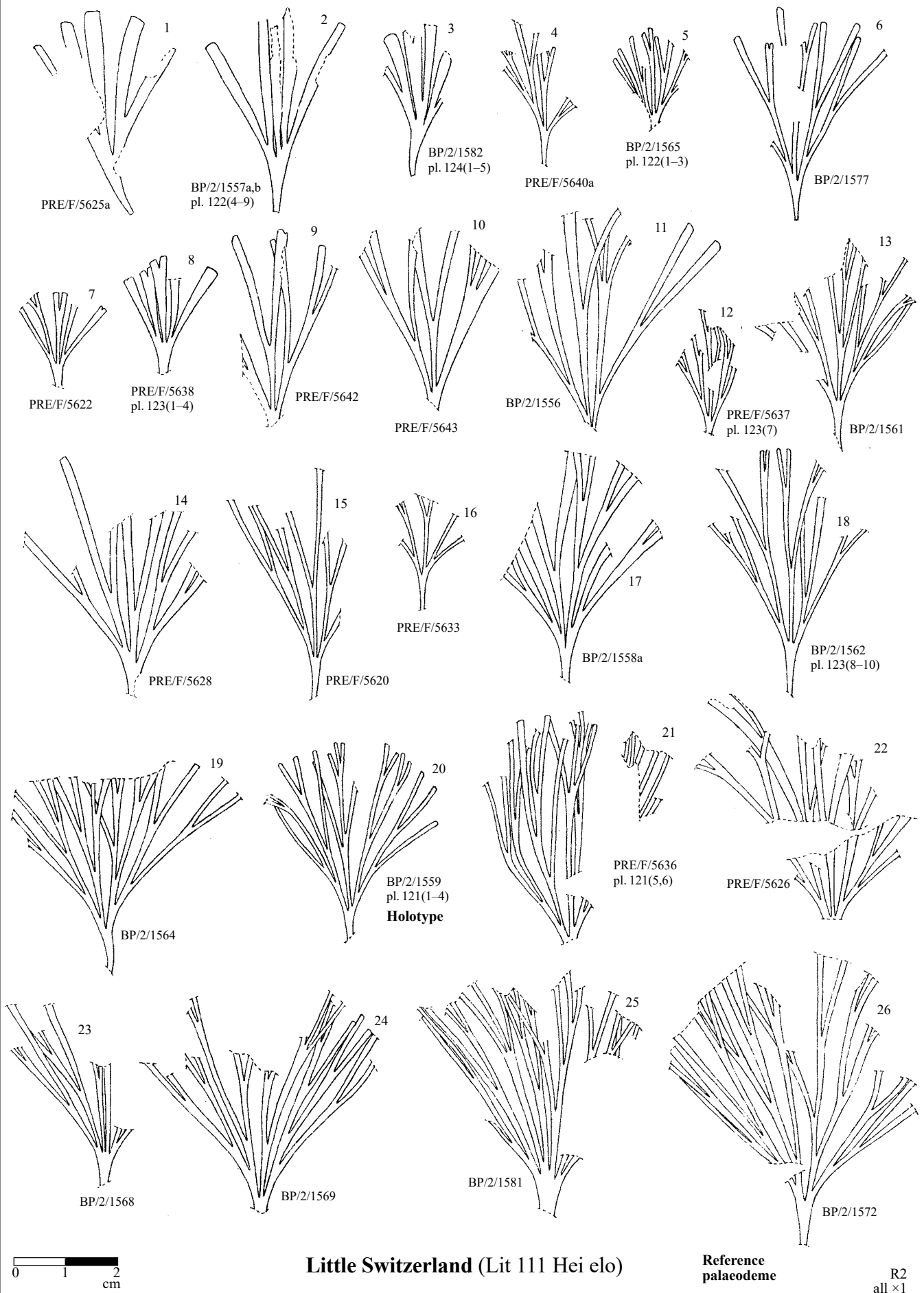
Kannaskoppianthus ♂ – 21 indivs (affil., Grade 4)

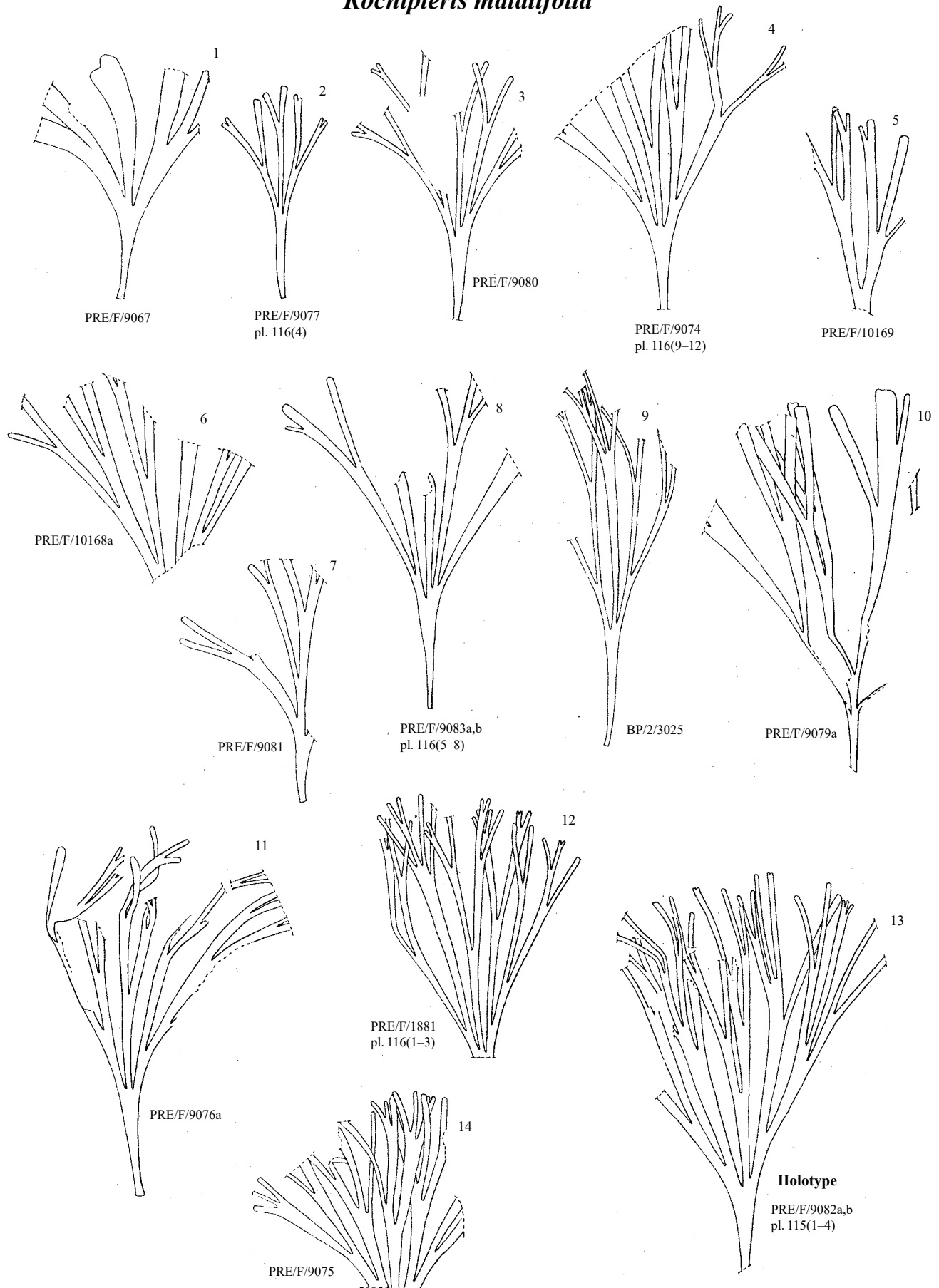
Taphonomy (*R. rollerii*) – parautochthonous

Kannaskoppianthus aasvoelensis



Aasvoëlberg (Aas 411 Dic/Sph)

Rochipteris switzifolia

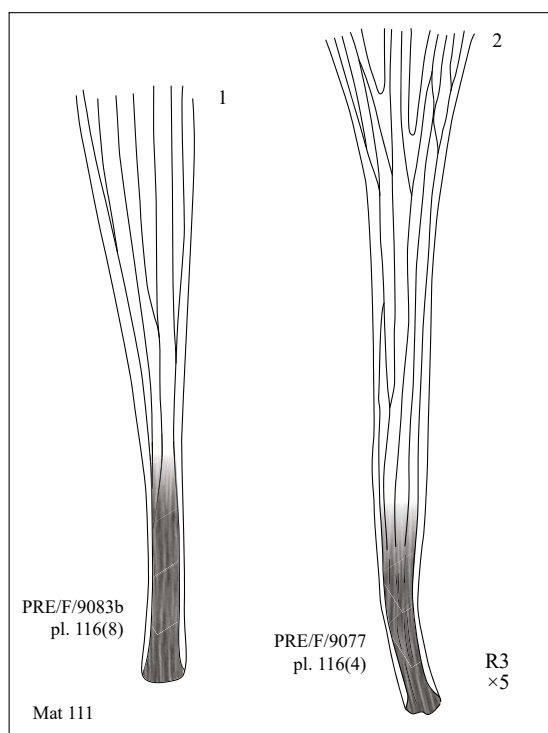
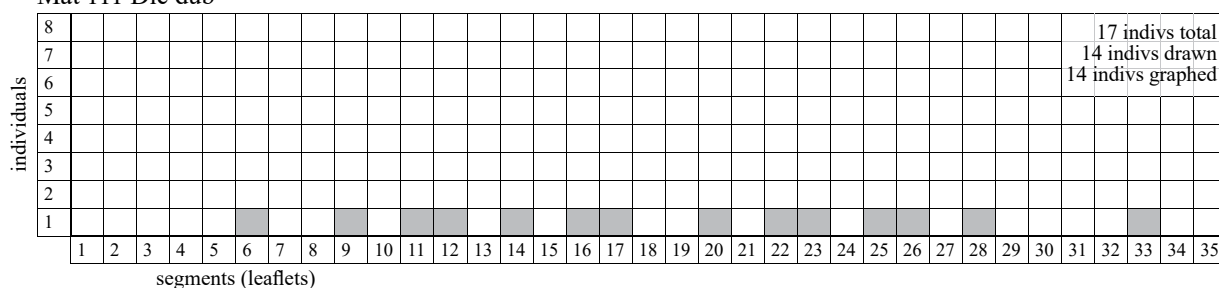
Rochipteris matatifolia

0 1 2
cm

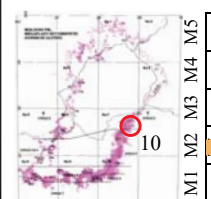
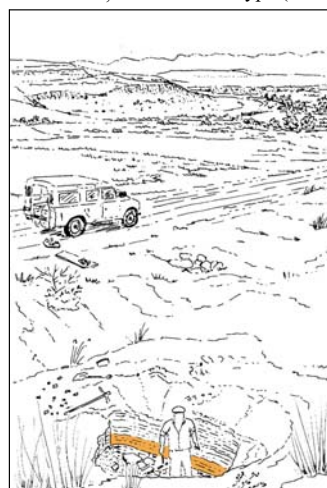
Matatiele (Mat 111 Dic dub)

Rochipteris matatifolia

Mat 111 Dic dub

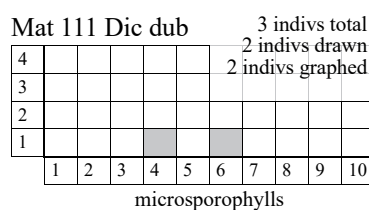
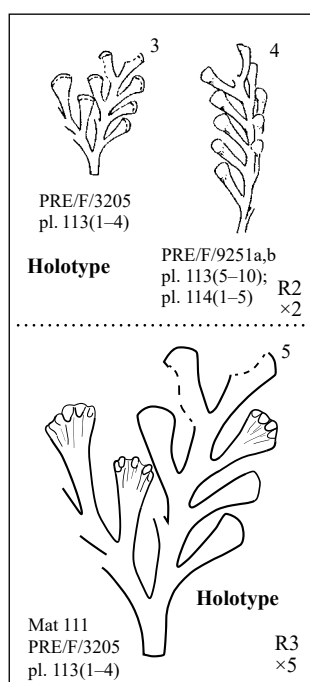


28°48.34'E; 30°20.84'S Type (& Ref. Pal.) loc.



10. Mat 111

Kannaskoppianthus matatiparvus



Matatiele (Mat 111 Dic dub)

Matatiele (Mat 111 Dic dub)

Habitat: *Dicroidium* riparian forest (immature, type 2)

Collection: 1082 slabs, 65 man-hrs cleaving

Rochipteris matatifolia (17 indivs)

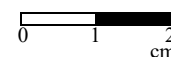
attached to shoots – nil

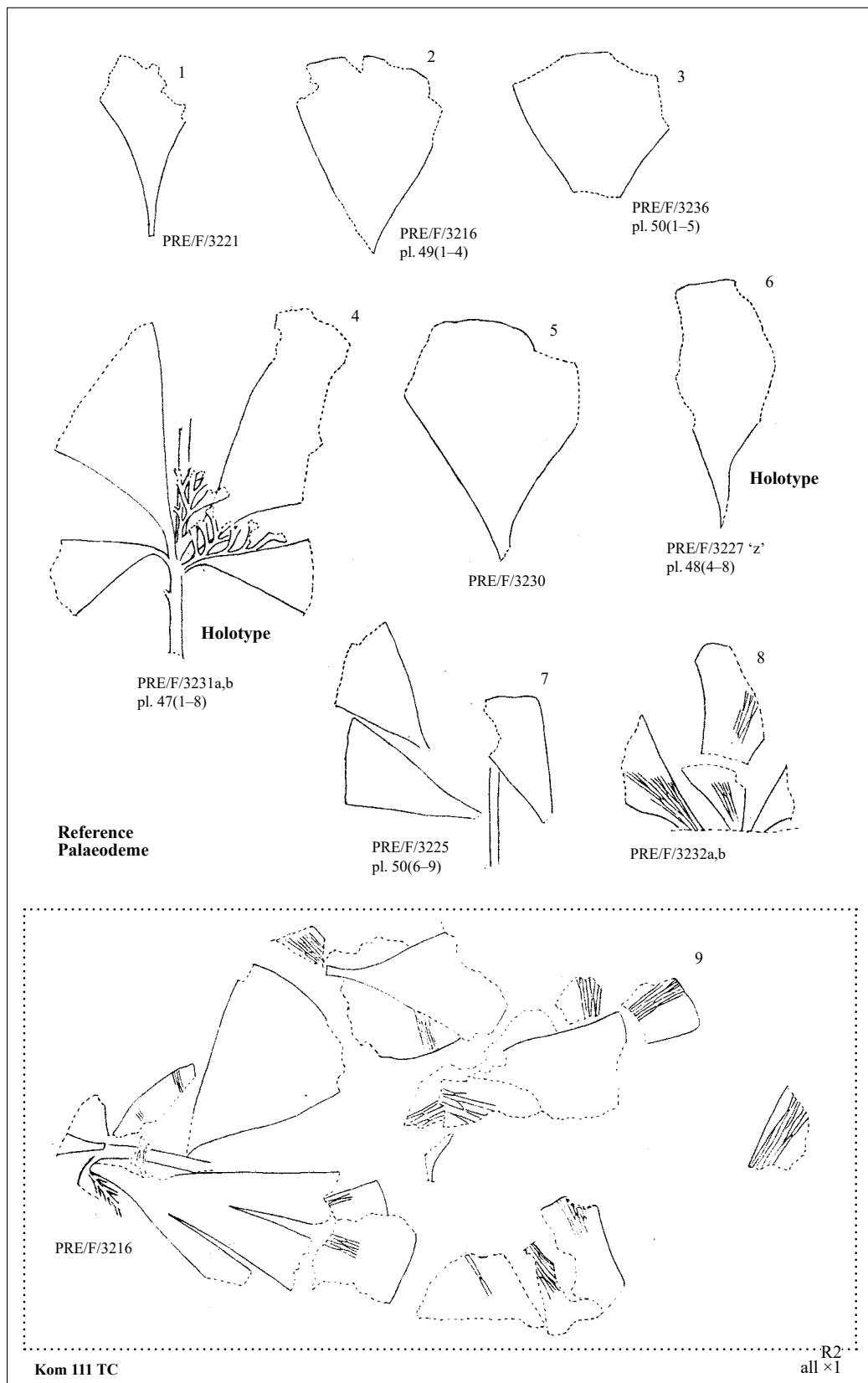
```
clusters – nil
```

Kannaskoppia ♀ – nil

Kannaskoppianthus ♂ – 3 indivs (affil. Grade 3 to *R. matatifolia*)

Taphonomy (*R. matatifolia*) – allochthonous

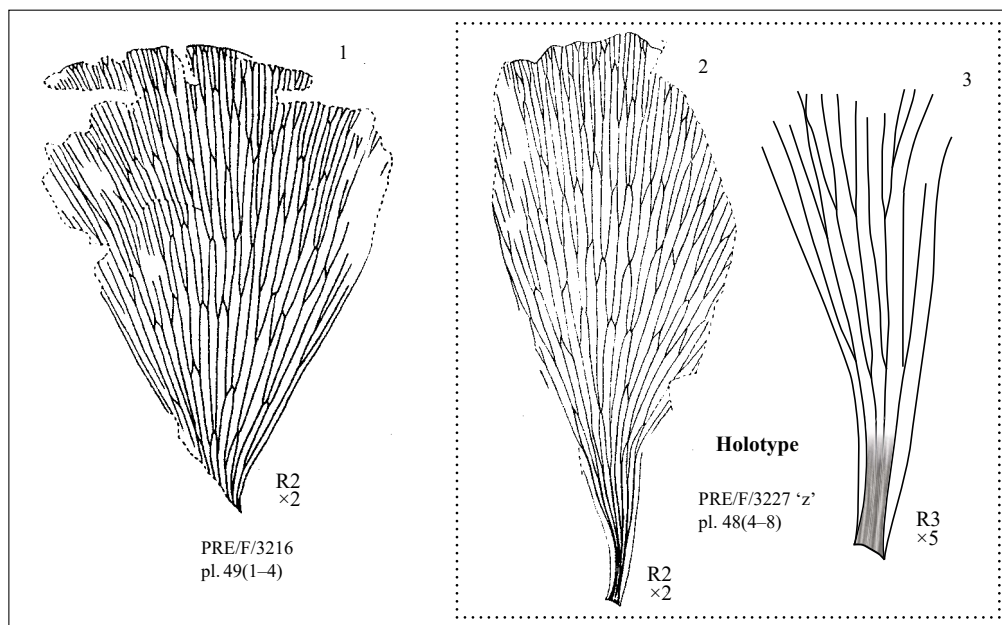
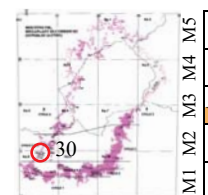
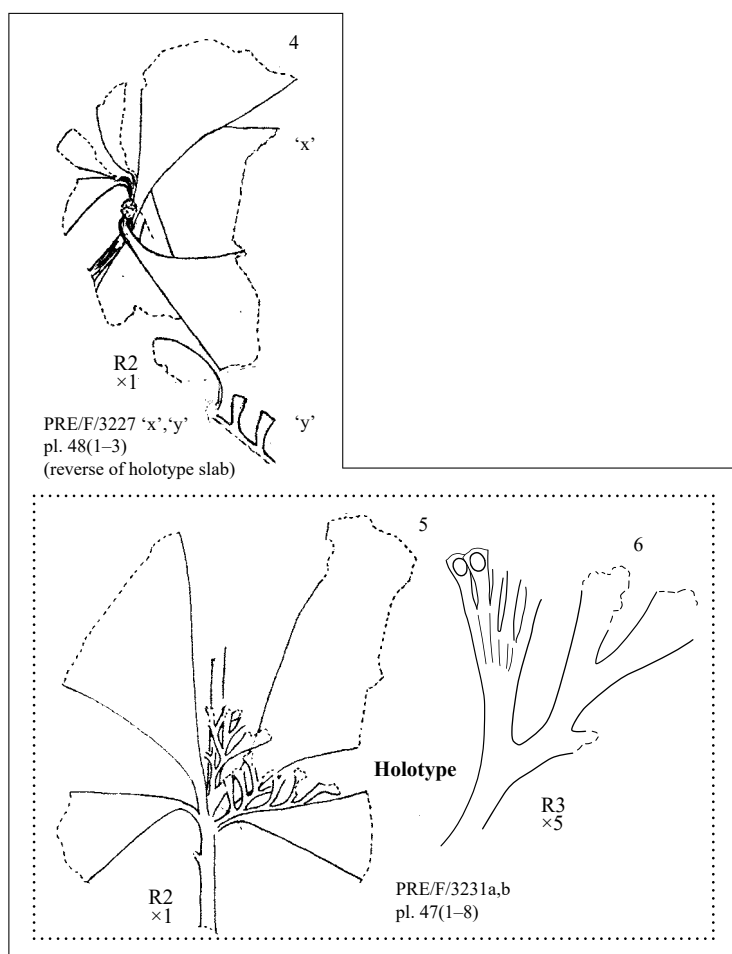


Rochipteris komifolia

9 indivs appear on the colour plates
(5 of which are illustrated here)



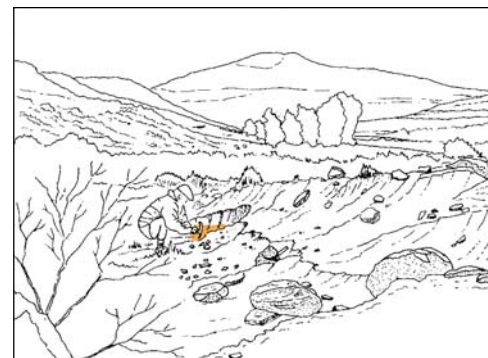
Kommandantskop (Kom 111 Sph dic)

Rochipteris komifolia*Kannaskoppianthus komanthus*

30. Kom 111

26°33.13'E; 31°03.35'S

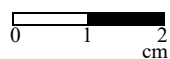
Type (& Ref. Pal.) locality

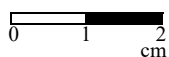
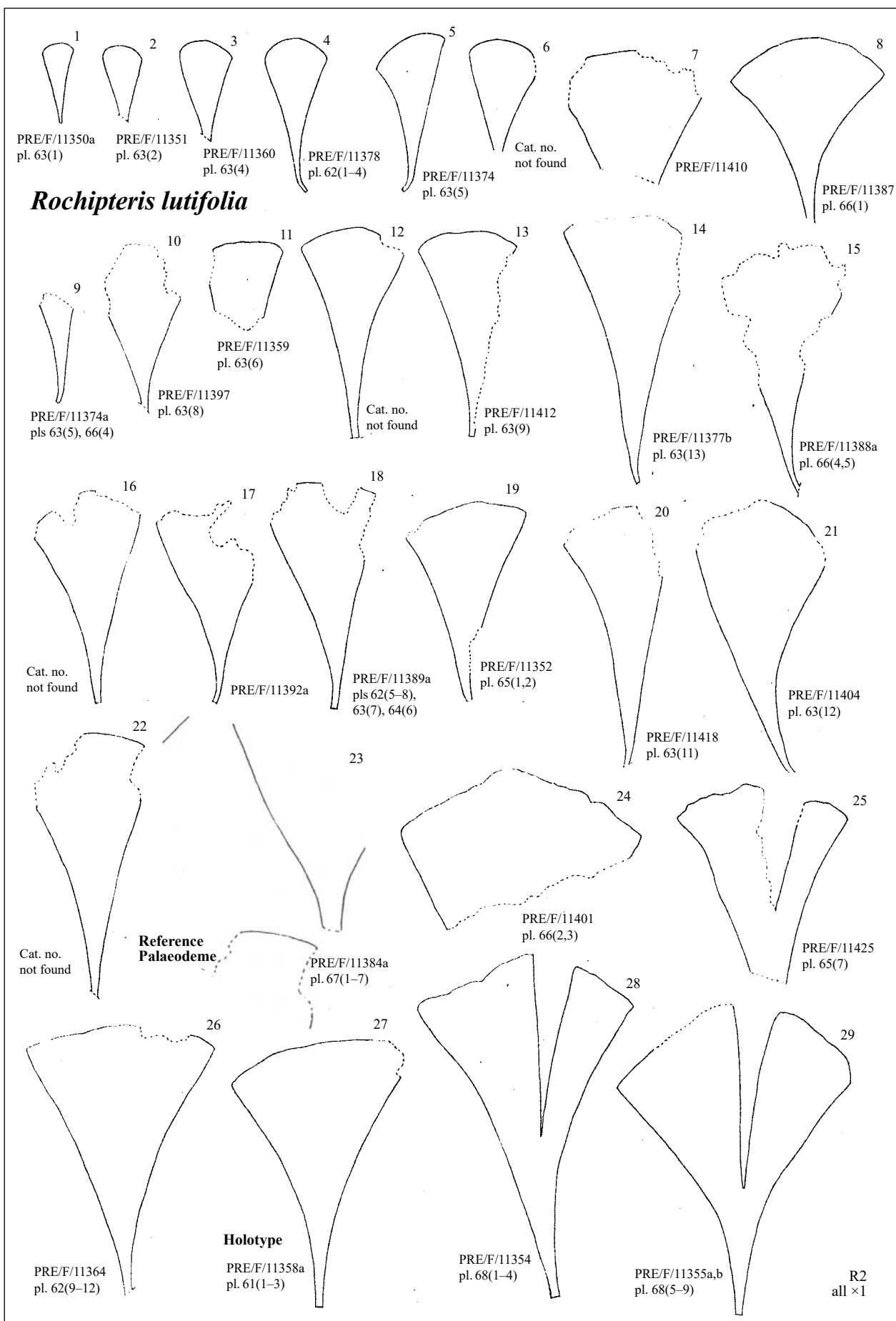
**Kommandantskop (Kom 111 Sph/Dic),****Habitat:** *Dicrodium* open woodland**Collection:** 168 slabs, 10 man-hrs cleaving***Rochipteris komifolia*** (29 indivs)

attached to shoots (leaves & ♂) – 3 slabs

attached to shoots (leaves only) – 11 slabs

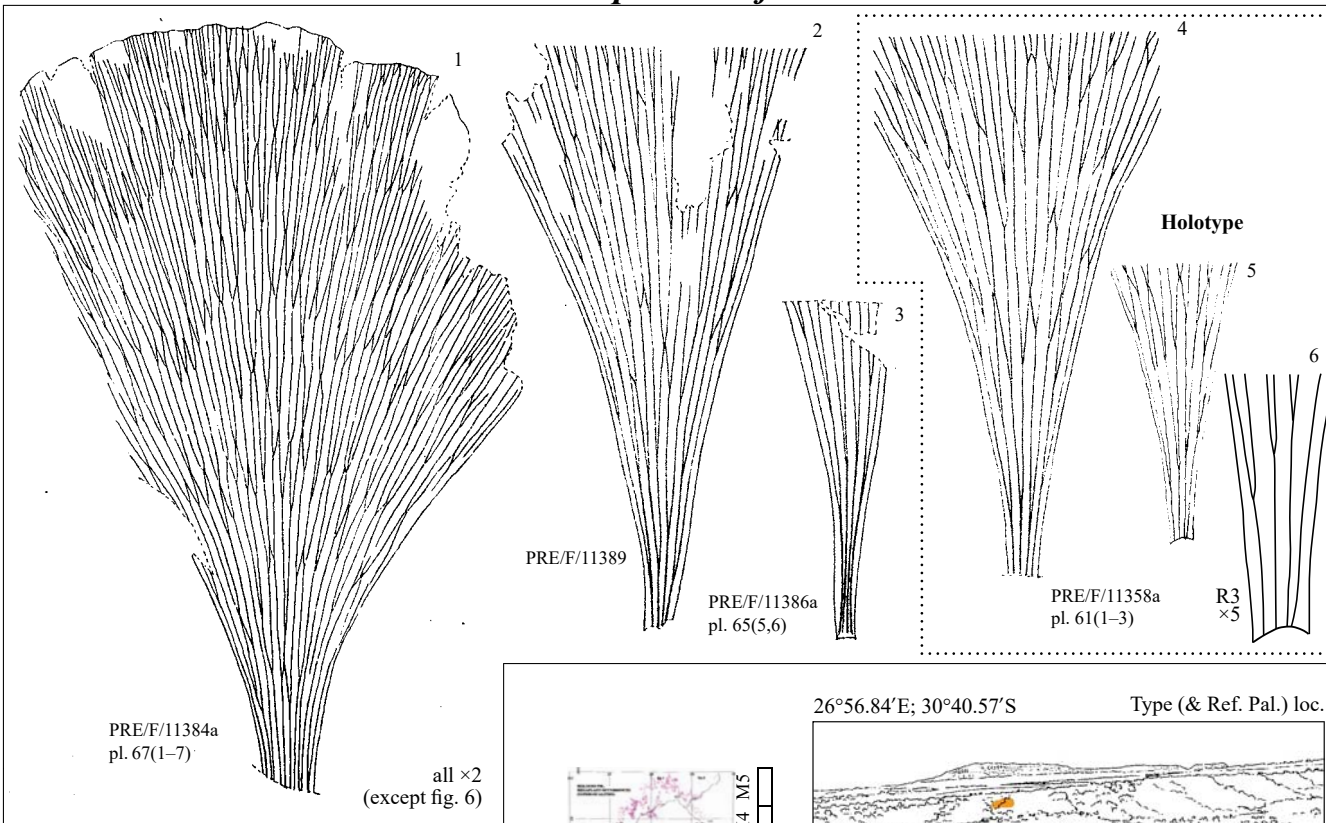
clusters – 7 slabs (2–5 leaves)

Kannaskoppia ♀ – nil***Kannaskoppianthus*** ♂ – 2 indivs (affil., Grade 5)**Taphonomy** (*R. komifolia*) – paraut.-autochthonous**Kommandantskop (Kom 111 Sph dic)**



Lutherskop (Lut 311 Hei elo)

Rochipteris lutifolia

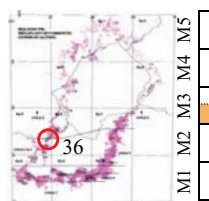


Lut 311 Hei elo

16 indivs total
10 indivs drawn
8 indivs graphed

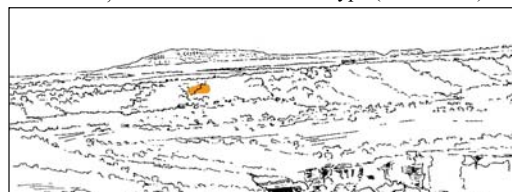
4															
3															
2															
1															
	1	2	3	4	5	6	7	8	9	10	11	12			

microsporophylls



26°56.84'E; 30°40.57'S

Type (& Ref. Pal.) loc.



Lutherskop (Lut 311 Hei elo)

Habitat: *Heidiphyllum* thicket

Collection: 589 slabs, 50 man-hrs cleaving

Rochipteris lutifolia (66 indivs)

attached to shoots – nil

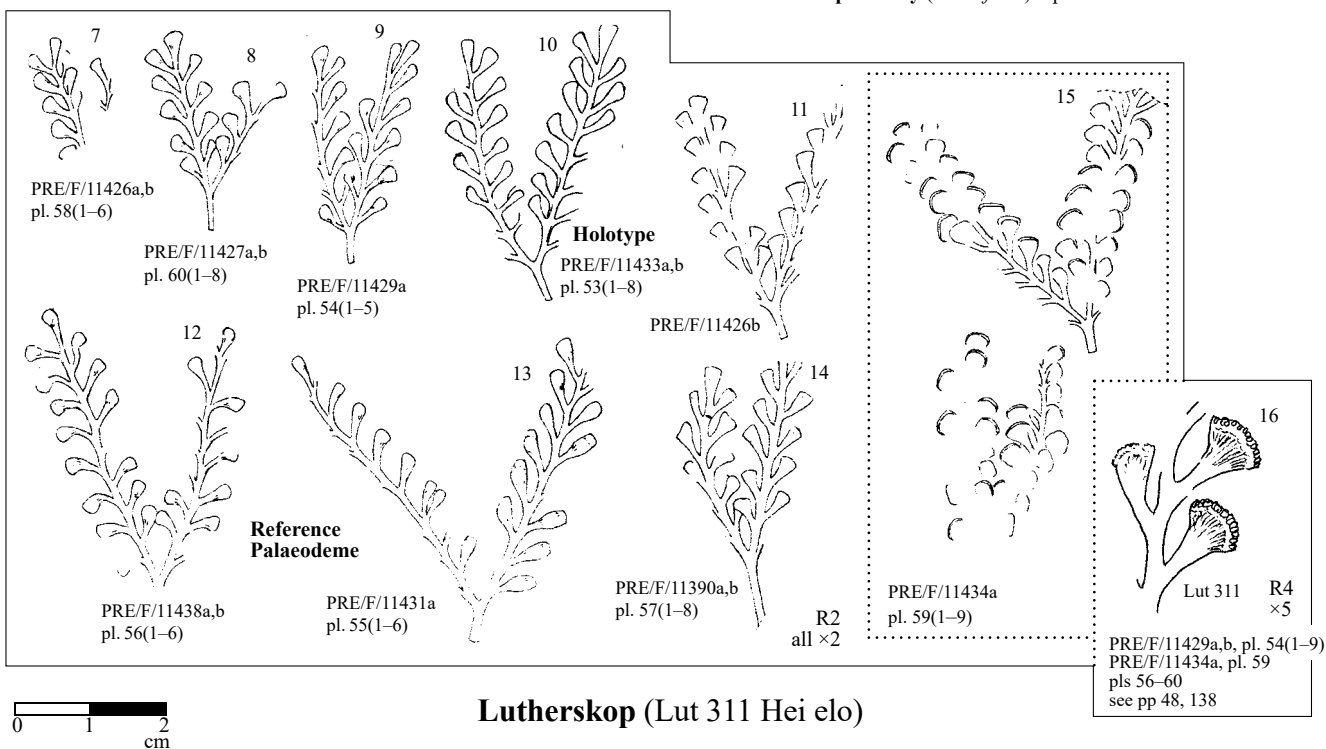
```
clusters – nil
```

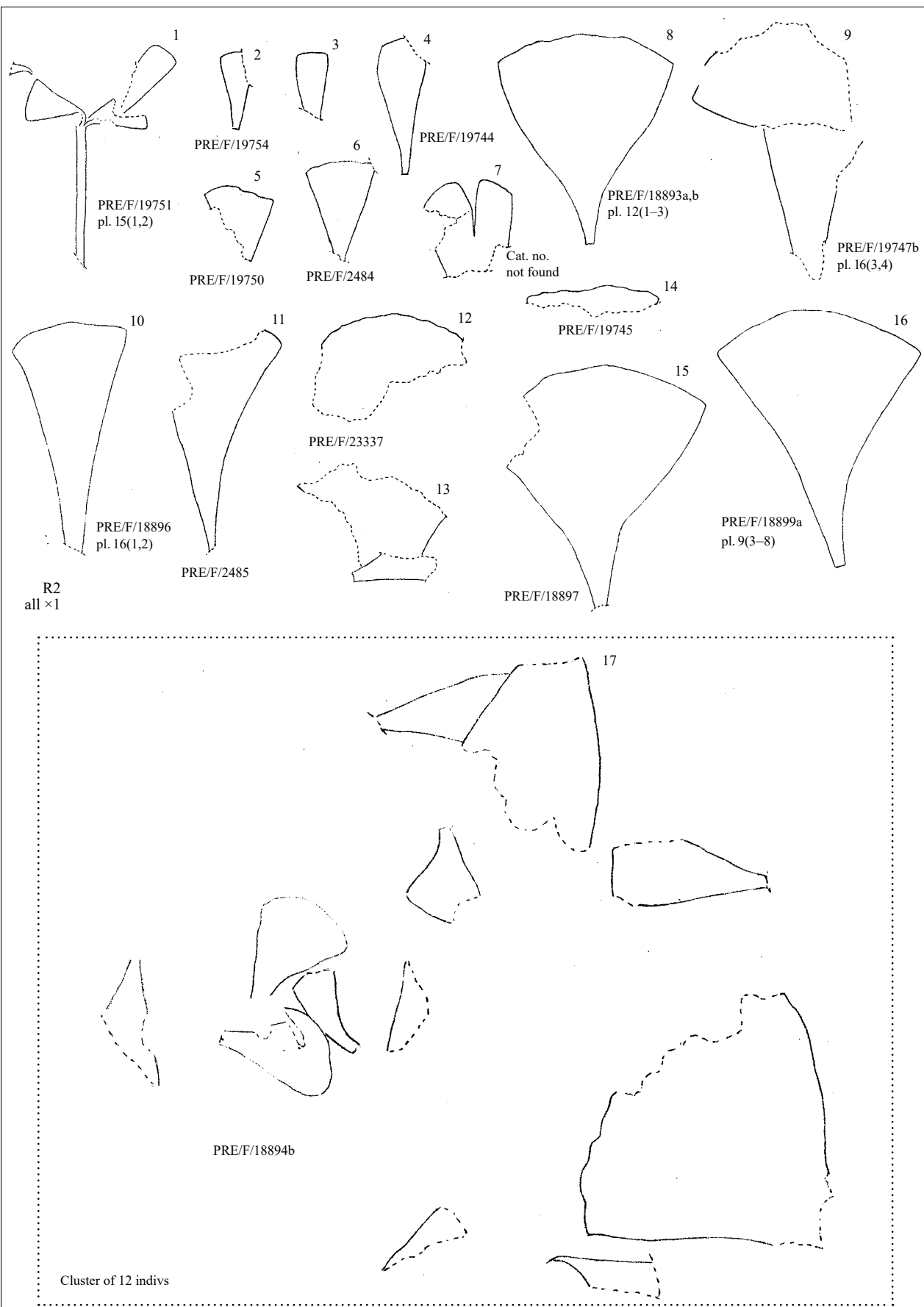
Kannaskoppia ♀ – nil

***Kannaskoppianthus* ♂** – 16 indivs (affil., Grade 4)

Taphonomy (*R. lutifolia*) – parautochthonous

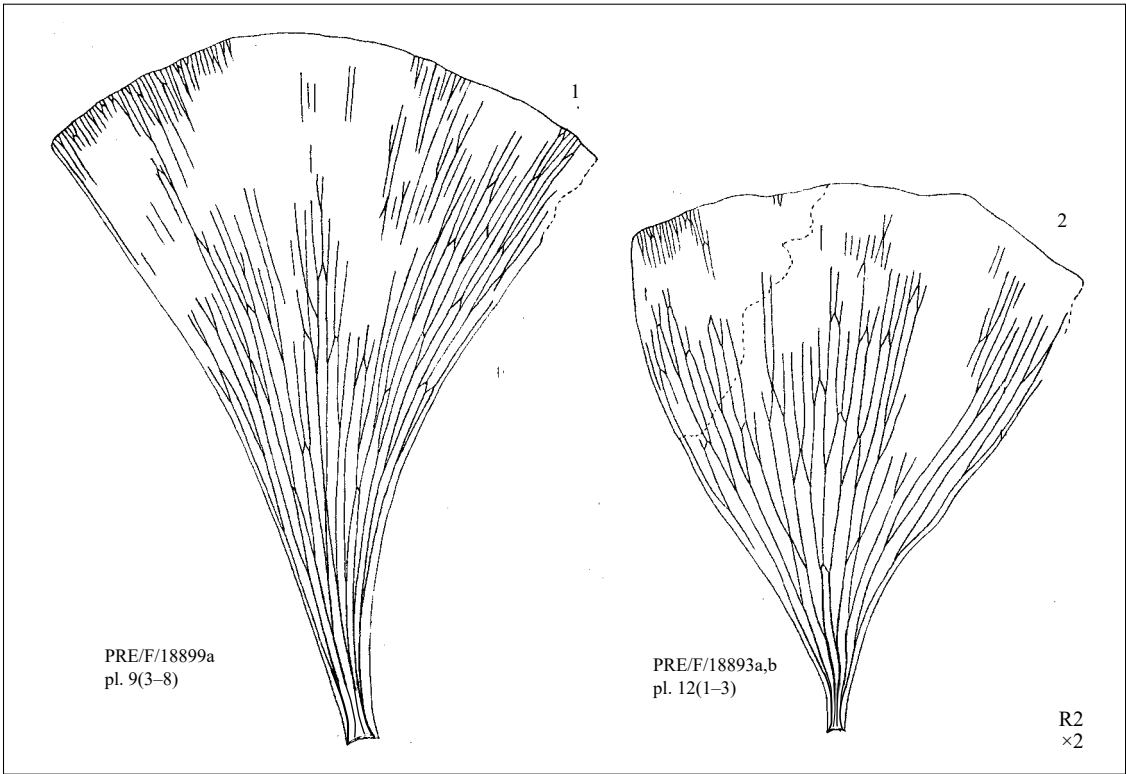
Kannaskoppianthus lutinerus



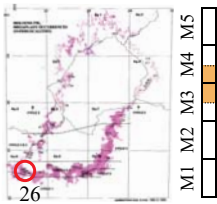
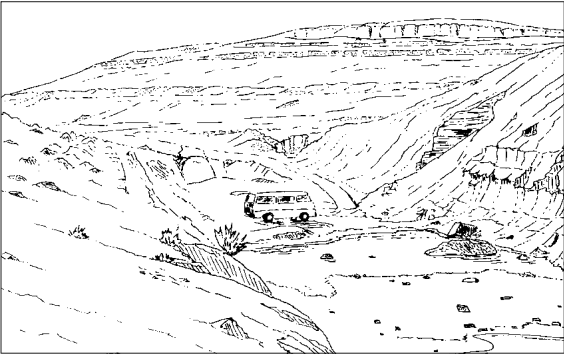
Rochipteris lutifolia

Cyphergat (Cyp 111 Dic cra)

Rochipteris lutifolia



26°25.88'E; 31°27.14'S Type (& Ref. Pal.) loc.



Cyphergat (Cyp 111 Dic cra), Open cast

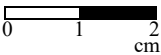
Habitat: *Dicroidium* open woodland
Collection: 362 slabs, 100 man-hrs cleaving

Rochipteris lutifolia (80 indivs)
attached to shoots – ?1 indiv.
clusters of 2–10 indivs – >10 slabs
clusters of 12 indivs – 1 slab

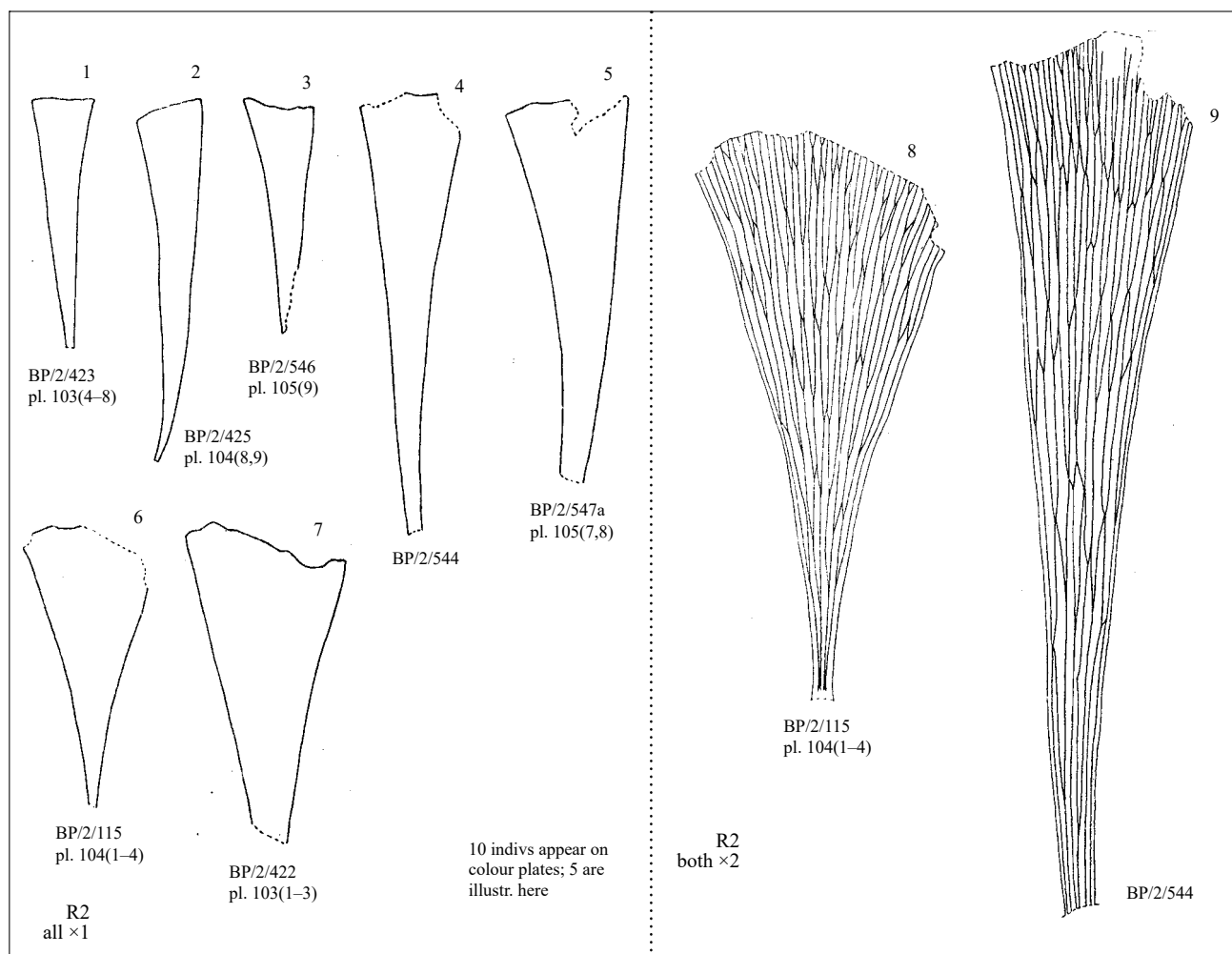
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – nil

Taphonomy (*R. lutifolia*) – parautochthonous

26. Cyp 111

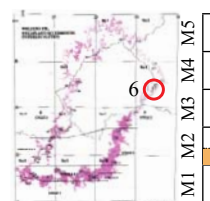


Cyphergat (Cyp 111 Dic cra)

Rochipteris obtriangulata

29°27.3'E; 29°33.54'S

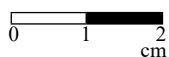
Type (& Ref. Pal.) loc.



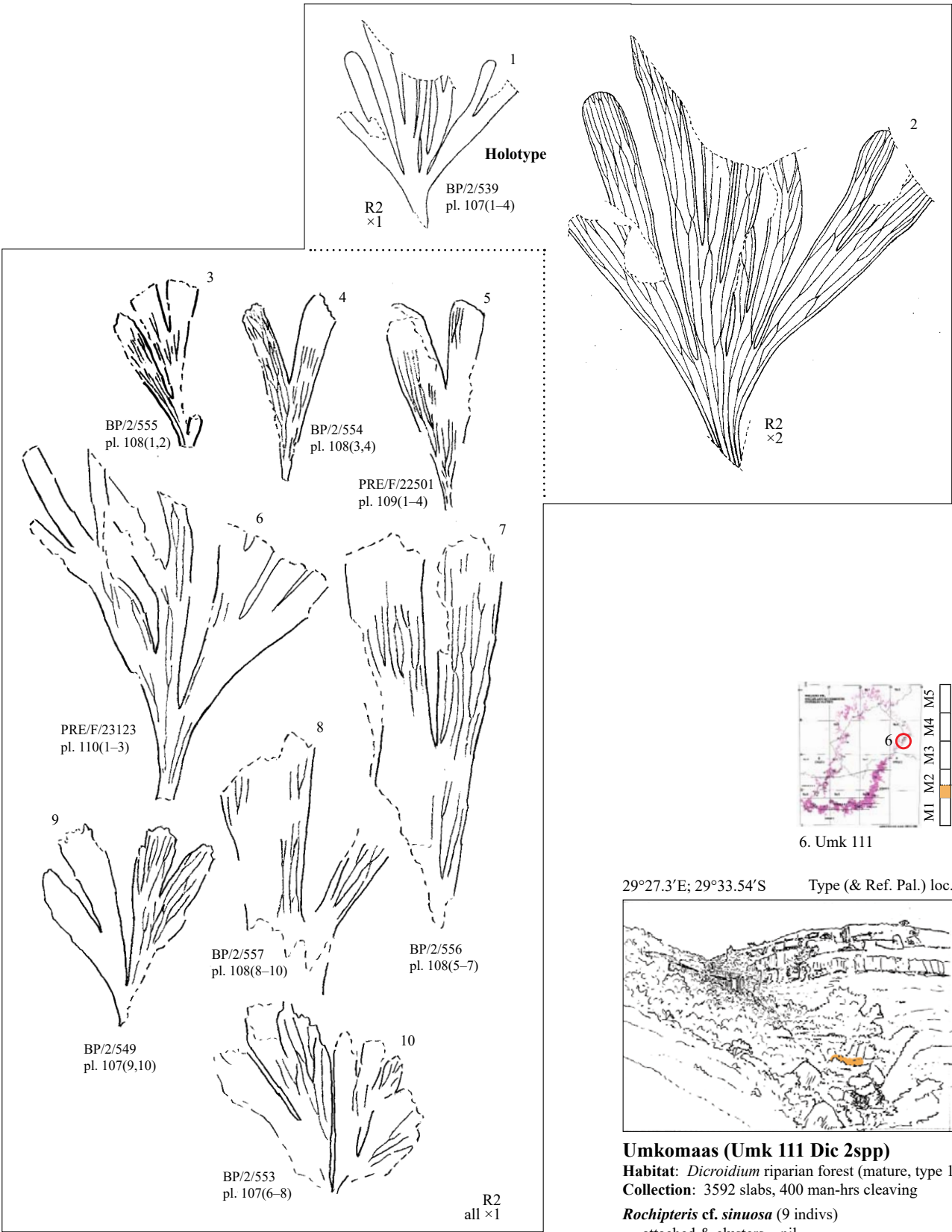
6. Umk 111

Umkomaas (Umk 111 Dic 2spp)**Habitat:** *Dicroidium* riparian forest (mature, type 1)**Collection:** 3592 slabs, 400 man-hrs cleaving*Rochipteris obtriangulata* (19 indivs, no clusters)

attached & clusters – nil

Kannaskoppia ♀ – nil*Kannaskoppianthus* ♂ – nil**Taphonomy** (*R. obtriangulata*) – parautochthonous
(*R. cf. sinuosa*) – allochthonous**Umkomaas (Umk 111 Dic 2spp)**

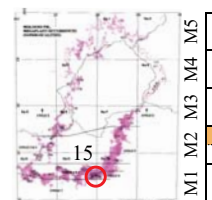
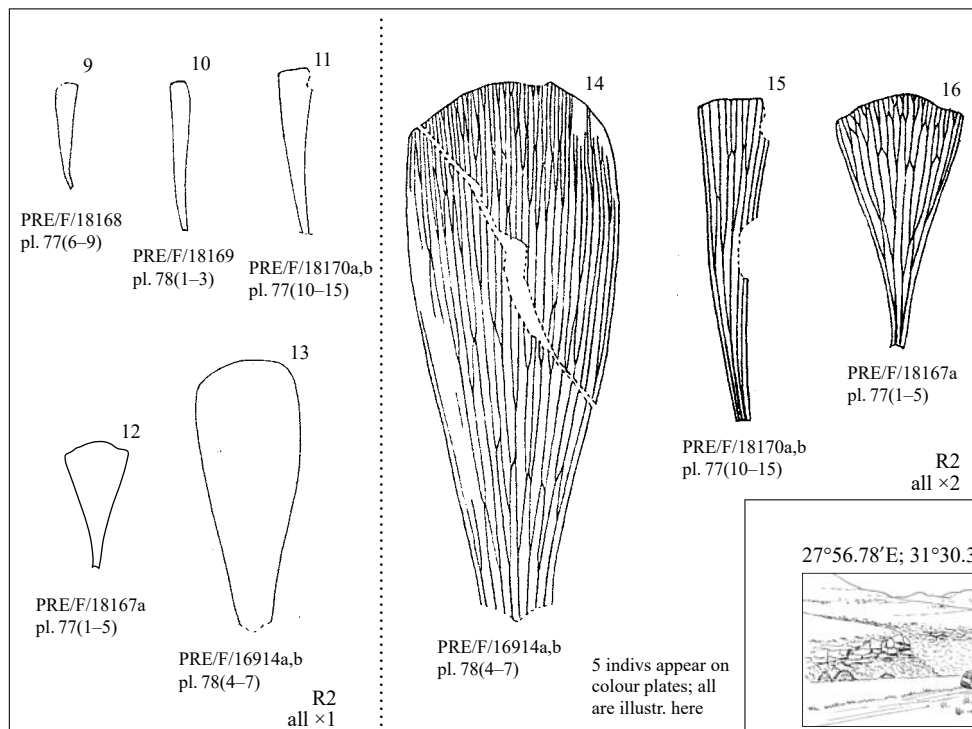
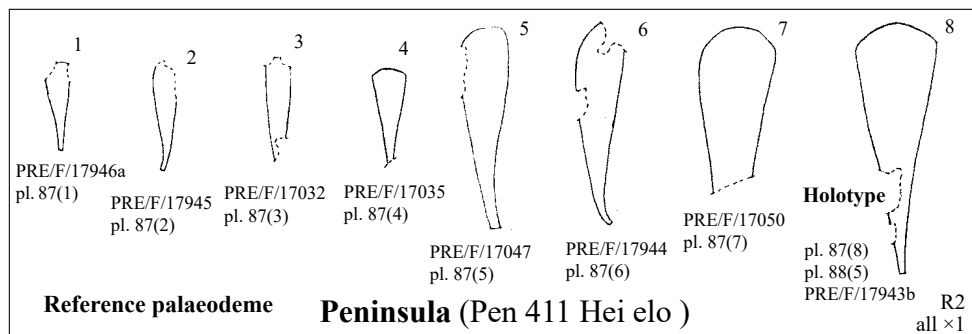
Rochipteris cf. sinuosa



29°27.3'E; 29°33.54'S Type (& Ref. Pal.) loc.



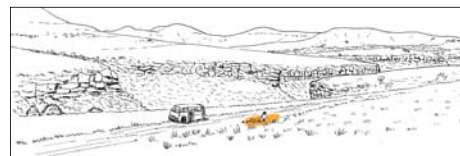
Umkomaas (Umk 111 Dic 2 spp)
Habitat: *Dicrodium* riparian forest (mature, type 1)
Collection: 3592 slabs, 400 man-hrs cleaving
Rochipteris cf. sinuosa (9 indivs)
attached & clusters – nil
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – nil
Taphonomy (*R. obtriangulata*) – parautochthonous
(*R. cf. sinuosa*) – allochthonous

***Rochipteris penensis* J.M.And. & H.M.And., sp. nov.**

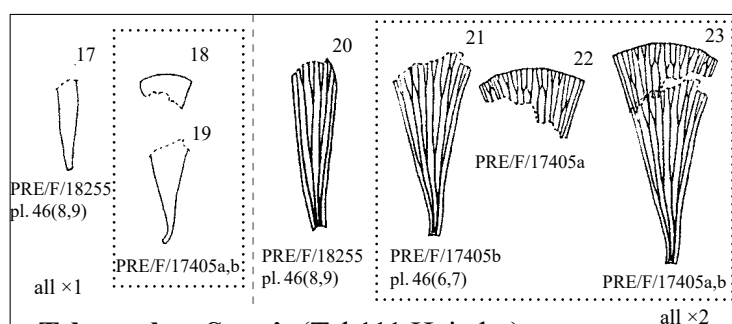
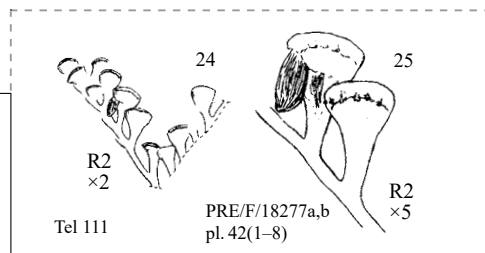
15. Pen 311, 411

27°56.78'E; 31°30.35'S

Type (& Ref. Pal.) loc.

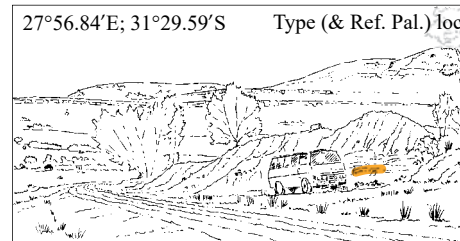
**Peninsula (Pen 411 Hei elo), Lunchspot****Habitat:** *Heidiphyllum* thicket**Collection:** 204 slabs, 70 man-hrs cleaving***Rochipteris penensis*** (10 indivs)

attached & clusters – nil

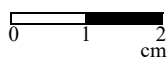
Kannaskoppia ♀ – nil***Kannaskoppianthus*** ♂ – 4 indivs (not affil. here)**Taphonomy** (*R. penensis*) – allochthonous**Telemachus Spruit (Tel 111 Hei elo)****Sister palaeodeme**2 indivs appears
on colour plates; as
illustr. here***Kannaskoppianthus telepentatus***
(affiliated ♂ strobilis, as at sister TC)

27°56.84'E; 31°29.59'S

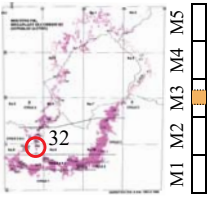
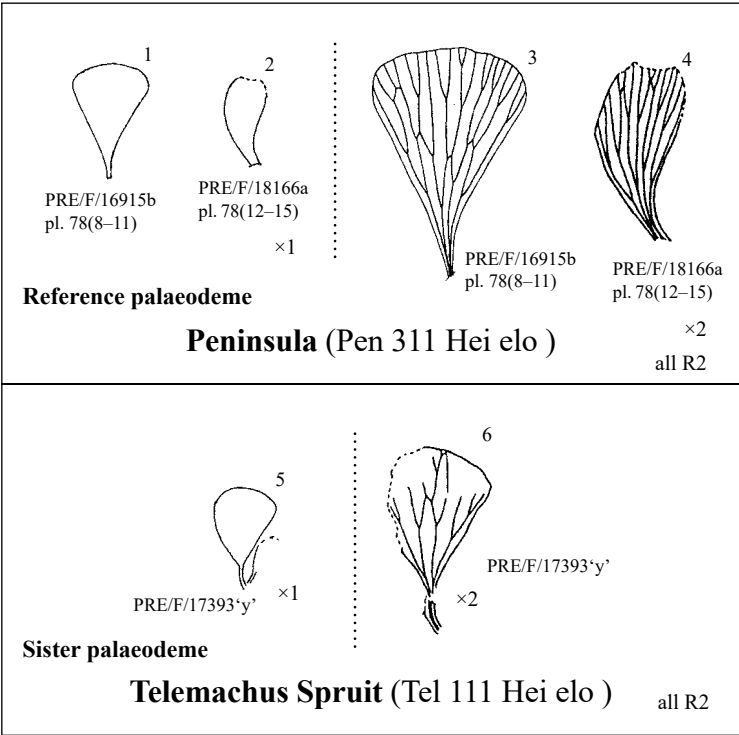
Type (& Ref. Pal.) loc.

**Peninsula (Pen 311 Hei elo), Campsite Quarry****Habitat:** *Heidiphyllum* thicket**Collection:** 155 slabs, 35 man-hrs cleaving***Rochipteris penensis*** (5 indivs)

attached & clusters – nil

Kannaskoppia ♀ – nil***Kannaskoppianthus*** ♂ – nil**Taphonomy** (*R. penensis*) – allochthonous

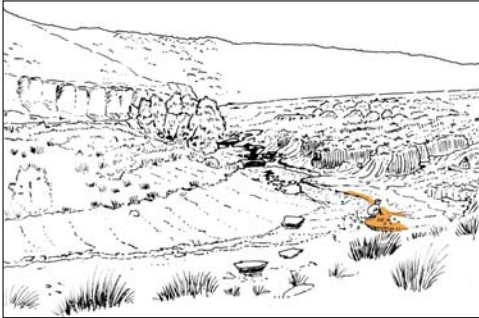
Rochipteris pusilla Holmes & H.M.And., 2005



32. Tel 111

26°47.78'E; 31°02.86'S

Type (& Ref. Pal.) loc.

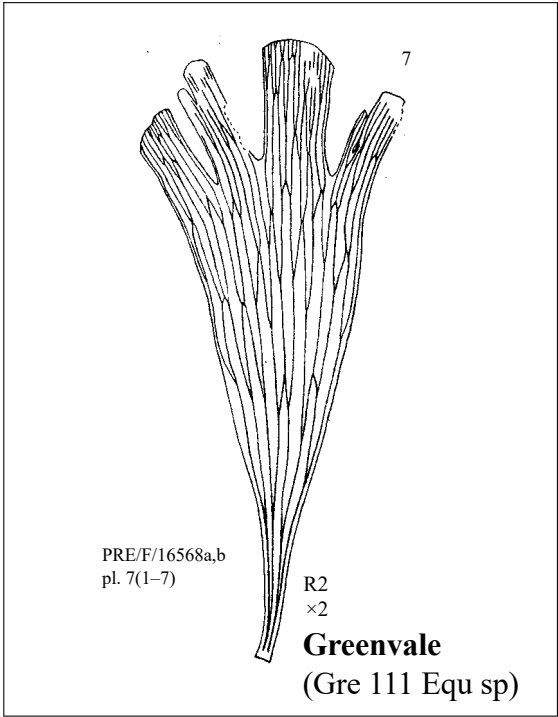


Telemachus Spruit (Tel 111 Hei elo)

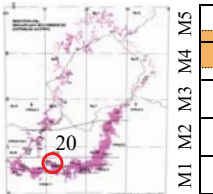
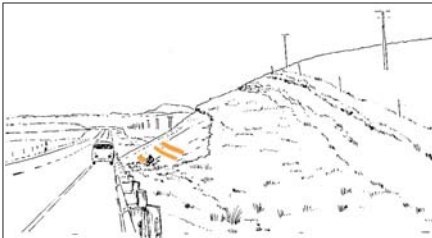
Habitat: *Heidiphyllum* thicket
Collection: 581 slabs, 90 man-hrs cleaving
Rochipteris pusilla (1 indiv.)
attached & clusters – nil
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – 4 indivs (not affil. here)
Taphonomy (*R. pusilla*) – allochthonous

Rochipteris sp.

This single virtually complete specimen is closest to *R. distivena*, in having similar divided tips and open venation, but lacks the characteristic deep division of the leaf and is of much smaller size, which suggests it may represent a distinct species.



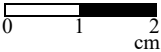
27°08.94'E; 31°23.62'S Type (& Ref. Pal.) loc.



20 Gre 111, 121

Greenvale (Gre 111 Equ sp)

Habitat: Equisetophyte marsh
Collection: 213 slabs, 25 man-hrs cleaving
Rochipteris sp. indet. (1 indiv.)
Kannaskoppia ♀ – nil
Kannaskoppianthus ♂ – nil
Taphonomy (*R. sp. indet.*) – allochthonous



HYPODIGM CHARTS; GONDWANA TRIASSIC (GT)

Petriellales/Kannaskoppia, illustrations & identification

The concept of the hypodigm chart was introduced in And. & And. (1983, p.74) for our *Dicroidium* monograph, and followed in subsequent Molteno volumes (And. & And., 1989, 2003, 2008, 2018). It aims at documenting all illustrations (photographs or sketches) in the published Gondwana Triassic (GT) literature for the group of plants being described – in this case the Petriellales/*Kannaskoppia* and affiliates. Each specimen is identified according to our current taxonomic review and arranged by geographic and stratigraphic occurrence.

Our species identifications, as per the present volume, appear in the final column of the hypodigm.

The hypodigm is a fundamental aid to establishing nomenclature following the rules of priority according to ICN 2018.

Gondwana Triassic occurrence

The layout focuses attention on assemblages and palaeodemes, and provides the data for the GT distributions plotted on the genus pages. The subregion gives the names and numbers for the productive degree squares listed; details are given elsewhere. While the formation and number codes (age, millions of years) refer to Fig. 2 (p. 5) as followed here (see Part 1, ‘Sampling & Occurrence’; Chart 2, pp 4, 5).

Gondwana Triassic correlations

At stage level, global and Gondwana Triassic floral correlations were updated by And., And. & Cleal (2007). Though the correlations have been further updated here, they are still in need of thorough revision based on the most recent absolute dating and palynological data around the Gondwana Triassic (Mancuso *et al.*, 2020 & other references as listed, Chart 2, p. 5).

Accessibility

In the current volume the aim is to make the hypodigm more readily accessible, more user-friendly. The hypodigm tables have been elaborated on by accompanying them, continent by continent, with relevant parts of the Gondwana Triassic map and correlation chart, and of the ‘productive degree squares’ and ‘Megaplant-bearing Formations’ tables. In the case of the Africa tables, sketches of the foliage and strobilus species (female and male) are also added.

Gondwana Triassic *Rochipteris* species

Those species described from around the Gondwana Triassic from Carruthers (1872) on, are discussed below under five general morphological groups (these could be considered subgenera). Reference to the Molteno species described in this volume is made where relevant.

Group 1 – *R. lacerata*; large leaves variously divided to about half the length of lamina

Rochipteris lacerata (Arber, 1917) Herbst *et al.*, 2001

The type specimen from New Zealand (Hypodigm, Chart 3, pp 110, 111) was first reported and figured as *Chiropteris lacerata* by Arber (1913) and then described and refigured at a later date (1917). This single leaf has a deep division, is fairly complete on one side with clear lacerate tips, whilst the other half is incomplete and the diagnostic base is missing. The size exceeds 50 mm in length and 30 mm in breadth. The venation shows clear anastomose on the lamina to near the leaf tips. Retallack (1980) made new collections from various localities in New Zealand, placed *Chiropteris lacerata* in the genus *Ginkgophytopsis* and synonymized it with the two species *Chiropteris biloba* and *Chiropteris waitakiensis*, described as new by Bell *et al.* (1956); and transferred the leaf described as *Ginkgo digitata*. These collections and further ones (Retallack 1981, 1983) show deeply dissected to fairly entire leaves – all showing the characteristic anastomosing venation. Based on the illustrations, they appear to have much finer venation than the type specimen (there may be an error in the size as printed). Two leaf whorls are recorded by Retallack (1980, fig. 9C; 1983, fig. 7E).

Herbst *et al.* (2001, p. 262) discussed the leaf *Cyclopteris lacerata* Quenstedt, which was later transferred to *Chiropteris*. Kustatcher & Van Konijnenburg-Van Cittert (2011, p. 232) described further *Chiropteris lacerata* leaves from Germany and regarded the New Zealand species as a junior synonym. This was an error because they had not referred to the papers of Retallack (1980) and Herbst *et al.* (2001).

From South America (Hypodigm, Chart 1, pp 106, 107), Llantenes Basin, Menendez (1951) described leaves as *Chiropteris copiapensis*; subsequently identified as *R. lacerata* by Retallack (1980) and Herbst *et al.* (2001).

Further leaves were described from the Llantenes Basin by Artabe *et al.* (1998) as *Ginkgophytopsis lacerata*. Later, Herbst *et al.* (2001) described leaves from the Copiapo and El Tranquilo basins as *R. lacerata*. These records from various localities in South America show a diverse morphology of dissected leaves and need to be re-evaluated as to whether they all belong to *R. lacerata*.

At this stage it is difficult to establish the circumscription (borders/limits) of this species which has been applied to a variety of leaves. The incomplete type specimen, lacking the diagnostic base, has resulted in variable interpretation. The majority of the collections from New Zealand are regarded here as belonging to *R. lacerata*, while the usage in South America is questioned. From the Molteno there is some overlap in morphology with *R. telefolia*, but *R. lacerata* leaves are generally smaller with finer venation, and similarly *R. distinerva* has more open venation, while *R. lacerata* has finer venation especially towards the tips. The Molteno fossils which were previously called *R. lacerata* have been placed elsewhere (Hypodigm, Chart 2, pp, 108, 109). The two New Zealand species, *Chiropteris waitakiensis* and *C. biloba* (Bell *et al.*, 1956), synonymized with *R. lacerata* by Retallack (1980), are accepted.

Rochipteris incisa Holmes & H.M.And., 2005

This species described from Australia, Nymboida Basin, is based on 11 specimens from two localities. The type is somewhat similar to the type of *R. lacerata* figured by Arber (1917) but is

much more dissected with leaf tips broadly obtuse. There is some overlap in morphology with *R. telefolia* from the Molteno, but the leaves are generally smaller and have not been found attached or associated with male strobili.

Group 2 – *R. rollerii*; small to medium leaves variously divided to more than half the length of lamina

Rochipteris rollerii (Frenguelli, 1946) Bodnar *et al.*, 2020

Frenguelli (1946) originally described his material, from Cacheuta, Argentina, as a species of *Baiera*. A study of the specimens by one of the authors (HMA, 12 October 1999, La Plata) confirmed that the leaves had anastomosing venation and did not belong to *Baiera*. Bodnar *et al.* (2020) have now restudied the Frenguelli (1946) specimens, described further ones from Cacheuta and nominated a lectotype. They regarded some leaves, identified by Frenguelli (1946) as *Baiera cuyana*, on the same slab as the lectotype, to belong to *R. rollerii*. They still considered *B. cuyana* as a valid species of *Baiera*, as the original leaf from Barreal (Frenguelli, 1942) did not show anastomosing venation; however, in shape, it is rather similar to *Rochipteris* leaves. The Molteno palaeodemes compare well with the Cacheuta collection of leaves in shape and size. Note that the reconstruction of the leaf by Frenguelli (1946, fig. 1b) has an extra four segments and that none of the leaves photographed have that many segments. The other leaf (Frenguelli 1946, fig. 1a) was reconstructed with bifurcating venation instead of anastomosing veins and this leaf, nominated as the lectotype, has been re-illustrated by Bodnar *et al.* (2020, fig. 5A). This species is common at the type locality and overlaps with *R. truncata* occurring at the same horizon.

Rochipteris alexandriana Herbst *et al.*, 2001

This species was based on two leaves from El Tranquilo, Argentina, by Herbst *et al.*, 2001. The type specimen of *Rochipteris alexandriana* nominated by Herbst *et al.* (2001, fig. 8D) has up to two divisions of the lamina and fairly narrow segments. It is similar to leaves in the *R. rollerii* population in the more divided and thinner end of the range; and is also similar to leaves in the *R. switzifolia* range that are not up to four times divided and with broader segments. In the Molteno, these two species are regarded as distinct palaeodemes in assemblages deriving from separate habitats, and being associated with distinct male strobili. It could be that in Argentina, once more specimens are known, a separate palaeodeme exists to support the retention of this species. At present, the two leaves described by Herbst *et al.* (2001), fall more closely in *R. rollerii* and the diagnosis does not cover the deeply divided leaves with multiple segments (up to 28) of *R. switzifolia*. In their synonymy they included two unnamed leaves from the Molteno (now described as two new species). They did not mention or compare their leaves with similar ones described by Frenguelli (1946) from Cacheuta and seem to have been unaware of that literature. Frenguelli's (1946) leaves were placed by Bodnar *et al.* (2020) in *R. rollerii* with a lectotype nominated from the original material. This type has somewhat broader leaf segments than the Herbst *et al.* (2001, fig. 8D) type specimen but is very similar to the second specimen (fig. 8H). Based on the palaeodemes from the Molteno, both specimens could belong in one or other population of Molteno *R. rollerii* leaves but as only two specimens have been described, it is difficult to decide.

An attached group of leaves from Antarctica were identified as *R. alexandriana* by Bomfleur *et al.* (2014). These would now fit better into one of the Molteno species, *R. switzifolia* or *R. matatifolia* that are more deeply divided, up to four times, resulting in finer segments. However, as the detail of the venation in the petiole is not clear enough in their illustrations, it is difficult at present to place them in either.

Group 3 – *R. cuneata*; small to medium leaves, mainly entire

Rochipteris cuneata (Carruthers, 1872) Herbst *et al.*, 2001

This is the earliest species to be described from Gondwana (Tivoli Coal Mine, Ipswich Basin, Australia), originally under the genus *Cyclopteris* by Carruthers (1872, p. 355, pl. 27 (fig. 5)) and has been applied to various subsequent finds. It is unfortunate that the type specimen (housed in the Natural History Museum, London; catalogue number V. 4197, Rozefelds, 1986) is incomplete, with the diagnostic base missing. A subsequent leaf described from the same locality (Tivoli Coal Mine) is recorded by Jack & Etheridge (1892, p. 378), though not figured, it is described as complete and “more or less petiolate-like”. Another leaf described by this name (Shirley 1898, pl. 23) has neither the tip nor base preserved but clearly shows anastomosing venation. Seward (1903) described a leaf under this name from the Molteno Formation at Cyphergat (equivalent to Cyp 111). Du Toit (1927) redescribed the same leaf and exposed the base to show a narrow petiole. Subsequent collections from this locality and the reference palaeodeme (Lut 311) have resulted in a good population of leaves which are all smaller than the type specimen of Carruthers (1872) and have a distinct cuneate shape. This population from Cyp 111 is now placed in *R. lutifolia*. Note that Du Toit (1927, t-fig. 3B) placed a second incomplete leaf from Umk 111 in this species which is here classified as belonging to *R. cf. sinuosa* due to the characteristic widely spaced venation. Subsequently Retallack (1980; 1983, fig. 7A) described a single incomplete specimen from New Zealand as *R. cuneata* which is here placed in *R. lacerata* (Hypodigm, Chart 3, pp 110, 111). The specimens described as *R. cuneata* by Herbst *et al.* (2001, p. 264, fig. 3(A–C), pl. 8(F,G)) from Chile and Argentina are also close to *R. copiapensis* but show a more obtuse distal margin.

Rochipteris tasmanica (Walkom, 1926) Herbst *et al.*, 2001 (as per Squires, 2012)

This species was based on a single specimen from Tasmania by Walkom (1926). In a previous paper Walkom (1925b) regarded a similar leaf described by Johnston (1888) as *Sagenopteris salisburyoides* as not having anastomosing veins and belonging to *Ginkgoites*. Walkom (1926) said his leaf was similar to *R. cuneata* described from Cyphergat in the Molteno by Seward (1903, pl. 9(4)).

The Walkom specimen is similar in shape and size to the population of leaves collected from Cyphergat but as it lacks the defining characters of the base and petiole it is not possible to say if it is the same. The species requires further study from the type locality. Retallack (1983) described two leaves (the larger one is fragmentary and the other is small with a semi-circular shape) as *Ginkgophytopsis tasmanica* (p. 145, fig. 7B,C). They are close to *R. tasmanica*, in being small and entire, but the very fine venation sets them apart from the type specimen. These two leaves are placed as *Rochipteris* sp. indet. in the hypodigm table.

Rochipteris nymboidensis Holmes & H.M.And., 2005

This species from Nymboida, Clarence-Moreton Basin, Australia, is based on one almost complete specimen with very fine venation (c. 30–35 per 10 mm across the mid-upper portion of the lamina. It is larger (> 63 mm long) and has finer venation than the leaves of *R. lutifolia* from Lut 311 and is considered distinct. It shows some similarity to the type of *R. cuneata* (Ipswich Basin) but is larger and the shape is clearly more cuneate. The venation is probably finer but is difficult to compare in more detail with the type specimen.

Rochipteris obtriangulata Holmes & H.M.And., 2005

This species was based on a remarkable slab from Nymboida, Australia, bearing a nearly complete whorl of leaves and portions of another two whorls and isolated leaves. The foliage is arranged

in a close spiral or in a terminal whorl of 8–10 leaves on a narrow stem. The leaf bases are hidden in the matrix and it is not possible to observe the actual point of attachment. The wedge-shaped leaves compare closely in size and shape with the isolated leaves from the Molteno (Umk 111). They may appear to have a longer base, but this is due to the Nymboida leaves being foreshortened as they curve down into the sediment.

Rochipteris truncata (Frenguelli, 1946) Morel *et al.*, 2011

Frenguelli (1946) originally described this material, from Cacheuta, Argentina, as a species of *Ginkgoites*. A study of this material by one of the authors (HMA, 12.10.1999, La Plata) confirmed that the leaves had anastomosing venation and did not belong to *Ginkgoites*. Morel *et al.* (2011, fig. 2(1)) described further specimens and nominated a lectotype from Frenguelli's (1946, fig. 7(1)) material and refigured it. Bodnar *et al.* (2020), in describing further specimens, included dissected leaves in this species; which would be better placed in *R. rollerii*. The undivided cuneate lamina and truncate tip of this leaf sets it apart from *R. rollerii* in the Molteno and, while similar to *R. obtriangulata*, it is a shorter leaf and not as narrow at the base. *R. truncata* is regarded as a separate species, with the population from Cacheuta being morphologically between *R. obtriangulata* and the similar species *R. penensis*.

From the Cretaceous of Australia, McLoughlin *et al.* (2000) described *Ginkgophytopsis truncata*, which is a similar but much larger leaf and is here considered a separate species – although Gnaedinger & Zavattieri (2017) regarded it as conspecific with *Rochipteris truncata* from Argentina.

Rochipteris turbata Holmes & H.M.And., 2005

This single whorl of leaves from Nymboida, Australia, bears two virtually complete and another five partial leaves. Due to the 3D nature of the specimen, the actual attachment to a stem is hidden in the matrix and it is not possible to see the base of the leaves. The species was separated from *R. obtriangulata* on the basis of the expanding lamina, cuneate shape and rounded leaf apex (not truncate). It has a similar shape and venation density (20–25 per 10 mm) to *R. lutifolia* and *R. komifolia* in the Molteno. As the defining character of the veins in the petiole of the Molteno species is not visible in this Nymboida specimen, it is retained as a distinct species.

Rochipteris pusilla Holmes & H.M.And., 2005

Due to the small size, similar shape and open venation, the Molteno specimens have been placed in this species which is based on a single specimen from Nymboida and has a slightly undulate upper margin. As so few specimens occur in the four assemblages from the Molteno, the specific identity is somewhat provisional.

Group 4 – *R. copiapensis*; large leaves entire to occasionally partly divided

Rochipteris copiapensis (Solms-Laubach, 1899) Herbst *et al.*, 2001

The original collection from Chile (Solms-Laubach, 1899, pl. 13 (1–4)) is illustrated by three large, incomplete leaves. Two show the basal area and are entire, while the third, lacking the base, shows a few notches at the distal end. Herbst *et al.* (2001) revised *R. copiapensis* and made a new species, *R. chilensis* (Solms-Laubach, 1899) Herbst *et al.* (2001) nominating the notched leaf (Solms-Laubach, 1899, pl. 13(3–4)) as the type. In the latter species, they included further specimens which are all entire (Herbst *et al.*, 2001, fig. 6(A–H), pl. 8(L)), and which could readily be placed in

R. copiapensis. These specimens should all be restudied so that a correct assessment can be made on the validity of *R. chilensis*. However one interprets these species, they are clearly apart from the Molteno specimens in being about twice as large and in not showing any deep division of the lamina. Herbst *et al.* (2001, p. 266) remarked that the Du Toit (1927) specimen, originally described as *Chiropteris copianpensis*, is a different species. The subsequent collection of a further 19 individuals from the same Molteno locality, is now placed in *R. obtriangulata*.

Rochipteris chilensis (Solms-Laubach, 1899) Herbst *et al.* 2001
Consult text for *R. copiapensis*.

Group 5 – *R. etheridgei*; large leaves variously divided with clasping base.

Rochipteris etheridgei (Arber, 1917) Barone-Nugent *et al.*, 2003

This species from Leigh Creek, Australia, was first described by Arber (1917) as a *Chiropteris*. It was later transferred to *Psymphyllum* by Chapman & Cookson (1926) and more recently to *Rochipteris* by Barone-Nugent *et al.* (2003). This species has a distinct auriculate clasping base/flare 4–6 mm wide. Incomplete leaves, without the base, show similarities to *R. lacerata* in the flabellate shape and dissected lamina. The cuticle as described by Barone-Nugent *et al.* (2003), with papillate epidermal and subsidiary cells, is rather different to that obtained for Molteno leaves by And. & And. (2003). Consult Part 2 (p. 51).

Rochipteris ginkgooides Barone-Nugent *et al.*, 2003

This species, described from the Ipswich Basin, Australia, is based on four variable specimens (a small portion of a fifth exists) from two localities. The holotype (QMF 12586) is similarly dissected to a second more complete leaf (QMF 12588) but in neither is the base preserved. A smaller leaf (QMF 182630) has a relatively broad lamina and narrow base with the suggestion of a clasping base/flare. Another leaf (QMF 26012), with only the base figured, has a distinct clasping base/flare. This is referred to as “base expanded into a broad but short sheath” in the description by Barone-Nugent *et al.* (2003, p. 281) and is similar to the clasping base/flare occurring in *R. etheridgei*. These leaves show an overall similarity to *R. telefolia* (Tel 111), but the characteristic clasping base/flare of the base is unknown in this assemblage and in any other leaves from the Molteno. The leaves are known attached (in two specimens) for *R. telefolia* and are thus separated from this somewhat similar-shaped species.

Rochipteris sinuosa Holmes & H.M.And., 2005

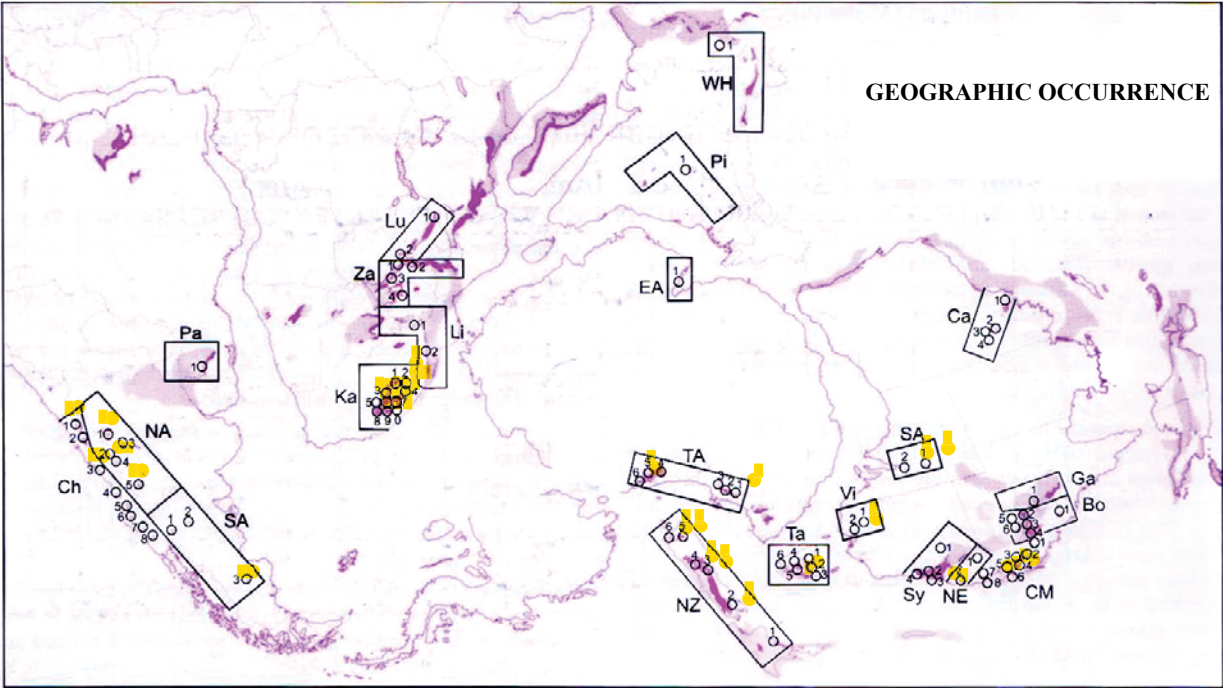
This species was based on a single unique leaf from Nymboida, Australia, primarily on the widely spaced sinuous venation. The base of the leaf shows an expansion, suggesting a clasping base which although not preserved in its entirety is considered natural and not an artifact. The Molteno leaf is provisionally placed in this species as it is similar in size, with a deeply divided lamina, and venation. However, as the base is incomplete, it is not possible to ascertain whether it also has the clasping characteristic. Clasping bases or flanges are found in *R. etheridgei* (Arber, 1917) Barone-Nugent *et al.*, 2003, a large leaf with numerous divisions in the upper part of the lamina, and in *R. ginkgooides* Barone-Nugent *et al.*, 2003, also a large leaf with variable deep divisions. Holmes & H.M.And. (2005) compared *R. sinuosa* to leaves of similar size (40–60 mm) from the Llantenes, Argentina, described by Menendez (1951) which differ in being more cuneate in shape and not deeply divided.

Tab. 1. *Rochipteris*: Geographic occurrence of species, Gondwana Triassic.

Molteno species		SAm				SAf				Ind		Ant	Aus									
		Ch	NA	SA	Pa	Lu	Za	Li	Ka	WH	PI	TA	NZ	Ca	SA	Ga	Bo	CM	NE	Sy	Vi	Ta
1	<i>R. vincularis</i>								✓													
2	<i>R. telefolia</i>								✓													
3	<i>R. distivena</i>								✓													
4	<i>R. rollerii</i>		✓						✓													
5	<i>R. switzifolia</i>								✓													
6	<i>R. matatifolia</i>								✓													
7	<i>R. komifolia</i>								✓													
8	<i>R. lutifolia</i>								✓													
9	<i>R. obtriangulata</i>								✓									✓				
10	<i>R. cf. sinuosa</i>								✓													
11	<i>R. penensis</i>								✓													
12	<i>R. pusilla</i>								✓									✓				
	<i>R. sp. indet.</i>								✓													

Other Gondwana Triassic species																						
1	<i>R. alexandriana</i>		?	✓								✓										
2	<i>R. copiapensis</i>	✓		✓																		
3	<i>R. cuneata</i>	?		?														✓		?	cf.	
4	<i>R. etheridgei</i>														✓							
5	<i>R. ginkgoides</i>																	✓				
6	<i>R. incisa</i>																	✓				
7	<i>R. lacerata</i>	?	✓	✓								cf.	✓									
8	<i>R. nymboidensis</i>																	✓				
9	<i>R. sinuosa</i>																	✓				
10	<i>R. tasmanica</i>																				✓	
11	<i>R. truncata</i>		✓																			
12	<i>R. turbata</i>																	✓				
	<i>R. sp. indet.</i>	✓	?										✓		✓			✓		✓	✓	✓

Fig. 1. Gondwana Triassic megaplants.

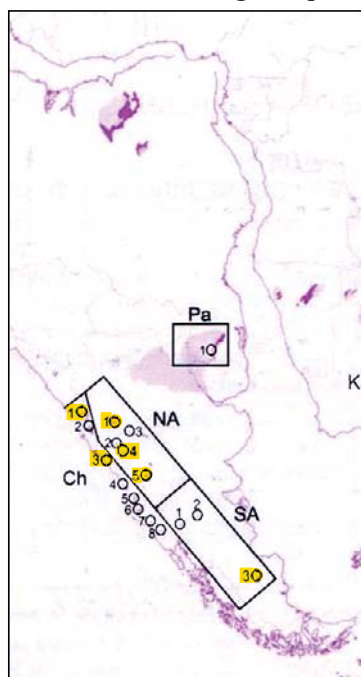


30 Subregion (degree square), with *Rochipteris* (& affiliates) Updated from And. & And. (1983, 1989, 2003)

SAm South America	SAf Southern Africa	Ind India	Ant Antarctica	Aus Australia
Ch Chile	Lu Luangwa Valley	WH W. Himalayas	TA Transantarctic Mts	NZ New Zealand
NA N. Argentina	Za Zambezi Valley	PI Peninsula India		Ca Canning Basin
SA S. Argentina	Li Limpopo Valley			SA S. Australia
Pa Parana Basin	Ka Karoo Basin			Ga Galilee Basin
				Bo Bowen Basin
				CM Clarence/Moreton B.
				NE New England Fold belt
				Sy Sydney Basin
				Vi Victoria
				Ta Tasmania

	Hypodigm charts; <i>Rochipteris et alii</i> , Gondwana Triassic (GT) occurrences						
Chart 1.							
	AUTHOR	REGION & SUBREGION	FORMATION (beds, horizons)		LOCALITY	NAME (as in literature)	
SOUTH AMERICA							
		Chile (Ch)		Ma			
1899	Solms-Lau. & Stein.	Copiapo	Ch1	207	La Ternera	Q. de la Ternera	<i>Chiropteris copiapensis</i> sp. nov.
2001	Herbst <i>et al.</i>	“	“	“	“	Q. Cachivarita	<i>Rochipteris lacerata</i> comb. nov.
“	“	“	“	“	“	“	<i>Rochipteris copiapensis</i> comb. nov.
“	“	“	“	“	“	“	<i>Rochipteris chilensis</i> sp. nov.
“	“	“	“	“	Las Breas	Punto del Vento	<i>Rochipteris cuneata</i> comb. nov.
“	“	“	“	“	La Ternera	?Q. Cachivarita	<i>Rochipteris</i> sp.
1970	Azcárate & Fasola	Los Villos	CH3	207	?Los Molles	Los Molles	<i>Chiropteris copiapensis</i>
2012	Herbst & Troncoso	Atacama	Ch ?	242	Q. del Salitre	Q. de Döna Ines Chica	cf. <i>Rochipteris</i> sp.
		N. Argentina (NA)					
2011	Lutz <i>et al.</i>	Ischigualasto	NA1	234	Los Rastros	Q. del León	<i>Rochipteris alexandriana</i>
1946	Frenguelli (87)	Cacheuta	NA4	233	Potrerrillos	Cacheuta Hill	<i>Baiera rollerii</i> sp. nov.
2011	Morel <i>et al.</i>	“	“	“	“	“	<i>Baiera rollerii</i>
2020	Bodnar <i>et al.</i>	“	“	“	“	“	<i>Rochipteris rollerii</i> comb. nov.
1946	Frenguelli (87)	“	“	“	“	“	<i>Baiera cuyana</i>
2011	Morel <i>et al.</i>	“	“	“	“	“	<i>Baiera cuyana</i>
1946	Frenguelli (87)	“	“	“	“	“	<i>Ginkgoites truncata</i> sp. nov.
2020	Bodnar <i>et al.</i>	“	“	“	“	“	<i>Rochipteris truncata</i>
1946	Frenguelli (87)	“	“	“	“	El Challao	<i>Baiera bidens</i>
“	“	“	“	“	“	“	<i>Ginkgoites truncata</i> sp. nov.
2011	Morel <i>et al.</i>	“	“	“	“	“	<i>Rochipteris truncata</i> comb. nov.
2007	Artabe <i>et al.</i>	“	“	“	“	Perfil cerro Bayo	<i>Rochipteris</i> sp.
1951	Menendez	Llantenos	NA5	233	Llantenos	Arroya Llantenos	<i>Chiropteris copiapensis</i>
1998	Artabe <i>et al.</i>	“	“	233	“	“	<i>Ginkgophytopsis lacerata</i>
		S. Argentina (SA)					
2001	Herbst <i>et al.</i>	El Tranquilo	SA3	235	Cãnadõn Largo	Estancia Cãnadõn	<i>Rochipteris cuneata</i> comb. nov.
“	“	“	“	“	“	“	<i>Rochipteris alexandriana</i> sp. nov.
“	“	“	“	“	Laguna Colorado	Estancia Cãnadõn	<i>Rochipteris lacerata</i> comb. nov.
“	“	“	“	“	“	“	<i>Rochipteris copiapensis</i> comb. nov.
	Jurassic	S. Argentina (SA)					
2017	Gnaed. & Zavat.	Neuquén	SA		Nestares	downstream of Alicurá Dam	<i>Rochipteris copiapensis</i>

SAM, Productive degree squares



SAM, Productive degree squares (megaplants)

SUPERREGION (continent)		Degree square		Quantity		Quality		Cuticle		Publ. cover		Biozones		Localities	
REGION (basin)		Lat.	Long.												
Subregion (* square)															
SOUTH AMERICA (SAM)															
CHILE (Ch)															
1	Copiapo	27	70	3	3	-	2	1	3						
2	Alto del Carmen	29	71	•	•	-	1	1	1						
3	Los Villos	32	72	2	2	-	2	1	2						
4	Curicó	34	72	•	•	-	1	1	1						
5	Pocillas	36	73	•	•	-	1	1	1						
6	Concepción	37	73	3	3	-	2	2	2						
7	Temuco	38	73	•	•	-	1	1	2						
8	Valdivia	39	73	•	•	-	1	1	1						
N. ARGENTINA (NA)															
1	Ischigualasto	29	69	3	3	3	2	3	13						
2	Barreal	31	70	4	4	2	4	2	6						
3	Marayes	31	68	2	3	-	2	1	1						
4	Cacheuta	32	70	4	4	3	3	3	10						
5	Llantenos	35	69	3	3	-	3	2	2						
S. ARGENTINA (SA)															
1	Paso Flores	40	72	2	3	-	2	1	1						
2	Los Menucos	40	69	1	2	-	1	1	1						
3	El Tranquilo	47	70	2	3	-	2	1	1						
PARANA BASIN (Pa)															
1	Santa Maria	29	54	2	3	-	2	1	1						

Triassic

outcrop
subsurface

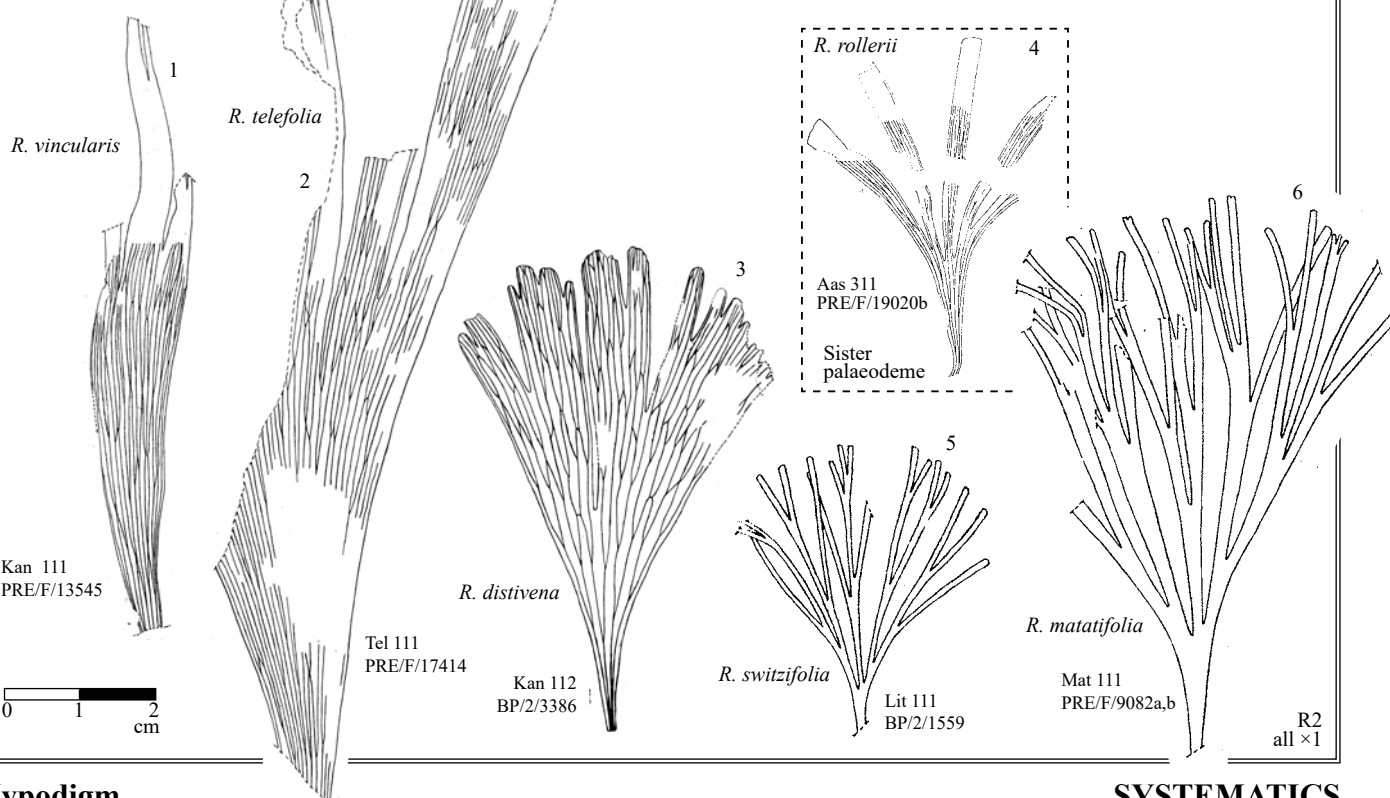


regions
subregions (° squares)

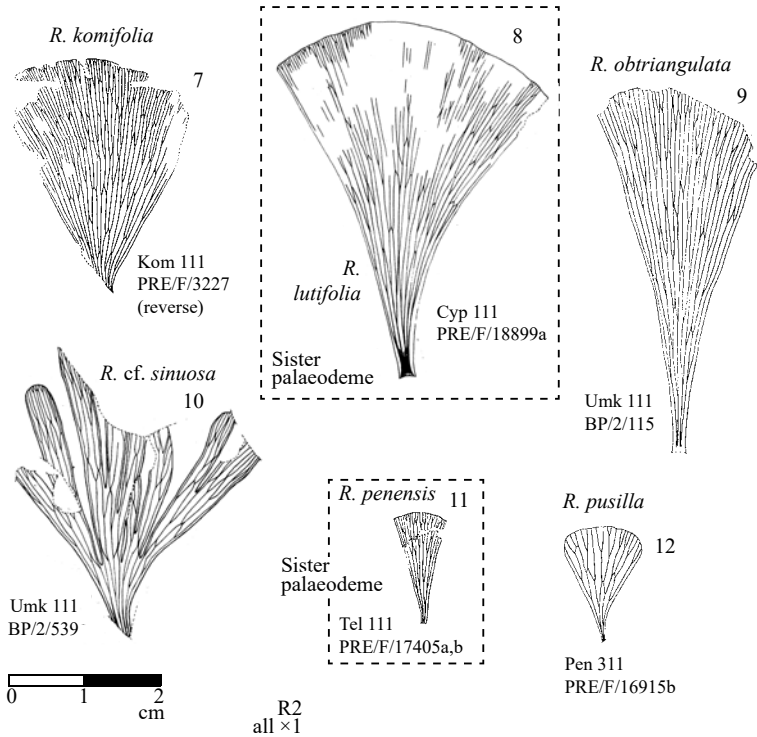
50 with *Rochipteris*

• map, correlation chart & tables (lower half of page) extracted from Part. 1 'Sampling & Occurrence' (Chart 2, p.4)

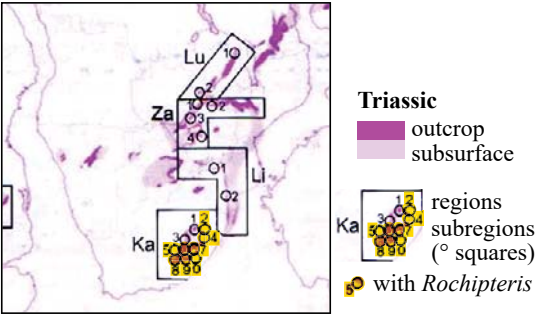
Hypodigm charts; <i>Rochipteris</i> , Gondwana Triassic (GT) occurrences							
Chart 2.							
	AUTHOR	REGION & SUBREGION	FORMATION		LOCALITY	NAME (as in literature)	
AFRICA							
			Ma				
1889	Feistmantel	Karoo Basin	Ka 8	233	Molteno	Cyphergat	<i>Anthrophyopsis</i> (?) sp.
1903	Seward	“	“	“	“	“	<i>Chiropteris cuneata</i>
1927	Du Toit	“	“	“	“	“	<i>Chiropteris cuneata</i>
“	“	“	Ka 4	“	“	Upper Umkomaas	<i>Chiropteris cuneata</i>
“	“	“	“	“	“	“	<i>Chiropteris copiapensis</i>
“	“	“	“	“	“	“	“
1983	And. & And.	Karoo Basin	“	“	Molteno	Umkomaas (Umk 111)	<i>Ginkgophytopsis</i> sp. A
“	“	“	Ka 8	“	“	Kommandantskop (Kom 111)	“ <i>cuneata</i>
“	“	“	Ka 7	“	“	Matatiele (Mat 111)	“ <i>lacerata</i>
“	“	“	“	“	“	“	“ sp. B
“	“	“	Ka 4	“	“	Umkomaas (Umk 111)	“ sp. C
“	“	“	“	“	“	“	“ sp. D
1985	And. & And.	“	Ka 7	“	“	Matatiele (Mat 111)	“ <i>lacerata</i>
2003	And. & And.	Karoo Basin	Ka 9	“	Molteno	Kannaskop (Kan 111)	<i>Kannaskoppifolia vincularis</i> sp. nov.
“	“	“	“	“	“	Peninsula (Pen 311)	“ sp. A
“	“	“	“	“	“	“	“ sp. B
“	“	“	Ka 4	“	“	Umkomaas (Umk 111)	“ sp. C
“	“	“	Ka 8	“	“	Cyphergat (Cyp 111)	“ sp. D
“	“	“	Ka 5	“	“	Lutherskop (Lut 311)	“ sp. D
“	“	“	Ka 8	“	“	Kommandantskop (Kom 111)	“ sp. D
“	“	“	Ka 9	“	“	Peninsula (Pen 311)	“ sp. E
“	“	“	Ka 8	“	“	Aasvoëlberg (Aas 211)	“ sp. E
“	“	“	“	“	“	Aasvoëlberg (Aas 311)	“ sp. E
“	“	“	“	“	“	Aasvoëlberg (Aas 411)	“ sp. E
“	“	“	Ka 2	“	“	Little Switzerland (Lit 111)	“ sp. F
“	“	“	Ka 7	“	“	Matatiele (Mat 111)	“ sp. F
“	“	“	Ka 4	“	“	Umkomaas (Umk 111)	“ sp. G
“	“	“	Ka 8	“	“	Telemachus Spruit (Tel 111)	“ sp. H
“	“	“	Ka 9	“	“	Kannaskop (Kan 112)	“ sp. I
“	“	“	Ka 8	“	“	Aasvoëlberg (Aas 111)	<i>Kannaskoppianthus lutinumerus</i> sp. nov.
2007	And., And. & Cleal	“	Ka 9	“	“	Kannaskop (Kan 111)	<i>Kannaskoppia vincularis</i>
“	“	“	Ka 9	“	“	Peninsula (Pen 311)	<i>Kannaskoppifolia</i> sp. E



sketches (s) photos (p)	indivs	ILLUSTRA- TIONS	IDENTIFICATION (this volume)											
			<i>R. vincularis</i>	<i>R. telefolia</i>	<i>R. distivena</i>	<i>R. rollerii</i>	<i>R. switzifolia</i>	<i>R. matatifolia</i>	<i>R. komifolia</i>	<i>R. lutifolia</i>	<i>R. obtriangulata</i>	<i>R. cf. sinuosa</i>	<i>R. penensis</i>	<i>R. pusilla</i>
			1	2	3	4	5	6	7	8	9	10	11	12
			Molteno species											
s	1	pl 2(4)												
s	1	pl 9 (4)								✓				
s	*	t.fig 3(A)								✓				
s	1	t-fig 3(B)										✓		
s	1	t.fig 3(C,E)									✓			
s	1	t.fig 3(D)					✓							
s	p	1	pl 10(1)								✓			
	p	1	pl 10(2)						✓					
	p	1	pl 10(3)		✓									
	p	1	pl 10(4)					✓						
	p	1	pl 10(5)				✓							
	p	1	pl 10(6)									✓		
	p	*	pl 192(3)		✓									
s	14	pp 295,297, pls 106,107	✓											
s	1	p 296(5)												✓
s	1	p 296(4)											✓	
s	1	p 297(1)									✓			
s	1	p 296(3)								✓				
s	1	pl 111								✓				
	p	1	pls 108(4,5)						✓					
s	1	p 297(3)				✓								
	p	1	pl 113(5,6)				✓							
	p	1	pl 114(6)				✓							
	p	1	pl 115(9)				✓							
s	1	p 297(6)					✓							
	p	2	pl 114(11,12)						✓					
s	1	p 297(7)										✓		
s	6	p 297(2), pl 119		✓										
s	1	p 297(5)			✓									
	p	1	pl 112(7,10)				✓							
s	1	p 185(1)		✓										
s	1	p 185(9)				✓								



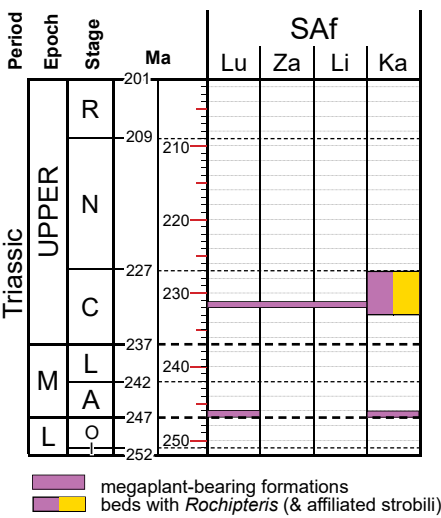
Saf, Productive degree squares (megaplants)



Saf, Productive degree squares (megaplants)

SUPERREGION (continent)		Degree square		Quantity	Quality	Cuticle	Publ. cover	Biozones	Localities						
REGION (basin)	Subregion (° square)	Lat.	Long.												
SOUTHERN AFRICA (Saf)															
LUANGWA VALLEY (Lu)															
1	N. Luangwa V.	10	32	1	1	1	1	1	•						
2	W. Luano V.	14	29	•	•	1	1	1	•						
ZAMBEZI VALLEY (Za)															
1	Kafue V.	15	28	•	•	1	1	1	•						
2	Urungwe	16	30	1	1	1	1	1	1						
3	Lake Kariba	17	27	3	3	2	1	8							
4	Gwelo	19	29	2	2	2	1	1	1						
LIMPOPO VALLEY (Li)															
1	Soutpansberg	22	30	1	1	1	1	1	1						
2	Komatipoort Cf.	25	31	1	1	1	1	1	1						
KAROO BASIN (Ka)															
1	Bethlehem	28	28	1	3	5	2	1	1						
2	Bergville	28	29	5	5	5	4	1	1						
3	Maseru	29	27	5	5	3	4	1	4						
4	Underberg	29	29	5	5	3	4	1	9						
5	Aliwal North	30	26	5	4	4	4	2	13						
6	Zastron	30	27	4	4	4	4	1	2						
7	Matatiele	30	28	4	4	4	4	1	5						
8	Molteno	31	26	5	4	4	4	1	19						
9	Elliott	31	27	4	4	4	4	2	14						
10	Maclear	31	28	4	4	4	4	1	1						

Saf, Megaplants, Trias. occurrence



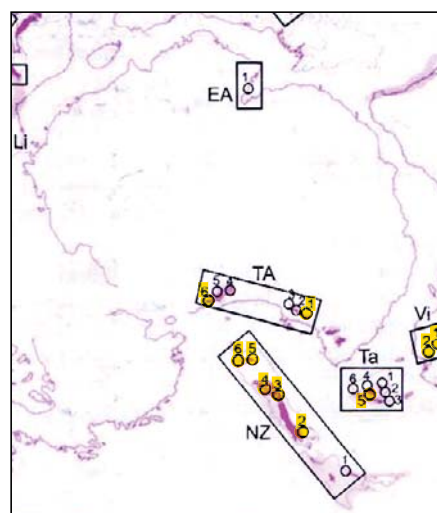
Saf, Megaplant-bearing Formations

SOUTHERN AFRICA	
Luangwa Valley (Lu)	
232	'U. Grit'
247	Ntawere
Zambezi Valley (Za)	
232	'Flags'
Limpopo Valley (Li)	
232	(Molteno)
Karoo Basin (Ka)	
233	Molteno
247	Burgersdorp

Ma – age marking base of Formation bar
beds with *Rochipteria* (& affiliated strobili)

	Hypodigm charts; <i>Rochipteris</i> , Gondwana Triassic (GT) occurrences						
Chart 3.							
	AUTHOR	REGION & SUBREGION		FORMATION		LOCALITY	NAME (as in literature)
ANTARCTICA							
		Ma					
		Trans-Antarctic Mts (TA)					
2014	Bomfleur <i>et al.</i>	Allan Nunatak	TA1	238	Lashly	Allan Hills	<i>Rochipteris alexandriana</i>
“	“	Shackleton Gl.	TA 6	“	?Falla	Alfie’s Elbow, Shackleton Gl.	<i>Rochipteris</i> sp. cf. <i>R. lacerata</i>
NEW ZEALAND							
		Ma					
		New Zealand (NZ)					
1985	Retallack	Nelson Syncl.	NZ2	206	Otapirian Stage	nr. Highfield Homestead	<i>Ginkgophytopsis lacerata</i>
“	“	“	“	“	“	“	<i>Ginkgophytopsis</i> sp.
1913	Arber	Mt Potts	NZ3	239	Tank Gully CM	Tank Gully	<i>Chiropteris lacerata</i>
1917	“	“	“	“	“	“	<i>Chiropteris lacerata</i> sp. nov.
1980	Retallack	Canterbury	NZ3	“	Tank Gully CM	Tank Gully	<i>Ginkgophytopsis lacerata</i> comb. nov.
1956	Bell <i>et al.</i>	S. Canterbury	NZ4	“	Black Jacks Congl.	Black Jacks, Waitaki R	<i>Chiropteris biloba</i> sp. nov.
“	“	“	“	“	“	“	<i>Chiropteris waitakiensis</i> sp. nov.
“	“	“	“	“	“	“	<i>Ginkgo digitata</i>
1983	Retallack	“	“	“	“	Benmore Dam	<i>Ginkgophytopsis cuneata</i>
“	“	“	“	“	“	“	<i>Ginkgophytopsis tasmanica</i> comb. nov.
“	“	“	“	“	“	“	<i>Ginkgophytopsis lacerata</i>
1981	“	N Otago	NZ4	“	Long Gully	Long Gully nr. Otematata	<i>Ginkgophytopsis lacerata</i>
1985	“	S.land Syncl.NW	NZ5	240	Taringatura Grp	Lake Gunn	<i>Ginkgophytopsis lacerata</i>
“	“	S.land Syncl.SE	NZ6	206	Otapirian Grp	Taylor’s Stream	<i>Ginkgophytopsis lacerata</i>
1994	Pole & Raine	“	“	“	Murihiku Supergrp.	Pollock Road	<i>Ginkgophytopsis</i> sp.

Ant, NZ, Productive degree squares



Triassic

outcrop
subsurface



regions
subregions (° squares)



with *Rochipteris*

Ant, NZ, Productive degree squares (megaplants)

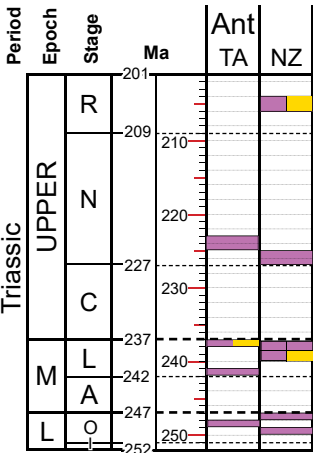
SUPERREGION (continent)		Degree square		Quantity	Quality	Cuticle	Publ. cover	Biozones	Localities
REGION (basin)		Lat.	Long.						
Subregion (° square)									
ANTARCTICA (Ant)									
TRANSANTARCTIC MTS. (TA)									
1	Allan Nunataks	76	155	3	4	-	2	1	3
2	Taylor Glacier	77	155	3	4	3	1	2	9
3	Portal Mt.	78	155	2	3	-	1	1	1
4	Beardmore Gl.	84	160	*	*	*	1	2	3
5	Mt. Burnstead	85	170	2	4	-	2	1	1
6	Shackleton Gl.	85	180	2	4	-	1	1	1
EASTERN ANTARCTICA (EA)									
1	Prince Charles Mts	70	68	3	3	5	3	1	3
AUSTRALASIA (Aus)									
NEW ZEALAND (NZ)									
1	SW Auckland	38	174	1	1	-	4	1	1
2	Nelson Syncline	41	173	1	1	-	4	2	3
3	Mt. Potts	43	170	3	3	-	4	1	1
4	Benmore Dam	44	170	3	3	-	4	1	3
5	Southland Syncl. (NW)	45	168	2	1	-	4	5	10
6	Southland Syncl. (SE)	46	169	2	1	-	4	2	7

beds with *Rochipteris* (& affiliated strobili)

			IDENTIFICATION (this volume)																									
sketch (s)	photo (p)	indivs	ILLUSTRATIONS	<i>R. vincularis</i>	<i>R. telefolia</i>	<i>R. disrivena</i>	<i>R. rollerii</i>	<i>R. switzfolia</i>	<i>R. matatfolia</i>	<i>R. komifolia</i>	<i>R. lutifolia</i>	<i>R. obtriangulata</i>	<i>R. cf. sinuosa</i>	<i>R. penensis</i>	<i>R. pusilla</i>	<i>R. alexandriana</i>	<i>R. copiapensis</i>	<i>R. cuneata</i>	<i>R. etheridgei</i>	<i>R. ginkgooides</i>	<i>R. incisa</i>	<i>R. lacerata</i>	<i>R. nymboldensis</i>	<i>R. sinuosa</i>	<i>R. tasmanica</i>	<i>R. truncata</i>	<i>R. turbata</i>	<i>R. sp. indet.</i>
				1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	–
				Molteno species												Other Gondwana Triassic species												
s	p	20	figs 2(A–C), 3(A–C)													✓												
p	11	fig 3(D–F)																				cf.						–
s	3	fig 9 (B2–B3)		...																								✓
s	2	fig 9 (C1,C2)		...																								✓
	1	pl 8(6)																				✓						
p	1	pl 3(8)																				✓						
s	p	3	figs 9(A–C), 10(J)																			✓						
s	2	t.fig 4(11, 12)																				✓						
s	2	t.fig 4(10, 14)																				✓						
s	2	t.fig 4(16)																				✓						
s	1	fig 7(A)																				✓						
s	1	fig 7(B,C)																				✓						✓
s	4	fig 7 (D–G)																				✓						
s	1	fig 10(C)																										✓
s	2	fig 8 (B1,B2)		...																								✓
s	3	fig 9 (D1–D3)		...																								✓
p	8	figs 4A, 6C																										✓

✓ Ant & NZ species

Ant, NZ, Megaplants, Trias. occurrence



Triassic Stages

- R Rhaetian
 - N Norian
 - C Carnian
 - L Ladinian
 - A Anisian
 - O Olenekian
 - I Induan
- megaplant-bearing formations
- beds with *Rochipteris* (& affiliated strobili)

Ant, NZ, Megaplant-bearing Formations

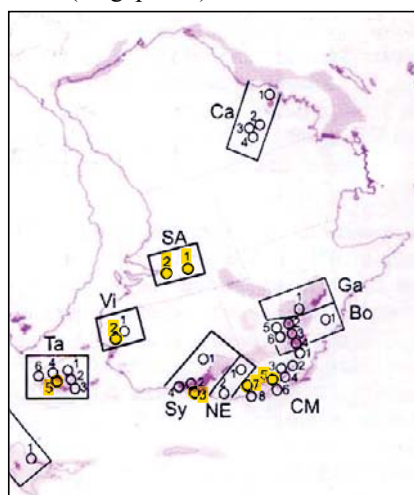
ANTARCTICA (TA, EA)	
Transantarctic Mts.	
238	Falla
"	Lashly C
242	Fremouw
249	Lashly A
Eastern Antarctica	
225	Flagstone Bench
New Zealand (NZ)	
206	(Southland)
227	(Southland)
239	Tank Gully
"	Black Jacks
"	Long Gully
240	(Southland)
250	"

Ma – age marking base of Formation bar

beds with *Rochipteris* (& affiliated strobili)

Hypodigm charts; <i>Rochipteris</i> , Gondwana Triassic (GT) occurrences							
Chart 4.							
	AUTHOR	REGION & SUBREGION		FORMATION (beds, horizons)		LOCALITY	NAME (as in literature)
AUSTRALIA							
		South Australia (SA)	Ma				
1895	Etheridge	Leigh Creek	SA1	238	Leigh Creek CM	? (Sweet collection)	<i>Anthrophyopsis</i> ? sp. ind.
1926	Chapm. & Cooks.	“	“	“	“	? (Sweet collection)	(?) <i>Psygmophyllum etheridgei</i>
1969	Amtsberg	“	“	“	“	Telford Open Cut	<i>Psygmophyllum</i> cf. <i>etheridgei</i>
2003	Barone-Nug. <i>et al.</i>	“	“	“	“	“ Pit M13	<i>Rhochipteris etheridgei</i> comb. nov.
1969	Ampsberg	Springfield B.	SA2	238	(unnamed)	Central Mesa	<i>Ginkgo antarctica</i>
2003	Barone-Nug. <i>et al.</i>	“	“	“	“	“	<i>Rochipteris</i> sp.
		Clarence-Moreton Basin (CM)					
1872	Carruthers	Ipswich/Esk	CM5	232	Tivoli	Tivoli Coal Mine	<i>Cyclopteris cuneata</i> sp. nov.
1898	Shirley	“	“	“	?	Brisbane (no details)	<i>Sagenopteris (Cyclopteris) cuneata</i>
1924	Walkom	“	“	241	Esk	Por. 42 Wivenhoe	<i>Ginkgoites</i> sp.
2003	Barone-Nug. <i>et al.</i>	“	CM6	233	Brassall subgroup	Springwood, S of Brisbane	<i>Rochipteris ginkgoides</i> sp. nov.
“	“	“	“	“	“	Petrie’s Q., N of Brisbane	“ “
2005	Holmes & H.M.And.	Nymboida	CM7	241	Basin Creek	Coalmine quarry	<i>Rochipteris obtriangulata</i> sp. nov.
“	“	“	“	“	“	“	<i>Rochipteris turbata</i> sp. nov.
“	“	“	“	“	“	“	<i>Rochipteris sinuosa</i> sp. nov.
“	“	“	“	“	“	“	<i>Rochipteris nymboidensis</i> sp. nov.
“	“	“	“	“	“	“	<i>Rochipteris pusilla</i> sp. nov.
“	“	“	“	“	“	Reserve Quarry	<i>Rochipteris incisa</i> sp. nov.
		Sydney Basin (Sy)					
1894	Etheridge	Sydney	Sy3	?	?	Cremorne bore	<i>Sagenopteris salisburyoides</i>
1925a	Walkom	“	“	248	Narrabeen-Gosford	Turrimetta Head	? <i>Rhipidospsis narrabeenesis</i> sp. nov.
		Victoria (Vi)					
1927	Chapman	Victoria	Vi2	238	Council Trench	Bacchus Marsh (Bald Hill)	<i>Psygmophyllum fergusonii</i> sp. nov.
2006	Webb & Mitchell	“	“	“	“	“	<i>Rochipteris</i> sp.
		Tasmania (Ta)					
1888	Johnston	Hobart	Ta5	231	Brady equivalent	Lords Hill	<i>Ginkgophyllum?</i> <i>australis</i> sp. nov
1926	Walkom	“	“	“	“	“	<i>Chiropteris tasmanica</i> sp. nov.

Aus, Productive degree squares (megaplants)



Triassic
 outcrop
 subsurface

Ta regions
 subregions (° squares)

with *Rochipteris*

Aus, Productive degree squares (megaplants)

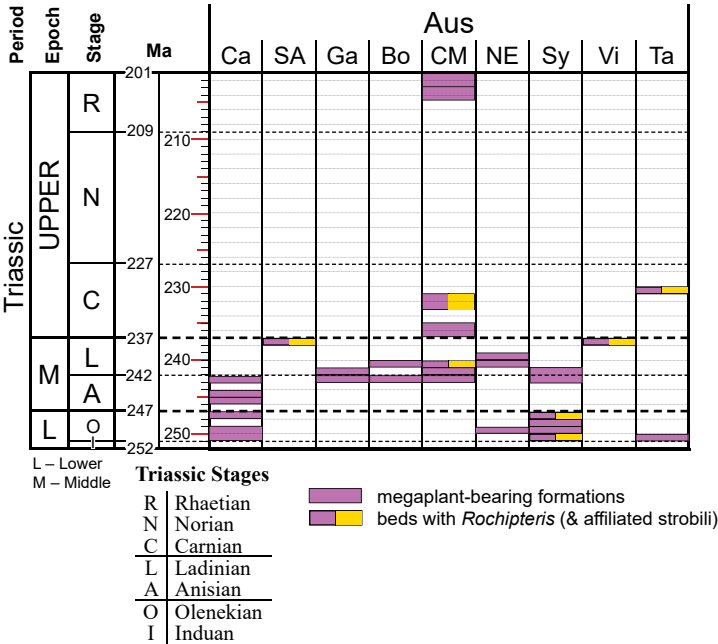
SUPERREGION (continent)		Biozones	Localities
REGION (basin)	Subregion (° square)		
AUSTRALIA (Aus)			
CANNING BASIN (Ca)			
1	Derby	1	2
2	Mt. Erskine	2	4
3	Mt. Ernest	2	8
4	Gregory Lake	2	3
SOUTH AUSTRALIA (SA)			
1	Leigh Creek Cf.	1	1
2	Springfield Cf.	1	1
GALILEE BASIN (Ga)			
1	Lennox	1	3
BOWEN BASIN (Bo)			
1	Carborough	1	1
2	Springure Shelf	1	1
3	Springure Anticl.	1	1
4	Dawson Range	1	1
5	Camaron Range	1	1
6	Taroom	1	3
CLARENCE/MORETON BASIN (CM)			
1	Callide Cf.	1	1
2	Gayndah	1	2
3	Tarong	1	5
4	Esk Trough (N)	1	17
5	Ipswich/Esk	3	54
6	Brisbane	2	14
7	Nymboida	1	4
8	Red Cliff	1	2
NEW ENGLAND FOLDBELT (NE)			
1	Delungra	1	2
2	Lorne Basin	1	4
SYDNEY BASIN (Sy)			
1	Dubbo	1	2
2	Blue Mts.	2	5
3	Sydney	2	23
4	Pictou	2	4
VICTORIA (Vi)			
1	Yandolt Hill	1	1
2	Bald Hill	1	1
TASMANIA (Ta)			
1	Postina	1	1
2	Ben Lomond	1	2
3	NE coast	1	17
4	Derwent Valley	1	2
5	Hobart	2	8
6	South Cape	1	2

beds with *Rochipteris* (& affiliated strobili)

sketch (s) photo (p)	indivs	ILLUSTRATIONS	IDENTIFICATION (this volume)																								
			<i>R. vicularis</i>	<i>R. telefolia</i>	<i>R. disivena</i>	<i>R. rolleri</i>	<i>R. switzfolia</i>	<i>R. matatfolia</i>	<i>R. komifolia</i>	<i>R. lutifolia</i>	<i>R. obtriangulata</i>	<i>R. cf. sinuosa</i>	<i>R. penensis</i>	<i>R. pusilla</i>	<i>R. alexandriana</i>	<i>R. copiapensis</i>	<i>R. cuneata</i>	<i>R. etheridgei</i>	<i>R. ginkgooides</i>	<i>R. incisa</i>	<i>R. lacerata</i>	<i>R. nymboldensis</i>	<i>R. sinuosa</i>	<i>R. tasmanica</i>	<i>R. truncata</i>	<i>R. turbata</i>	<i>R. sp. indet.</i>
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	–
			Molteno species												Other Gondwana Triassic species												
s	1	pl 4(2)															✓										
s	2	pls 23(20), 24(21)															✓										
p	3	pl 4(22–24)															✓										
s p	13	fig 3B, pls 1, 2															✓										
s	1	fig 2																								✓	
s p	*	fig 3C, pl. 4																								✓	
s	1	pl 27(5)															✓										
s	1	pl 23																								✓	
p	1	pl 21(3B)															cf.										
s p	4	fig 3A, pl 3(1,2,4–6)																✓									
p	1	pl 3(3)																✓									
p	2	figs 18(A–C), 19(A–D)									✓																
p	1	fig 20(A–C)																							✓		
p	1	fig 23(A–C)																									
p	1	fig 24(A–D)																				✓					
p	1	fig 25(A–C)												✓													
p	2	figs 21(A–C), 22(A)																	✓								
s	>2	pl 7(2)																								✓	
		pl 30(3,4)															cf.										
s p	2	pls 12(39), 13(44,45)																								✓	
s	1	fig 6(D)																								✓	
s	1	pl 27(3)																								✓	
s	1	pl 9(2)																						✓			

✓ Australia species

Aus, Megaplants, Trias. occurrence



Aus, Megaplant-bearing formations (beds, horizons)

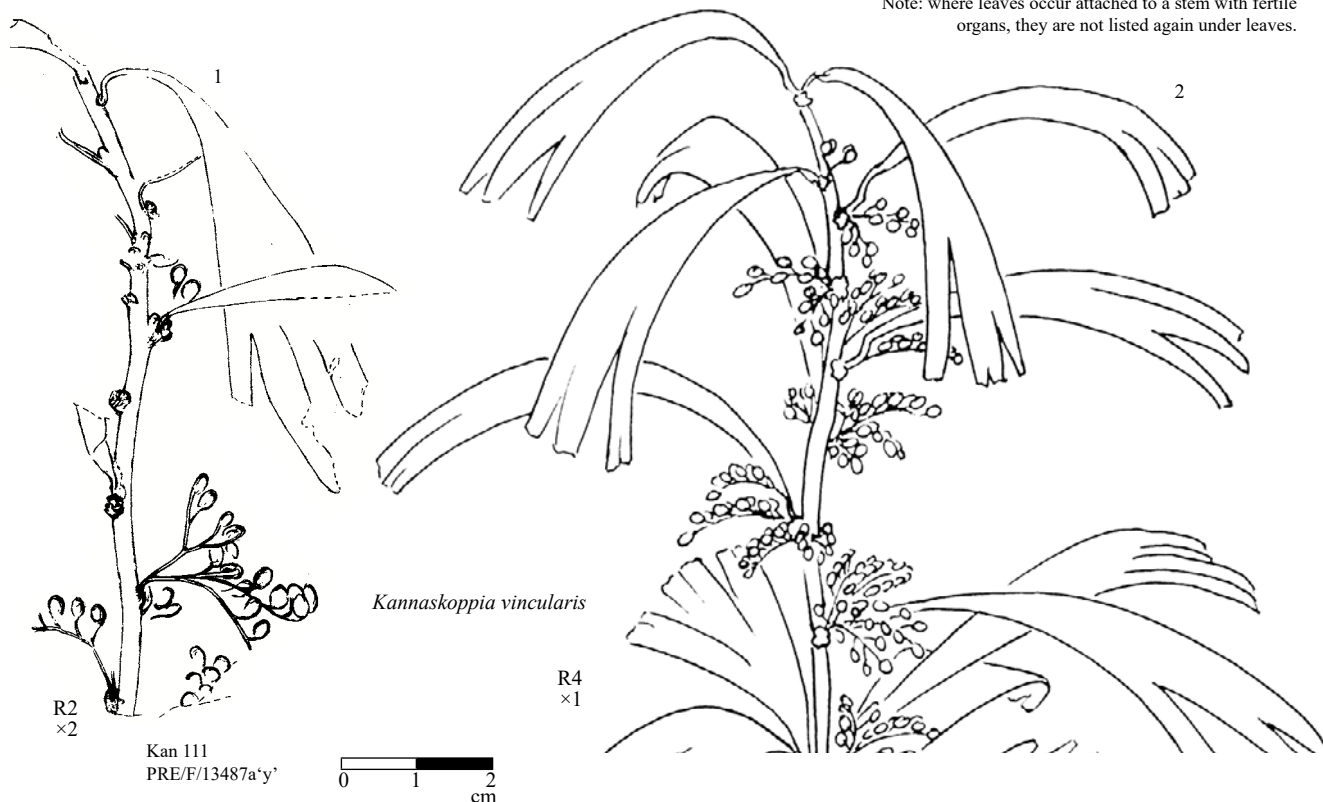
Canning Basin (Ca)		New England Foldbelt	
248	Culvida	240	Gragin
250	Erskine	241	Gunnee
251	Blina	250	Camden Head
Southern Australia (SA)		Sydney Basin (Sy)	
238	Leigh Creek	242	Benolong
"	Springfield	"	Wianamatta
		243	Hawkesbury
Galilee Basin (Ga)		248	Burralow
242	Moolayember	"	Gosford (U)
243	Clematis	"	Newport (U)
Bowen Basin (Bo)		249	Newport (M)
242	Moolayember	250	Garie
243	Clematis	"	Newport (L)
Clarence/Moreton Basin		251	Banks Wall
203	Raceview	"	Gosford (L)
205	Aberdare	"	Bald Hill
232	Callide	251	Patonga
"	Ipswich (U)	"	Bulgo
233	Tarong	Victoria (Vi)	
"	Ipswich (L)	238	Yandoit
"	Tingalpa	"	Bald Hill
"	Red Cliff	Tasmania (Ta)	
241	Esk	231	Brady
"	Nymboida	"	New Town
242	Neara	251	Knocklofty
243	Bryden		

Ma – age marking base of Formation bar
beds with *Rochipteris* (& affiliated strobili)

Chart 5. Hypodigm; *Kannaskoppia* & *Kannaskoppianthus*, Gondwana Triassic (GT) occurrences.

	AUTHOR	REGION & SUBREGION		FORMATION	LOCALITY	NAME	
SOUTH AMERICA							
			Ma				
1899	Solms-Lau. & Stein.	Copiapo	Ch1	207	La Ternera	<i>Acrocarpus ternerae</i> sp. nov. (male)	
1998	Artabe <i>et al.</i>	Llantenos	NA5	207	Llantenos	fertile material at level LLA15	
ANTARCTICA							
1994	Taylor <i>et al.</i>	Trans. Antarctic Mts	TA4	242	Fremouw	Fremouw Peak	<i>Petriellaea triangulata</i> sp. nov.
1996	Taylor	“	“	“	“	“	“ ‘cupule’
2009	Taylor & Taylor	“	“	“	“	“	“ <i>triangulata</i>
AFRICA							
1995	Cairncross <i>et al.</i>	Karoo Basin	Ka9	233	Molteno	Kannaskop (Kan 111)	<i>Ginkgophytopsis</i> sp.
1997	And. & And.	Karoo Basin	Ka9	233	Molteno	Kannaskop (Kan 111)	<i>Ginkgophytopsis</i> (leaf & ♂)
“	“	“	“	“	“	Little Switzerland (Lit 111)	“ (♂)
2003	And. & And.	Karoo Basin	Ka9	233	Molteno	Kannaskop (Kan 111)	<i>Kannaskoppia vincularis</i> sp. nov.
“	“	“	“	“	“	“	“
2003	And. & And.	Karoo Basin	Ka5	“	Molteno	Lutherskop (Lut 311)	<i>Kannaskoppianthus lutiinumerus</i> sp. nov.
“	“	“	“	“	“	Aasvoëlberg (Aas 111)	“
“	“	“	“	“	“	Aasvoëlberg (Aas 211)	“
“	“	“	“	“	“	Aasvoëlberg (Aas 311)	“
“	“	“	“	“	“	Aasvoëlberg (Aas 411)	“
“	“	“	Ka2	“	“	Little Switzerland (Lit 111)	“
“	“	“	Ka7	“	“	Matatiele (Mat 111)	“ <i>matatiparvus</i> sp. nov.
“	“	“	Ka8	“	“	Kommandantskop (Kom 111)	“ <i>irregularis</i> sp. nov.
“	“	“	“	“	“	“	“
“	“	“	Ka9	“	“	Kannaskop (Kan 112)	“
“	“	“	Ka8	“	“	Telemachus Spruit (Tel 111)	“ <i>lutiinumerus</i>
“	“	“	“	“	“	“	“ <i>telemagnus</i> sp. nov.
2007	And., And. & Cleal	Karoo Basin	Ka9	“	Molteno	Kannaskop (Kan 111)	<i>Kannaskoppia vincularis</i>
“	“	“	Ka8	“	“	Telemachus Spruit (Tel 111)	<i>Kannaskoppianthus lutiinumerus</i>
“	“	“	“	“	“	Aasvoëlberg (Aas 311)	“
2009	Taylor & Taylor	Karoo Basin	Ka9	233	Molteno	Kannaskop (Kan 111)	<i>Kannaskoppia vincularis</i>

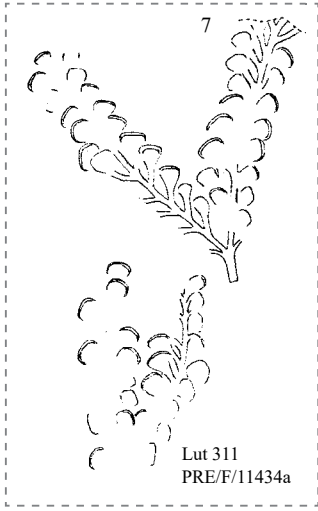
Note: where leaves occur attached to a stem with fertile organs, they are not listed again under leaves.



♀ *Kannaskoppia*

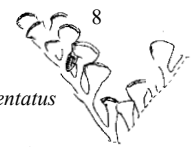
sketch (s)	photo (p)	indiv	ILLUSTRATIONS	<i>K. vincularis</i>	<i>K. telemagnus</i>	<i>K. irregularis</i>	<i>K. aasvoelensis</i>	<i>K. switzianthus</i>	<i>K. matatiparvus</i>	<i>K. komanthus</i>	<i>K. lutinumerus</i>	<i>K. telepentatus</i>	<i>K. ternae</i>	<i>P. triangulata</i>
				1	1	2	3	4	5	6	7	8	SAm & Ant	
				Molteno species										species
s	1	pl 14(5)											✓	
–	–	–												
s	p	>4	figs 1–31										✓	
	p	1	pl 4(4)										✓	
s	p	*	figs 30–32										✓	
s	p	2	p 472(c,d)	✓										
s	1	fig 2		✓										
s	1	fig 5						✓						
s	p	12	p 286(1–3), 288(1,2), 289(1–12)	✓										
			pls 104, 105, 106(1,2,6)											
s	p	5	p 290(1), 292(1,2), pl 110							✓				
	p	8	p 292(5), pl 112(1–6,8,9,11)				✓							
	p	2	pl 113(1–4)				✓							
	p	2	pl 114(1–5,7)				✓							
	p	7	p 292(4), pl 115(1–8)				✓							
s	1	p 290(3)						✓						
s	p	1	p 292(9), pl 144(8–10)					✓						
s	p	2	p 290(5), 293(1,2)							✓				
–	–		pl 108(1–3), 109							✓				
s	p	1	p 298(1), pl 117			✓								
s	p	2	p 290(6), pl 116								✓			
s	p	1	p 293(3), pl 118		✓									
s	1	p 185(1)		✓										
s	1	p 185(7)									✓			
s	1	p 185(8)					✓							
p	2	fig 33		✓										

K. lutinumerus



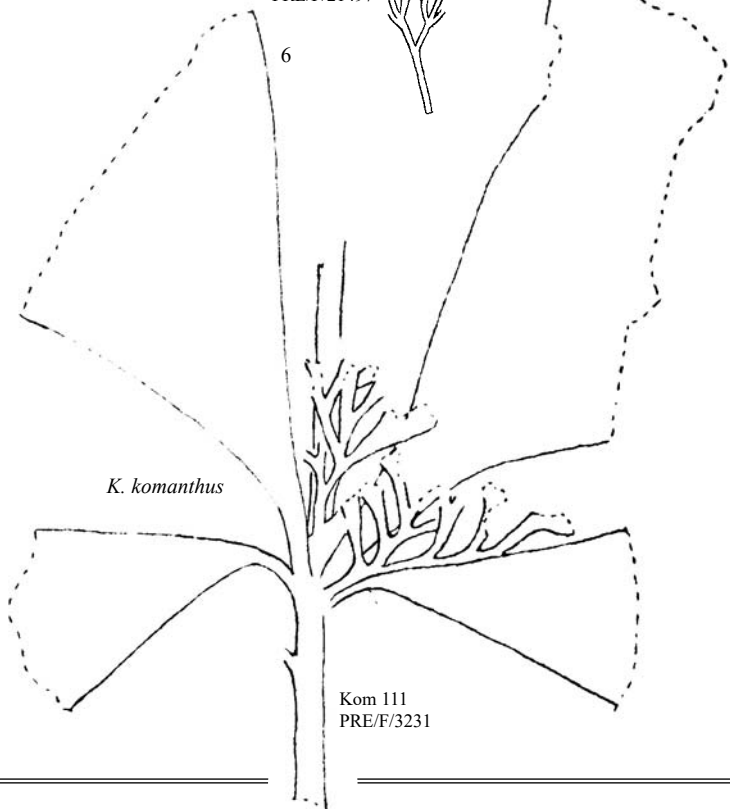
Lut 311
PRE/F/11434a

K. telepentatus



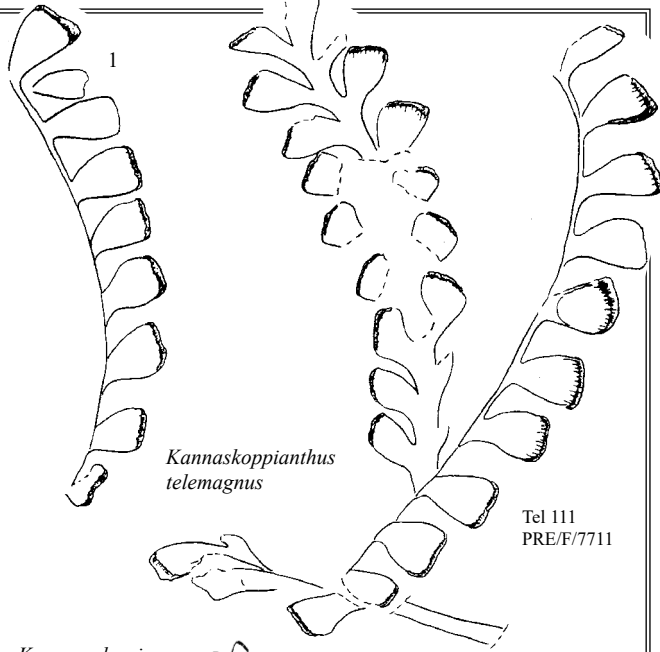
Tel 111
PRE/F/18277a,b

K. komanthus



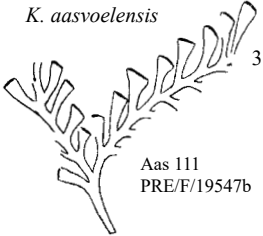
Kom 111
PRE/F/3231

K. telemagnus



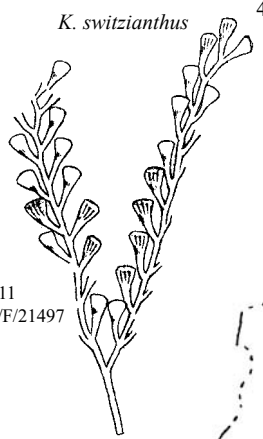
Tel 111
PRE/F/7711

K. aasvoelensis



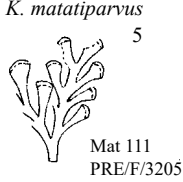
Aas 111
PRE/F/19547b

K. switzianthus



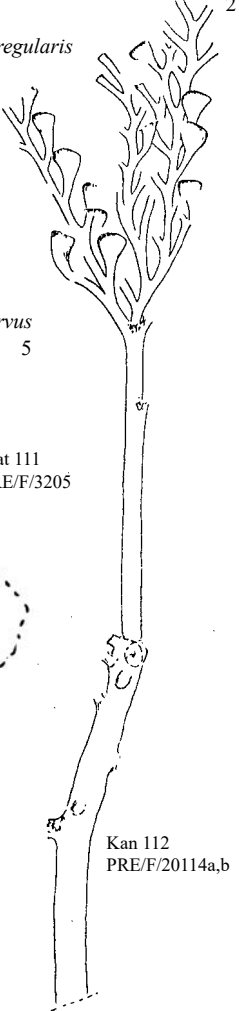
Lit 111
PRE/F/21497

K. matatiparvus



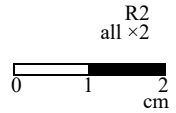
Mat 111
PRE/F/3205

K. irregularis



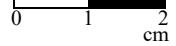
Kan 112
PRE/F/20114a,b

K. ternae



R2
all ×2

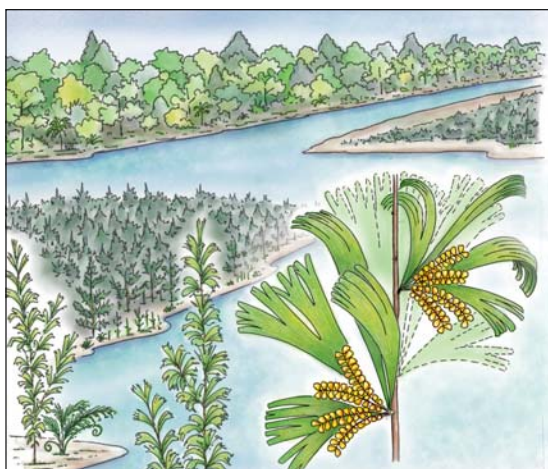
P. triangulata



0 1 2
cm

SYSTEMATICS

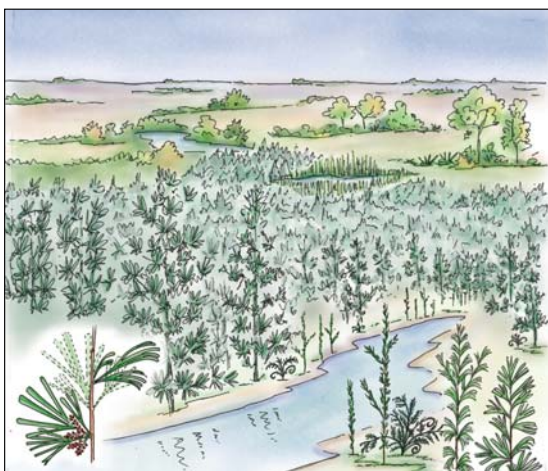
Hypodigm



Telemachus Spruit (Tel 111 Hei elo)



Matatiele (Mat 111 Dic dub)



Aasvoëlberg (Aas 111 Hei elo)



Kommandantskop (Kom 111 Sph/Dic)



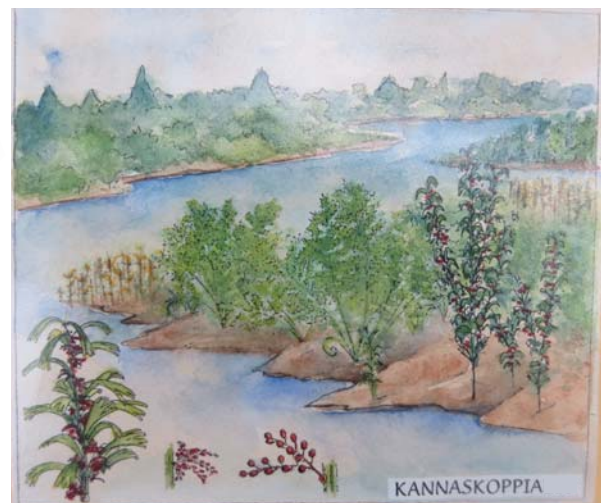
PART 3

THE WHOLE-PLANT GENUS & SPECIES



Ultimately, it is the whole-plant that we wish to visualize. As realistically as possible, let us imagine we're exploring the Molteno landscape live, 230 million years ago around midway through the Triassic during the Heyday of the Gymnosperms. Like botanists today, during the Heyday of the angiosperms, we're out there sampling the flora, experiencing its extraordinary diversity.

We note how each species within a genus has adapted to its own particular habitat. And we appreciate how each is in symbiotic harmony with the vertebrate and invertebrate faunas that have co-evolved with them during the explosive diversification of renewed life following the end-Permian Extinction. Colour, as in today's world, adds greatly to the beauty of this terrestrial panorama.



MOLTENO HABIT & HABITAT RECONSTRUCTIONS

Introduction

The habitats (Triassic scenarios showing where the plants grew) presented here are based on contextual information gleaned from taphonomic factors (how and where the fossils were deposited) and other clues (related deposits, extant plants, etc.). A similar exercise was undertaken in reconstructing the Molteno sphenophytes (And. & And., 2018). Reconstructing the form and habitat of these Molteno fossil plants is problematic as the basic information is often limited and various assumptions have to be made. However, it is a useful exercise as it forces the researcher to record what is known and to point out where gaps in knowledge exist.

It is fortunate that the Molteno Fm. has a good example of a crevasse splay deposit (locality Kannaskop, Kan 111, Cairncross *et al.*, 1995) where rapid burial has reduced taphonomical biases and led to the discovery of unique stems with attached leaves and female fruits (And. & And., 2003). All other Molteno localities show evidence of variously slower accumulation of fossils in rivers and lakes or through periodic flooding in the floodplain. To date, there is no evidence of volcanic ash having been preserved in the Molteno. Where this does occur over a broad extent, it is possible to accurately reconstruct the ancient landscape, as has been undertaken by Oplustil *et al.* (2014) for a peat-forming plant assemblage in the Middle Pennsylvanian from the Czech Republic; and by Wang *et al.* (2012) from the Permian of Mongolia. A useful review of reconstructions of past floras is provided by DiMichele & Gastaldo (2008) in their paper “Plant Palaeoecology in Deep Time”.

A summary of the evidence used to reconstruct the Antarctic *Rochipteris* plant is presented below, followed by that for the Molteno.

Antarctica habit reconstruction

Bomfleur *et al.* (2013) and Bomfleur *et al.* (2014, fig. 8, p. 1070) reconstructed the petriellalean (*Rochipteris*) plants as “low-growing, shade-adapted, perennial evergreens” and regarded them as pioneers and colonizers that “litter large quantities of seeds through ballistic dispersal”. Their reconstruction was based on the following considerations.

Link of stem to leaf

From their study of silicified peat (uppermost part of Member C, Fremouw Formation, Beacon Supergroup, Antarctica) the affiliation of stems described as *Rudoxylon serbetianum* and *Rochipteris* leaves was established. This was based on the similarities of the “basal leaf cross sections” and the “leaf traces in the cortical cushions of the foliated stem portions”.

In support of this is a comparison of the other stems in the peat, namely *Kykloxylon* (*Dicroidium* wood) and *Notophytum* (*Heidiophyllum* wood) which differ in morphology and size.

Nature of stem

Stems are “diminutive (<3 mm thick)”.

Contain up to four growth rings (see Fig. 4A,F).

Growth ring anatomy (gradual transition).

From this they inferred that the plants were less than a metre tall, perennial (grew up to four years) and evergreen.

Leaf anatomy

Shade-adapted leaves indicated by cellular structure of leaves found in peat.

Glands indicate durability.

Incurved leaf margins indicate ability to “acclimatise to unfavourable conditions”.

Seeds

Reported are the “vast number and small size of their seeds—borne in dehiscent seedpods” indicating a pioneer plant (but this is not substantiated with a reference).

Taphonomic features

The localities, namely Allan Hills and Alfie’s Elbow, both show evidence of “high-energy depositional events” based on the “assortment of otherwise rare plant taxa and the extraordinary high proportion of attached organs”.

Molteno habit reconstructions for *Kannaskoppia/Kannaskoppianthus/Rochipteris* whole-plants

For the plant-reconstruction drawings that follow, six points were taken into consideration. The evidence available for each is listed according to place of origin.

1. Nature of leaf attachment to stem

Molteno

Kan 111 – there are five sections of stem with foliage and strobili attached, and 12 sections with only foliage attached. These all show the leaf attached to a bulbous leaf cushion which is interpreted as a possible young short shoot by analogy to extant species with long/short shoot morphology, e.g. *Ginkgo biloba*.

Tel 111 – many leaves (c. 10) are attached to a stem (PRE/F/17406 & 17416, p. 70(1)), but due to their overlapping nature, the stem is not visible. The leaves are clustered into about four groups, indicating that each cluster arises from a common point of origin. A second specimen (PRE/F/12876, p. 70(4)) has three leaves attached to a bulbous leaf cushion and two other leaves closely associated.

Nymboida

Leaf whorls have been described in three species, but the actual attachment to the stem is difficult to decipher as in each case it is partly obscured by matrix.

Antarctica

In describing a specimen with leaves similarly attached, Bomfleur *et al.* (2014) used a different terminology (details below).

2. Number of leaves in a whorl/group attached to a bulbous leaf cushion

We assume there are generally about four leaves per group and this is shown in most of the reconstructions.

Molteno

Kan 111 – often less, usually two leaves (pp 67, 68).

Tel 111 – about four leaves per group in PRE/F/17406 & 17416 (p. 70(1)), three plus two in PRE/F/12876 (p. 70(4)).

Cyp 111 – four leaves attached in PRE/F/18751 (p. 96(1))

Nymboida

Leaves have been described as attached in close spirals along the stem in three species. The actual attachment is difficult to interpret. In Holmes & Anderson (2005, fig. 18B) up to seven leaves occur in a whorl and these may be grouped into three plus four leaves each, while another whorl shows six leaves all about equally spaced with some from a lower level (fig. 20).

Antarctica

Leaves attached to a stem were described by Bomfleur *et al.* (2014) as “each arising at an angle from a short (c. 1 mm long), apically inclined, cone shaped cushion-like protrusion of the cortex”. Based on the drawing (fig. 2C), the stem is 37 mm long (in their text it is given as 6 cm, but it is not clear how that was measured or if it included the leaves. From the photograph (fig. 2A), three leaves appear to arise from the same point on the stem (possibly at the tip) while some others appear to be individually attached.

New Zealand

Retallack (1980, fig. 9C; 1983, fig. 7E) illustrated two groups of 2–3 leaves that arise from a common point of origin.

Argentina

Herbst. *et al.* (2001, fig. 8L) illustrated a slab which shows two leaves lying almost parallel and possibly having a common origin.

3. Distance (spread) between leaves or bulbous leaf cushions along the stem

Molteno

Kan 111 – from 8–13 mm on mature stems bearing strobili and leaves; 5–25 mm on stems bearing only leaves (some of these may be regarded as long shoots, i.e. first year of growth).

Kan 112 – the stem with an attached male strobilus shows a similar morphology and 5–13 mm between leaf cushions.

Tel 111 – see discussion above.

Antarctica

Bomfleur *et al.* (2014, fig. 2A) show leaves attached at 5–10 mm (possibly up to 15 mm) intervals.

4. Size variation of leaves

Molteno

The attached leaves or those in a cluster are fairly constant in size and shape. However, the collections for a population (palaeodeme) show variable leaf sizes, beyond that chosen for the reconstruction which is regarded as representative for the palaeodeme.

Nymboida

Leaves occur in close spirals or whorls in three species. In *R. obtriangulata* Holmes & Anderson (2005, fig. 18B), the complete leaves are remarkably similar in size and this probably holds for the other two species; but as some leaves are incomplete this cannot be ascertained.

Antarctica

Bomfleur *et al.* (2014, fig. 2A): the attached and associated leaves are all very similar in size.

5. Width of stem

All known stems are of relatively small diameter as indicated.

Molteno

Kan111 – 2–4 mm; various known stems, some with female strobili attached (PRE/F/13487,13505) and others with leaves only (PRE/F/13521,13522).

Kan112 – 2.5 mm; one stem with male strobilus attached (PRE/F/20114).

Kom111 – 2 mm; one stem with male strobilus and leaves attached (PRE/F/3231a,b).

Antarctica

Allan Hills – c. 1 mm; one stem with leaves attached, Bomfleur *et al.* (2014, fig. 2A).

Alfie's Elbow – 1–3 mm; and permineralized stems, Bomfleur *et al.* (2014, fig. 4).

6. Branching

There is no evidence of branching available from any Gondwana Triassic deposits, but it has been introduced in some reconstructions to add variety and show the possibility of such.

Molteno Habitat

General; Habitats 1–7

The molteno habitats were first described by Anderson *et al.* (1998) and are summarized here in Part. 1 (pp 8, 9). There is a strong link between particular habitats and different *Kannaskoppia/Rochipteris* whole-plant species, as this discussion elaborates, and as is reflected in Tab.1 (pp 12, 13).

Heidiphyllum thicket (Habitat 5)

The most common habitat for the *Kannaskoppia/Rochipteris*

plant is the *Heidiphyllum* thicket; represented by 11 TCs. Two species occur in the *Heidiphyllum* thicket on channel sandbars in the braided-river system (Type 5b) and four species in the floodplain (Type 5a). The two species (*R. telefolia* and *R. distivena*) in Type 5b have relatively large leaves, while species with smaller leaves generally occur in Type 5a. In the latter, the leaves are undivided in *R. penensis* and *R. pusilla*, partly divided in *R. lutifolia*, and have up to two divisions in *R. rollerii*. Within this extensive habitat on the floodplain, these species are considered as occupying different niches.

Heidiphyllum was reconstructed by Anderson *et al.* (1998) and And. & And. (2003, p. 91) as belonging to a large erect shrub to small conical tree. Subsequently, Bomfleur *et al.* (2013) using information from permineralized fossils, reconstructed it as a conical tree 10–15 m tall and suggested the whole-plant should be called *Telemachus* after the female cone. Their proposal that the affiliated male cone is *Switzianthus* appears very unlikely as was discussed by Anderson *et al.* (2019b). The male cone is most probably *Odyssianthus* as initially suggested by And. & And. (2003, p. 84). In the Molteno habitat reconstructions, the *Telemachus/Heidiphyllum* plant is represented as a small immature tree in the flood plains or sand banks and as a tall mature tree elsewhere in the riverine forests.

Dicroidium riparian forest (Habitats 1 & 2)

A fairly common habitat for the *K/Rochipteris* plant is the *Dicroidium* riparian forest: three of the species, *R. switzifolia*, *R. obtriangulata* and *R. cf. sinuosa*, occur in the mature (type 1) and one, *R. matatifolia*, in the immature (type 2) versions of the forest.

Fern/*Kannaskoppia* meadow (Habitat 7)

A distinct habitat was named after the *K/Rochipteris* plant as the *Fern/Kannaskoppifolia* meadow by Anderson *et al.* (1998); and is here updated to *Fern/Kannaskoppia* meadow. The specimens with the unique attached female fruit and leaves from the Kan 111 TC are from this habitat. Only from one other TC (Kom 111), have we found attached fruit (in this case male) and foliage (*R. komifolia*). Of interest is that in the *Heidiphyllum* thicket (Habitat 5), *Rochipteris* often occurs in association with ferns (e.g. Tel 111 Hei elo, Aas 111 Hei elo).

Dicroidium woodland (Habitat 3)

From the *Dicroidium* woodland there occurs only one species, *R. lutifolia* (Cyp 111 Dic cra), that is well represented; while three further TCs have yielded isolated leaves from various other species.

Sphenobaiera woodland (Habitat 4)

From the *Sphenobaiera* woodland two species occur: *R. komifolia* from Kom 111 Sph/Dic, and *R. rollerii* from Aas 411 Dic/Sph. The latter is also the most common species in the *Heidiphyllum* thicket.

Equisetophyte marsh (Habitat 6)

From the Equisetophyte marsh there occurs only a single leaf from Gre 111 Equ sp recorded as species indet.

Molteno habit reconstruction notes

For each species of whole-plant the evidence and considerations used for the reconstructions are discussed.

Kannaskoppia vincularis / *Rochipteris vincularis*

Ref. pal.: Kannaskop Kan 111 Ast spA

Habit: Based on the collection of five sections of shoot with foliage and megasporophylls attached, plus 12 sections of shoot with foliage, this is the most secure of all the reconstructions. It was the first to be reconstructed and placed in its habitat (Cairncross *et al.*,

1995; And. *et al.*, 1998; And. & And., 2003). The initial concept is here retained. It is reconstructed as a slender erect woody shrub up to 1 m in height. Branching has been added as a possibility but there is no evidence for it.

Habitat: The *K. vincularis* plants are reconstructed as growing in Fern/*Kannaskoppia* meadows on channel sandbars in the braided-river system (Habitat 7). Subsequent to the initial publication of this habitat the fern element has been described as *Rooitodites integra* by And. & And. (2008, p. 56). This is now one of the few ferns in the Molteno and Gondwana Triassic known as a whole-plant with complete fronds attached to *in situ* rhizomes.

Kannaskoppianthus telemagnus* / *Rochipteris telefolia

Ref. pal.: Telemachus Spruit, Tel 111 Hei elo

Habit: Reconstructed as slender erect woody shrubs up to 1.5 m. This is regarded as the tallest of the Molteno *Rochipteris* species. The *R. telefolia* leaves in the Tel 111 TC range from 80–140 mm in length. The reconstructed leaf shoot (shown at $\times 1$ and $\times 1/2$) reflects this size range. One particular specimen (in two parts, PRE/F/17406a,b; PRE/F/17416, p70(1)) shows four to five groups of leaves, though none with their points of attachment are preserved. The lower portion shows the base, or near-base, of four leaves which, by their close proximity, suggests a common point of origin. These are depicted in the reconstruction as attached to a bulbous leaf cushion (as seen in specimens from Kan 111, pp 67, 68). As the actual attachment to the stem is not visible, these leaves could also be arranged spirally, as occurs on a long shoot in the extant *Ginkgo*. The attachment of a single clear cluster is evident in PRE/F/12876 (p. 70, fig. 4; pl. 43(4–6)). In the whole-plant reconstruction (p. 127), the leaves are depicted in a spiral arrangement near the tip and on a lower side-branch, whilst elsewhere as clusters spirally attached. Though evidence of branching is as yet unknown, it is considered a possibility as the plant is known to be woody (Bomfleur *et al.* 2014) and probably perennial.

Habitat: The *R. telefolia* plants are envisaged as growing in patches near the water's edge alongside a *Heidiphyllum* thicket (Habitat 5b, p. 127) on channel sandbars in a braided-river system. Some distance beyond the sandbars is a *Dicroidium* (Type 2) riparian forest. The ferns recorded are *Rooitodites integra* (1 indiv.), *Elantodites turneri* (51 indivs) (see And. & And., 2008, p. 86 for species description; p. 89 for position in Molteno floodplain biome), *Dictyophyllum bremerense* (4 indivs) and *Cladophlebis rosemariae* (2 indivs). *E. turneri* is well-represented in the collection with both fertile (7 indivs) and sterile fronds (44 indivs) and regarded as growing on the channel sandbars and probably in association with *R. telefolia*. The other three fern species could derive from the sandbars, where they would be very rare, but are considered as more likely derived from further afield in the *Dicroidium* riparian forest where they would be more common. The other gymnosperm species in the Tel 111 TC are considered to be mainly derived from this riparian forest: *Dicroidium* four species (6%), *Lepidopteris stormbergensis* (1%), *Ginkgoites telemachus* (23 indivs) and *Taeniopteris* two species (2%).

Kannaskoppianthus irregularis* / *Rochipteris distivena

Ref. pal.: Kannaskop, Kan 112 Hei elo (Upper End)

Habit: Reconstructed as slender erect woody shrubs up to 1 m in height. Only four leaves are known from the Kan 112 TC with this distinctive open venation and these range from 60 to an estimated 100 mm in length. The most complete leaf is the smallest (BP/2/3386); a nearly complete one (BP/2/3387) has the tips missing; and the largest (PRE/F/20120) has the base and tips missing. In the shoot reconstruction these three leaves are represented with the affiliated male strobilus. As the true length of these leaves is unknown, the reconstructed leaves in the $\times 1/10$ view have mainly been based on the length of the most complete leaves (60–80 mm). In general outline these leaves are similar to *R. telefolia*, but in venation they are clearly distinct.

Habitat: These *Rochipteris* plants are considered to be growing in clearings in a *Heidiphyllum* thicket (Habitat 5b, p. 8 (Fig. 1)) on channel sandbars in a braided-river system. Some distance beyond the sandbars is a *Dicroidium* (Type 2) riparian forest. The other very rare floral elements recorded from this TC are considered as being derived from this forest. This species, depicted as growing in a *Heidiphyllum*-clearing, is thus similar to *R. penensis* which also grows in such clearings but in the floodplain (Habitat 5a).

Kannaskoppianthus aasvoelensis* / *Rochipteris rollerii

Ref. pal.: Aasvoëlberg, Aas 111 Hei elo (Turner Shale)

Habit: Reconstructed as slender erect woody shrubs up to 1 m in height. Evidence of branching is unknown for this species but considered a possibility. This is by far the most common of the Molteno *Rochipteris* species, occurring in a total of 14 TCs. The palaeodemes reflect a broad range of leaf shape, with from few to many segments. The reconstructed leaves are depicted with 3–6 segments.

Habitat: For the Reference palaeodeme, it is regarded as growing in an area of high water table in the *Heidiphyllum* thicket of the floodplain. Here it is shown scattered near the water's edge around a small lake or marshland within the thicket. The dominants in the associated flora consist of *Heidiphyllum elongatum* (77%) and the fern *Cladophlebis janetae* (20%). This fern is shown as growing beside *R. rollerii* with fronds up to 400 mm in length. *R. rollerii* is also fairly common in a further two TCs in quite different habitats – namely Umk 111 Dic 2spp (21 indivs, riverine forest, Habitat 1) and Aas 411 Dic/Sph (2%, *Sphenobaiera* woodland, Habitat 4). This possibly reflects the taxonomic complexity in an ever-evolving flora and shifting habitats over one or two million years.

Kannaskoppianthus switzianthus* / *Rochipteris switzifolia

Ref. pal.: Little Switzerland, Lit 111 Dic/Hei

Habit: Reconstructed as slender erect woody shrubs up to 0.8 m in height with possible branching. The leaves in this palaeodeme show a wide range of variation, from those with two divisions as occur in *R. rollerii* to the more complex ones with up to four divisions and numerous segments (see pp 88, 89). In the reconstruction, the more divided leaves are depicted. The leaf species shows relatively minor differences from *R. matatifolia* and the main reason for considering them as separate species is the affiliation of the male strobili which show more distinct differences (as discussed elsewhere, pp 45, 46).

Habitat: This species is considered to be growing along the river margin bordered by *Dicroidium* riparian forest (type 1, mature). The forest is dominated by *Dicroidium* (50%), with *D. odontopteroides* the most common of the many species (And. & And., 1983). Lit 111 differs from Umk 111 and Mat 111, which also occur in this habitat, by having a far higher percentage of *Heidiphyllum elongatum* (23%) and is the only one to include *Dejerseya lunensis* (20%) (And. & And., 1989, p. 259). So far there are few clues as to what kind of plant *Dejerseya* may have been (And. & And., 1989, p. 256). Elsewhere it occurs in TCs dominated by *Heidiphyllum* (Aas 411, 80%; Win 111, 79%; Gre 121, 81%). At Lit 111, the probability is that both *Heidiphyllum* and *Dejerseya* washed in from a *Heidiphyllum* thicket habitat on a nearby riverine sandbank opposite the riverine forest. The habitat reconstruction sketch shows only the riverine forest with a great variety of plants (25 genera as recorded by And. & And., 2003, p. 10) and dominated by *Dicroidium* trees.

Kannaskoppianthus matatiparvus* / *Rochipteris matatifolia

Ref. pal.: Matatiele, Mat 111 Dic dub

Habit: Reconstructed as slender erect woody shrubs up to 0.8 m in height with possible branching. See notes given for the similar species *R. switzifolia*.

Habitat: This is considered to be growing along the edge of a river

alongside the *Dicroidium* riparian forest (type 2, immature) habitat. It occurs in a similar habitat to Lit 111 with *R. switzifolia* and hence the reconstruction shows many parallels. *Dicroidium* is dominant (89%), with *D. dubium* the most common species. In the reconstruction a twig with leaves of *D. dubium* has been inserted and is represented by the large tree in the foreground. A shrub of the long-leaved *Taeniopteris anavolans* (2%, And. & And., 1989, p. 374) is depicted in the foreground (front left).

Kannaskoppianthus komanthus* / *Rochipteris komifolia

Ref. pal.: Kommandantskop, Kom 111 Sph/Dic

Habit: Reconstructed as slender erect woody shrubs up to 0.8 m in height with possible branching. The reconstruction of the leaf shoot is based on two attached specimens (PRE/F/3227 and PRE/F/3231a,b). The latter specimen also has male strobili, *Kannaskoppianthus komanthus*, attached.

Habitat: This is considered to be a pioneer plant along the margin of small lakes, bordered by *Sphenobaiera* woodland, in the floodplain (Habitat 4). At this TC, *Sphenobaiera schenckii* (60%) is the dominant leaf species; and a twig with leaves is shown close up with many such trees in the background. The co-dominant, *Dicroidium crassinervis* (39%) is also depicted as a tree in the lakeside vegetation. The fern *Cladophlebis katherinae* (1%) is quite common and probably grew associated with *R. komifolia* near the water's edge, as depicted in the reconstruction.

Kannaskoppianthus luterius* / *Rochipteris lutifolia

Ref. pal.: Lutherskop, Lut 311 Hei elo (Oom-Piet's Campsite)

Habit: Reconstructed as slender erect woody shrubs up to 0.6 m in height. The extensive palaeodeme (66 indivs) reflects a broad range of leaf size from small to medium and occasionally with a cleft. The reconstructed leaf shoot reflects this range. To date, no attached leaves are known from this TC.

Habitat: Based on the reference palaeodeme, the species is regarded as growing in the *Heidiphyllum* thicket of the floodplain close to a seasonal stream draining into a small lake. This TC is dominated by *Heidiphyllum elongatum* (99%), but due to intensive sampling (50 man-hrs cleaving), a diverse flora of 19 species in 12 genera is known (And. & And., 2003, 2008, 2018). Many of these plants are seen as growing fairly distant from the deposition site across the small lake – as depicted in the habitat reconstruction. This species also occurs commonly at Cyp 111 Dic cra, a *Dicroidium* woodland site (Habitat 3, p. 8 (Fig. 1)).

Rochipteris obtriangulata

Ref. pal.: Umkomaas, Umk 111 Dic. 2spp (Waterfall Locality)

Habit: Reconstructed as slender erect woody shrubs up to 0.6 m in height. This species is represented by two attached leaf clusters from the Nymboida Flora (Australia). The reconstruction is partly based on these, with four leaves per cluster being considered most likely.

Habitat: As this species occurs in relatively low numbers, it is considered to be growing some distance from the deposition site, and possibly near the edge of, or in the undergrowth of, the riparian forest. *Dicroidium* (69%) is dominant at this TC, with *D. orbiculoides* and *D. elongata* being about equally common. The large tree to the left represents *D. orbiculoides*. The fern *Cladophlebis moltenensis* possibly grew alongside *Rochipteris* and has been added in the foreground of the sketch. The great diversity of plants occurring at Umk 111 (31 genera, 75 species) is reflected in the reconstruction sketch – though none of the others are singled out as representing any particular species.

Rochipteris cf. sinuosa

Ref. pal.: Umkomaas, Umk 111 Dic 2spp (Waterfall Locality)

Habit: Reconstructed as slender erect woody shrubs up to 0.4 m in height. The reconstruction is based on the leaves (with missing bases) from the Molteno. The only known leaf from Nymboida (Australia) shows a flanged base – which is not reflected in this reconstruction.

Habitat: This is a fairly rare species in the Molteno and is considered to be growing far from the deposition area, possibly in the undergrowth of the riparian forest. Being from the same TC as *R. obtriangulata*, the habitat reconstruction shows many similarities.

Rochipteris penensis

Ref. pal.: Peninsula, Pen 411 Hei elo (Lunchspot)

Habit: Reconstructed as slender erect woody shrubs up to 0.25 m in height. This is based on a small collection of 10 leaves and is a particularly small *Rochipteris* plant.

Habitat: Regarded as growing within clearings in the *Heidiphyllum* thicket of the floodplain. These clearings are possibly formed because they are either drier or wetter than the surroundings. The associated flora is comprised largely of *Heidiphyllum elongatum* (94%), sphenophytes (2%), ferns (3%, mostly *Cladophlebis rosemariae*) and a *Kurtzia* species awaiting description (50 indivs). The latter possibly grew in close proximity to *Rochipteris penensis*. They have not been depicted in the habitat reconstruction, the intent being to emphasize the clearing in the thicket.

Rochipteris pusilla

Ref. pal.: Peninsula, Pen 311 Hei elo (Campsite Quarry)

Habit: Reconstructed as slender erect woody shrubs up to 0.2 m in height. This is the smallest *Rochipteris* species in the Molteno and, although it occurs at four TCs, it is extremely rare.

Habitat: Regarded as growing in the undergrowth of the *Heidiphyllum* thicket of the floodplain. Besides *Heidiphyllum elongatum* (75%), *Dicroidium coriaceum* (25%) is recorded. However, this always occurs on separate bedding planes to *Rochipteris* and is regarded as having grown further afield and deposited in times of minor floods. *D. coriaceum* has thus not been depicted in the habitat sketch. An additional few non-gymnosperms have been recorded from this locality (And. & And., 2003, 2008, 2018).

TCs with attached organs

A total of five (of the 26) have yielded attached foliage and/or strobili specimens.

Stratigraphic occurrence – interestingly, they occur in sequence in the upper part of the Mayaputi M, and lowest part of the overlying Qiba M.

Geographic occurrence – all five of these TCs occur in the southern outcrop belt (Cyp 111, Kan 111, Kan 112), or just to its north (Kom 111, Tel 111).

Ecological occurrence

Kan 111 Ast spA: the only TC with female strobili (and includes 5 indivs with foliage mutually attached)

Kom 111 Sph/Dic: the only TC with male strobili and foliage mutually attached

Cyp 111 Dic cra: with many attached or clustered leaves (but with no affiliated strobili)

Tel 111 Hei elo: with attached & clustered foliage; and affiliated male (2 indivs)

Kan 112 Hei elo: with no attached or clustered foliage; and with one attached affiliated male.

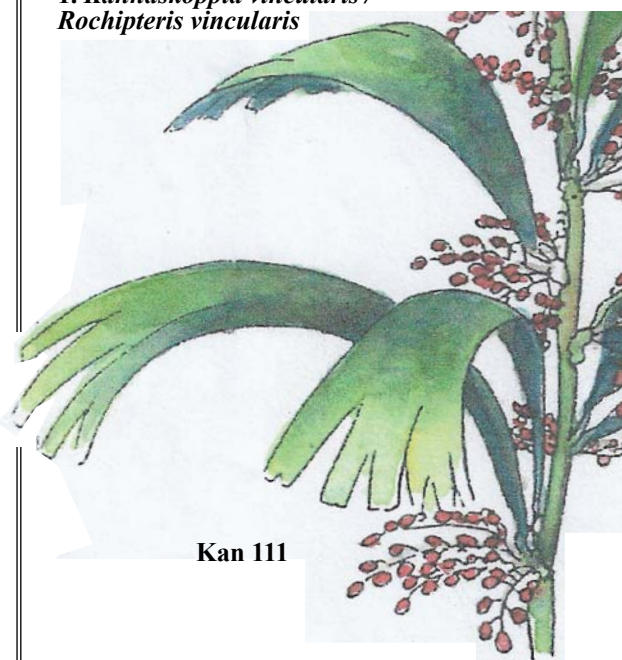
Colour renderings of the Molteno whole-plant Petriellales species

Portraying the Carnian heyday of the gymnosperms in the Triassic explosion of diversity following the end-Permian extinction.

Colour renderings of the foliage and fruiting organs are added as an integral part of the habit and habitat of the 12 Molteno whole-plant species recognized. Like with the angiosperms today, where the foliage of every species of tree or shrub within any genus or stretch of countryside appears to show a different variation of green, so it might be expected amongst the gymnosperms during their heyday of diversity. We reflect that concept in the reconstructions that follow, depicting the leaves showing a range of possible green colours for each species; and likewise for the fruiting bodies: in this case the spectrum from red, through orange to yellow is adopted.

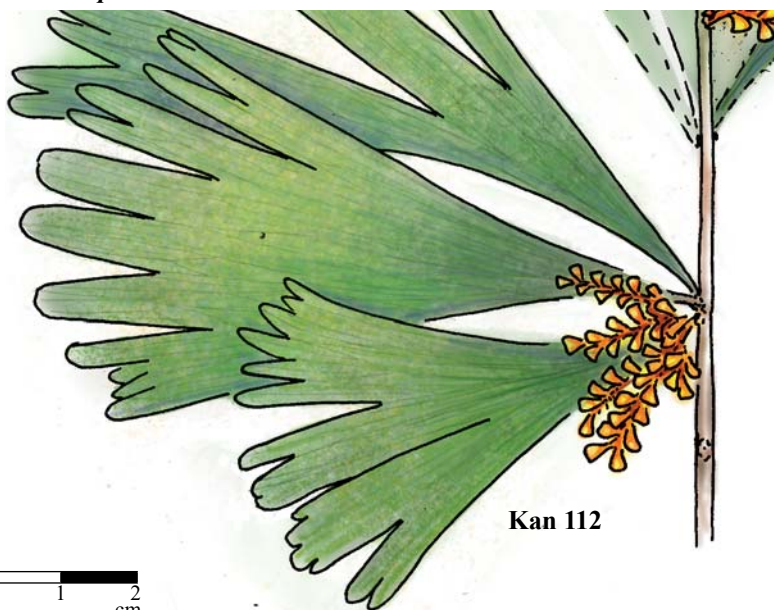
Original ink-sketch reconstructions by HMA;
colour rendering by Clara Anderson.

1. *Kannaskoppia vincularis* / *Rochipteris vincularis*

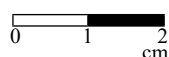


Kan 111

3. *Kannaskoppianthus irregularis* / *Rochipteris distivena*



Kan 112

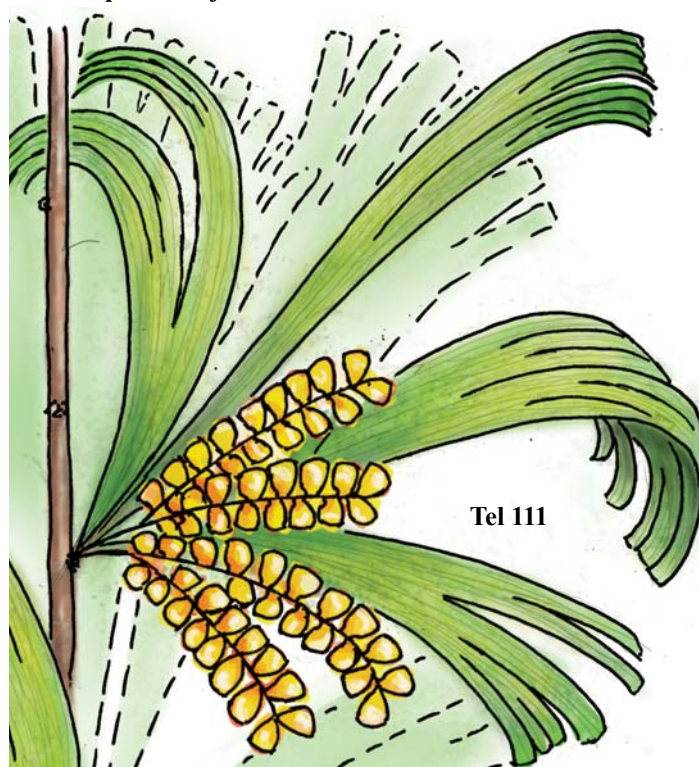


The 12 Molteno whole-plant Petriellales species

(Reference palaeodemes in brackets)

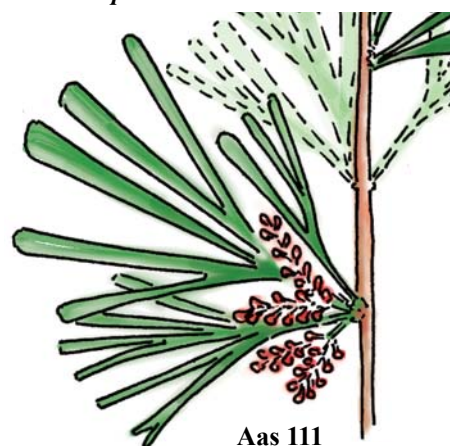
1. *Kannaskoppia vincularis*/*Rochipteris vincularis* (Kan 111)
2. *Kannaskoppianthus telemagnus*/*Rochipteris telefolia* (Tel 111)
3. *Kannaskoppianthus irregularis*/*Rochipteris distivena* (Kan 112)
4. *Kannaskoppianthus aasvoelensis*/*Rochipteris rollerii* (Aas 111)
5. *Kannaskoppianthus switzianthus*/*Rochipteris switzifolia* (Lit 111)
6. *Kannaskoppianthus matatiparvus*/*Rochipteris matatifolia* (Mat 111)
7. *Kannaskoppianthus komanthus*/*Rochipteris komifolia* (Kom 111)
8. *Kannaskoppianthus lutinumerus*/*Rochipteris lutifolia* (Lut 311)
9. *Rochipteris obtriangulata* (Umk 111)
10. *Rochipteris* cf. *sinuosa* (Umk 111)
11. *Rochipteris penensis* (Pen 411)
12. *Rochipteris pusilla* (Pen 311)

2. *Kannaskoppianthus telemagnus* / *Rochipteris telefolia*



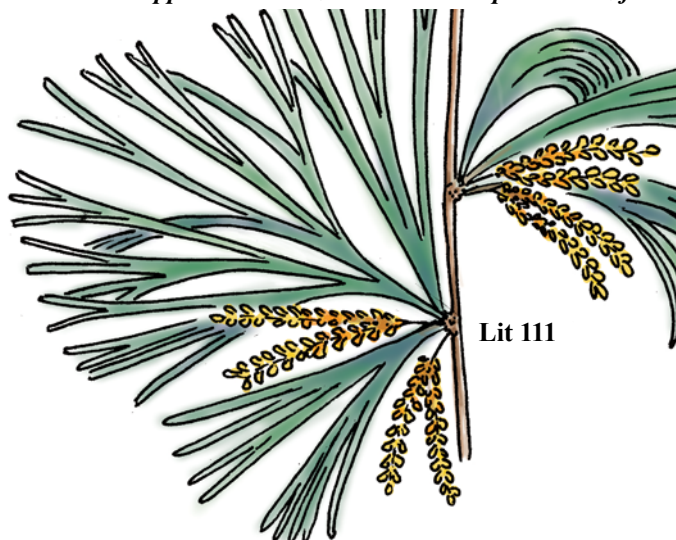
Tel 111

4. *Kannaskoppianthus aasvoelensis* / *Rochipteris rollerii*

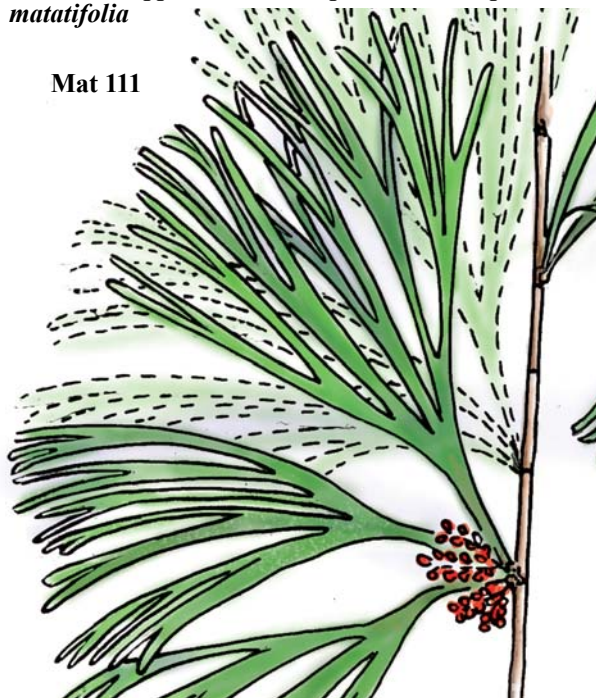
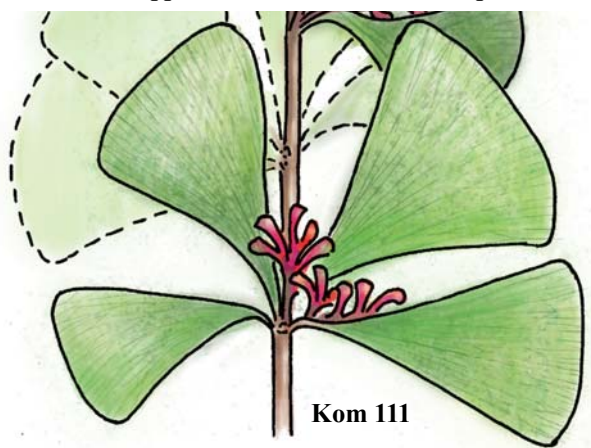
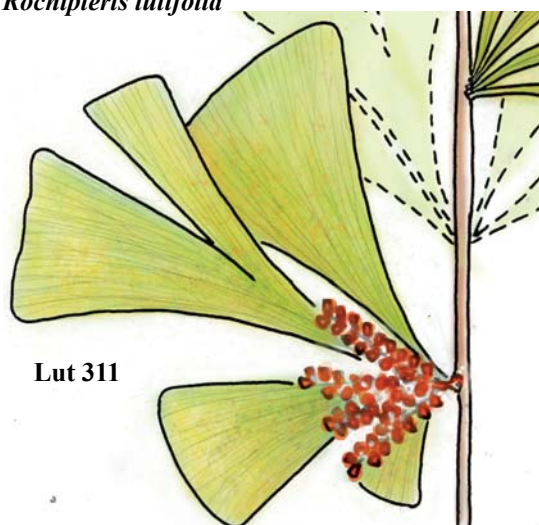
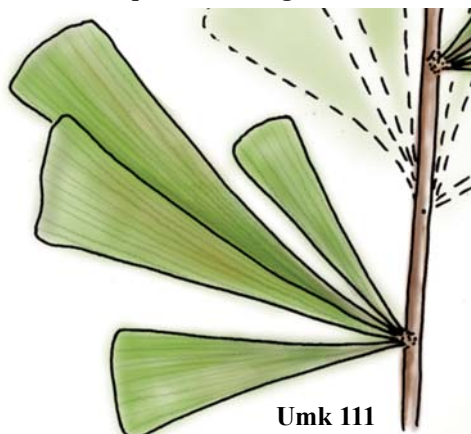


Aas 111

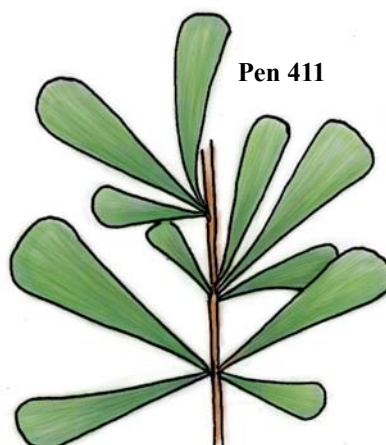
R4
all ×1

5. *Kannaskoppianthus switzianthus* / *Rochipteris switzifolia*6. *Kannaskoppianthus matatiparvus* / *Rochipteris matatifolia*

Mat 111

7. *Kannaskoppianthus komanthus* / *Rochipteris komifolia*8. *Kannaskoppianthus lutiunus* / *Rochipteris lutifolia*9. *Rochipteris obtriangulata*10. *Rochipteris* cf. *sinuosa*11. *Rochipteris penensis*

Pen 411

12. *Rochipteris pusilla*

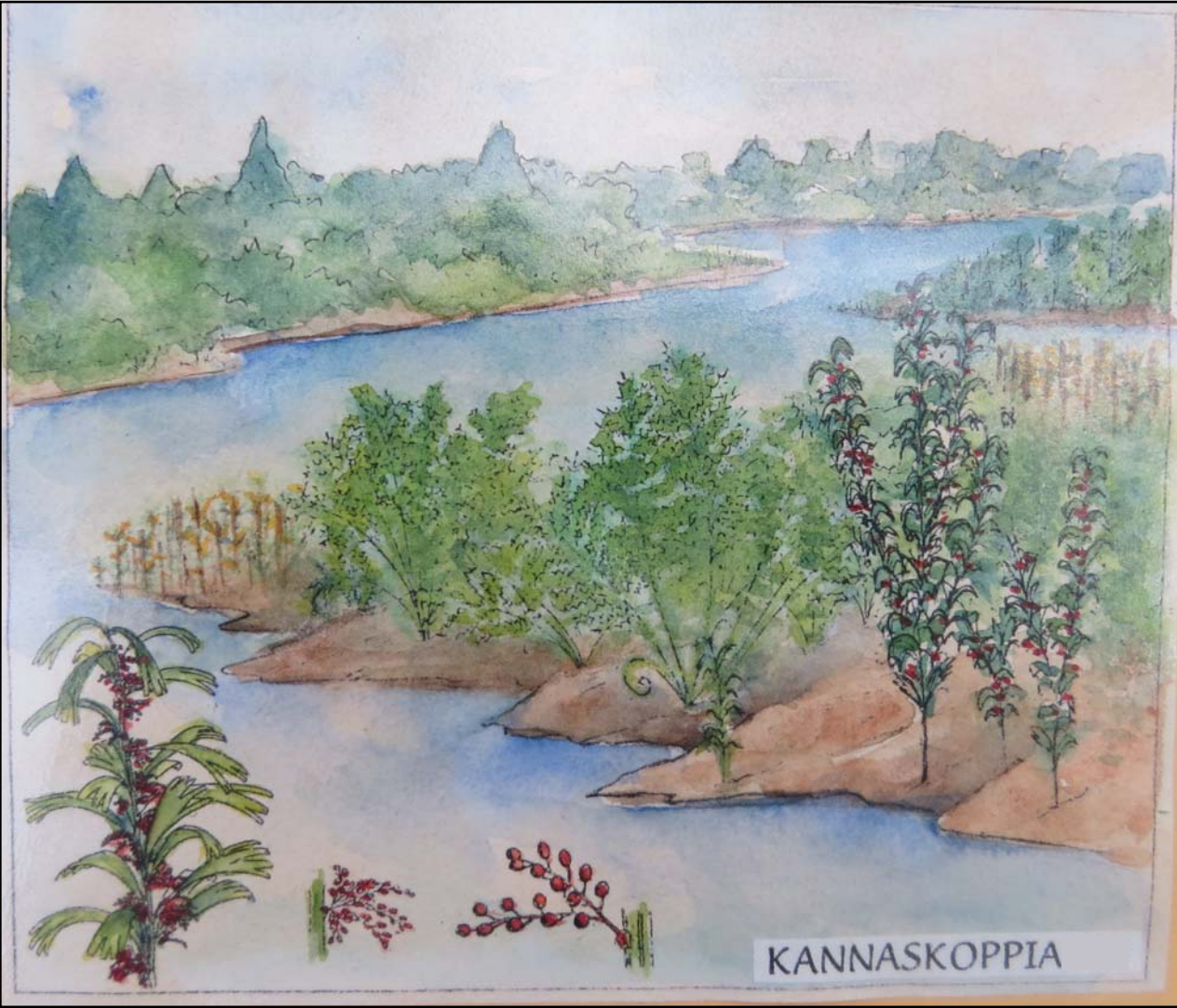
Pen 311

R4
all ×10 1 2
cm

Kannaskoppia vincularis / *Rochipteris vincularis*

Kannaskoppia (Kan III Ast spA)

1



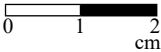
HMA, 1995

Whole-plant species (male-foliage)

Foliage – *Rochipteris vincularis* And. & And., 2003
Ref. pal.: Kan 111 Ast spA – 5% of assemblage (c. 45 slabs;
4 att. leaves & ♀; 12 att. leaves only; >25 indiv. leaves)
Female strobilis – *Kannaskoppia vincularis*
Ref. pal.: Kan 111 Ast spA – 50 indivs (4 att. ♀ & leaves)
Affiliation (female/foliage) – Grade 5 (attached)
Rarity () – 5% of assemblage (common)
Taphonomy – autochthonous
Habit – slender erect woody shrubs up to 1.0 m in height
Habitat – Fern/*Kannaskoppia* meadow; channel sandbar in braided-river system

Kannaskop (Kan 111 Ast spA) TC
Collection – 365 slabs, 30 man-hrs cleaving
Dominants – ferns 63%, horsetails 22%, *Heidiphyllum* 10%
Biodiversity – vegetative total, 6 spp
Non-gymnosperms 4 spp; gymnosperms 3 spp
Other Kannaskoppiaceae: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudoctenis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris

Gnetopsida

Genera (×5)

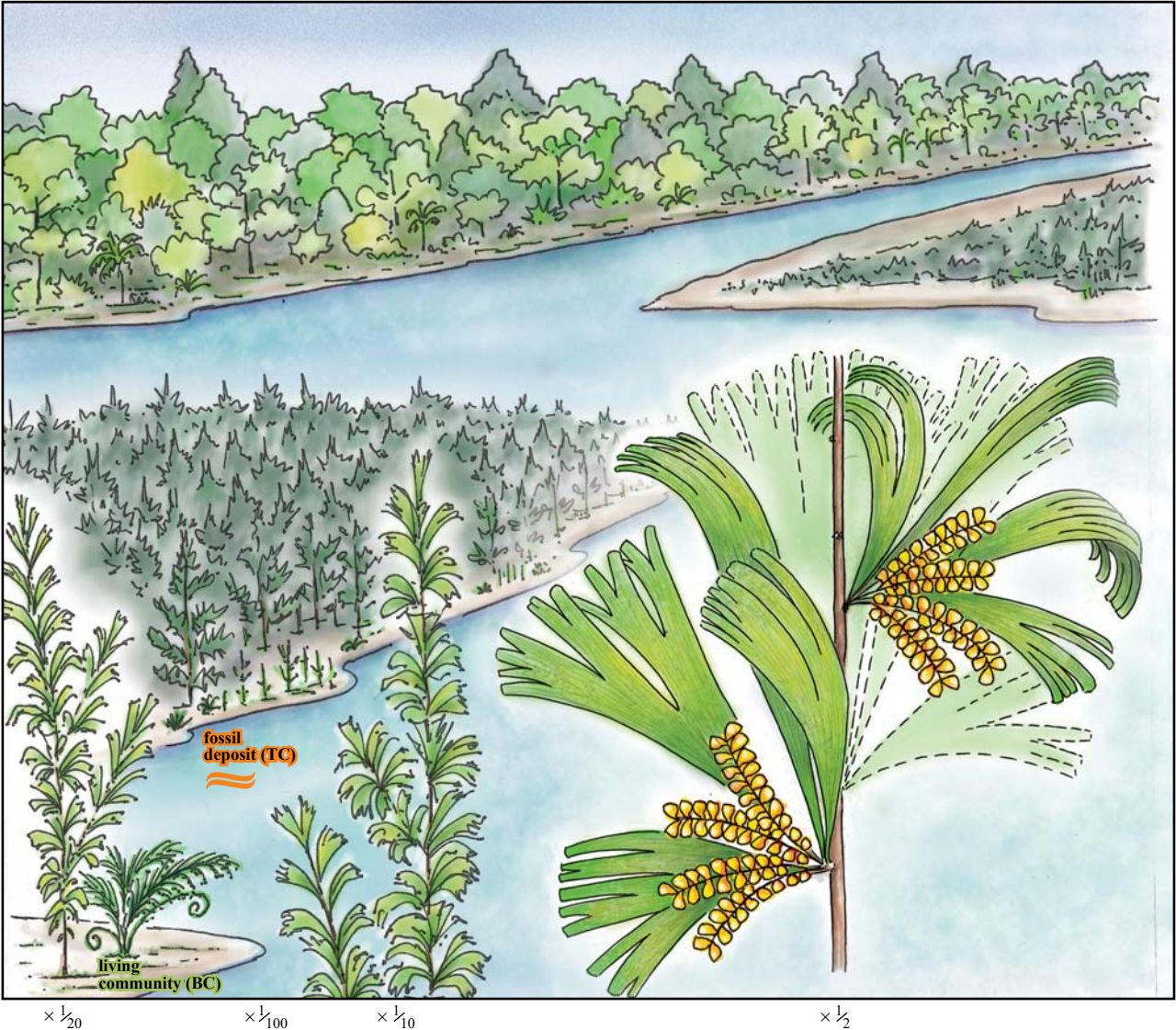
TC as @ Kan 111		
gen	spp	indivs
–	–	–
–	–	–
–	–	–
–	–	–
2	2	22%
1	1	63%
–	–	–
1	1	10%
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
1	1	5%
1	1	2
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
6	6	

Key
5%: of TC
2 indivs in TC

Kannaskoppianthus telemagnus / *Rochipteris telefolia*

Telemachus Spruit (Tel 111 Hei elo)

1



Whole-plant species (male-foilage)

Foliage – *Rochipteris telefolia* And. & And., sp. nov.
Ref. pal.: Tel 111 Hei elo – 30 indivs (2 att., 1 cluster, 27 isol. leaves)
Male strobilis – *Kannaskoppianthus telemagnus* And. & And., 2003
Ref. pal.: Tel 111 Hei elo – 2 indivs (1 cluster of 4 detached strobilus limbs, 1 fragment)
Affiliation (male/foilage) – Grade 4 (good), both spp unique to Tel 111
Rarity (Ø) – 30 indivs in 90 man-hrs (1 per 3 man-hrs); rare
Taphonomy – autochthonous-parautochthonous;
medium-energy flow regime
Habit – slender erect woody shrubs up to 1.5 m in height
Habitat – *Heidiphyllum* thicket; channel sandbar in braided-river system;
growing in patches near the water’s edge.

Telemachus Spruit (Tel 111 Hei elo) TC

Collection – 581 slabs, 90 man-hrs cleaving
Dominants – *Heidiphyllum* 89%, *Dicroidium* 6%, ferns 58 indivs
Biodiversity – vegetative total, 20 spp
Non-gymnosperms 7 spp, gymnosperms 13 spp
Other Kannaskoppiaceae:
Foliage: *R. pusilla* (1 indiv), *R. penensis* (2 indivs)
Strobili: *Kannaskoppianthus telemagnus* (2 indivs)
K. telepentatus (2 indivs)

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes

Moltano foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudoctenis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)

Bennettitopsida

Halleyoctenis
Taeniopteris

Gnetopsida

Genera (×5)

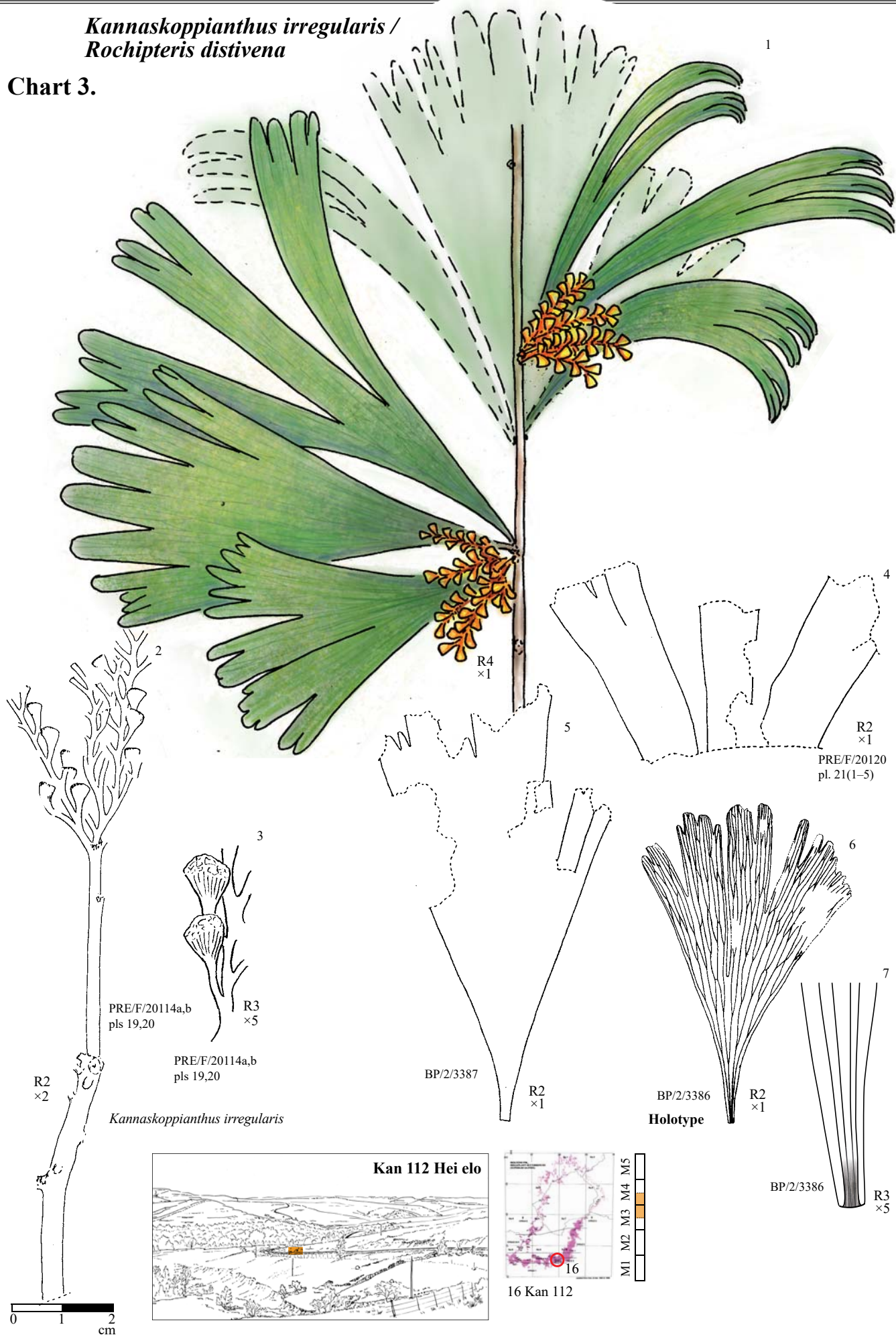
TC as @ Tel 111		
gen	spp	indivs
–	–	–
1	1	1%
–	–	–
–	–	–
–	–	–
3	3	48
*	3	58
1	1	89%
–	–	–
–	–	–
–	–	–
–	–	–
1	1	1%
1	1	23
–	–	–
1	4	6%
1	3	33
–	–	–
1	1	1
–	–	–
1	2	2%
–	–	–
11 gen	20 spp	

Key
6%: of TC
33 indivs in TC

HMA & Clara A., June 2020

Kannaskoppianthus irregularis /
Rochipteris distivena

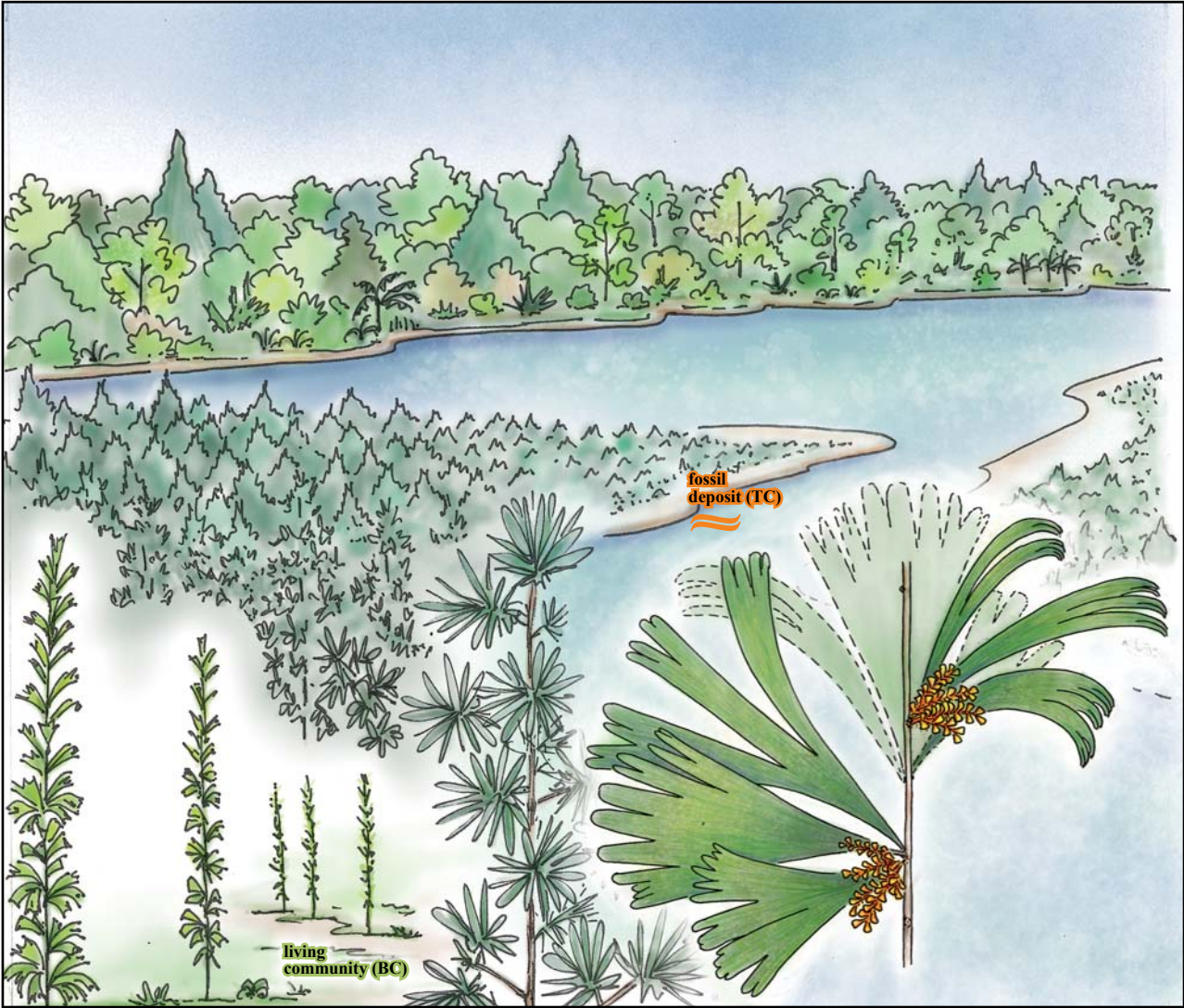
Chart 3.



Kannaskoppianthus irregularis / *Rochipteris distivena*

Kannaskop (Kan 112 Hei elo)

1



HMA & Clara A., June 2020

Whole-plant species (male-foilage)
Foliage – *Rochipteris distivena* And. & And., sp. nov.
Ref. pal.: Kan 112 Hei elo – 4 indivs (attached & clusters nil)
Male strobilis – *Kannaskoppianthus irregularis* And. & And., 2003
Ref pal.: Kan 112 Hei elo – 5 indivs
Affiliation (male/female) – Grade 3 (fair), other options less likely
Rarity () – 4 indivs in 13 man-hrs (1 per 3 man-hrs); rare
Taphonomy – parautochthonous
Habit – slender erect woody shrubs up to c. 50 cm in height
Habitat – *Heidiphyllum* thicket; channel sandbar in braided-river system.

Kannaskop (Kan 112 Hei elo) TC
Collection – 145 slabs, 13 man-hrs cleaving
Dominants – *Heidiphyllum* 98%
Biodiversity – vegetative total, 13 spp
Non-gymnosperms 4 spp, Gymnosperms 9 spp
Other Kannaskoppiaceae:
Foliage: *R. rollerii* (10 indivs), *R. telefolia* (2 indivs),
R. pusilla (1 indiv), *R. penensis* (2 indivs)
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes

Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudocallis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris

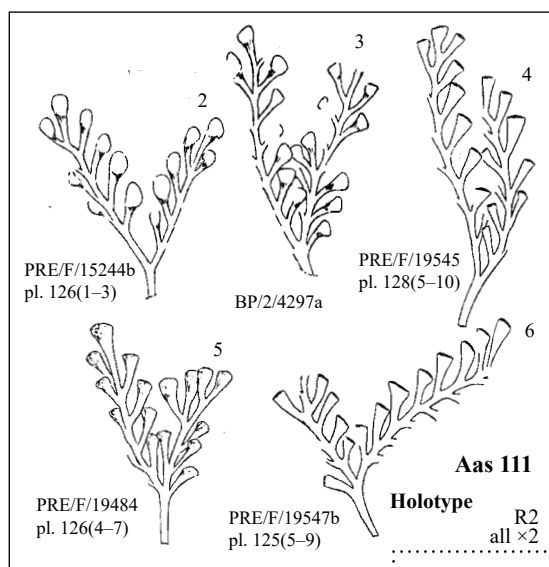
Gnetopsida

Genera (×5)

TC as @ Kan 112		
gen	spp	indivs
–	–	–
–	–	–
–	–	–
–	–	–
1	1	6
2	2	7
–	–	–
1	1	98%
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
1	1	1%
1	5	19
–	–	–
–	–	–
1	1	2
–	–	–
1	1	1
–	–	–
–	–	–
8 gen	13 spp	

Key
1%: of TC
19 indivs in TC

Chart 4.

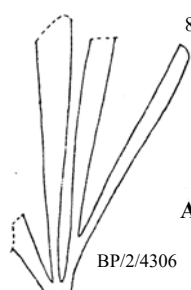
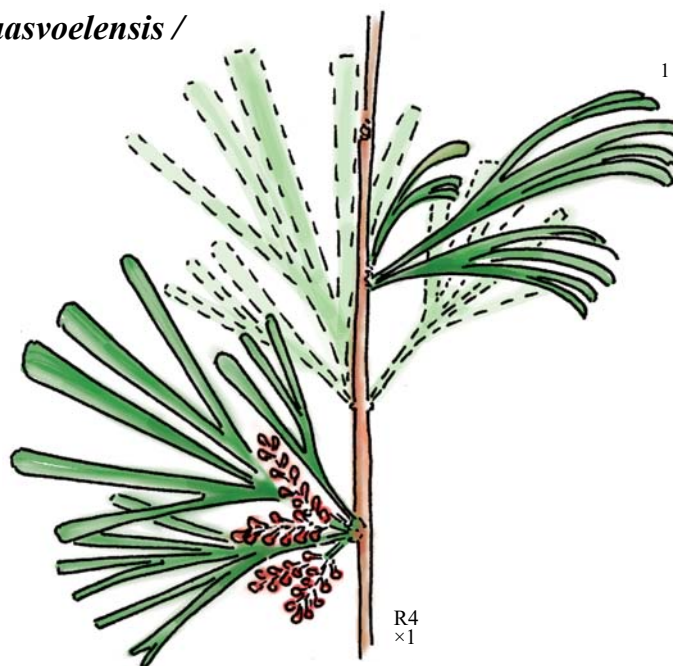
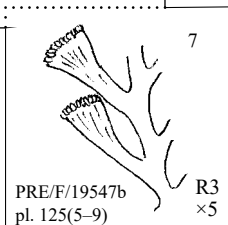
Kannaskoppianthus aasvoelensis /
Rochipteris rollerii*Kannaskoppianthus aasvoelensis*

10 indivs total
7 indivs drawn
6 indivs graphed

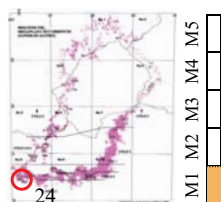
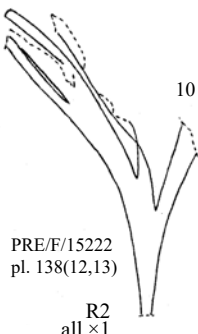
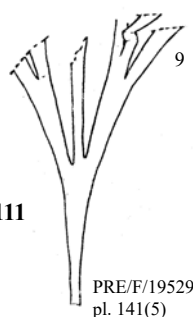
Aas 111 Hei elo

	1	2	3	4	5	6	7	8	9	10
4										
3										
2										
1										

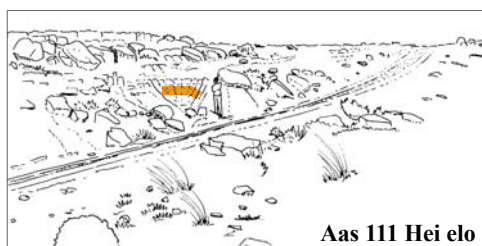
microsporophylls



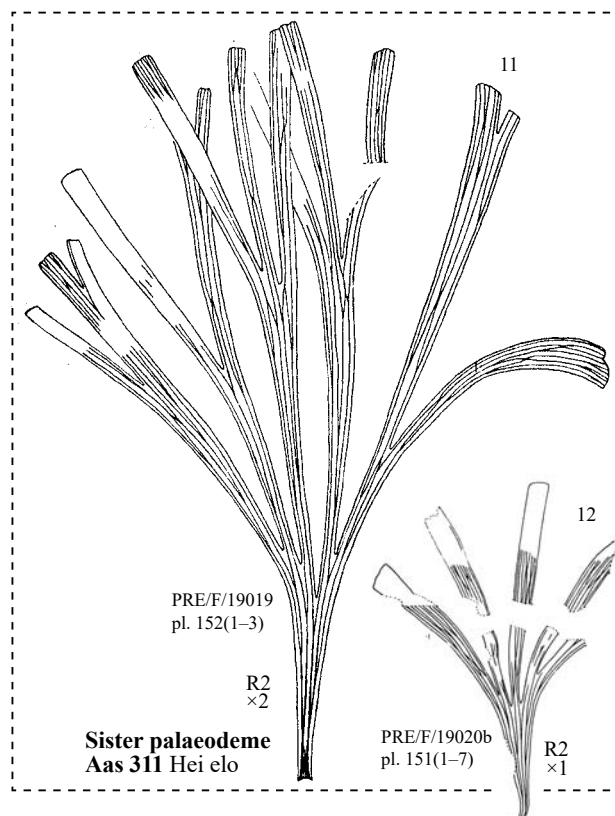
Aas 111



24 Aas 111



Aas 111 Hei elo



Aas 111 Taphonomy (elaborated)

A counterpart to the two *Heidiphyllum*-thicket Peninsula sites (Pen 311 and Pen 411) near the eastern corner of the southern outcrop belt of the Molteno, are three *Heidiphyllum*-thicket Aasvoëlberg sites (Aas 111, Aas 211, Aas 311) at the western corner of the outcrop. They likewise occur along strike, in this case, with some 7 km separating them.

It is relevant to consider the rarity of *Dicroidium* and *Sphenobaiera*, dominants in the woodland further afield:

Aas 111: *Dicroidium* (7 indivs), *Sphenobaiera* (1 indiv) – in 40 man-hrs cleaving

Aas 211: *Dicroidium* (0 indivs), *Sphenobaiera* (0 indivs) – in 35 man-hrs cleaving

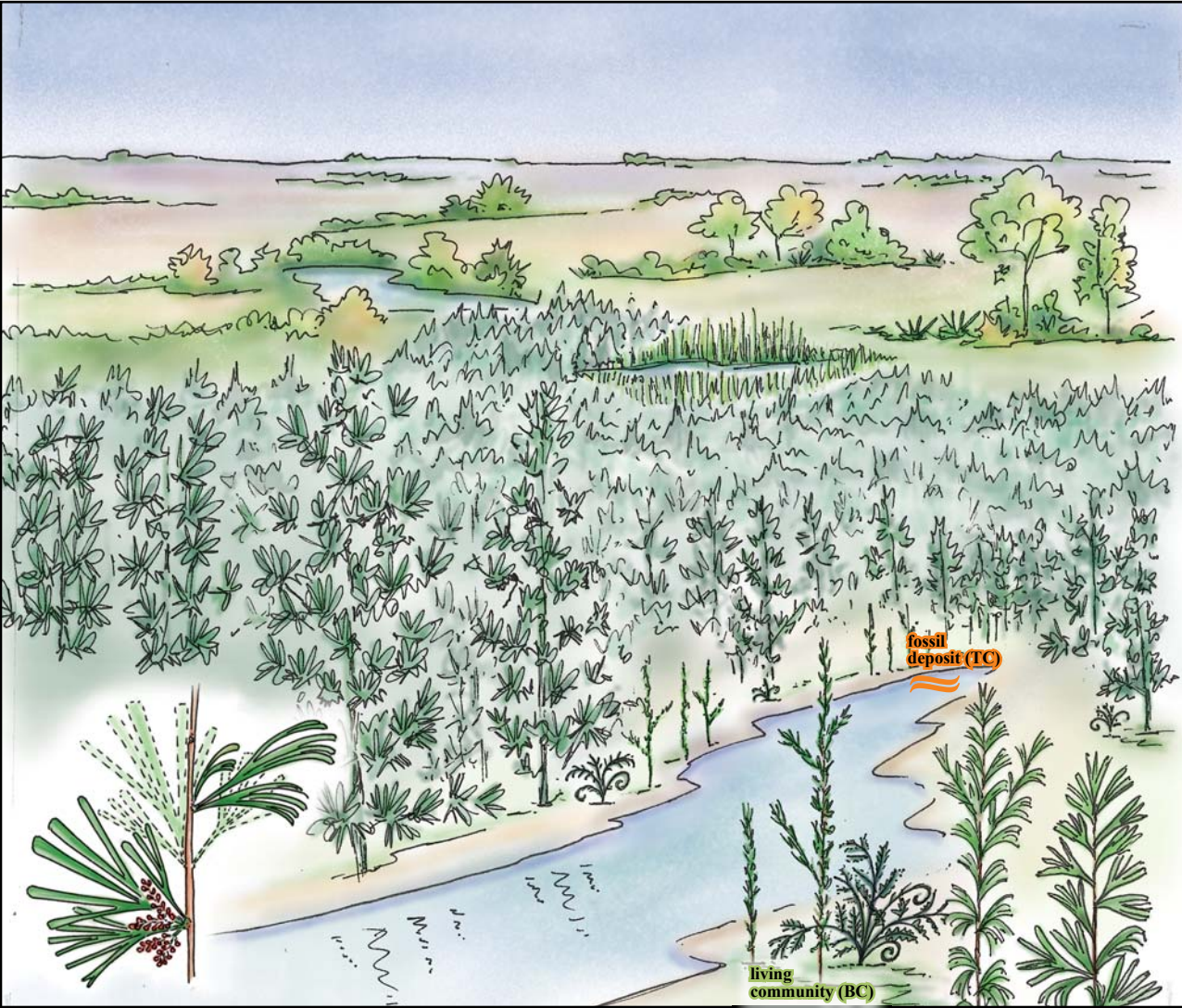
Aas 311: *Dicroidium* (15 indivs), *Sphenobaiera* (9 indivs) – in 140 man-hrs cleaving

In each case, these dominant genera out in the woodland beyond the *Heidiphyllum* thickets, are very rare to absent in the assemblages (TCs). Our interpretation, as suggested in the habitat sketch, is that the fossil deposit occurred in an area of high water table (with small transitory lakes) largely surrounded by the coniferous thicket.

Kannaskoppianthus aasvoelensis / *Rochipteris rollerii*

Aasvoëlberg (Aas 111 Hei elo)

1



HMA & Clara A., June 2020

Whole-plant species (male-foliage)

Foliage – *Rochipteris rollerii*
Ref. pal.: Aas 111 Hei elo – 2% (c. 50 slabs, att. nil, clusters 6)
Male strobilis – *Kannaskoppianthus aasvoelanthus*
Ref. pal.: Aas 111 Hei elo – 21 indivs (nil clustered or attached)
Affiliation (male-foliage) – Grade 4 (good)
Rarity () – 2% of assemblage; sparse
Taphonomy – parautochthonous
Habit – slender erect woody shrubs up to 1.0 m in height
Habitat – *Heidiphyllum* thicket; in area of high water table in the flood-plain; scattered near water’s edge around small lake or marshland within the thicket.

Aasvoëlberg (Aas 111 Hei elo) TC

Collection – 291 slabs, 40 man-hrs cleaving.
Dominants – *Heidiphyllum* 77%, ferns 20%
Biodiversity – vegetative total, 13 spp
Non-gymnosperms 7 spp, gymnosperms 6 spp
Other Kannaskoppiaceae: nil

Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudocallis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)
Bennettitopsida
Halleyoctenites
Taeniopteris

Gnetopsida

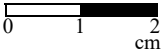
Genera (×5)

TC as @ Aas 111		
gen	spp	indivs
–	–	–
*	2	17
–	–	–
–	–	–
1	1	10
3	4	20%
1	1	77%
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
1	1	1
1	2	7
1	1	2%
–	–	–
–	–	–
–	–	–
–	–	–
1	1	2
–	–	–
–	–	–

Key
2%: of TC
2 indivs in TC

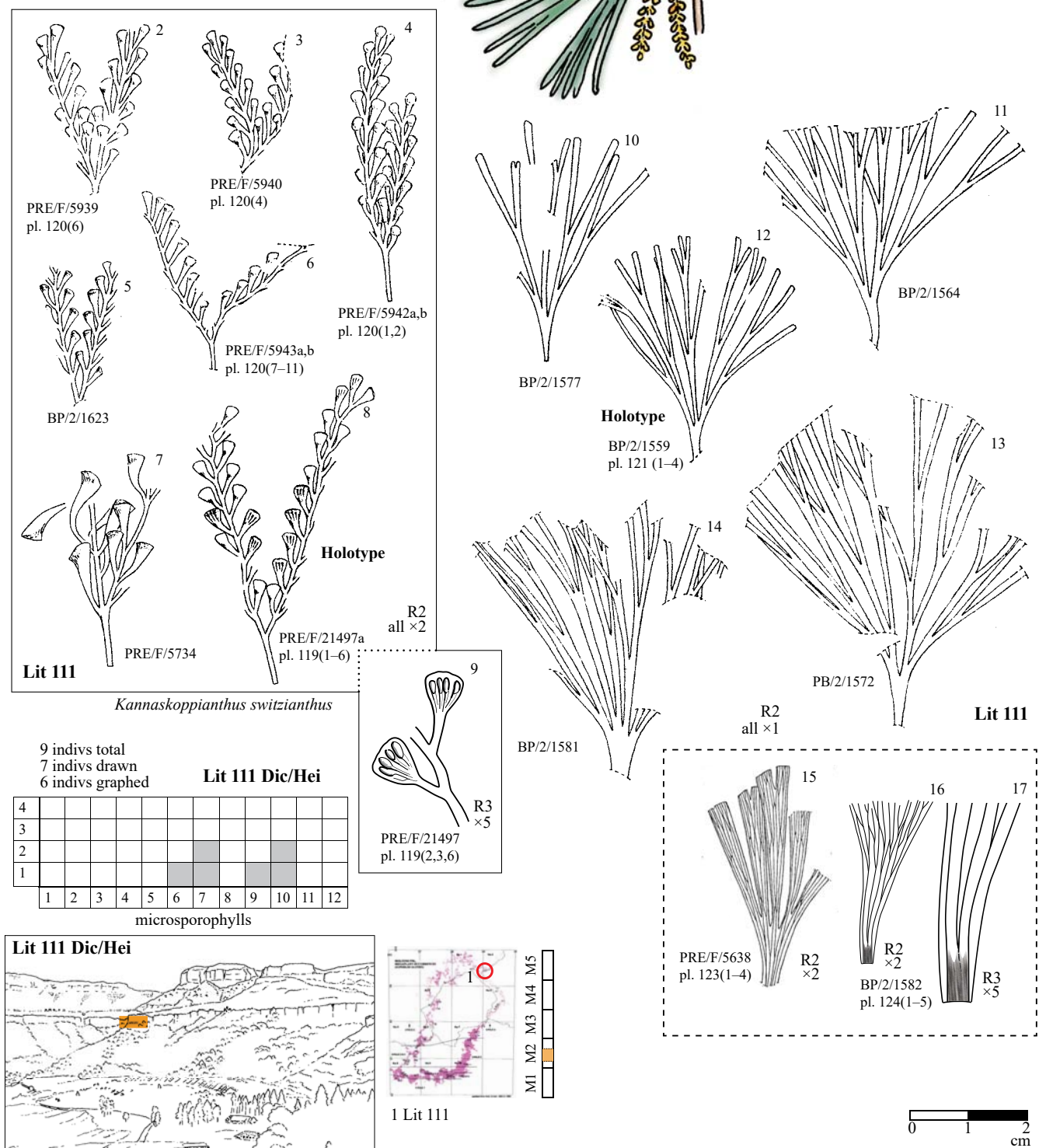
10gen 13spp

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Kannaskoppianthus switzianthus /
Rochipteris switzifolia

Chart 5.



Kannaskoppianthus switzianthus / *Rochipteris switzifolia*

Little Switzerland (Lit 111 Dic/Hei)

1



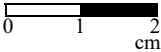
Whole-plant species (male-foilage)

Foliage – *Rochipteris switzifolia* And. & And., sp. nov.
Ref. pal.: Lit 111 Dic/Hei – 55 indivs (attached & clusters nil)
Male strobilis – *Kannaskoppianthus switzianthus* And. & And., sp. nov.
Ref. pal.: Lit 111 Dic/Hei – 9 indivs (attached & clusters nil)
Affiliation (male/foilage) – Grade 3–4 (virtually exclusive), backed up at other sites
Rarity () – 55 indivs in 550 man-hrs (1 per 1 man-hr); rare
Taphonomy – strictly allochthonous
Habit – slender erect woody shrubs up to 0.8 m in height; scattered patches a little in from water’s edge
Habitat – *Dicroidium*-dominated mature riparian forest;

Little Switzerland (Lit 111 Dic/Hei) TC

Collection – 2173 slabs, 550 man-hrs cleaving
Dominants – *Dicroidium* 50%, *Heidiphyllum* 23%, *Sphenobaiera* 1%
Biodiversity – vegetative total, 38 spp
Non-gymnosperms 6 spp, gymnosperms 32 spp
Other Kannaskoppiaceae:
Foliage: *R. vincularis* (1 indiv)
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida
Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida
Pseudoclenis
Other genera (×3)

Ginkgoopsida
Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)

Bennettitopsida

Halleyoclenis
Taeniopteris

Gnetopsida

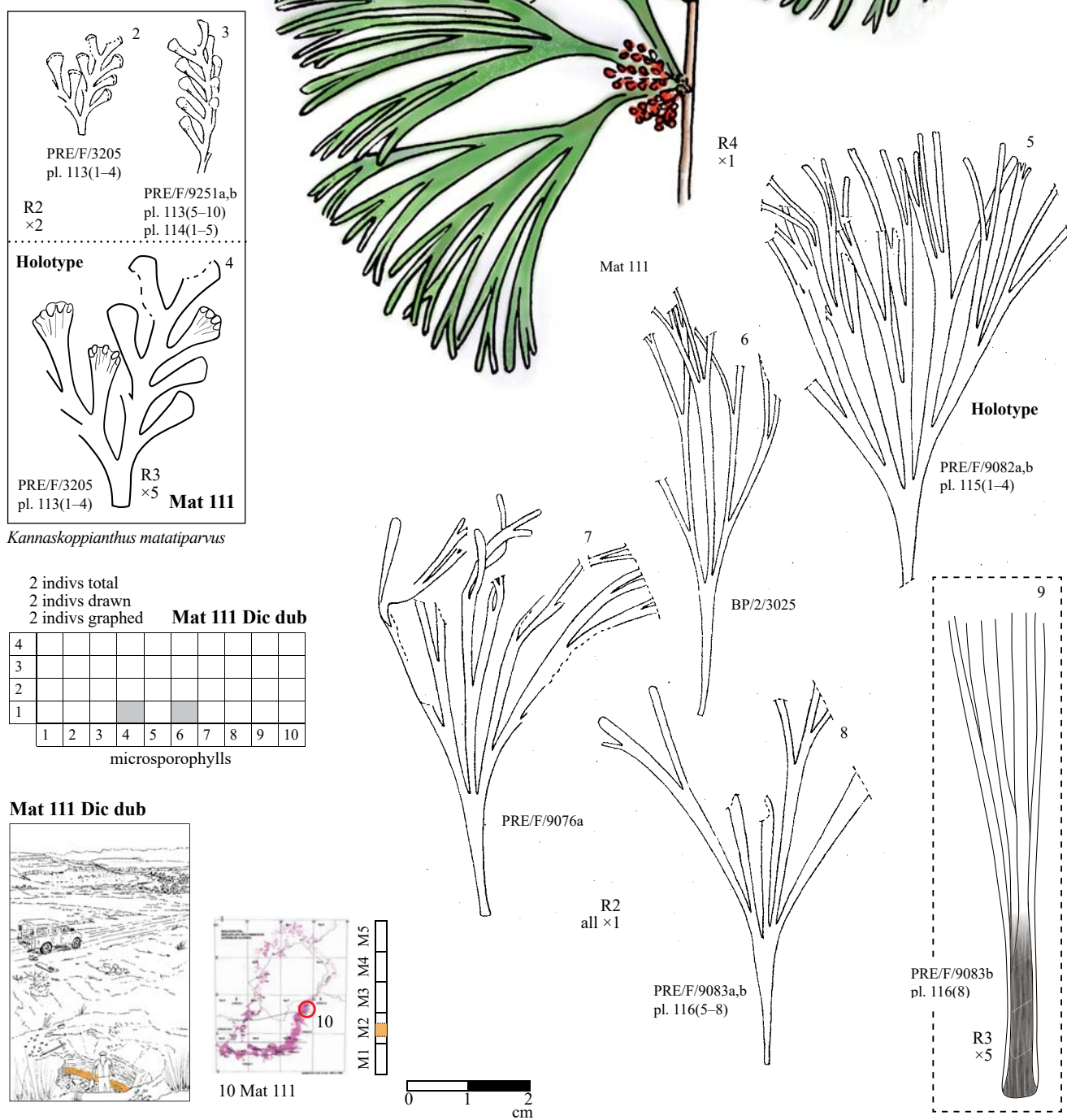
Genera (×5)

TC as @ Lit 111		
gen	spp	indivs
1	1	14
1	1	2
–	–	–
–	–	–
1	1	10
3	3	10
1	1	23%
1	1	40
–	–	–
1	2	48
2	2	7
1	1	1%
1	2	4
1	2	1%
1	8	50%
1	2	56
2	2	20%
2	2	18
1	1	8
1	2	78
3	4	54
25 gen	38 spp	

Key
50%: of TC
55 indivs in TC

Kannaskoppianthus matatiparvus /
Rochipteris matatifolia

Chart 6.



Kannaskoppianthus matatiparvus / *Rochipteris matatifolia*

Matatiele (Mat 111 Dic dub)

1



× 1/20

× 1/10

× 1/2

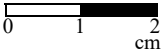
Whole-plant species (male-foliage)

Foliage – *Rochipteris matatifolia* And. & And., sp. nov.
Ref. pal.: Mat 111 Dic dub – 17 indivs (attached & clusters nil)
Male strobilis – *Kannaskoppianthus matatiparvus* And. & And., 2003
Ref. pal.: Mat 111 Dic dub – 3 indivs (attached & clusters nil)
Affiliation (male/foliage) – Grade 3 (alternative less likely)
Rarity () – 17 indivs in 65 man-hrs (c. 1 per 3 man-hrs); rare
Taphonomy – parautochthonous-allochthonous
Habit – slender erect woody shrubs up to 1.0 m in height
Habitat – *Dicroidium* riparian forest (type 2), bordering channels in immature landscape; in patches along rather broader, flatter ground adjacent to the river.

Matatiele (Mat 111 Dic dub) TC

Collection – 1082 slabs, 65 man-hrs cleaving
Dominants – *Heidiphyllum* 4%, *Dicroidium* 89%, horsetails 20 indivs
Biodiversity – vegetative total, 25 spp
Non-gymnosperms 7 spp, gymnosperms 18 spp
Other Kannaskoppiaceae:
Foliage: *R. telefolia* 2%
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudoctenis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris

Gnetopsida

Genera (×5)

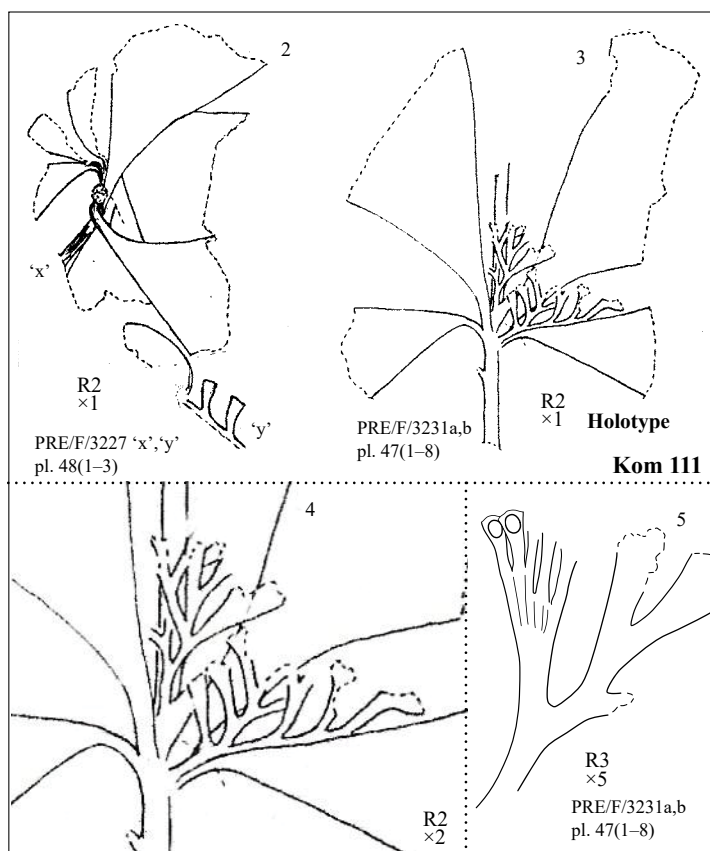
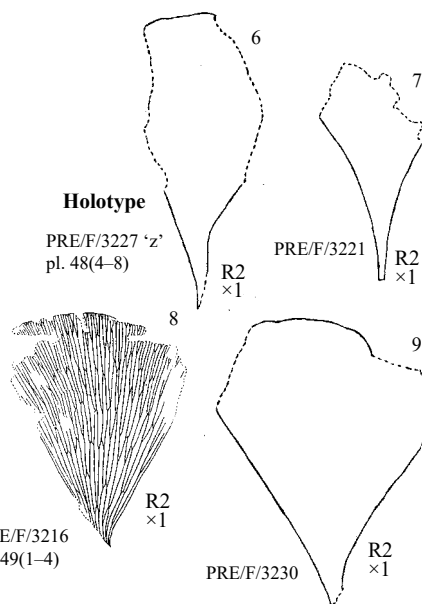
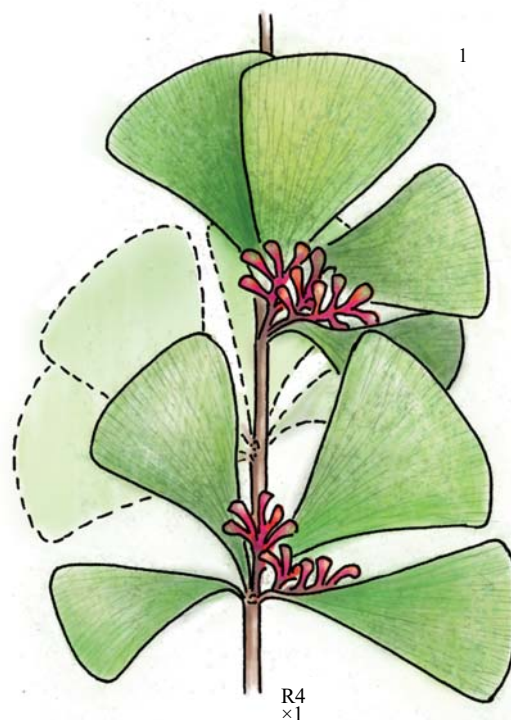
TC as @ Mat 111		
gen	spp	indivs
1	1	1
–	–	–
1	1	1
1	1	1
2	2	20
2	2	7
1	1	4%
–	–	–
–	–	–
1	2	12
–	–	–
–	–	–
1	1	1%
1	1	25
1	1	18
1	5	89%
1	2	2%
1	3	3
–	–	–
–	–	–
1	1	2%
–	–	–
1	1	2

Key
2%: of TC
3 indivs in TC

17gen 25spp

HMA & Clara A., June 2020

Chart 7. *Kannaskoppianthus komanthus* / *Rochipteris komifolia*

*Kannaskoppianthus komanthus***Holotype**PRE/F/3227 'z'
pl. 48(4–8)

PRE/F/3221

R2
×1R2
×1PRE/F/3216
pl. 49(1–4)

PRE/F/3230

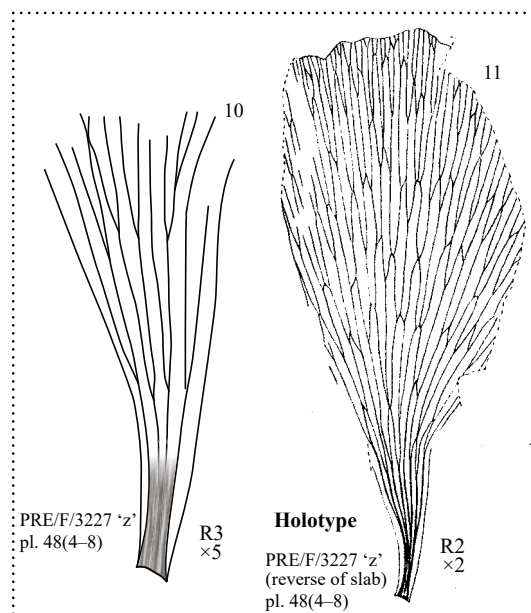
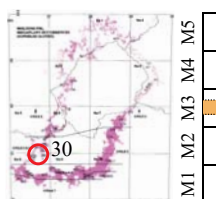
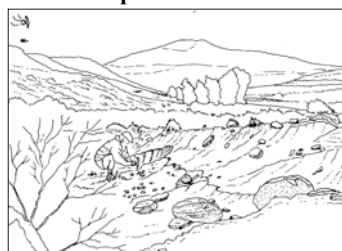
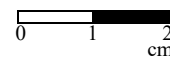
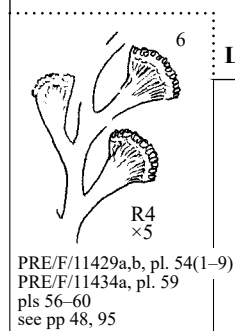
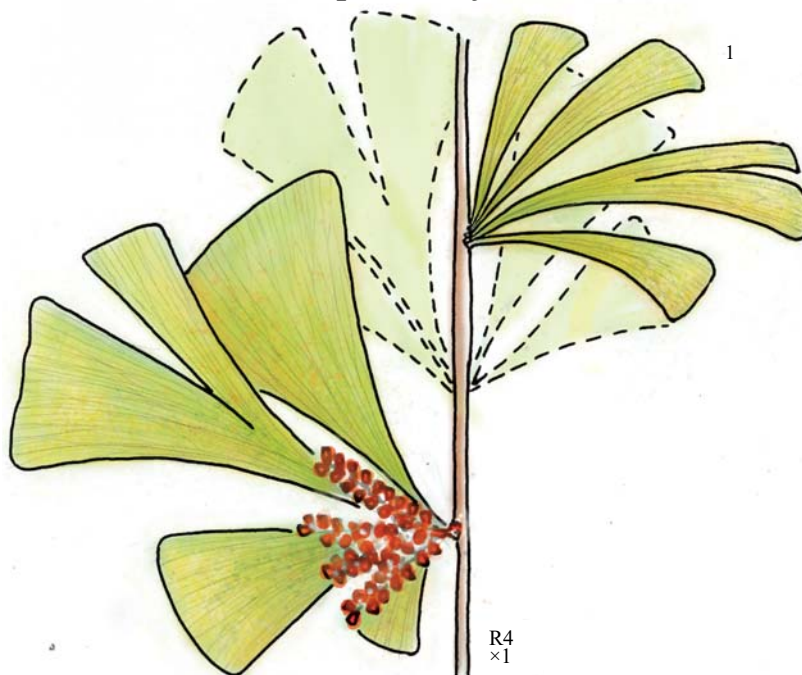
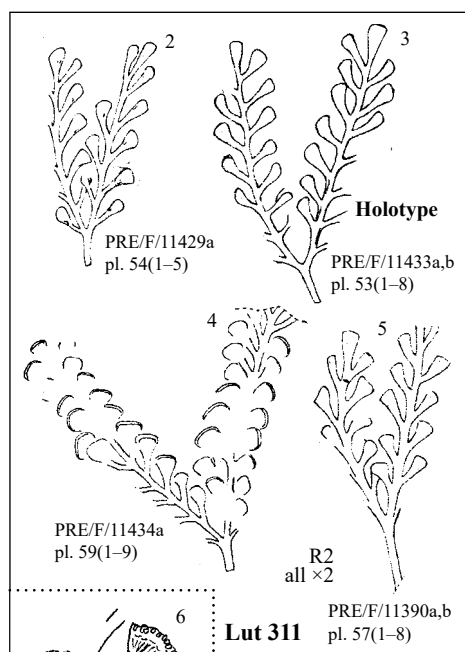
R2
×1**Holotype**PRE/F/3227 'z'
(reverse of slab)
pl. 48(4–8)**Kom 111 Sph/Dic****Kom 111**

Chart 8. *Kannaskoppianthus lutinumerus* / *Rochipteris lutifolia*



Lut 311

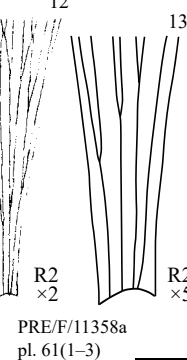
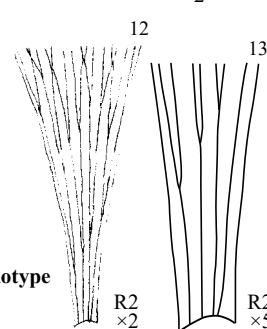
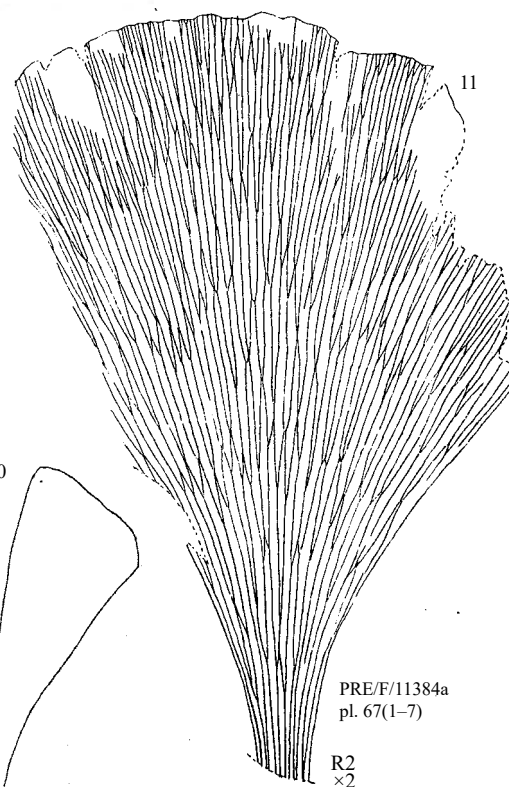
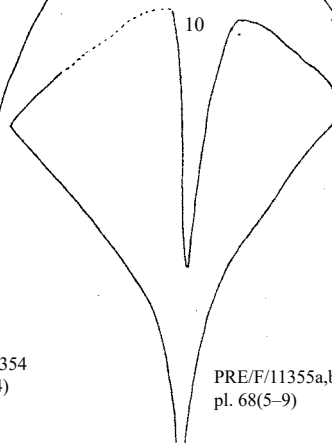
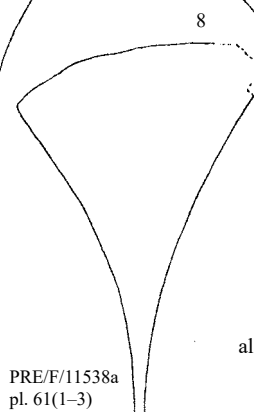
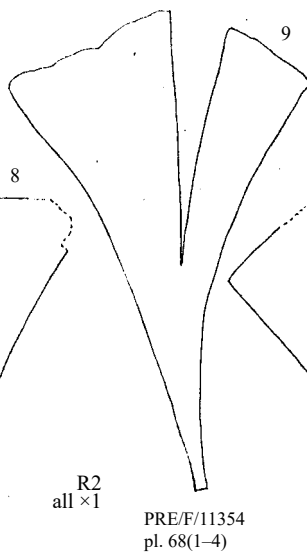
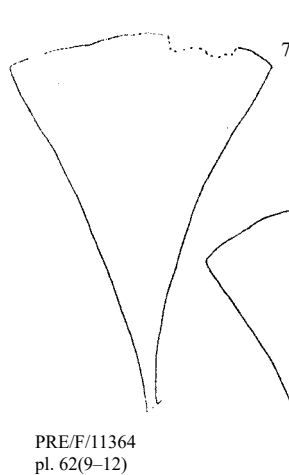
16 indivs total
10 indivs drawn
8 indivs graphed

Lut 311 Hei elo

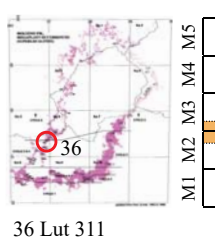
	1	2	3	4	5	6	7	8	9	10	11	12
4												
3												
2												
1												
	1	2	3	4	5	6	7	8	9	10	11	12

microsporophylls

Kannaskoppianthus
lutinumerus



Lut 311 Hei elo



36 Lut 311

Holotype

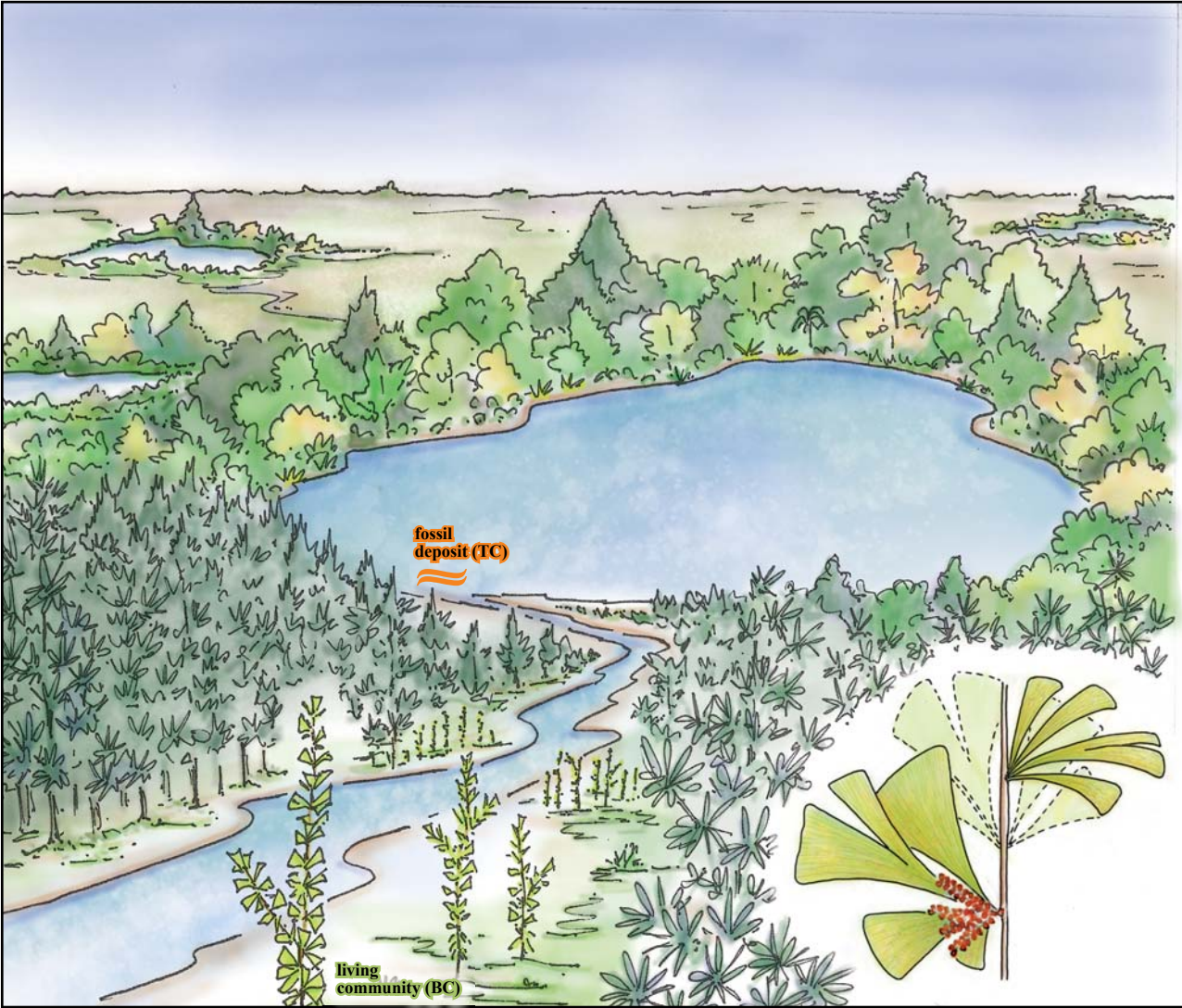
PRE/F/11358a
pl. 61(1-3)

0 1 2
cm

Kannaskoppianthus lutinerus / *Rochipteris lutifolia*

Lutherskop (Lut 311 Hei elo)

1



HMA & Clara A., June 2020

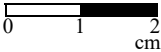
Whole-plant species (male-foliage)

Foliage – *Rochipteris lutifolia* And. & And., sp. nov.
Ref. pal.: Lut 311 Hei elo – 66 indivs (attached & clusters nil)
Male strobilis – *Kannaskoppianthus lutinerus* And. & And., 2003
Ref. pal.: Lut 311 Hei elo; 16 indivs (attached nil, 2 small clusters)
Affiliation (male/foliage) – Grade 4, (exclusive,
no other Kannaskoppiaceae in the TC)
Rarity () – 66 indivs in 50 man-hrs (c.1 per man-hr); rare
Taphonomy – parautochthonous
Habit – slender erect woody shrubs up to 0.6 m in height
Habitat – *Heidiphyllum* thicket; in area of high water table in the flood-
plain; scattered near water’s edge around small lake and adjacent to
thicket; *Dicroidium* & *Sphenobaiera* dominate the far side of the quite
large lake.

Lutherskop (Lut 311 Hei elo) TC

Collection – 589 slabs, 50 man-hrs cleaving
Dominants – *Heidiphyllum* 99%, *Dicroidium* 58 indivs,
Horsetails 30 indivs
Biodiversity – vegetative total, 19 spp
Non-gymnosperms 5 spp, gymnosperms 14 spp
Other Kannaskoppiaceae:
Foliage: nil
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

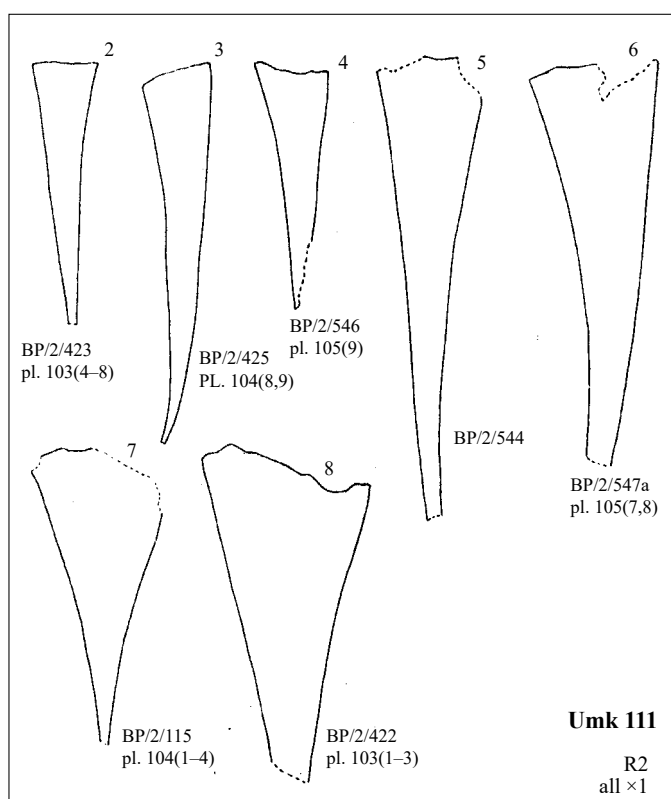
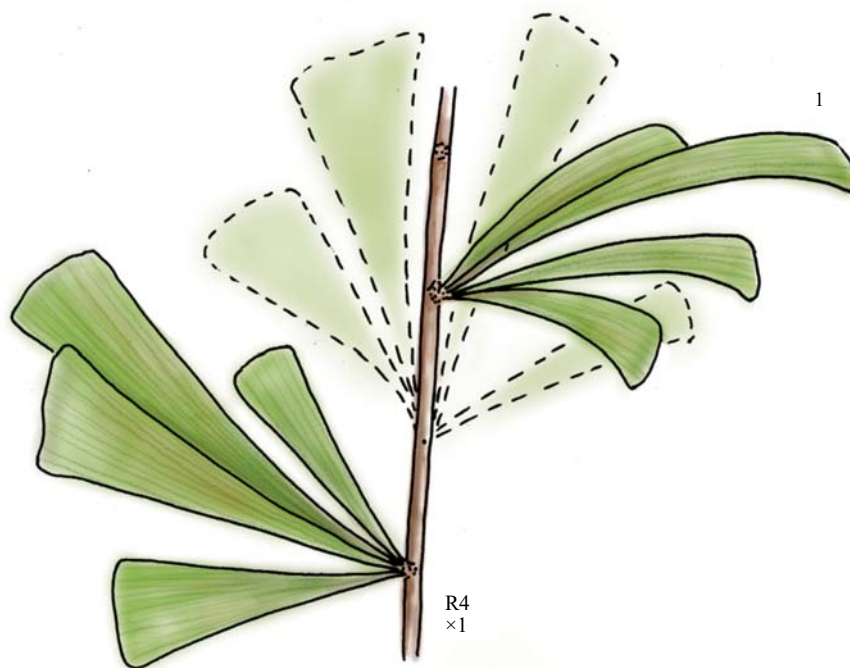
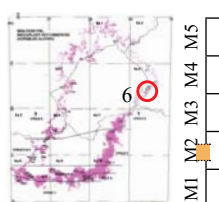
Pinopsida
Heidiphyllum
Rissikia
Other genera (×2)
Cycadopsida
Pseudocallis
Other genera (×3)
Ginkgoopsida
Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

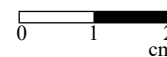
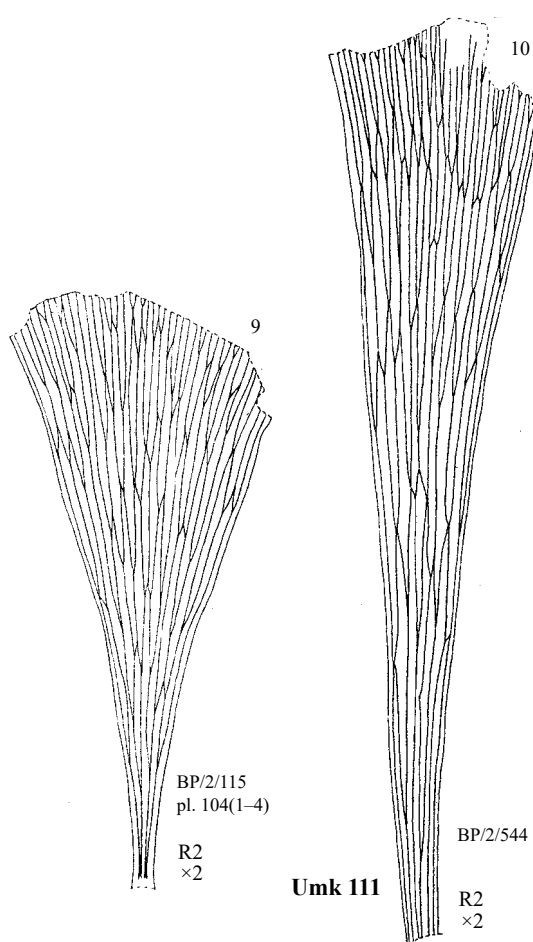
Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris
Gnetopsida
Genera (×5)

TC as @ Lut 311		
gen	spp	indivs
1	1	6
1	1	1
–	–	–
–	–	–
–	–	–
2	2	30
1	1	3
1	1	99%
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
1	2	19
–	–	–
1	2	29
1	3	58
1	1	66
1	2	5
–	–	–
1	1	2
–	–	–
1	1	23
1	2	9
12gen	19spp	

Key
99%: of TC
66 indivs in TC

Chart 9.***Rochipteris obtriangulata*****Umk 111 Dic 2spp**

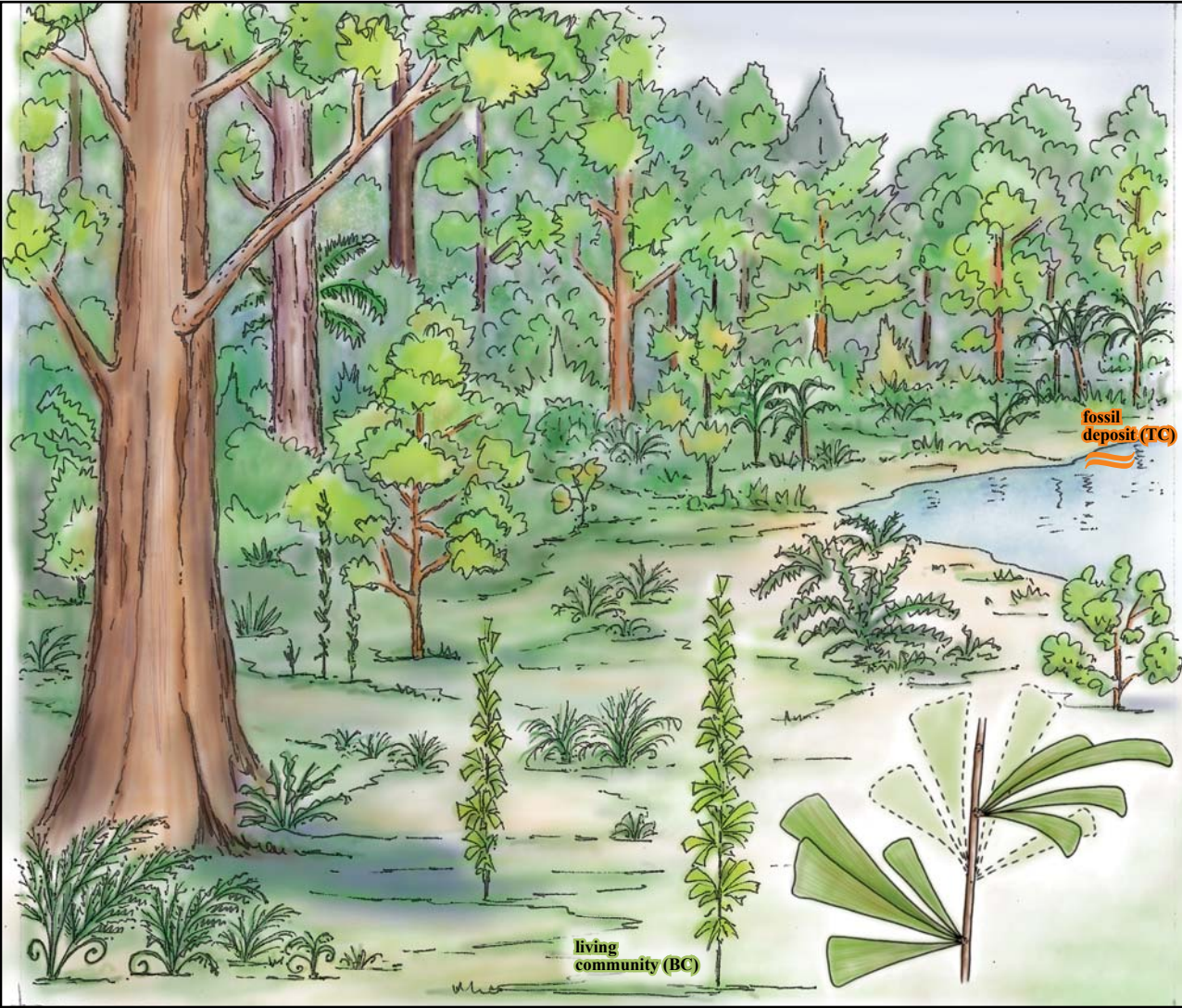
6 Umk 111



Rochipteris obtriangulata

Umkomaas (Umk 111 Dic 2spp)

1



HMA & Clara A., June 2020

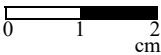
Whole-plant species (foliage)

Foliage – *Rochipteris obtriangulata* Holmes & And., 2005
Ref. pal.: Umk 111 Dic 2spp – 19 indivs (attached & clusters nil)
Male strobilis – nil
Affiliation (male/foliage) – nil
Rarity () – 19 indivs in 400 man-hrs (1 per 20 man-hrs); v. rare
Taphonomy – parautochthonous to allochthonous
Habit – slender erect woody shrubs up to c. 60 cm in height
Habitat – *Dicroidium*-dominated mature riparian forest; pioneer in a relatively open clearing fairly close to the river’s edge.

Umkomaas (Umk 111 Dic 2spp) TC

Collection – 3592 slabs, 400 man-hrs cleaving
Dominants – *Dicroidium* 69%, *Heidiphyllum* 7%, *Sphenobaiera* 5%
Biodiversity – vegetative total, 75 spp
Non-gymnosperms 29 spp, gymnosperms 46 spp
Other Kannaskoppiaceae:
Foliage: *R. rollerii* (21 indivs), *R. lutifolia* (1 indiv.),
R. cf. sinuosa (9 indivs)
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida

Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida

Pseudocallis
Other genera (×3)

Ginkgoopsida

Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris

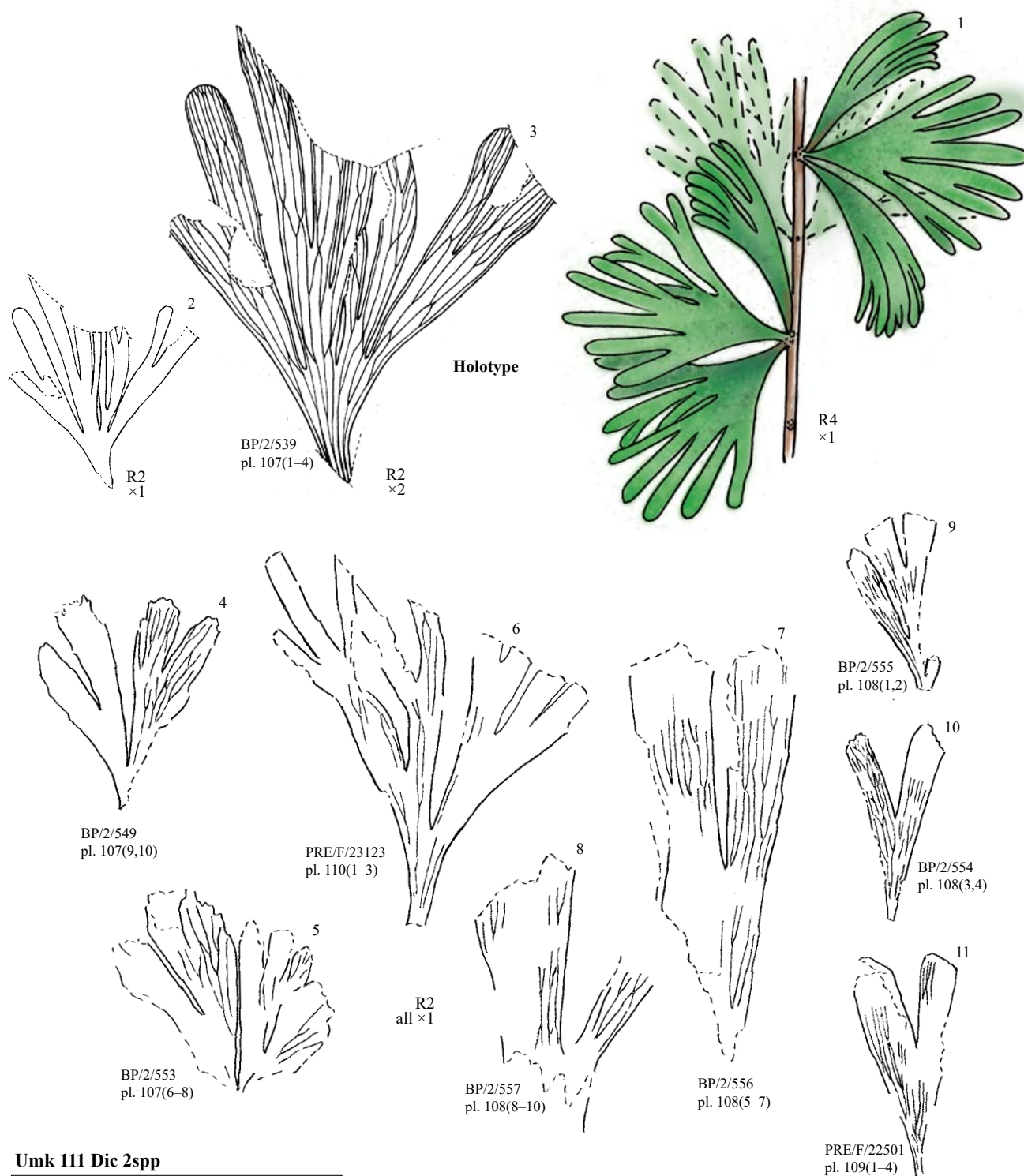
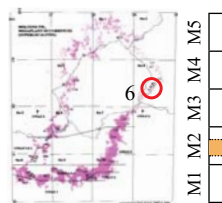
Gnetopsida

Genera (×5)

TC as @ Umk 111		
gen	spp	indivs
1	1	41
1	1	26
–	–	–
–	–	–
3	8	2%
8	13	1%
1	1	7%
1	1	5%
1	1	20
1	4	1%
2	3	42
1	1	1%
–	–	–
1	5	5%
1	8	69%
1	4	50
2	8	19
1	1	1
–	–	–
1	4	55
4	5	5%

31 gen 75 spp

Key
69%: of TC
50 indivs in TC

Chart 10.***Rochipteris cf. sinuosa*****Umk 111 Dic 2spp**

0 1 2
cm

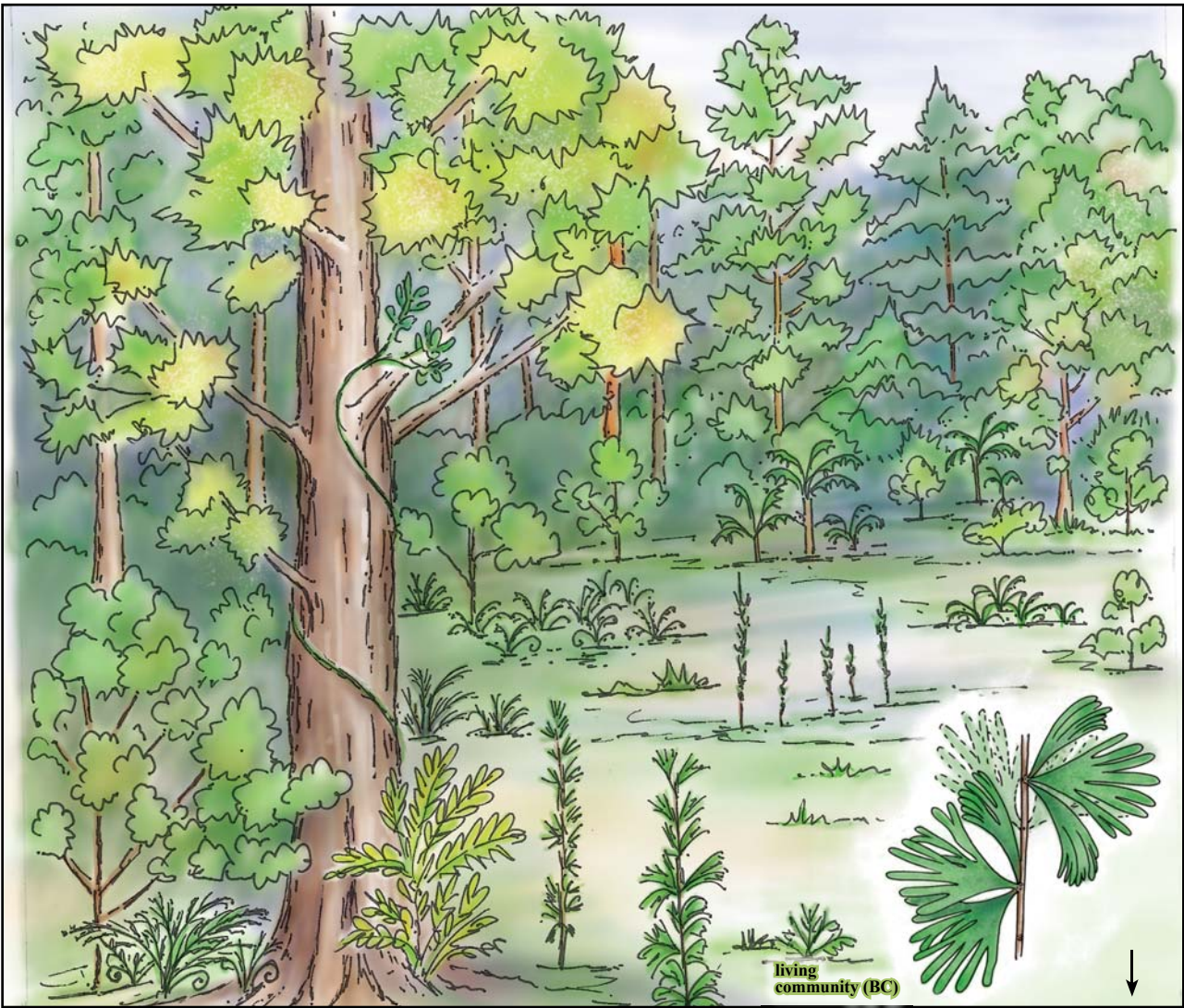
Taphonomy (elaborated)

As we know of species within a genus out in nature, each occupies a somewhat different habit, however subtle. In this light, and in view of the fact that we have 19 indivs of *R. obtriangulata* versus 9 of *R. cf. sinuosa*, our rendered sketches for these two species aim to portray these distinctions – *R. obtriangulata* being a pioneer in clearings closer to the river's bank; and *R. cf. sinuosa*, also a pioneer, but in clearings deeper within the forest.

Rochipteris cf. *sinuosa*

Umkomaas (Umk 111 Dic 2spp)

1



HMA & Clara A., June 2020

fossil
deposit (TC)

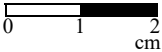
Whole-plant species (foliage)

Foliage – *Rochipteris* cf. *sinuosa* And. & And., sp. nov.
Ref. pal.: Umk 111 Dic 2spp – 9 indivs (isolated leaves)
Male strobilis – nil
Affiliation (male/foliage) – nil
Rarity () – 9 indivs in 400 man-hrs (1 per 40 man-hrs); v. rare
Taphonomy – allochthonous
Habit – slender erect woody shrubs up to c. 40 cm in height
Habitat – *Dicroidium*-dominated mature riparian forest; pioneer in a relatively small clearing fairly deep in the forest and relatively distant from the river’s edge.

Umkomaas (Umk 111 Dic 2spp) TC

Collection – 3592 slabs, 400 man-hrs cleaving
Dominants – *Dicroidium* 69%, *Heidiphyllum* 7%, *Sphenobaiera* 5%
Biodiversity – vegetative total, 75 spp
Non-gymnosperms 29 spp, gymnosperms 46 spp
Other Kannaskoppiaceae:
Foliage: *R. rollerii* (21 indivs), *R. obtriangulata* (19 indivs),
R. lutifolia (1 indiv.)
Strobili: nil

References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes



Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida
Heidiphyllum
Rissikia
Other genera (×2)

Cycadopsida
Pseudocallis
Other genera (×3)

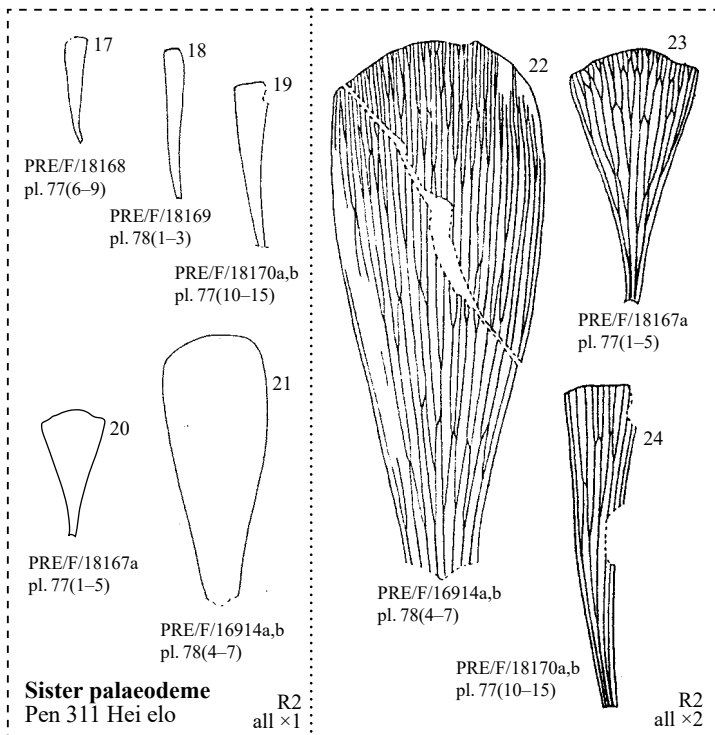
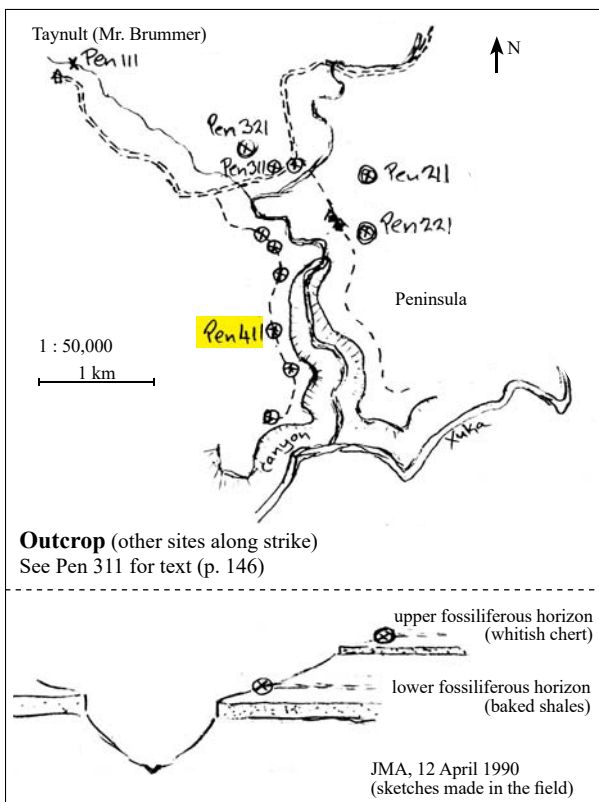
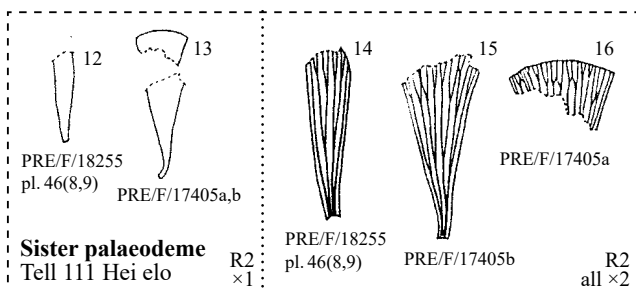
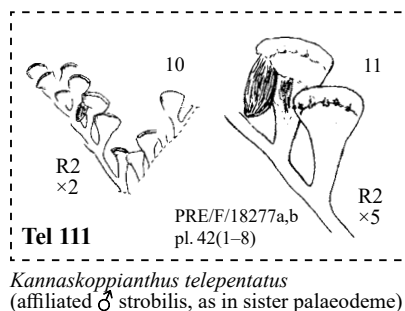
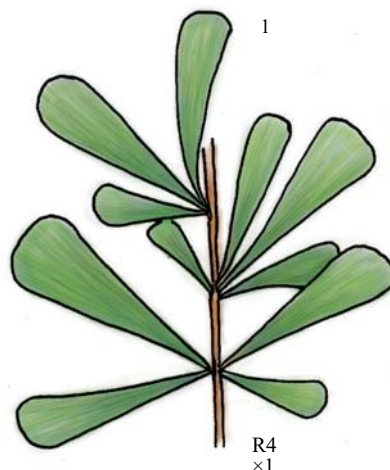
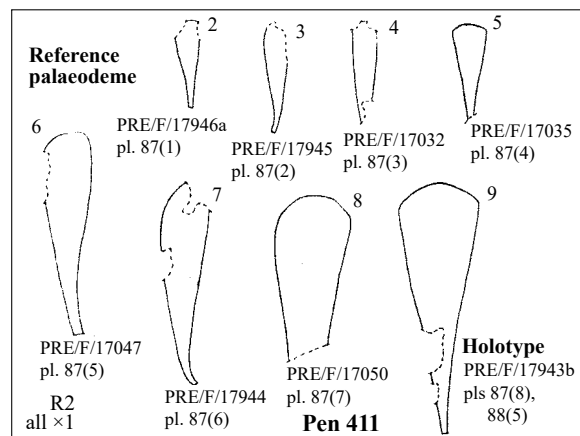
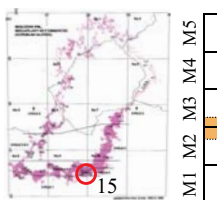
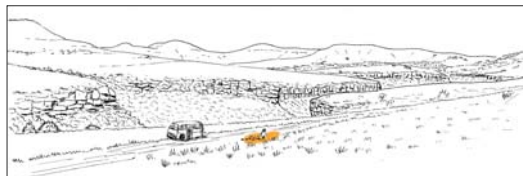
Ginkgoopsida
Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.
Genera (×3)
Bennettitopsida
Halleyoctenis
Taeniopteris

Gnetopsida
Genera (×5)

TC as @ Umk 111		
gen	spp	indivs
1	1	41
1	1	26
–	–	–
–	–	–
3	8	2%
8	13	1%
1	1	7%
1	1	5%
1	1	20
1	4	1%
2	3	42
1	1	1%
–	–	–
1	5	5%
1	8	69%
1	4	50
2	8	19
1	1	1
–	–	–
1	4	55
4	5	5%
75		

Key
69%: of TC
50 indivs in TC

Chart 11.***Rochipteris penensis*****Pen 411 Hei elo**

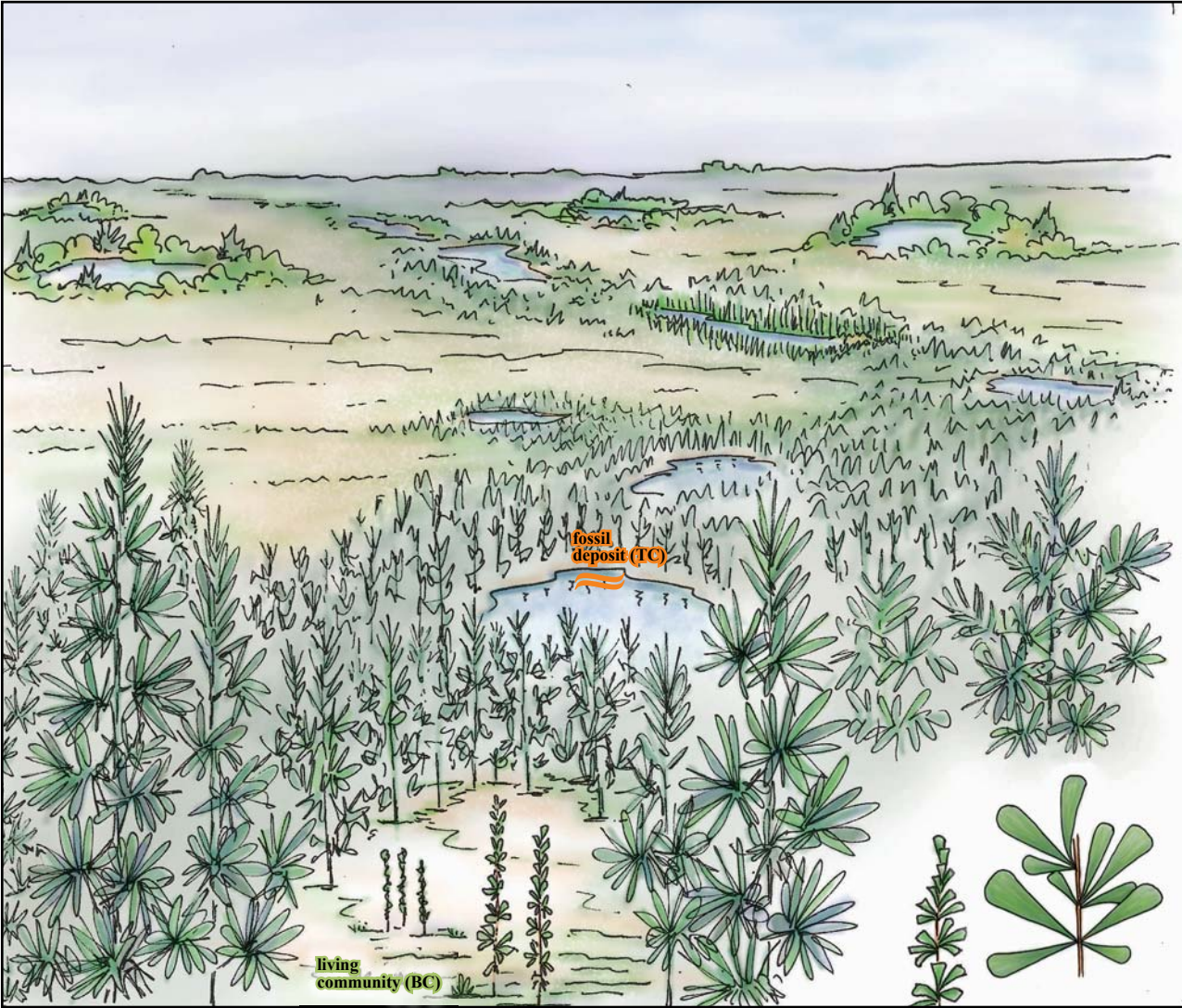
15 Pen 311, 411

0 1 2 cm

Rochipteris penensis

Peninsula (Pen 411 Hei elo)

1



HMA & Clara A., June 2020

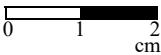
Whole-plant species (foliage)

Foliage – *Rochipteris penensis* And. & And., sp. nov.
Ref. pal.: Pen 411 Hei elo – 10 indivs (isolated leaves)
Male strobilis – nil
Affiliation (male/foliage) – nil
Rarity () – 10 indivs in 70 man-hrs (1 per 7 man-hrs); v. rare
Taphonomy – parautochthonous-allochthonous
Habit – slender erect woody shrubs up to c.30 cm in height
Habitat – *Heidiphyllum* thicket; in area of high water table in the flood-plain; in limited clearings within the thicket, relatively close (20–50 m) to a small lake or marshland/wetland.

Peninsula (Pen 411 Hei elo) TC

Collection – 204 slabs, 70 man-hrs cleaving
Dominants – *Heidiphyllum* 94%, ferns 3%, horsetails 2%
Biodiversity – vegetative total, 11 spp
Non gymnosperms 6 spp, gymnosperms 5 spp
Other Kannaskoppiaceae:
Foliage: *R. rollerii* (70 indivs)
Strobili: *Kannaskoppianthus* (4 indivs); Grade 4 affil. (with *R. rollerii*)

Taphonomy (elaborated)
See Pen 311 for text (p. 146)



References
And. & And. (2003): general
“ “ (2008): ferns
“ “ (2018): sphenophytes

Molteno foliage taxa

Non-gymnosperms

Muscites
Marchantites
Thallites, etc.
Lycopods
Horsetails
Ferns

Gymnosperms

Pinopsida
Heidiphyllum
Rissikia
Other genera (×2)
Cycadopsida
Pseudocallis
Other genera (×3)
Ginkgoopsida
Lepidopteris
Ginkgoites
Sphenobaiera
Dicroidium
Rochipteris
Other genera (×4)

Classes indet.

Genera (×3)

Bennettitopsida

Halleyoctenis

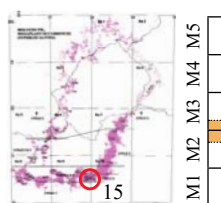
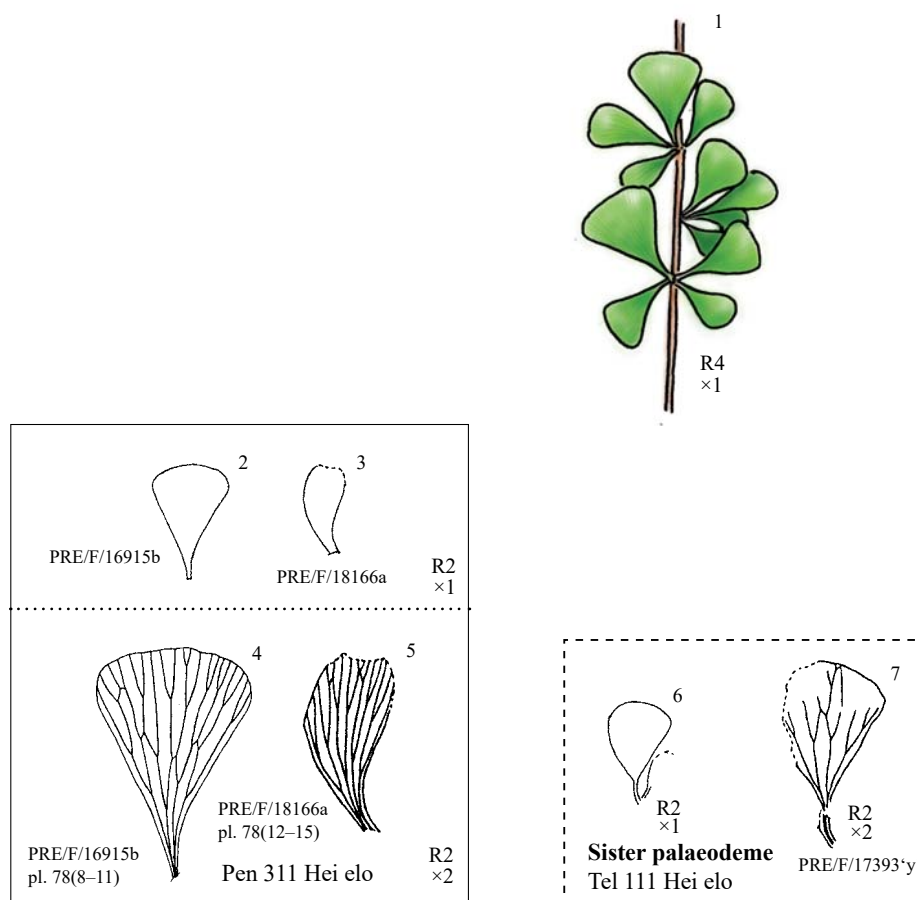
Gnetopsida

Genera (×5)

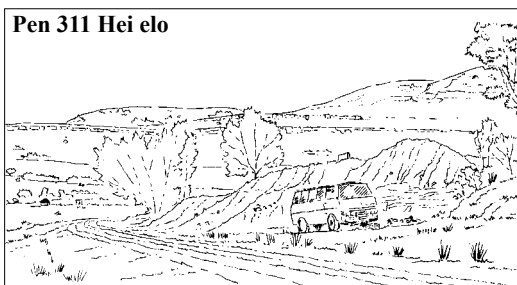
TC as @ Pen 411		
gen	spp	indivs
1	1	1
1	1	3
–	–	–
–	–	–
1	1	2%
1	1	3%
–	–	–
1	1	94%
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
1	1	13
1	2	80
1	1	50
–	–	–
–	–	–
–	–	–
–	–	–
–	–	–
8	11	

Key
94%: of TC
80 indivs in TC

Chart 12.

Rochipteris pusilla

15 Pen 311, 411

**Pen 311 Outcrop** (for other sites along strike, see sketch (p.144))

Pen 411 lies 1.25 km along contour/outcrop south of Pen 311. Though we only collected from these two sites, we traced the winding contour on which they occur along a narrow sand road noting seven *Heidiphyllum* thicket sites across a 1.6 km north–south stretch of sloping grassland. In nature, the *Heidiphyllum* thicket occurred particularly commonly, either over long stretches or over repeated shorter stretches.

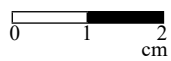
For comparison, see the text (p. 130) for the Aasvoëlberg sites (Aas 111, Aas 211, Aas 311), occurring along strike.

Pen 311 Taphonomy (elaborated)

Interestingly, all three *Rochipteris* species (41 indivs) occur on bedding surfaces packed with *Heidiphyllum*. No single specimen of *Dicroidium* (very largely *D. coriaceum*) – though it is a co-dominant (at 25%) along with *Heidiphyllum* (75%) in the TC – is found in our collection on any slab with *Rochipteris*.

Our interpretation of this is that the *Dicroidium* foliage will have been washed into the deposit from the *Dicroidium*-woodland further afield (to the right in our sketch) during storm/flooding events from that side. Note that the area of high water table adjacent (to the right) of the *Heidiphyllum* thicket in which the deposit occurs is shown clear of the conifers.

In clear contrast, **Pen 411 Hei elo**, occurring just '1.25 km along contour/strike south of Pen 311', is exclusively dominated by *Heidiphyllum* (94%) and includes no *Dicroidium* foliage. Our habitat sketch in this case (for Pen 411, p. 145) differs in detail, particularly with the fossil deposit (TC) shown surrounded by *Heidiphyllum* thicket preventing any *Dicroidium* from the woodland further afield getting swept in by storm water.





PART 4

COLOUR PLATES

STROBILI & FOLIAGE

With the focus in this volume being on one particular family and on the whole-plant genus (and species), the layout of these 162 plates – very largely in colour – follows the stratigraphic sequence of the 26 productive assemblages (TCs), rather than taxonomic classification.

The 26 TCs are laid out in stratigraphic sequence, youngest to oldest, down through the five members of the formation; and within each TC, the strobili – with fuller coverage – appear first, followed by the foliage.

COLOUR PLATES

Coverage

Included is a generous coverage of both fertile and foliage species from the 26 Molteno sites (TCs) from which material of the Kannaskoppiaceae family have been found. Unlike in our previous two volumes (on the ferns & horsetails) – where we had separate sections on black-and-white and colour plates – in this volume we have focussed largely on colour.

Colour vs black & white (bl. & wh.)

Of the 162 plates, the large majority (109 plates) are exclusively colour; 20 plates are exclusively bl. & wh.; whilst 33 are mixed, with colour and bl. & wh. For some TCs, e.g. Lit 111, Umk 111 in dark carbonaceous rock, the original bl. & wh. photos (processed pre-digital era in the darkroom) are difficult to distinguish and marked by an asterisk.

Arrangement

Sites: The 26 Molteno sites are laid out through the chapter in stratigraphic sequence, youngest above, oldest below, matching the arrangement of data elsewhere in the volume – notably the coverage of sites (sketches and text).

Taxa: For those sites where both fertile specimens and foliage occur, we cover first the strobili. Where more than one species within either occurs, the order is as per our taxonomic coverage – from the best represented whole-plant taxa to those least securely defined.

Specimens: Where multiple (two or more) specimens appear on a plate, they are clearly grouped for easy visualization; and numbered accordingly. The order – for any particular specimen – is from smaller to larger magnification. Part and counterpart (indicated by an a and b) are included where these complement one another, and/or as quality warrants it.

Magnification

A standard set of magnifications – $\times 1$, $\times 2$, $\times 5$, $\times 10$, $\times 15$, $\times 20$, $\times 40$ (rarely $\times 15$, $\times 30$, $\times 80$) – is followed, facilitating ready comparison of specimens from different species or sites. A 2 cm scale is added to each plate, negating the need of a scale bar on each photograph.

Plant–insect interaction

Based on the work of Conrad Labandeira, Smithsonian, Washington, as outlined in our latest Molteno volume on the sphenophytes (And. & And. 2018), all plant groups found in the formation “were affected by plant herbivores”; and all basic modes of insect herbivory found in the modern world occur in Molteno plants. This is clearly evidenced by the insect damage types preserved amongst the Kannaskoppiaceae plants, as illustrated in the colour plates that follow, and in the selection of images lining this page.

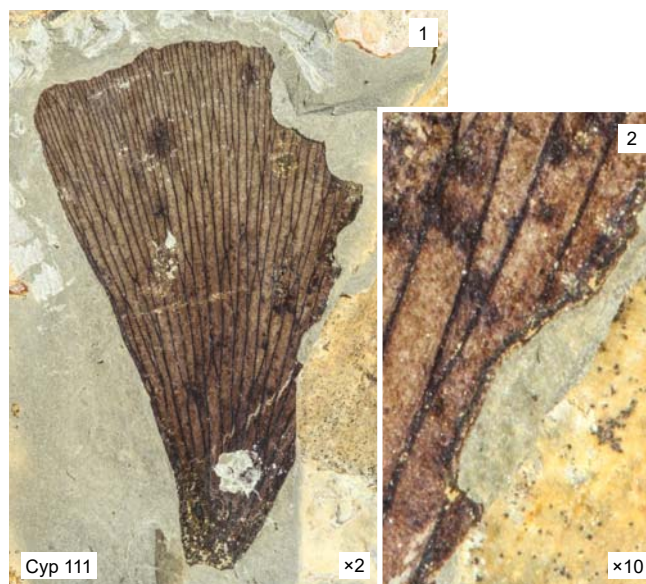
Quite evident is that some sites show more insect damage than others. A high proportion of foliage specimens from Cyphergat (Cyp 111), for instance, show well-preserved marginal feeding (e.g. figs 1, 2 to the right).



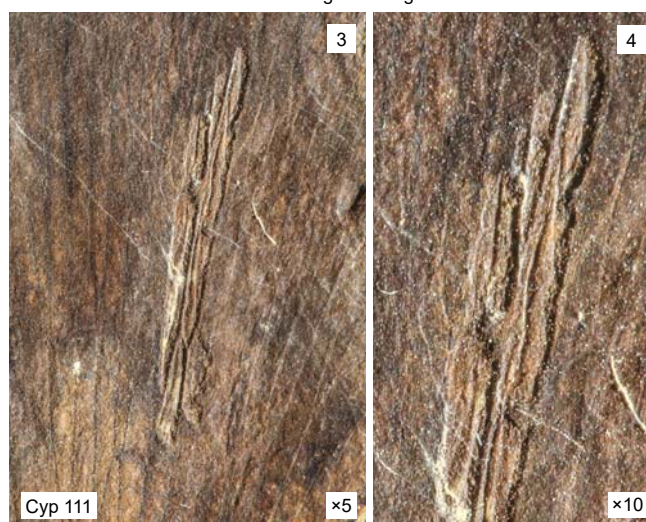
leaf-tip feeding



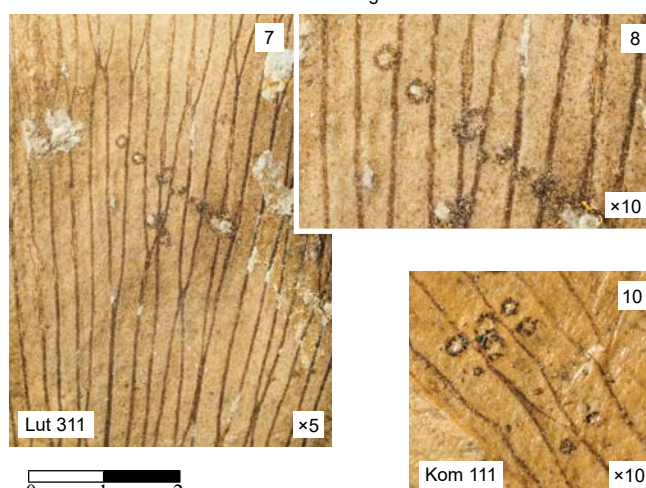
oviposition



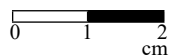
leaf-margin feeding



leaf mining



piercing & sucking



1



Tell 111

×1

3



Kom 111

×10

5



Lut 311

×2

6



Mat 111

×5

8



Aas 111

×5

2



Aas 411

×1

4



Kan 111

×5

7



Cyp 111

×5

9



Cyp 111

×1

10



Mat 111

×1

11



Kan 112

×2

TABLE of CONTENTS

TCs	Locality	Assemblages (taphocoenosis)		Members	man-hours cleaving	♀ <i>Kannaskoppia</i>	♂ <i>Kannaskoppianthus</i>	♂ <i>Rochipteris</i>	attached organs	plate numbers (1st pl. of TC)
1	Cala Road	Cal 211	Hei elo	T 5	2	–	–	5		1
2	Greenvale	Gre 121	Hei elo		10	–	2	22		3
3	"	" 111	Equ sp		25	–	–	1		7
4	Boesmanshoek Pass	Boe 112	Dic cor	Qiba	6	–	–	1		8
5	Cyphergat	Cyp 111	Dic cra		100	–	–	83	0	9
6	Kannaskop	Kan 112	Hei elo		15	–	5	19	♂	19
7	"	" 111	Ast spA		30	50	–	5	0 ♀	23
8	Telemachus Spruit	Tel 111	Hei elo		90	–	4	33	0	41
9	Kommandantskop	Kom 111	Sph/Dic	Mayaputi	10	–	2	30	0 ♂	47
10	Vineyard	Vin 111	Dic odo		10	–	–	2		51
11	Lutherskop	Lut 311	Hei elo		50	–	16	66		53
12	Koningskroon	Kon 211	Ast 2spp		393	–	–	4		69
13	Peninsula	Pen 311	Hei elo	f	35	–	–	41		73
14	"	" 411	" "		70	–	4	80		79
15	Kapokkraal	Kap 111	Dic/Ris	e	65	–	–	6		89
16	Nuwejaarspruit	Nuw 111	Dic zub	d	21	–	–	1		91
17	Winnaarspruit	Win 111	Hei elo	Indwe	20	–	–	4		92
18	Hlatimbe	Hla 213	Dic elo		60	–	–	7		94
19	Umkomaas	Umk 111	Dic 2spp		400	–	–	50		97
20	Sani Pass	San 111	Dic cra	b	30	–	–	3		111
21	Matatiele	Mat 111	Dic dub		65	–	3	2		113
22	Little Switzerland	Lit 111	Dic/Hei	a	550	–	9	56		119
23	Aasvoëlberg	Aas 111	Hei elo		40	–	21	2		125
24	"	" 211	Hei elo		35	–	1	19		143
25	"	" 311	Hei elo		140	–	4	26		145
26	"	" 411	Dic/Sph	Bamboesberg	512	–	21	150		153
		Total TCs	26			1	12	26		
		Total individuals				50	92	%		

T: Tsomo

Total: 162 plates

Of the 100 Molteno assemblages (TCs) sampled,
26 have yielded specimens of the *Kannaskoppia* family.

All 26 TCs have yielded foliage;
12 TCs, close on half, have yielded male strobili,
whilst just a single TC (Kan 111) has yielded female strobili.

– female strobili ♀ (1 TC)

– male strobili ♂ (12 TCs)

– foliage 0 (26 TCs)

5 – % of assemblage (TC)

4 – indivs in assemblage (TC)

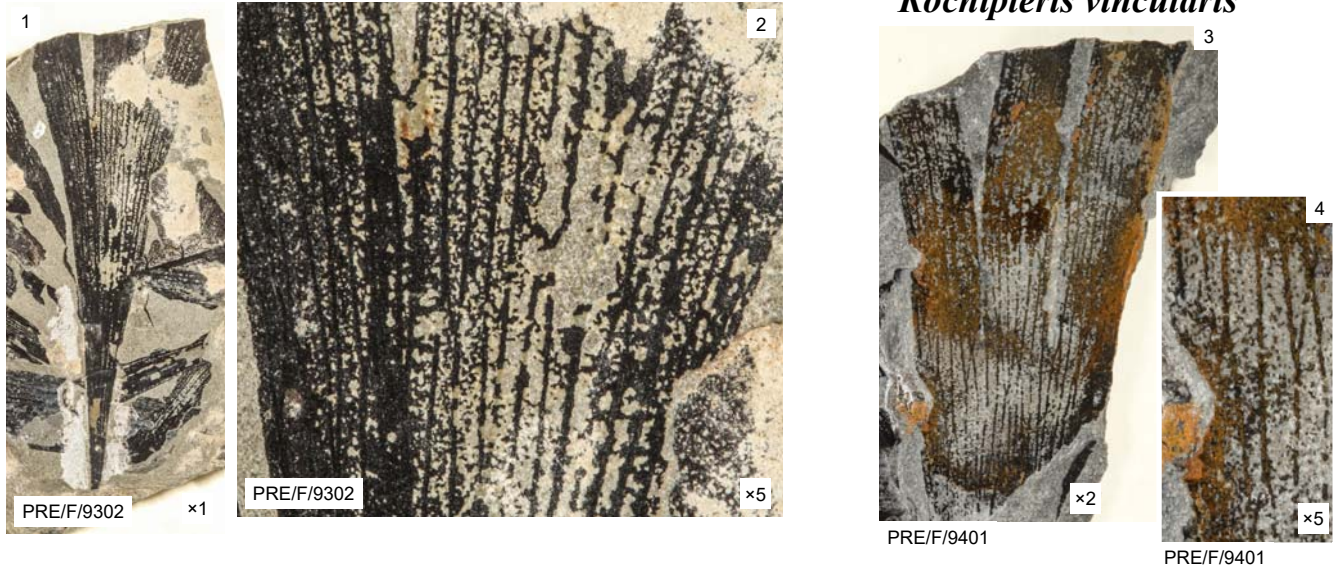
0

1

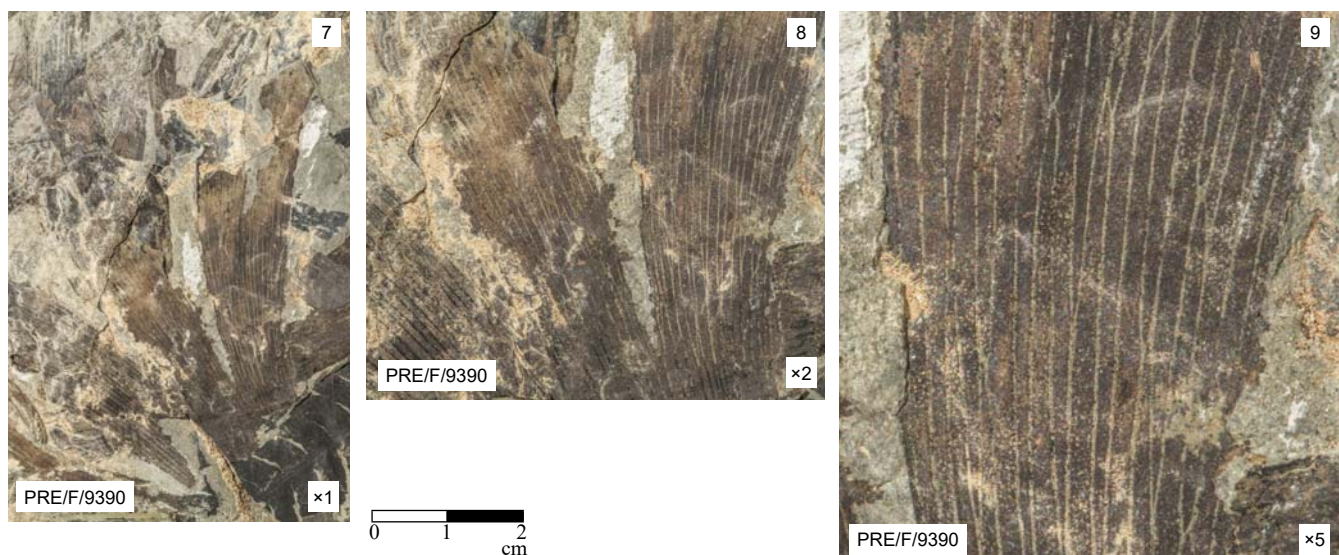
2

cm

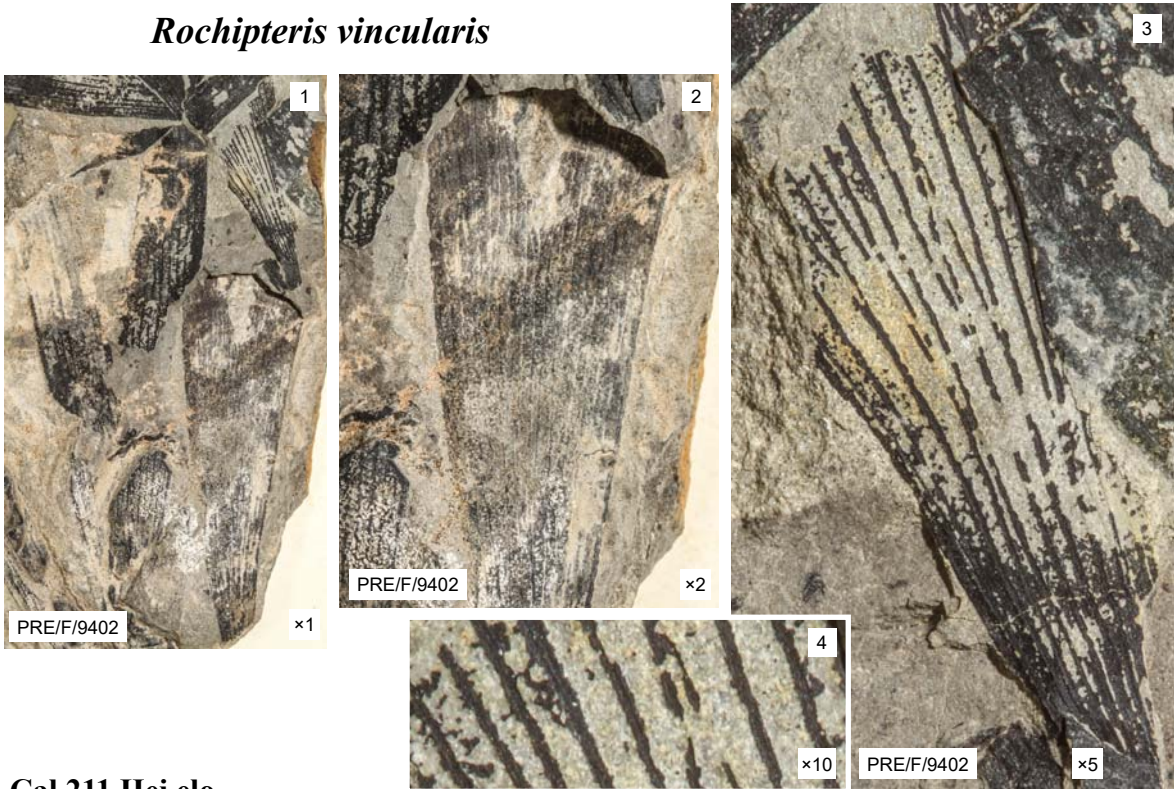
COLOUR PLATES

Rochipteris vincularis

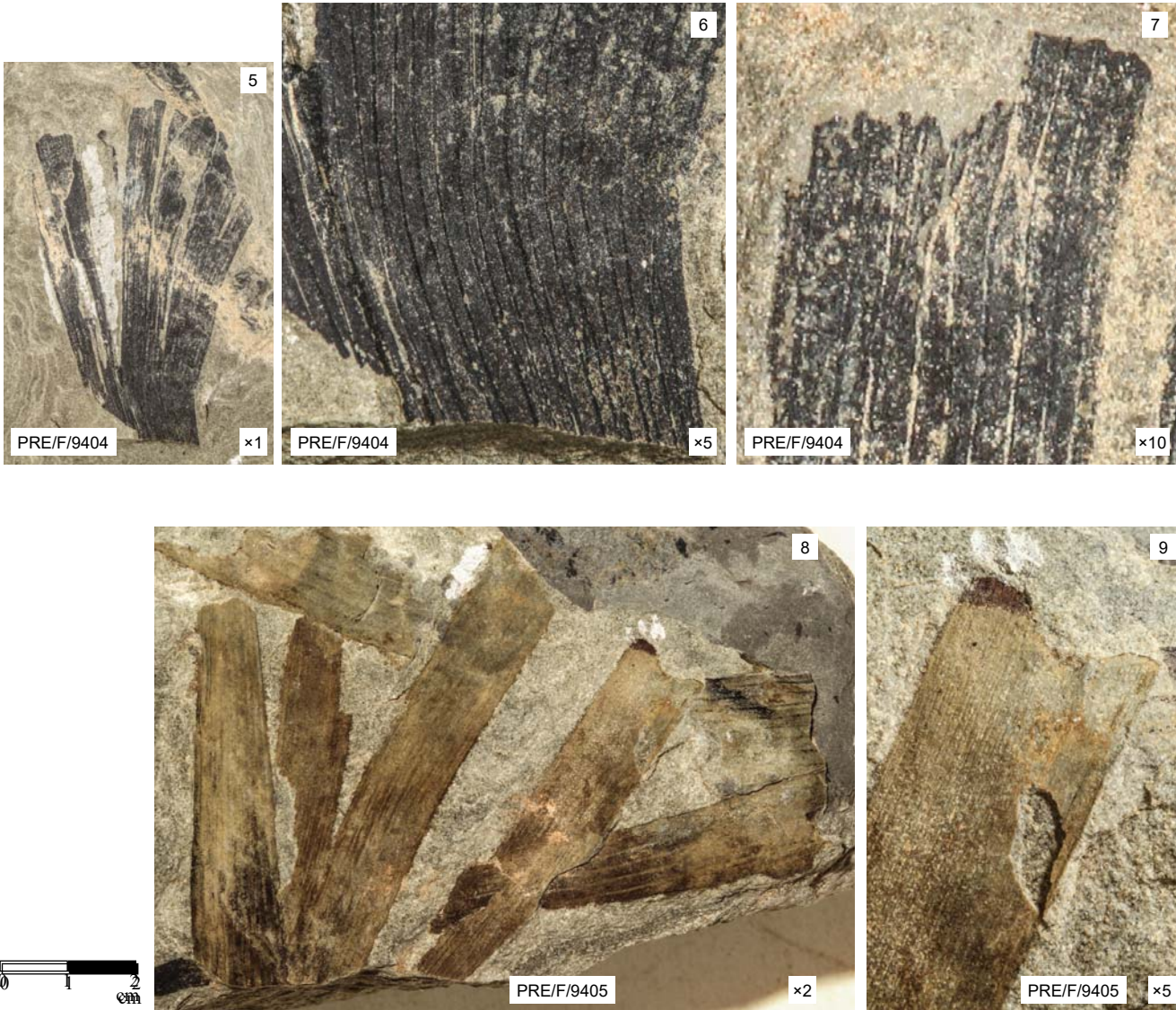
Cal 211 Hei elo

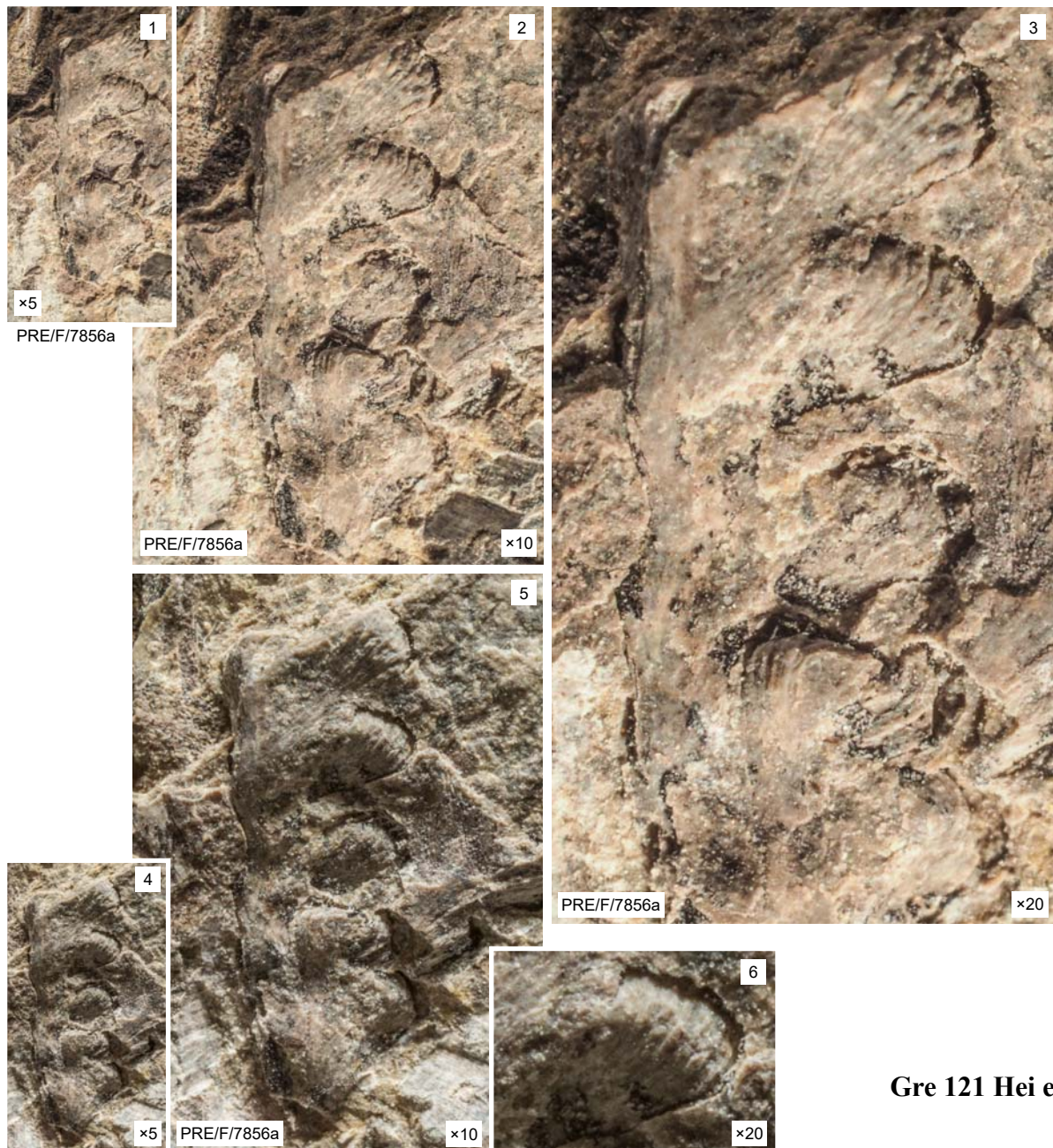


Rochipteris vincularis

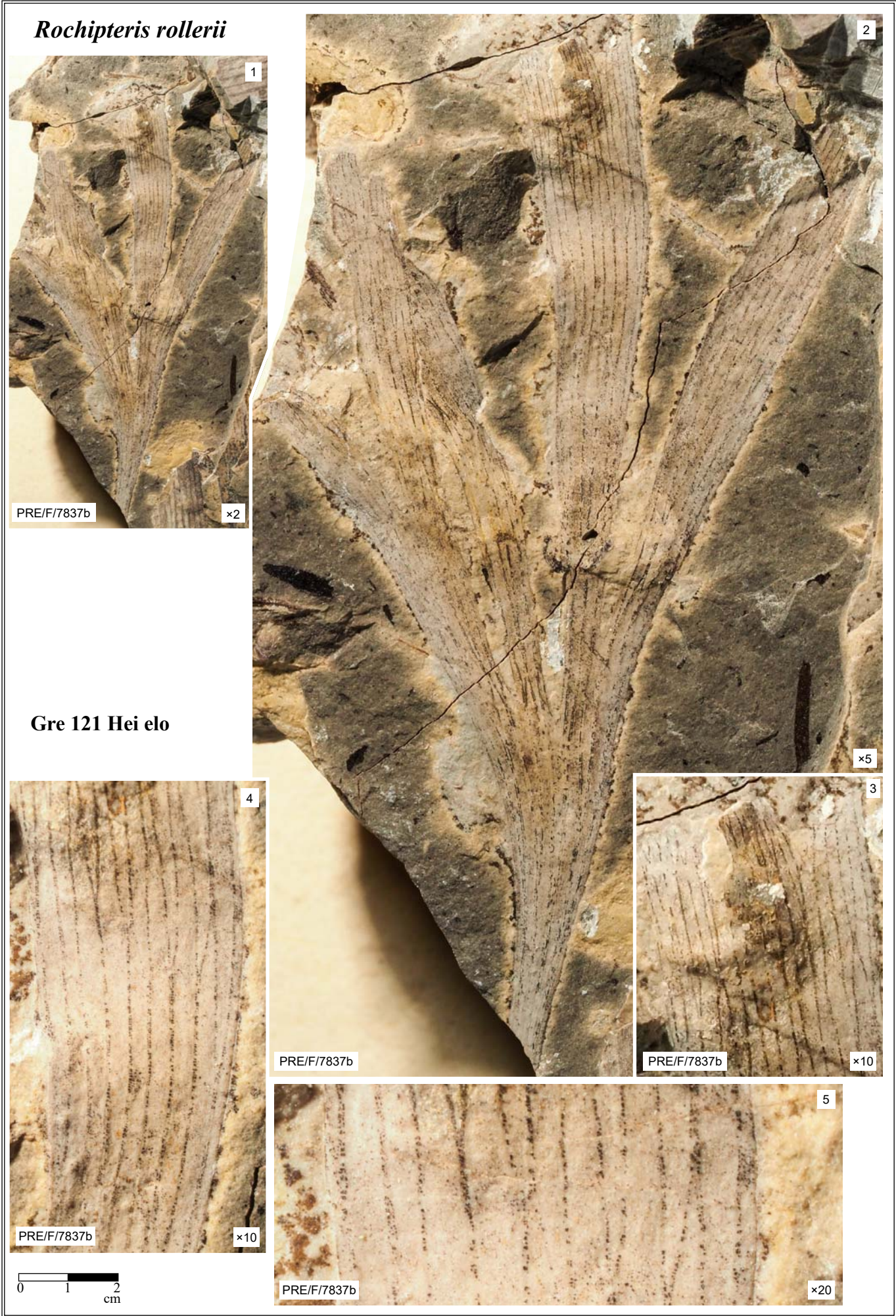


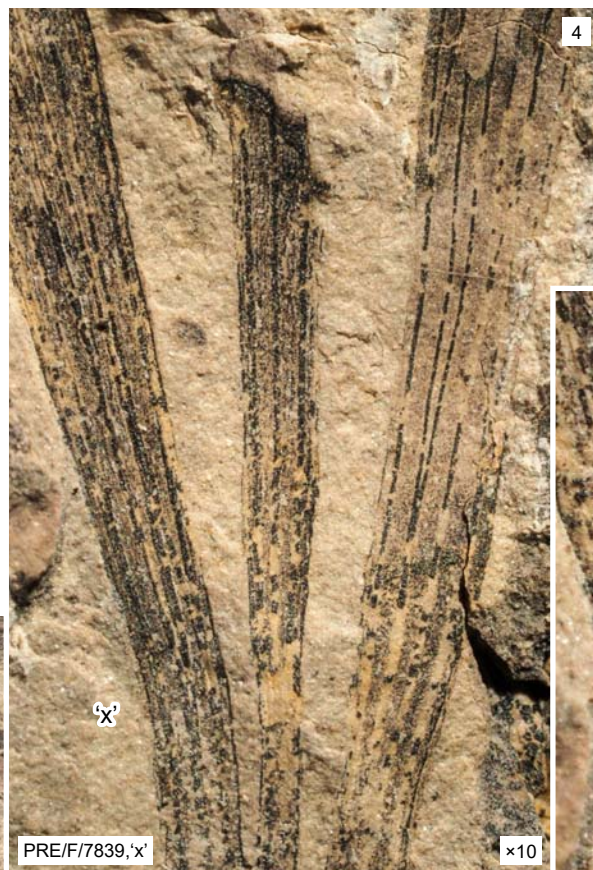
Cal 211 Hei elo



Kannaskoppianthus aasvoelensis

Gre 121 Hei elo

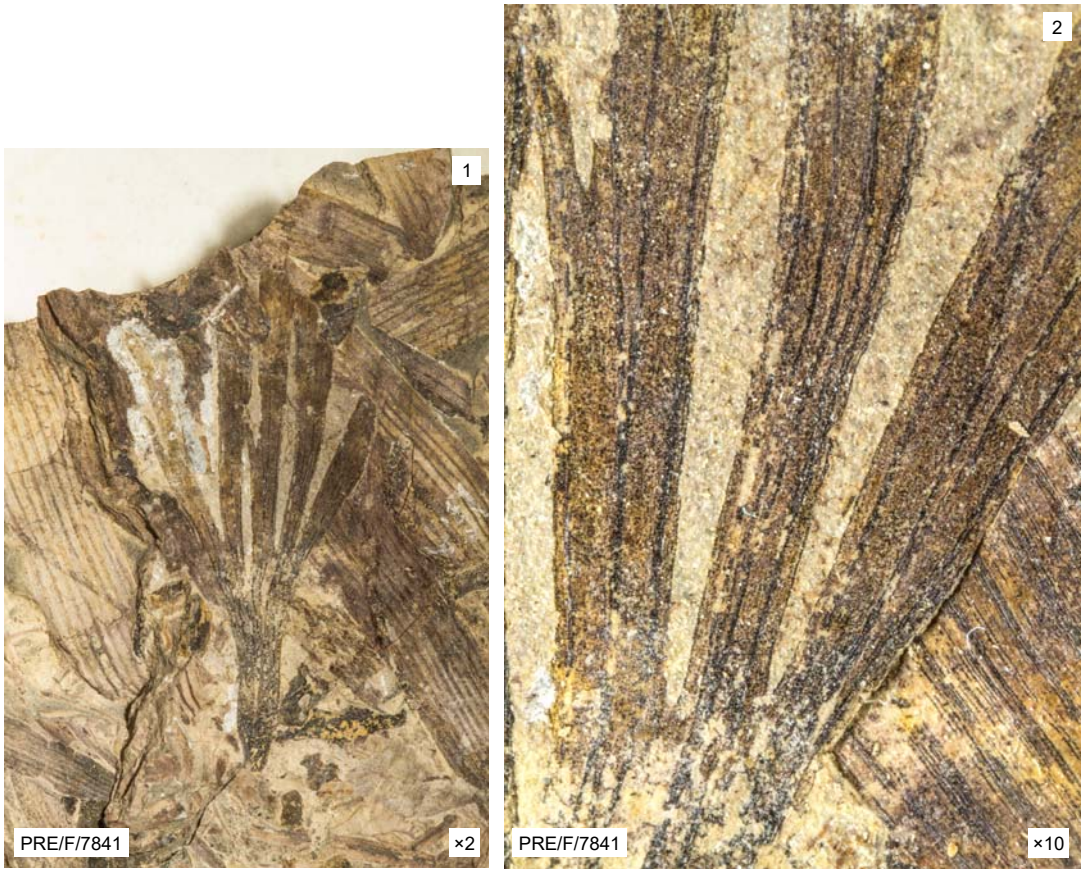


Rochipteris rollerii

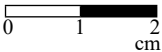
Gre 121 Hei elo



Rochipteris rollerii

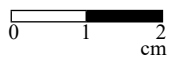


Gre 121 Hei elo



Rochipteris sp. indet.

Gre 111 Equ sp

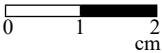


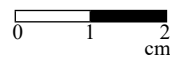
* part & counterpart combined
(PRE/F/16568a flipped to match)

Rochipteris pusilla

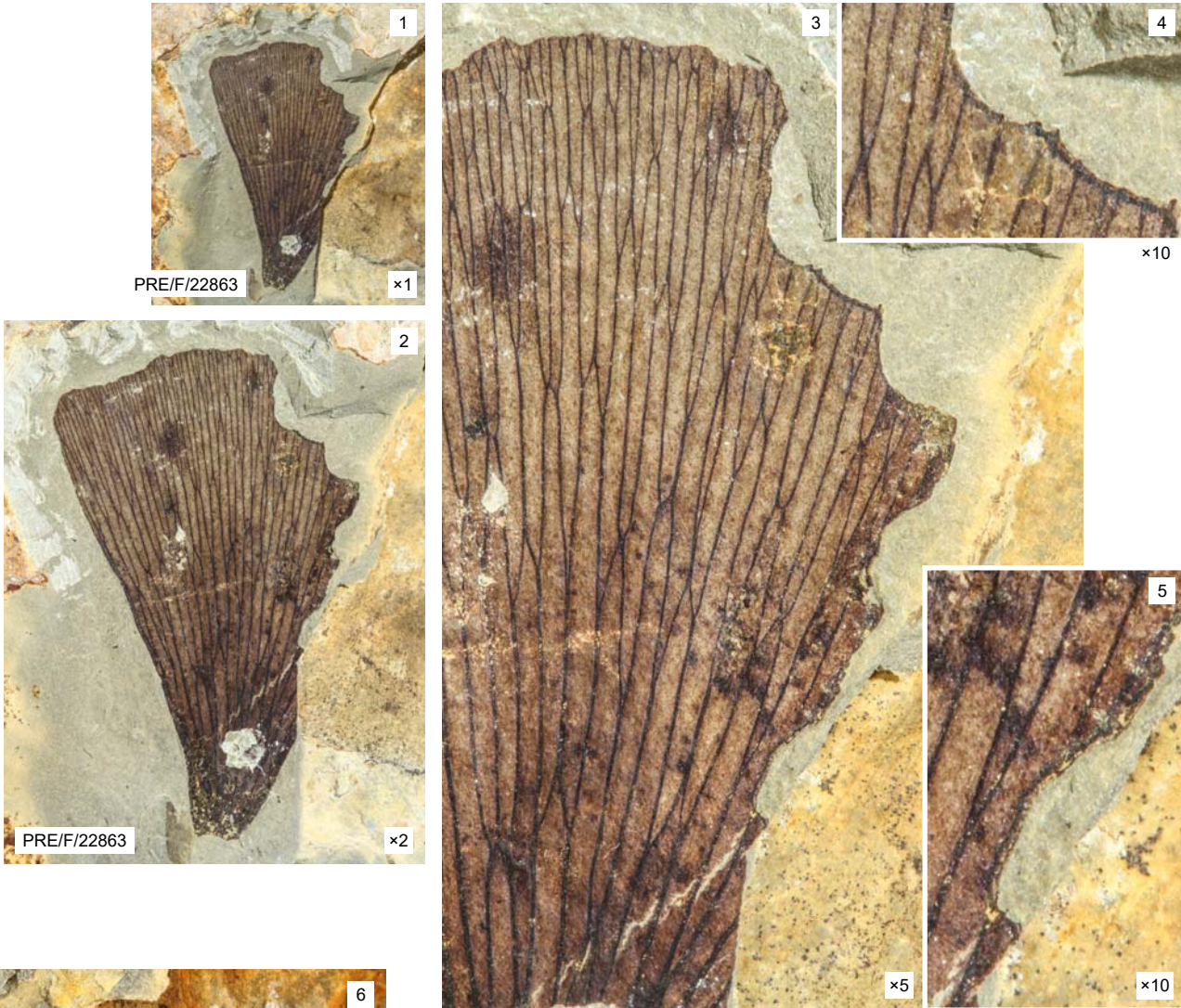


Boe 112 Dic cor

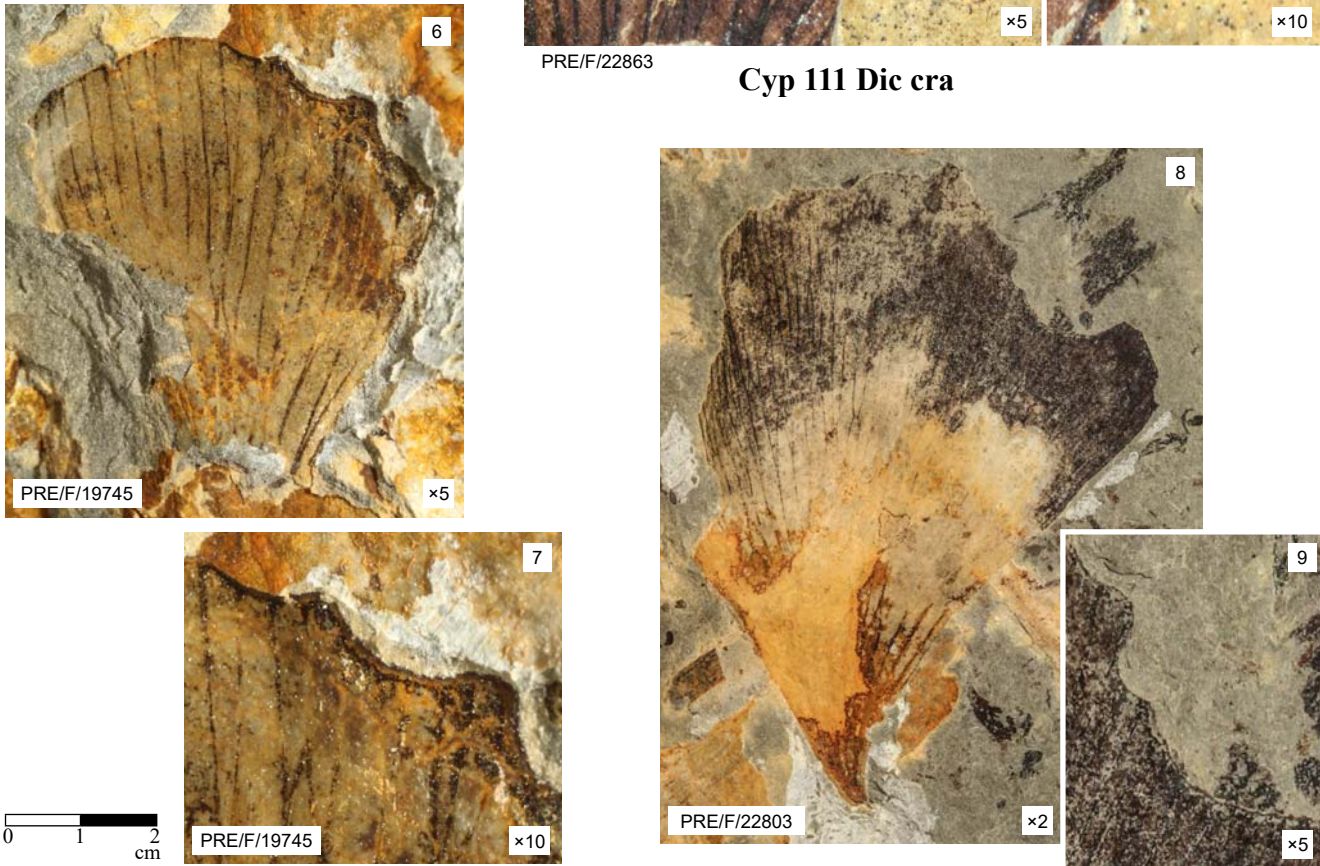


Rochipteris lutifolia*Cyp 111 Dicra*

Rochipteris lutfolia

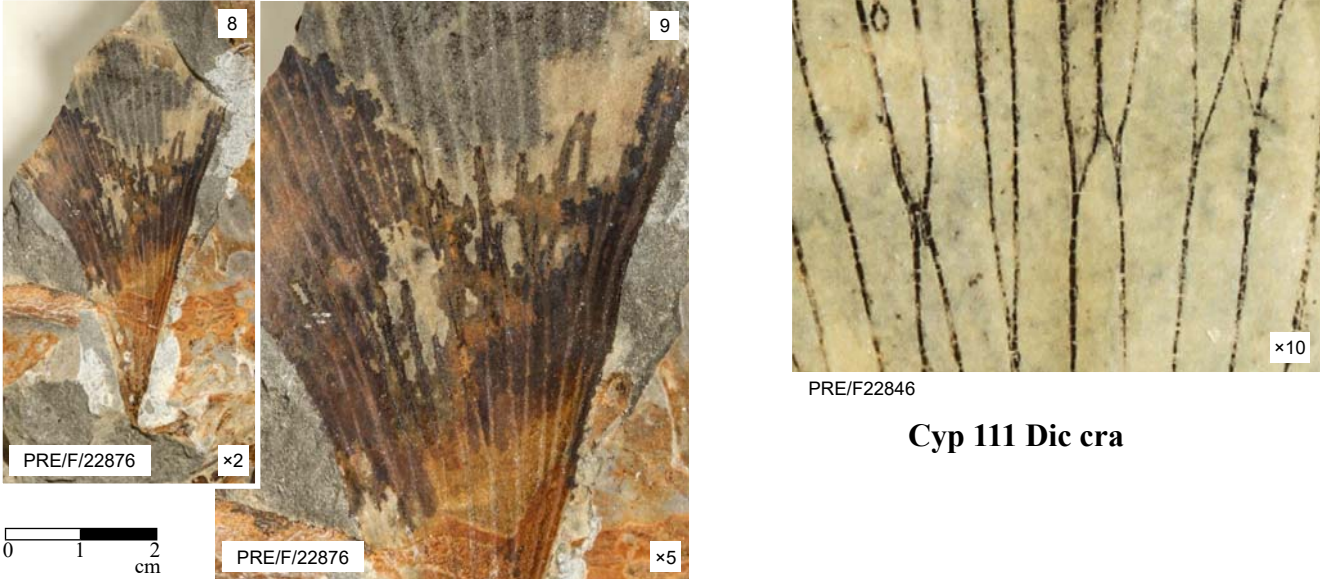
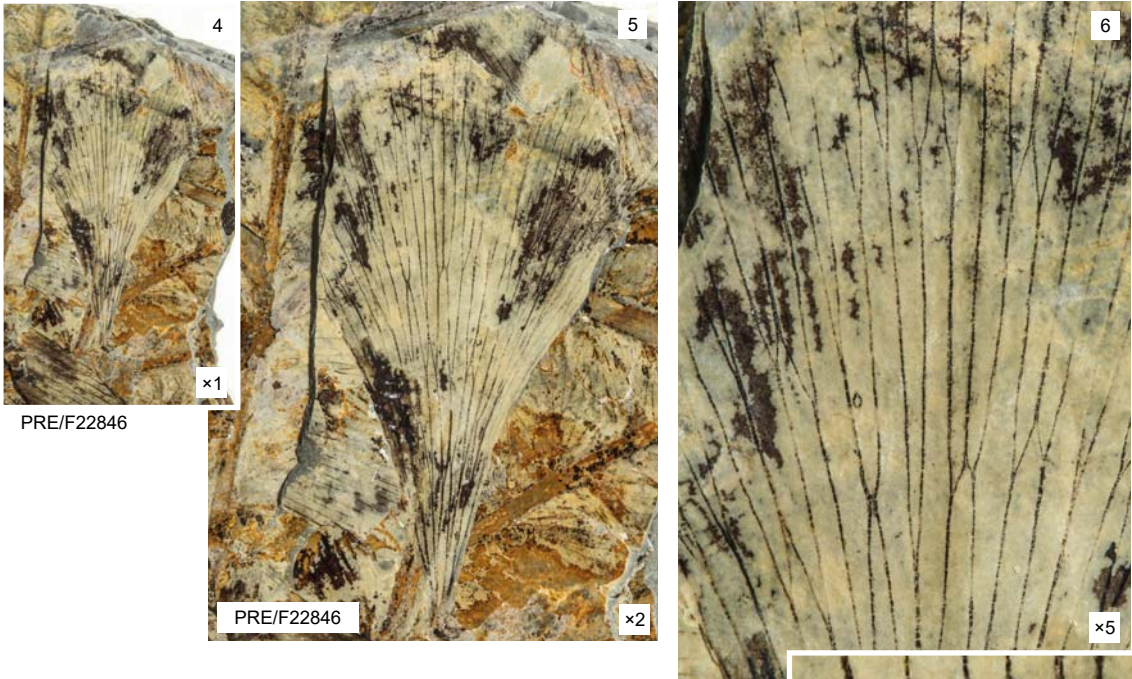
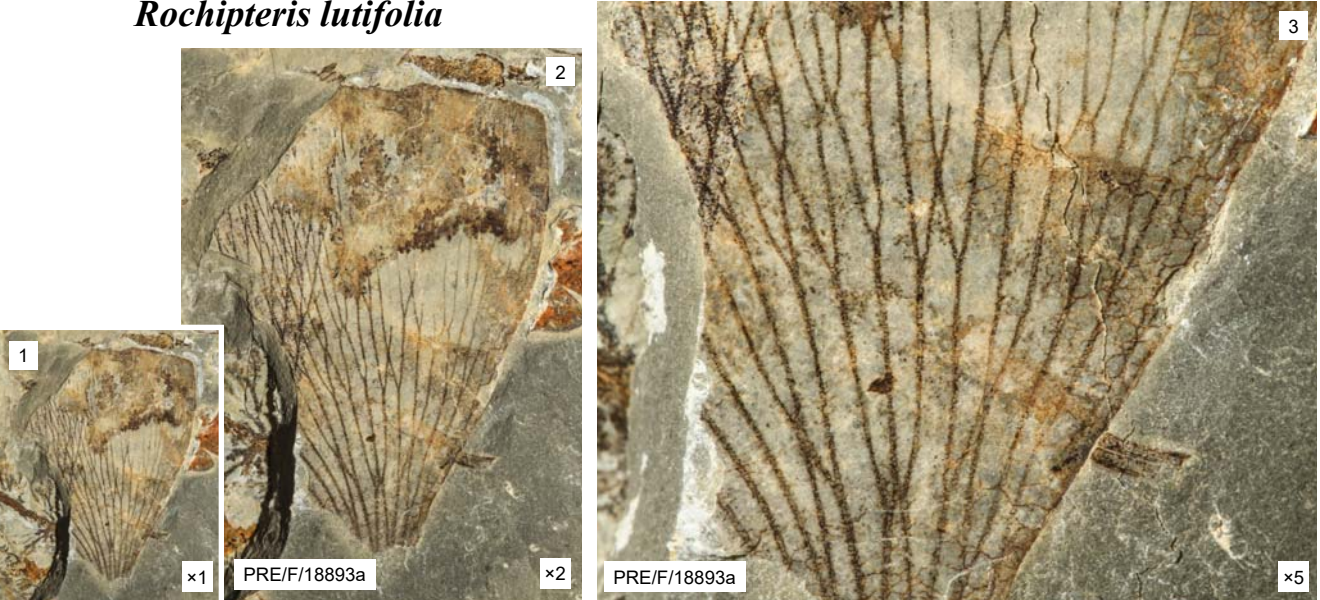


Cyp 111 Dic cra

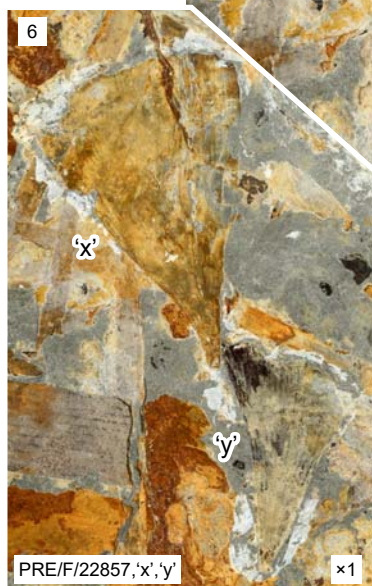
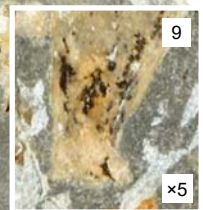
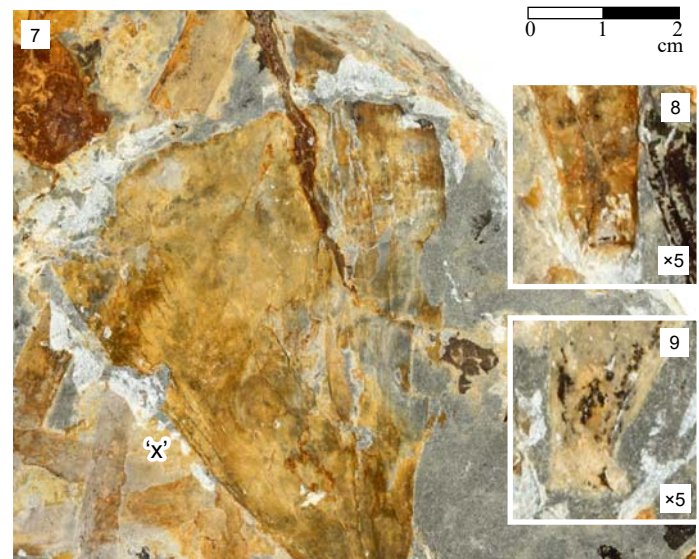


Rochipteris lutifolia**Cyp 111 Dic cra**

Rochipteris lutifolia

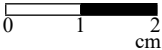
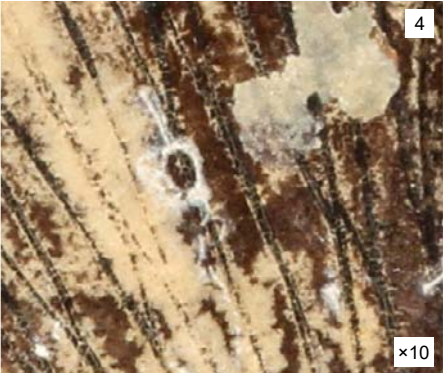
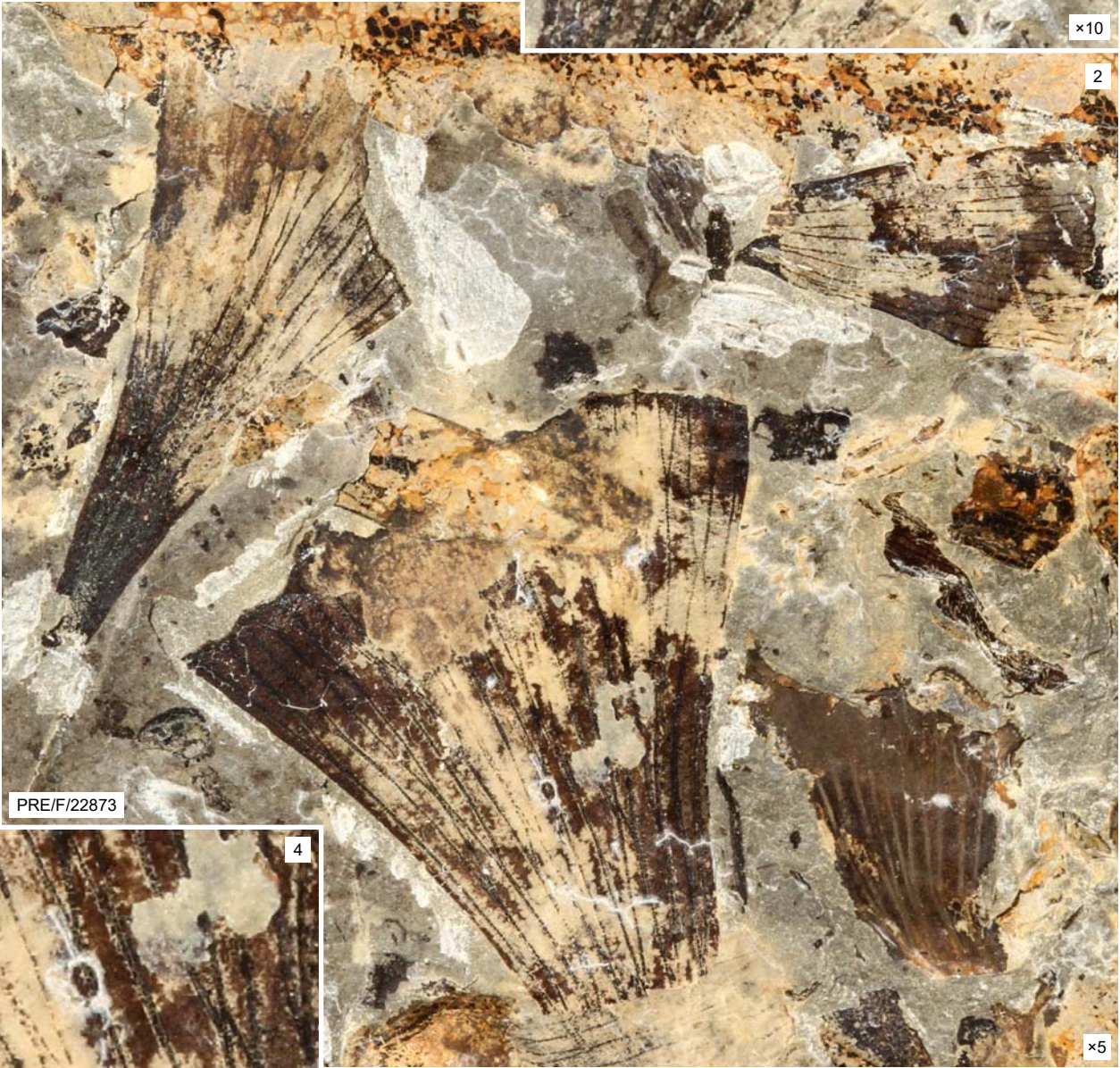
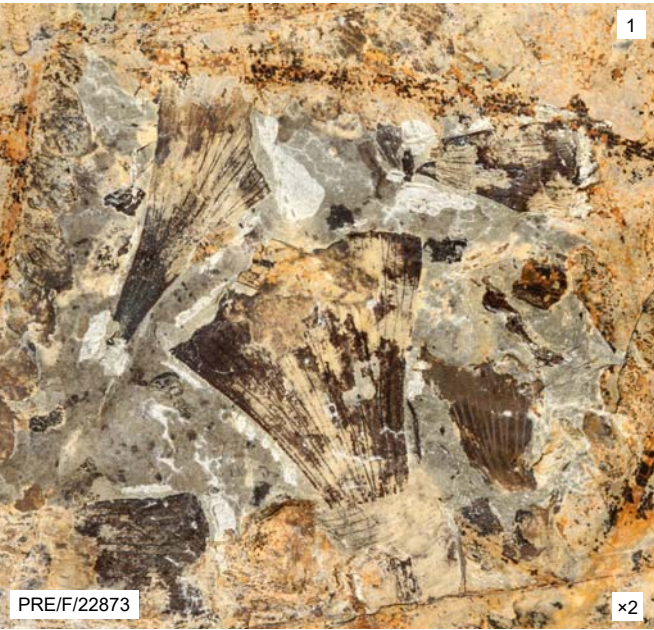


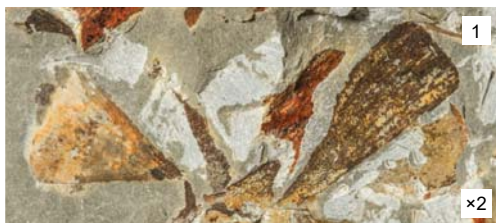
Cyp 111 Dic cra

Rochipteris lutifolia**Cyp 111 Dic cra**

Rochipteris lutifolia

Cyp 111 Dic cra



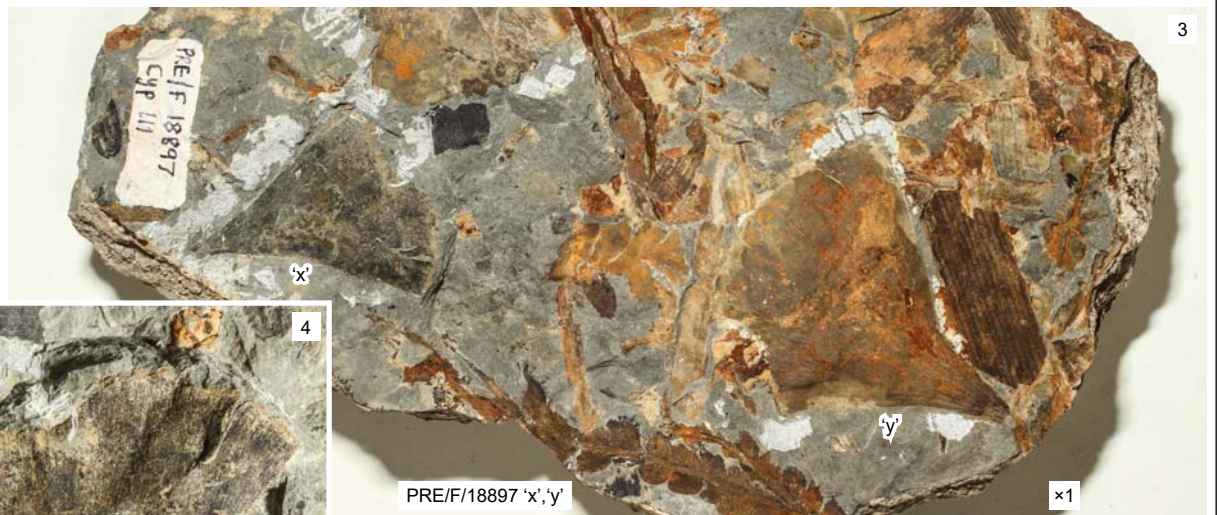
Rochipteris lutifolia

PRE/F/19751



PRE/F/19751

Cyp 111 Dic cra



PRE/F/18897 'x', 'y'



PRE/F/18897 'x'



6

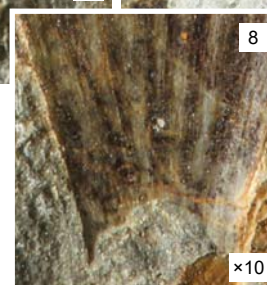
PRE/F/18897 'x'

×10



5

×5



8

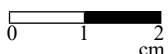
×10



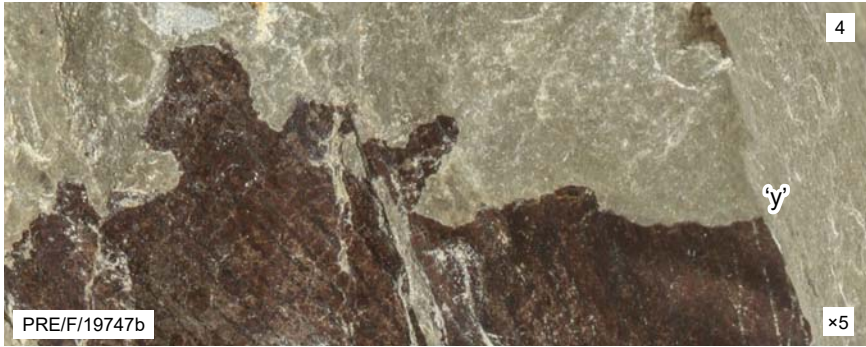
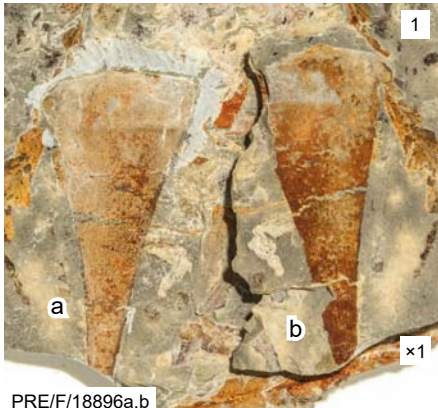
7

PRE/F/18897 'y'

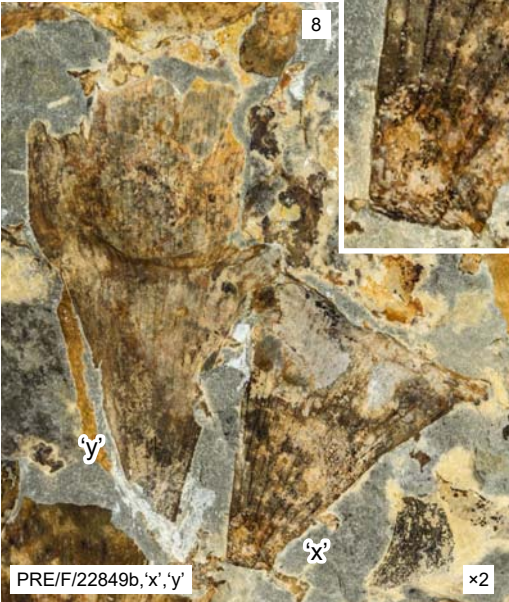
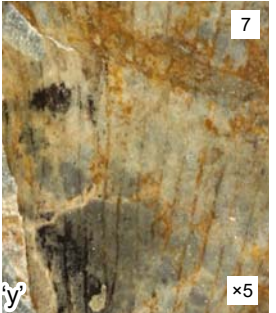
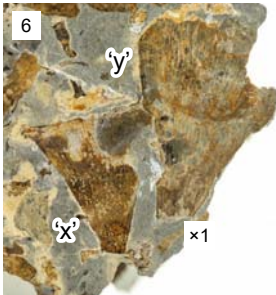
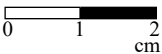
×5

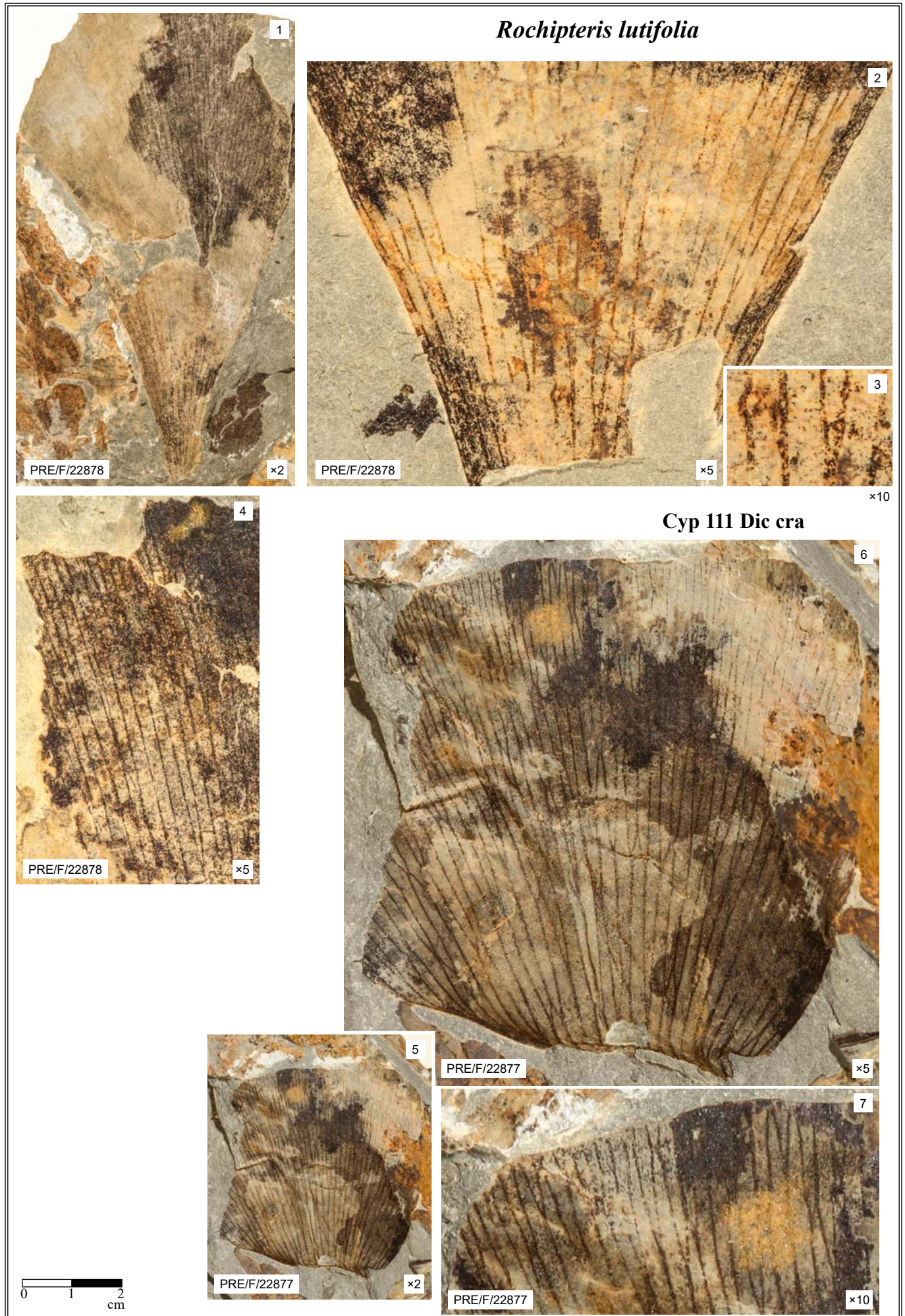


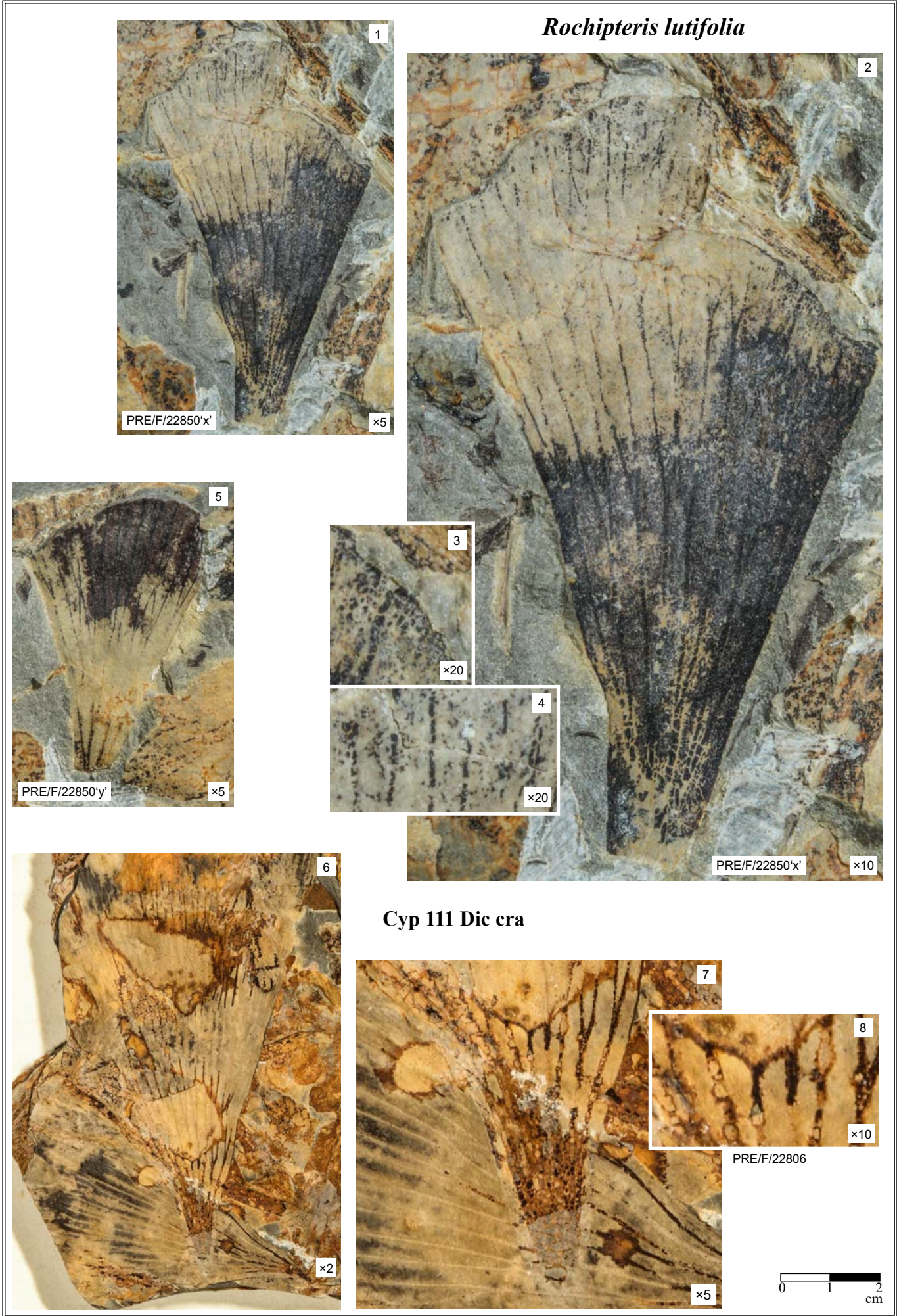
Rochipteris lutifolia

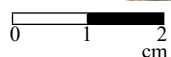
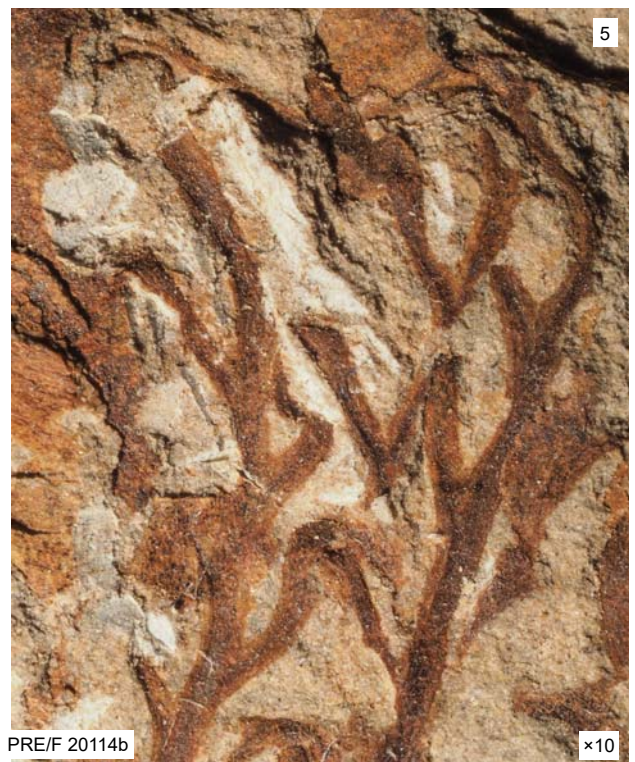


Cyp 111 Dic cra







Kannaskoppianthus irregularis

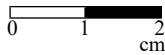
**Reference
palaeodeme**
(pls 19–20)

Kan 112 Hei elo

Kannaskoppianthus irregularis



Kan 112 Hei elo



Rochipteris distivena

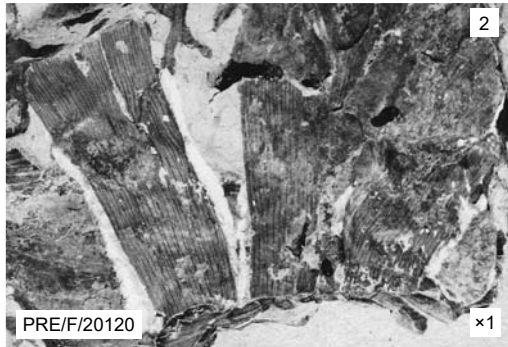
PRE/F/20120



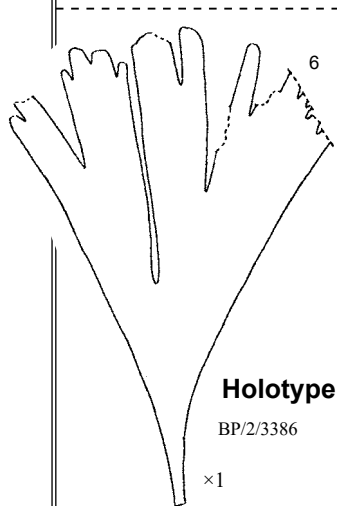
PRE/F/20120



PRE/F/20120

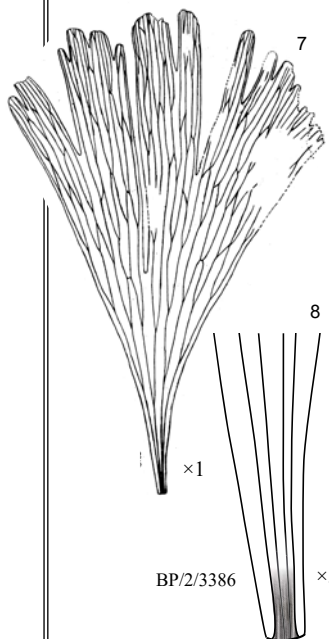


PRE/F/20120

**Holotype**

BP/2/3386

x1



BP/2/3386

x5

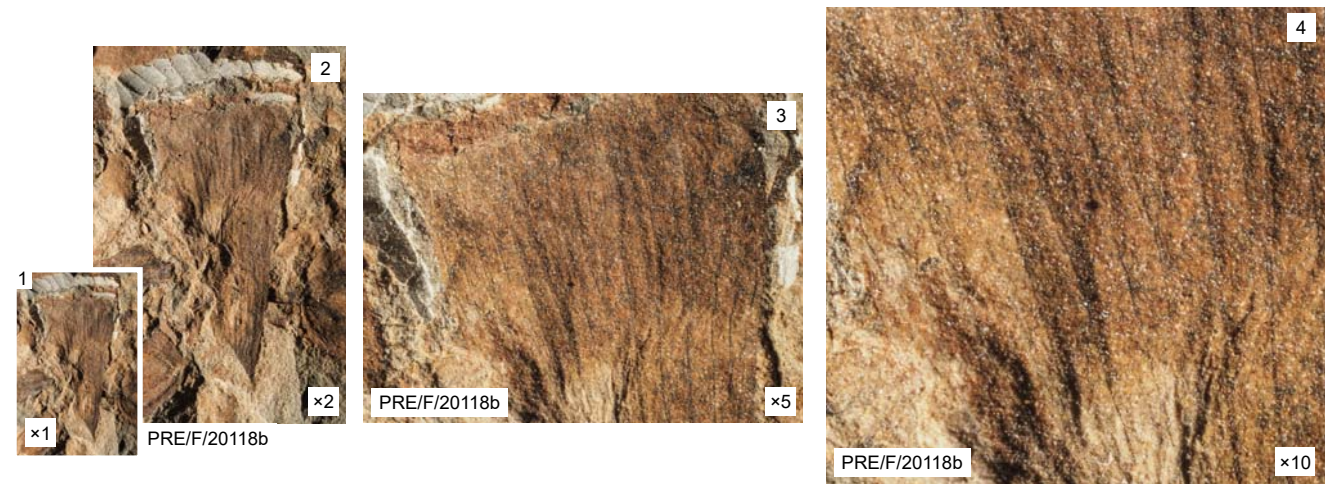


PRE/F/20120

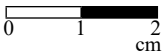
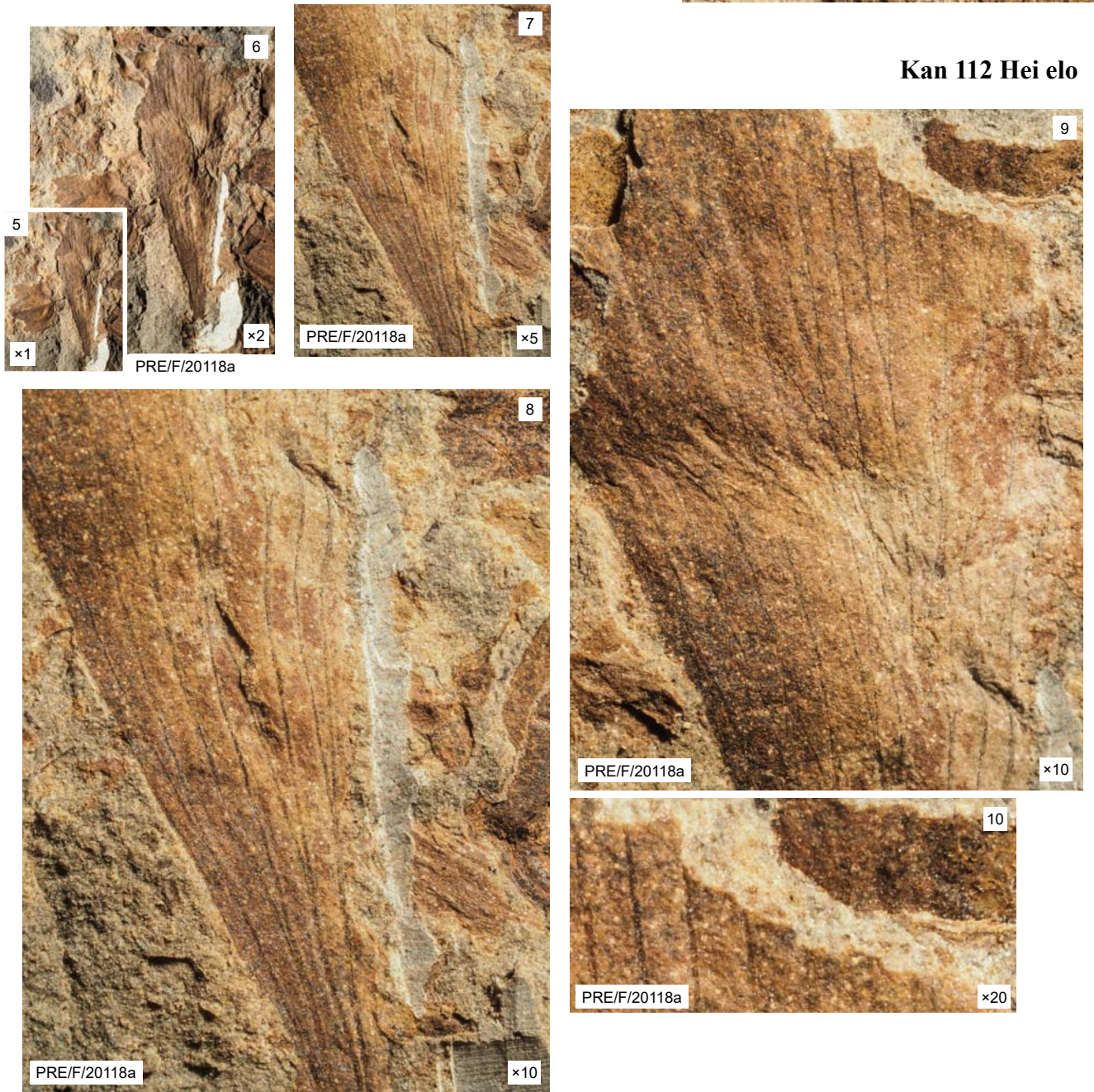
x10

Reference palaeodeme
(pls 21–22)**Kan 112 Hei elo**0 1 2
cm

Rochipteris distivena



Kan 112 Hei elo





PRE/F/13487a'y

Holotype

x1



PRE/F/13487a'y

x2

***Kannaskoppia vincularis* /
*Rochipteris vincularis***

Reference palaeodeme
(pls 23–40)

3



PRE/F/13487a'y

x5

0 1 2
cm

Kan 111 Ast spA

Kannaskoppia vincularis / *Rochipteris vincularis*



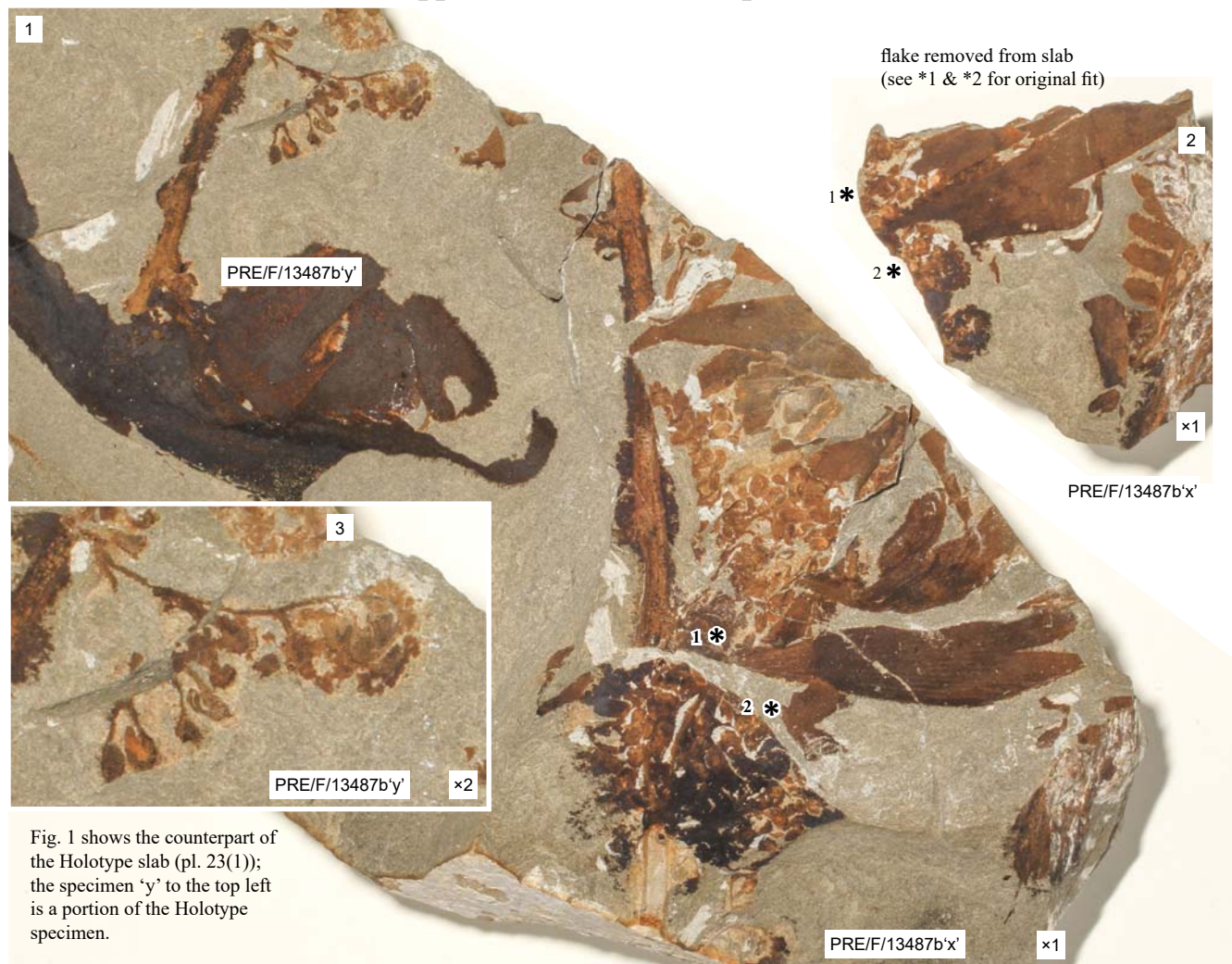
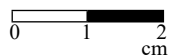
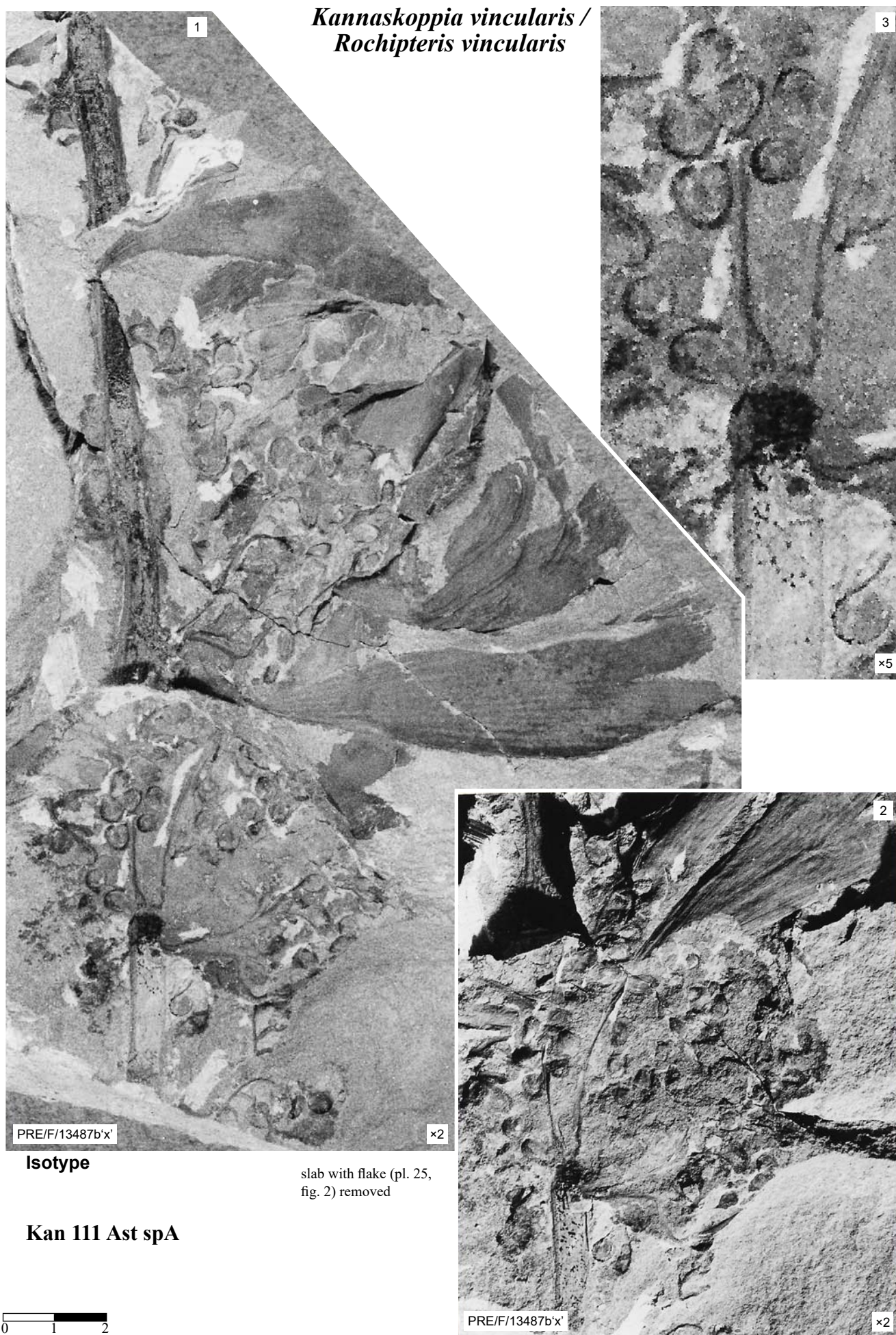
Kannaskoppia vincularis / *Rochipteris vincularis*

Fig. 1 shows the counterpart of the Holotype slab (pl. 23(1)); the specimen 'y' to the top left is a portion of the Holotype specimen.

Isotype**Kan 111 Ast spA**



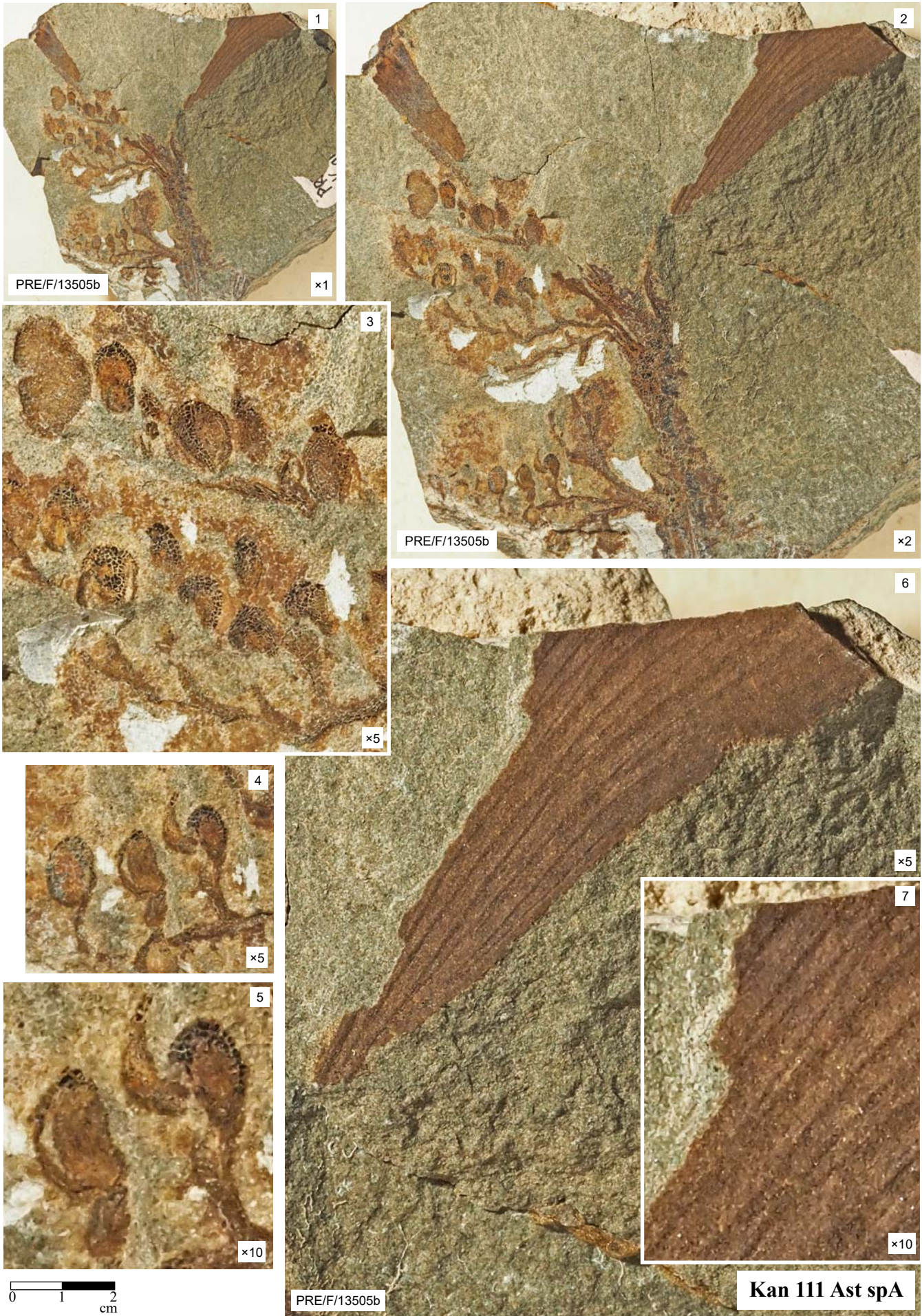
***Kannaskoppia vincularis* /
*Rochipteris vincularis***



Kan 111 Ast spA



Kannaskoppia vincularis / *Rochipteris vincularis*

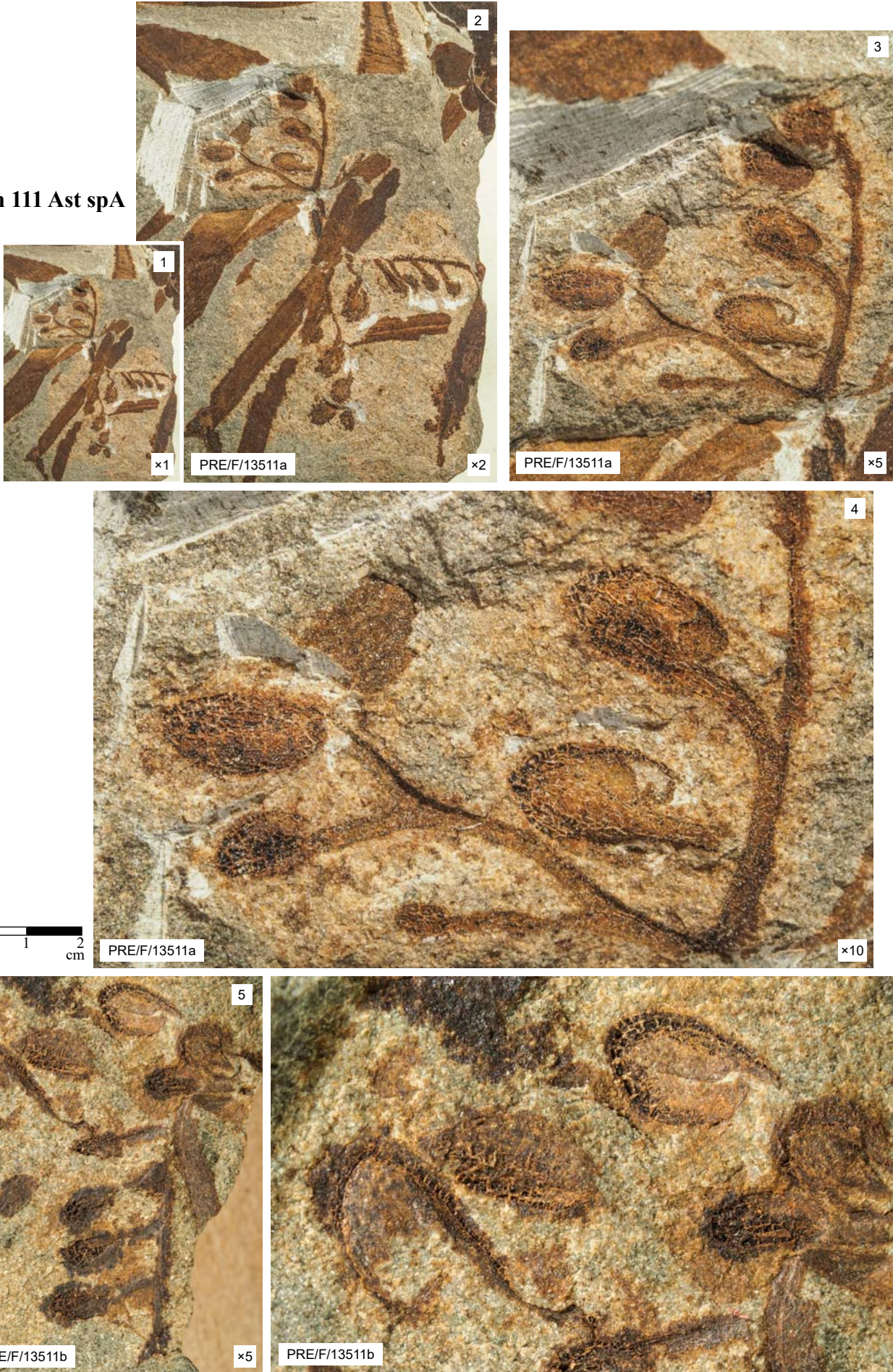


Kannaskoppia vincularis / *Rochipteris vincularis*

Kan 111 Ast spA

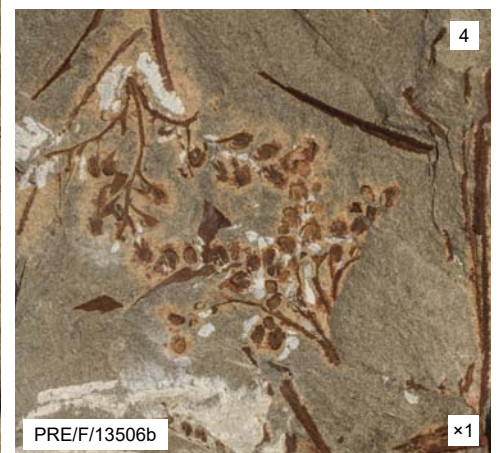
Kannaskoppia vincularis

Kan 111 Ast spA

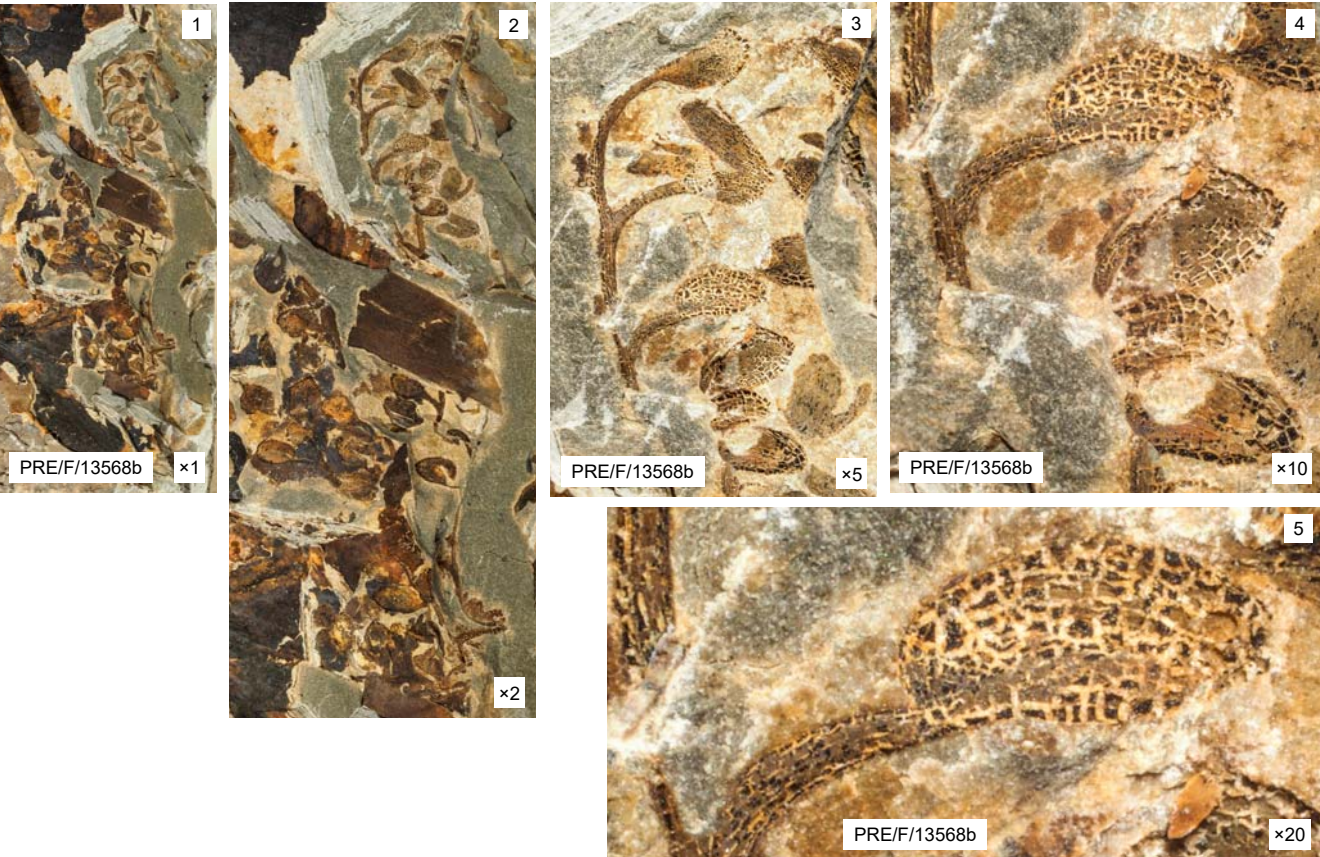


Kannaskoppia vincularis

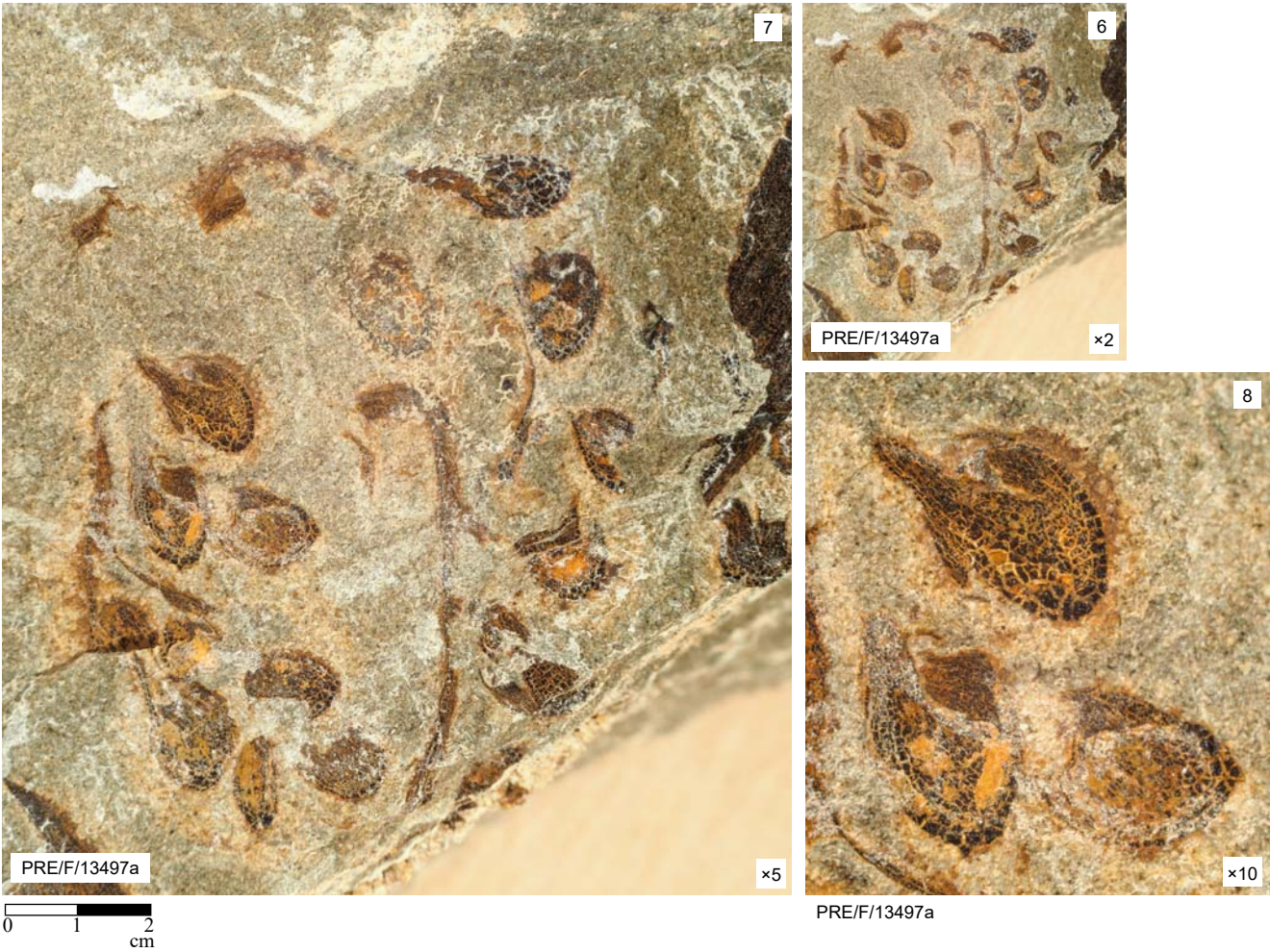
Kan 111 Ast spA

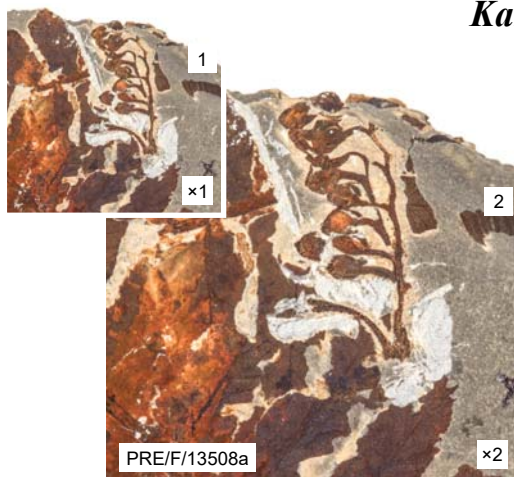


Kannaskoppia vincularis



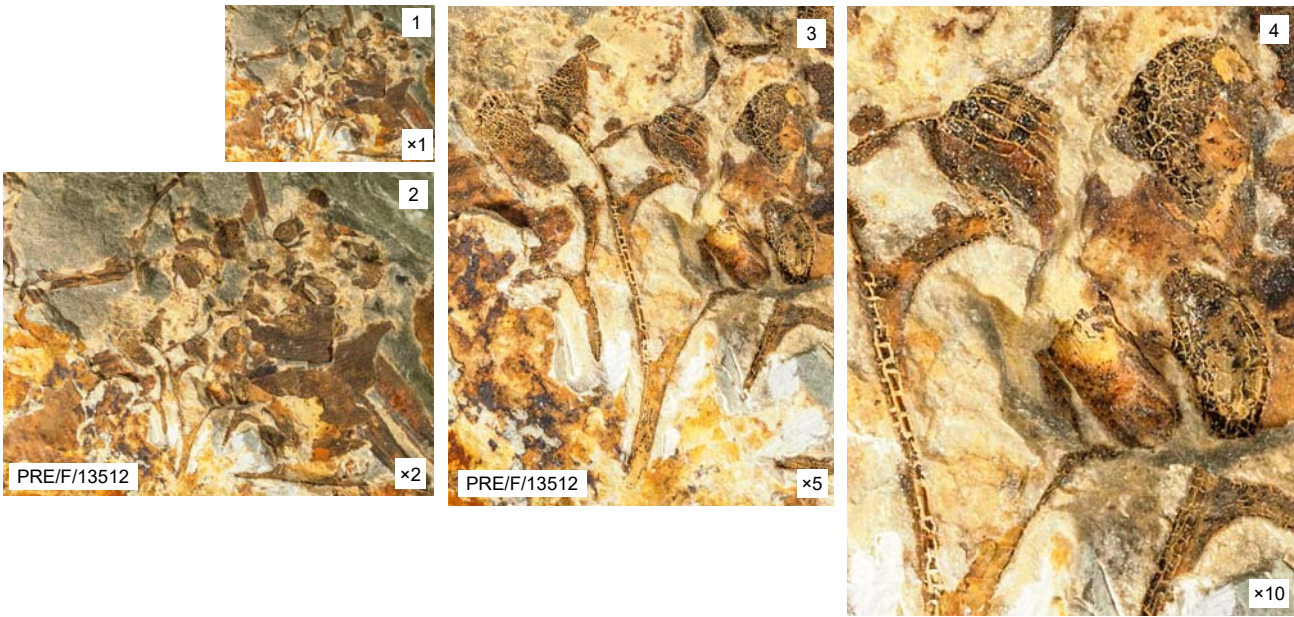
Kan 111 Ast spA



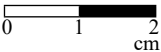
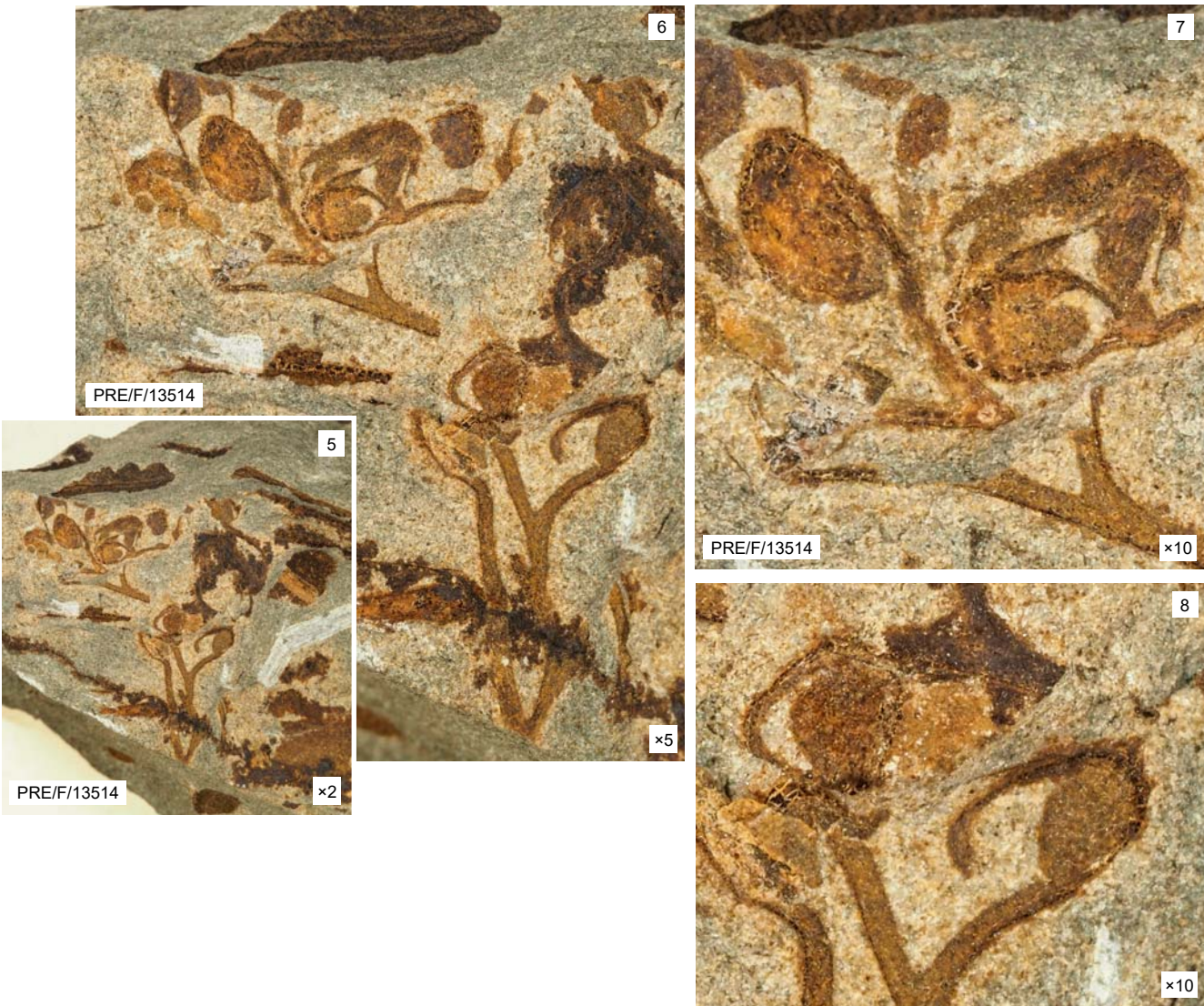
Kannaskoppia vincularis

Kan 111 Ast spA

Kannaskoppia vincularis



Kan 111 Ast spA



Kannaskoppia vincularis

PRE/F/13518

Kan 111 Ast spA



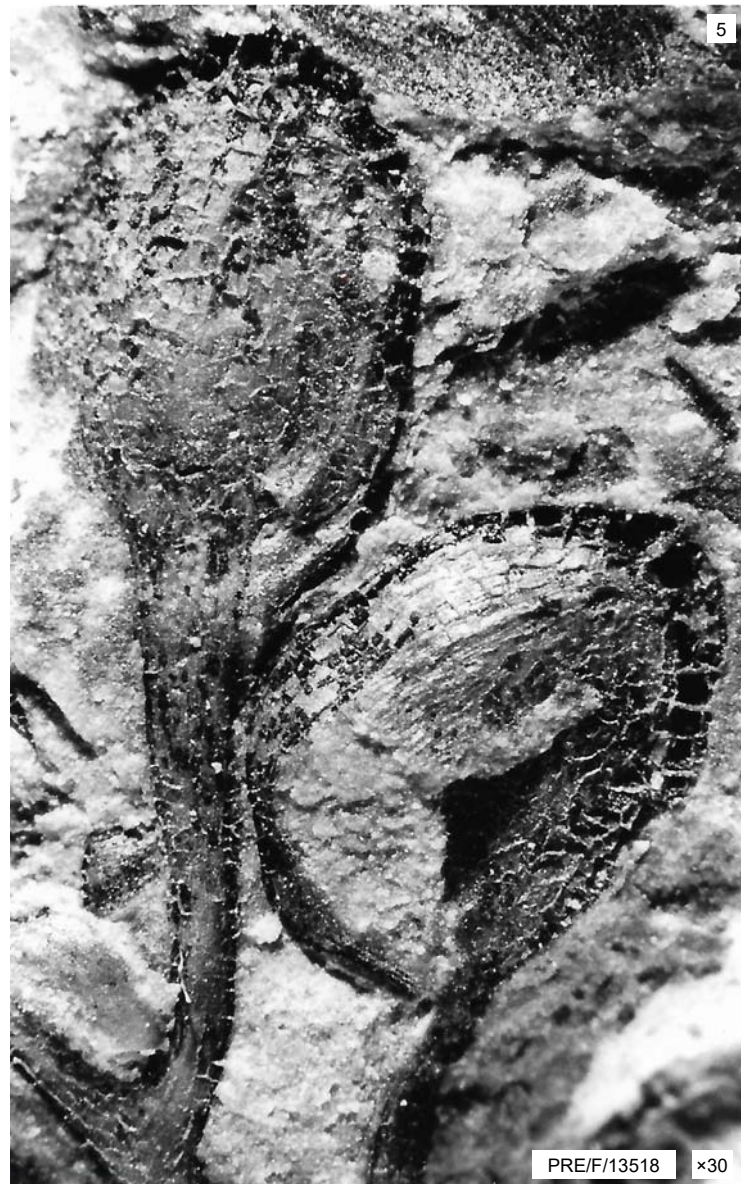
PRE/F/13518



PRE/F/13518



PRE/F/13518



PRE/F/13518

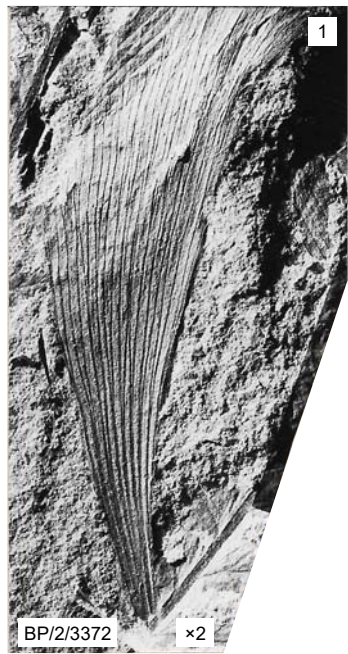
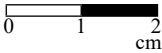
×30

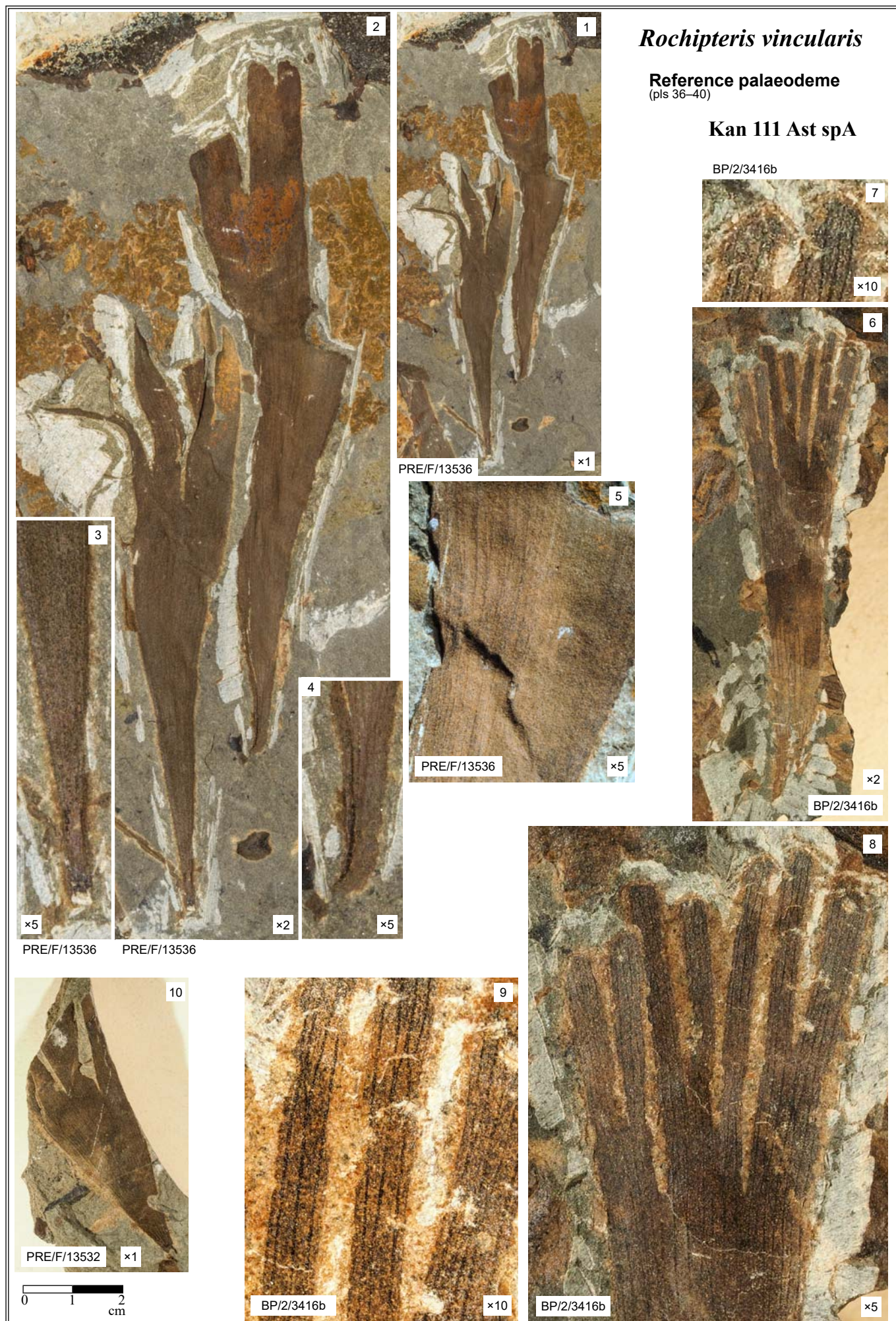


*Rochipteris
vincularis*

Reference palaeodeme
(pls 36–40)

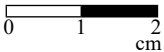
Kan 111 Ast spA

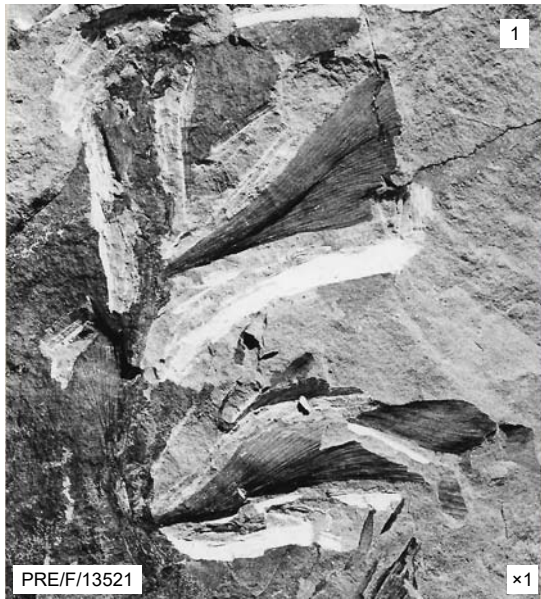




Rochipteris vincularis

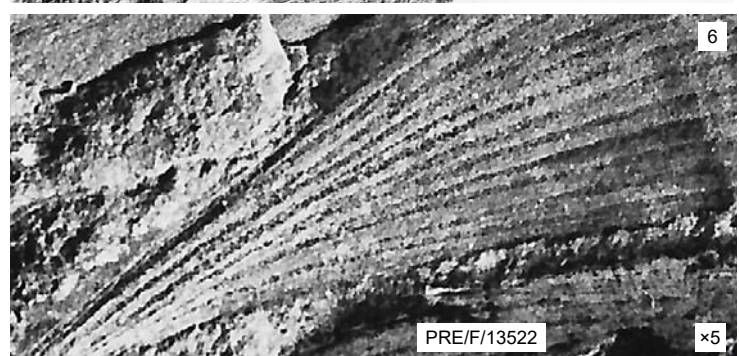
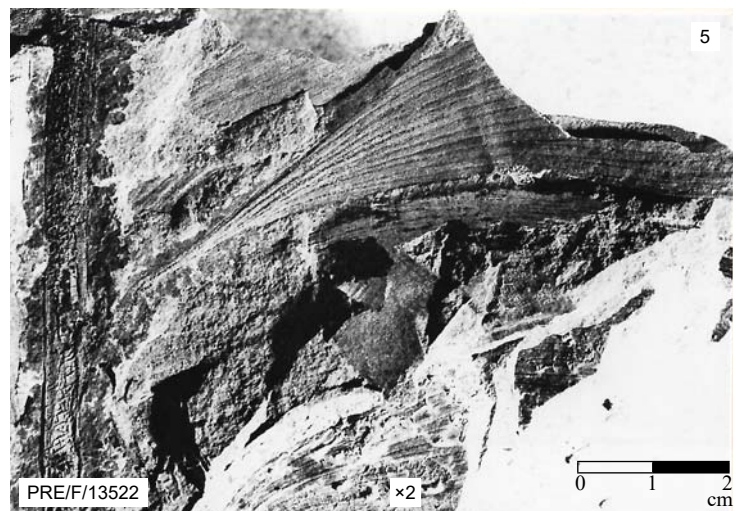
Kan 111 Ast spA



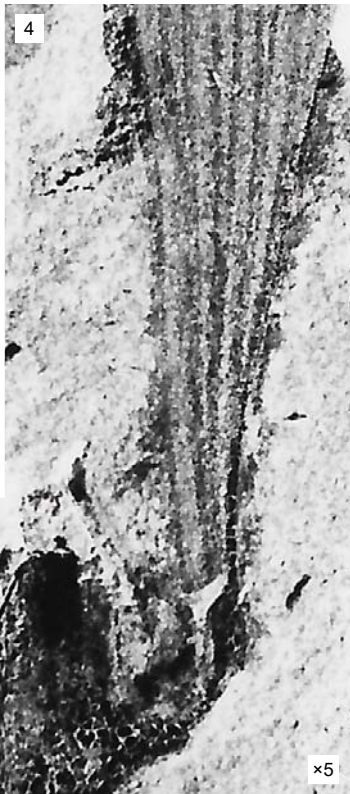
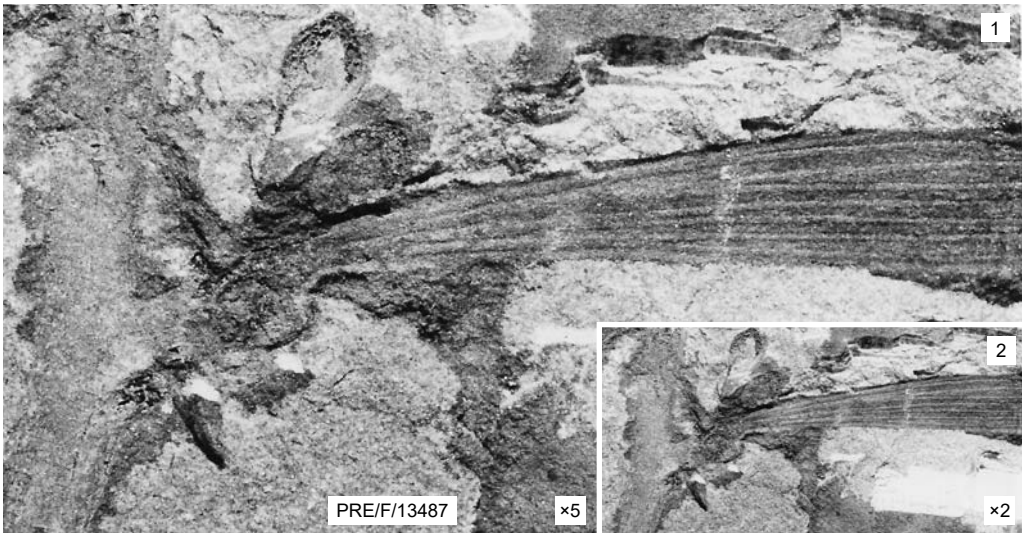
Rochipteris vincularis

Holotype

Kan 111 Ast spA

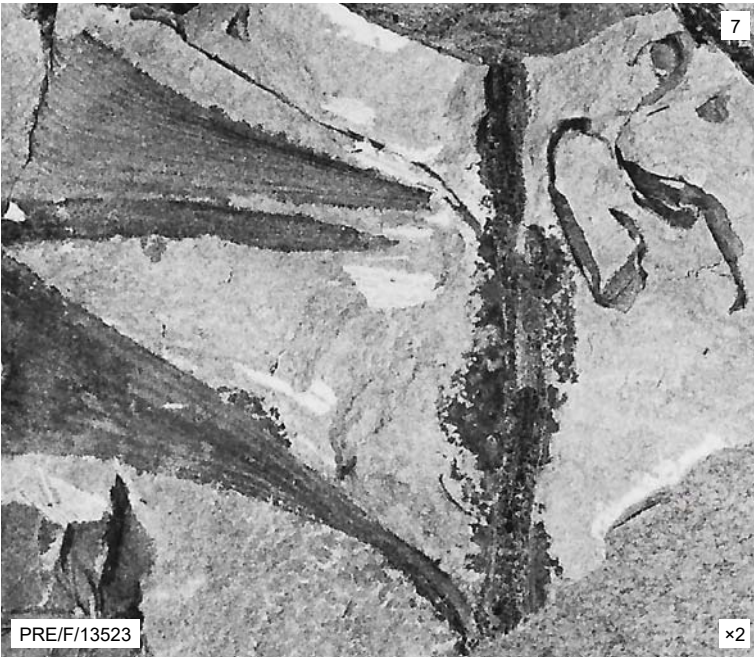


*Rochipteris
vicularis*



Kan 111 Ast spA

0 1 2
cm



Kannaskoppianthus telemagnus

Reference palaeodeme



Holotype



Tel 111 Hei elo



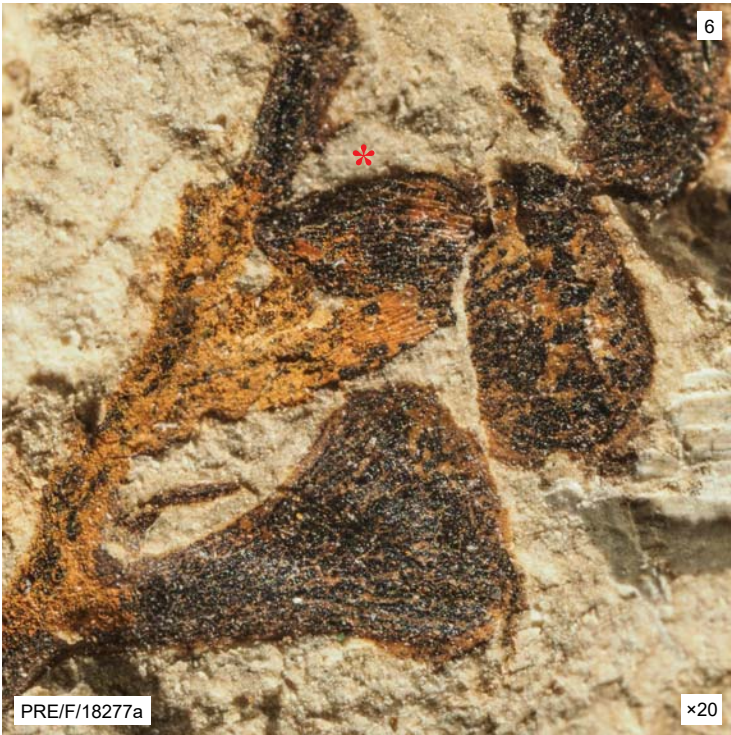
0 1 2 cm PRE/F/7711

Kannaskoppianthus telepentatus

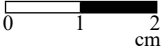
Reference palaeodeme



Holotype



Enlargement of inset in fig. 4, with asterisks showing attached microsporangium

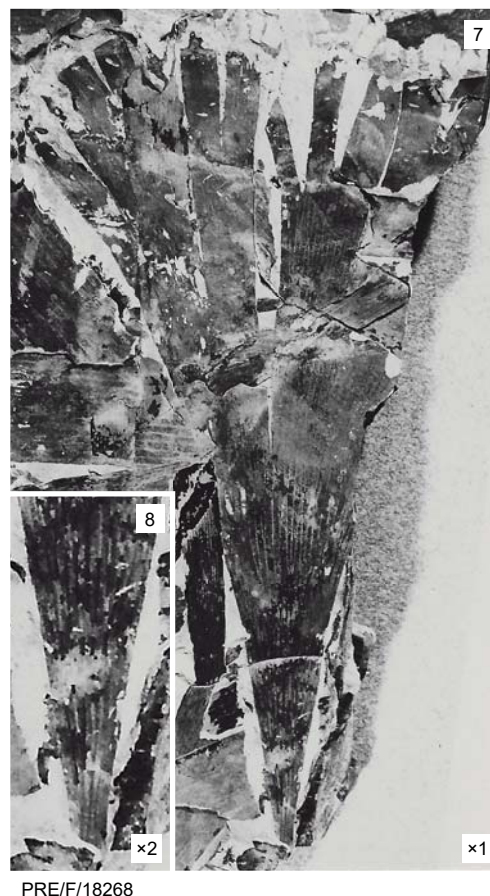


Tel 111 Hei elo

Microsporangium

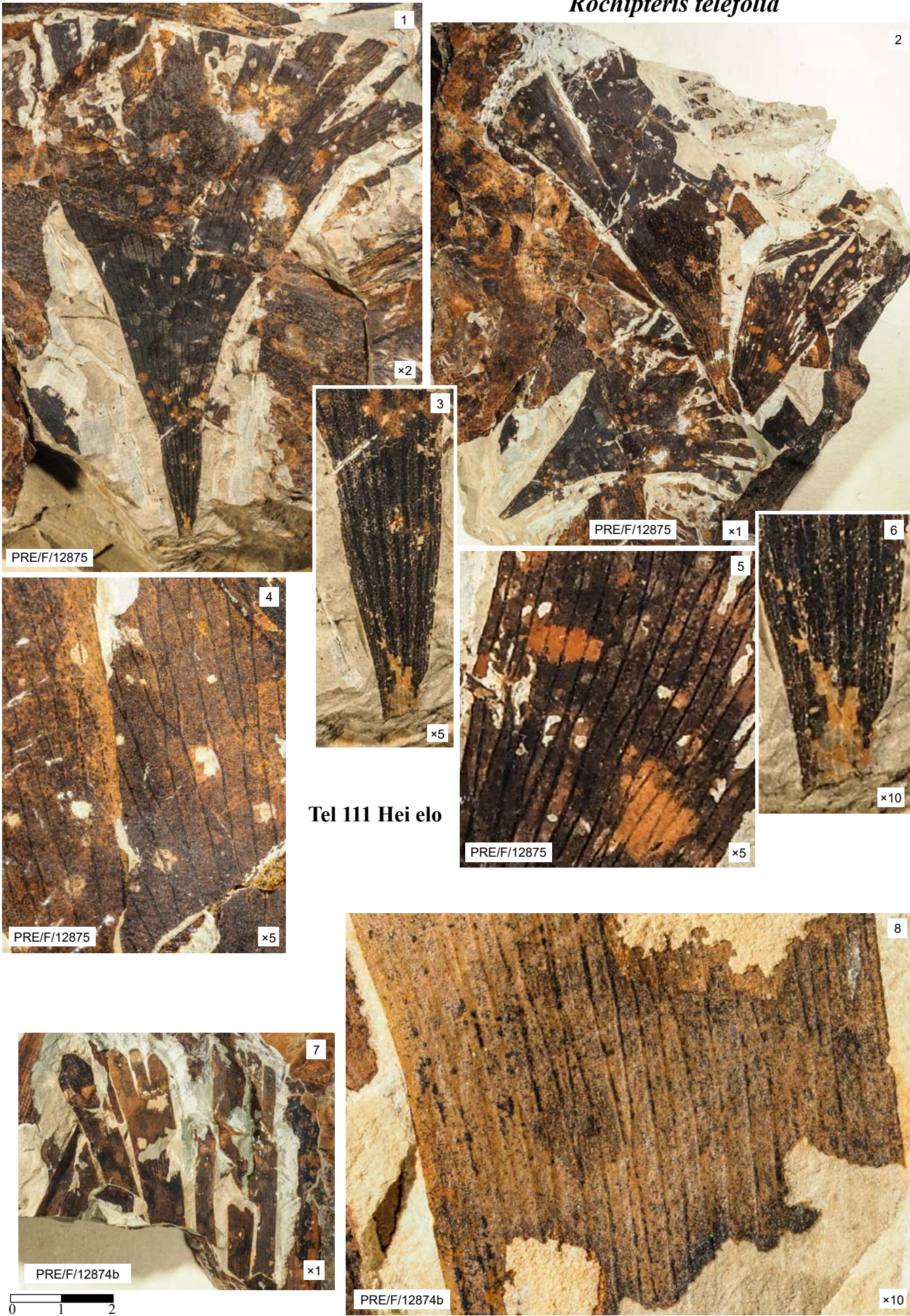
Rochipteris telefolia

Reference palaeodeme
(pls 43–46)

**Tel 111 Hei elo**

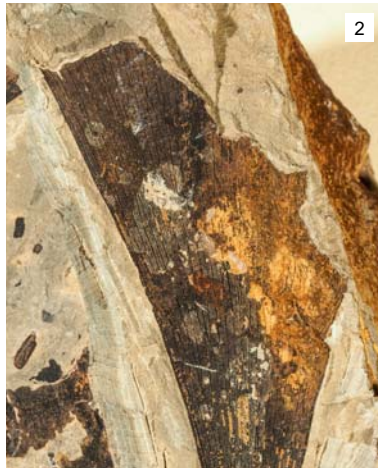
0 1 2
cm

Rochipteris telefolia

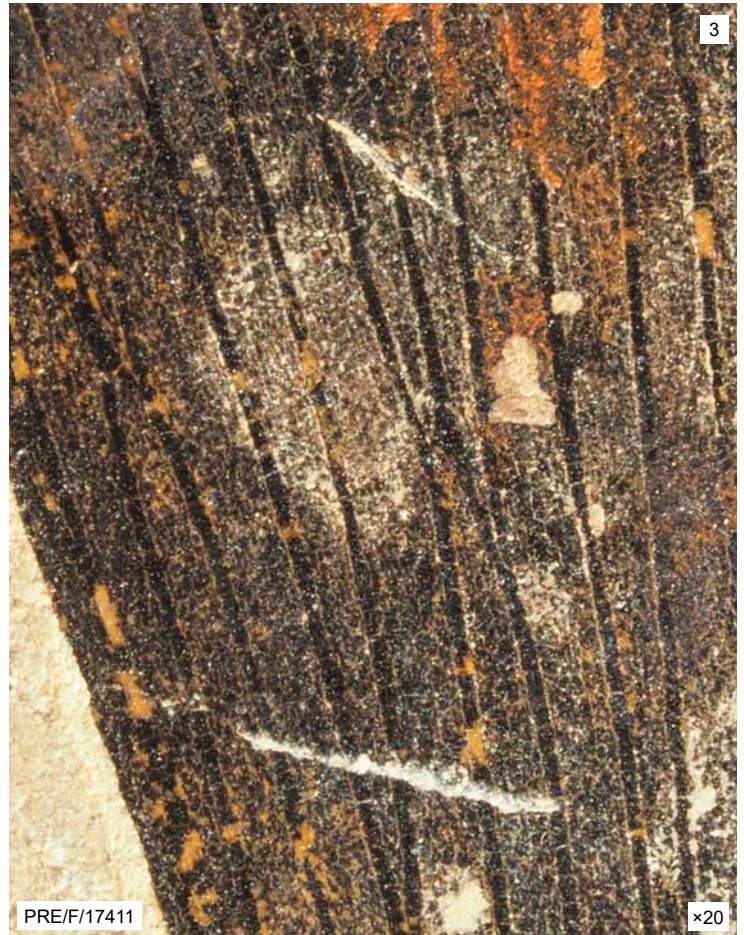


Rochipteris telefolia

PRE/F/17411



PRE/F/17411



PRE/F/17411



PRE/F/17411

Tel 111 Hei elo



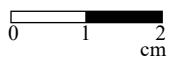
x5



PRE/F/17413



x2

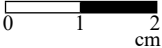


PRE/F/17413

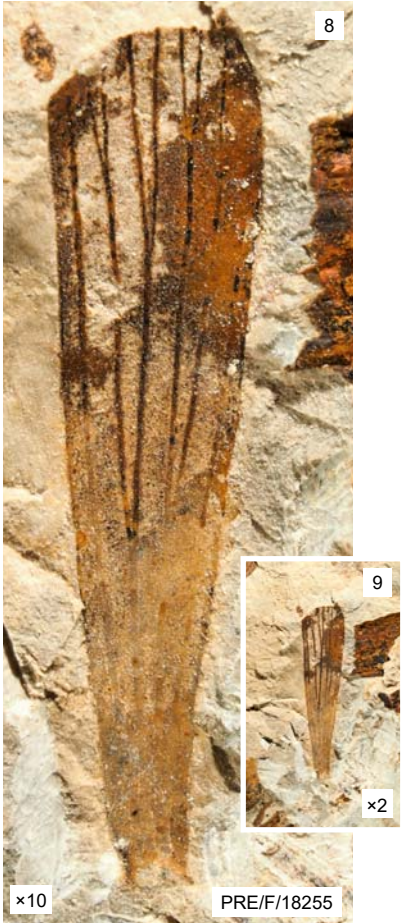
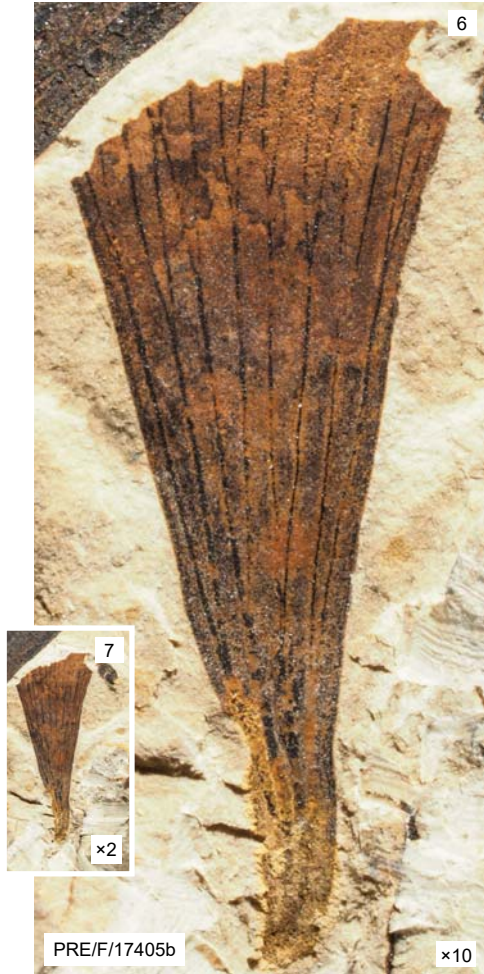
Rochipteris telefolia



Tel 111 Hei elo



Rochipteris penensis



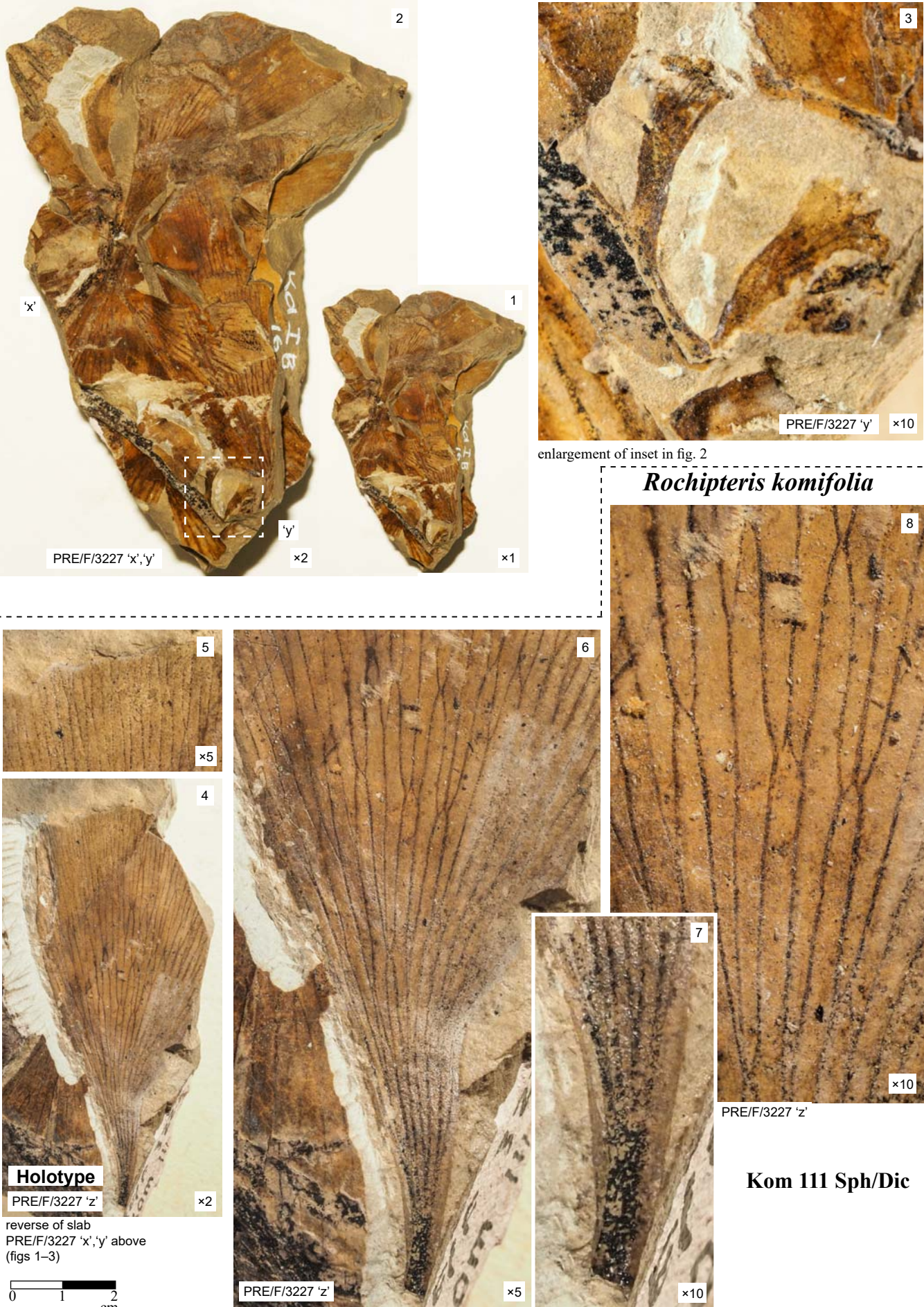
***Kannaskoppianthus komanthus* /
*Rochipteris komifolia***



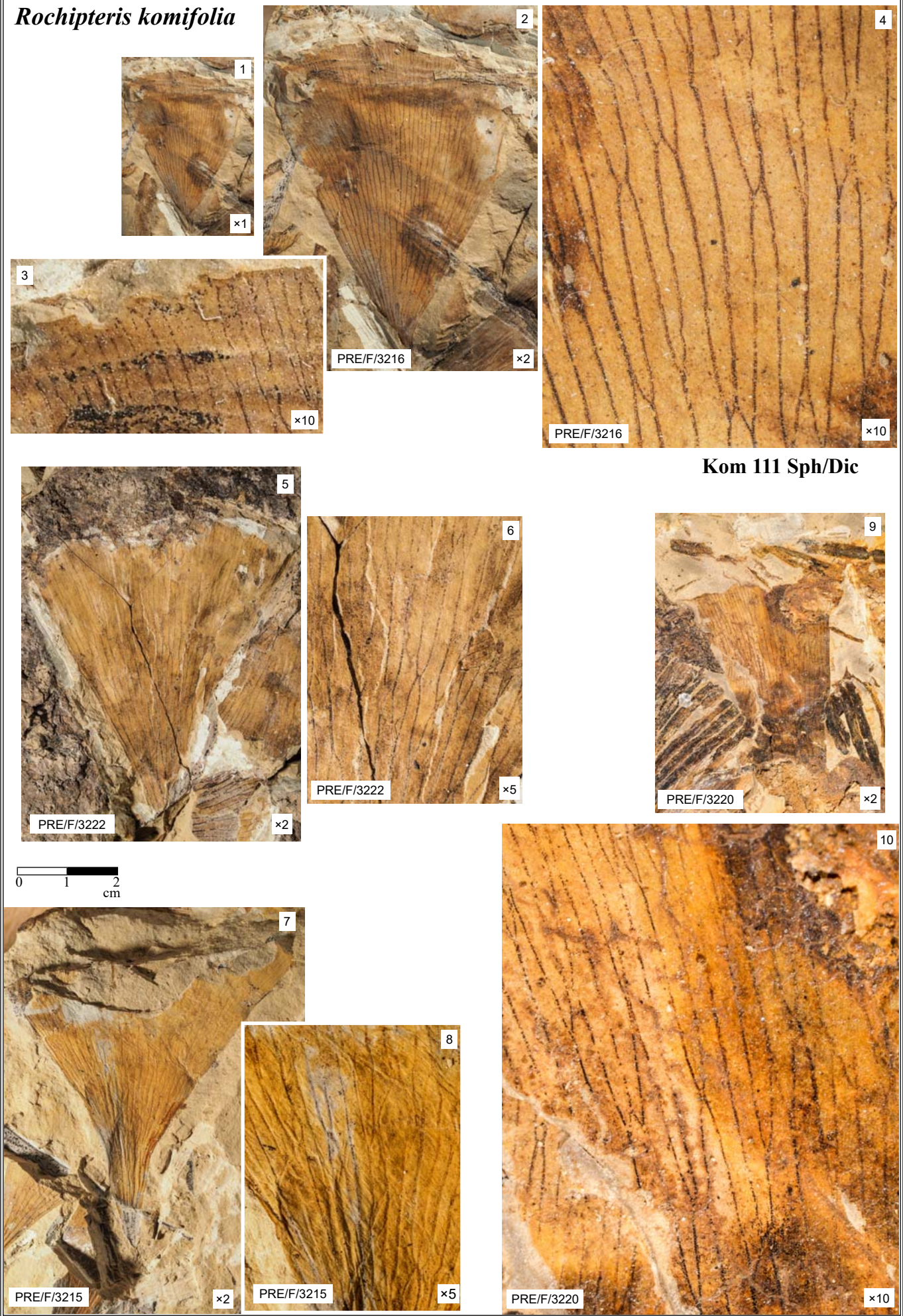
Kom 111 Sph/Dic

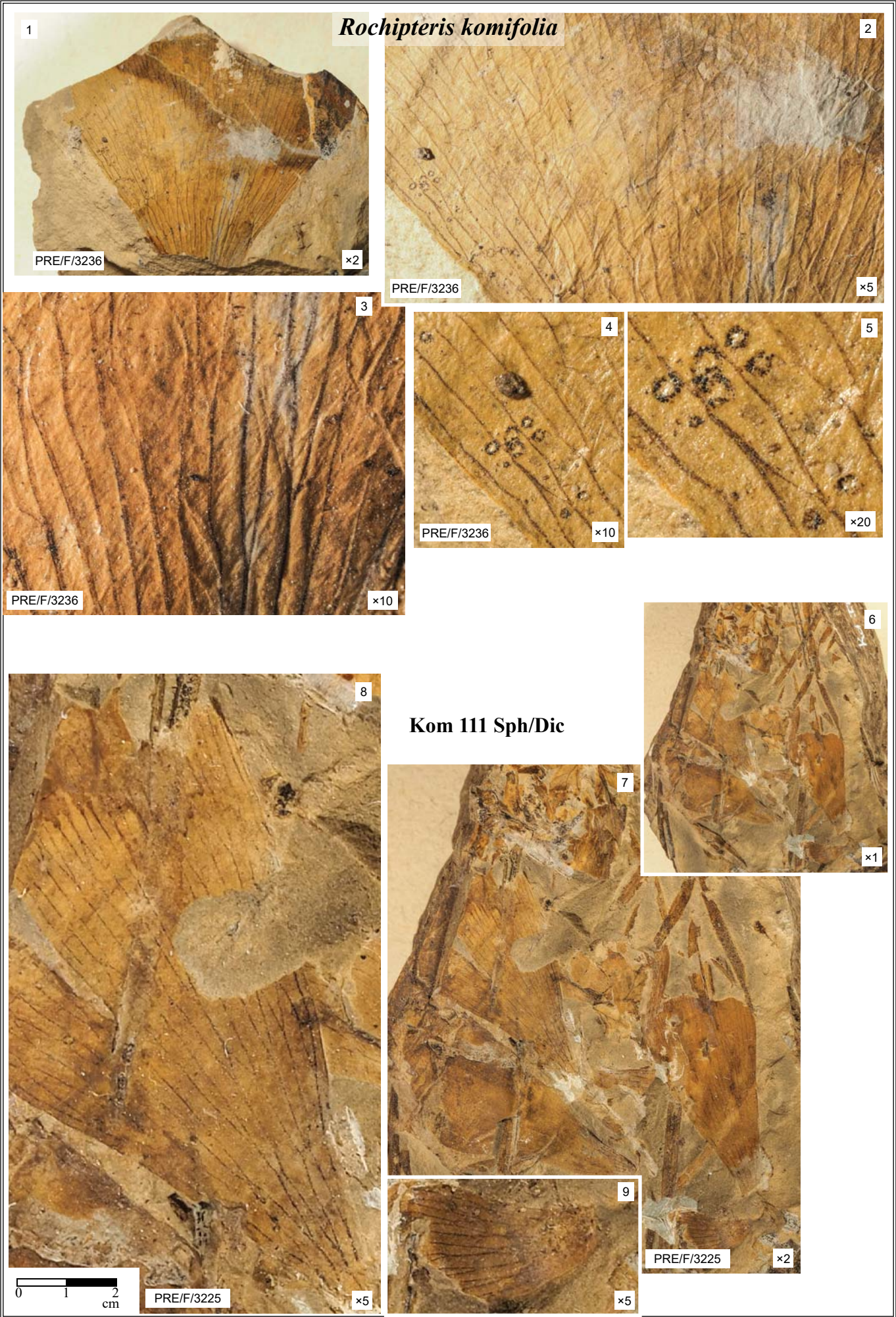


Kannaskoppianthus komanthus / *Rochipteris komifolia*

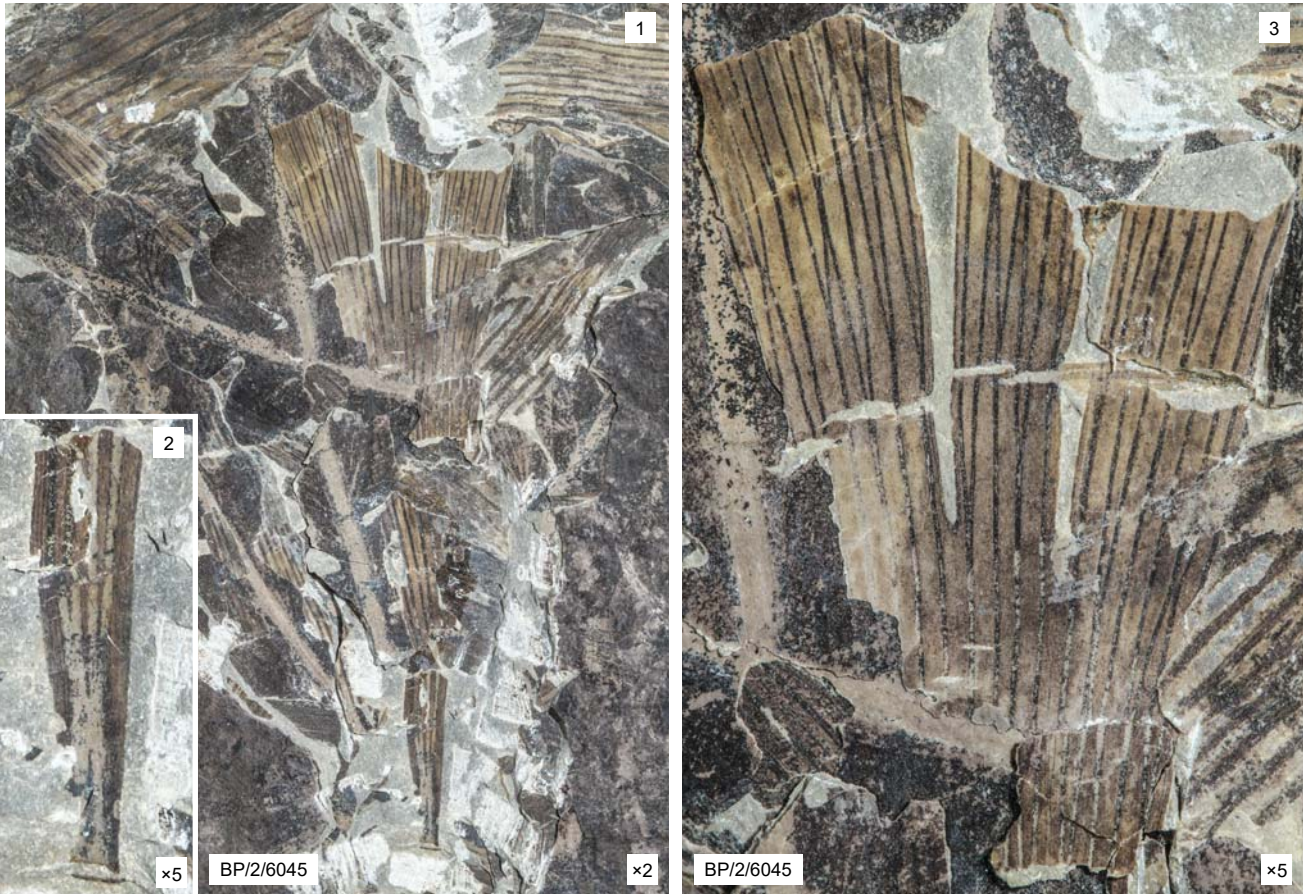


Rochipteris komifolia

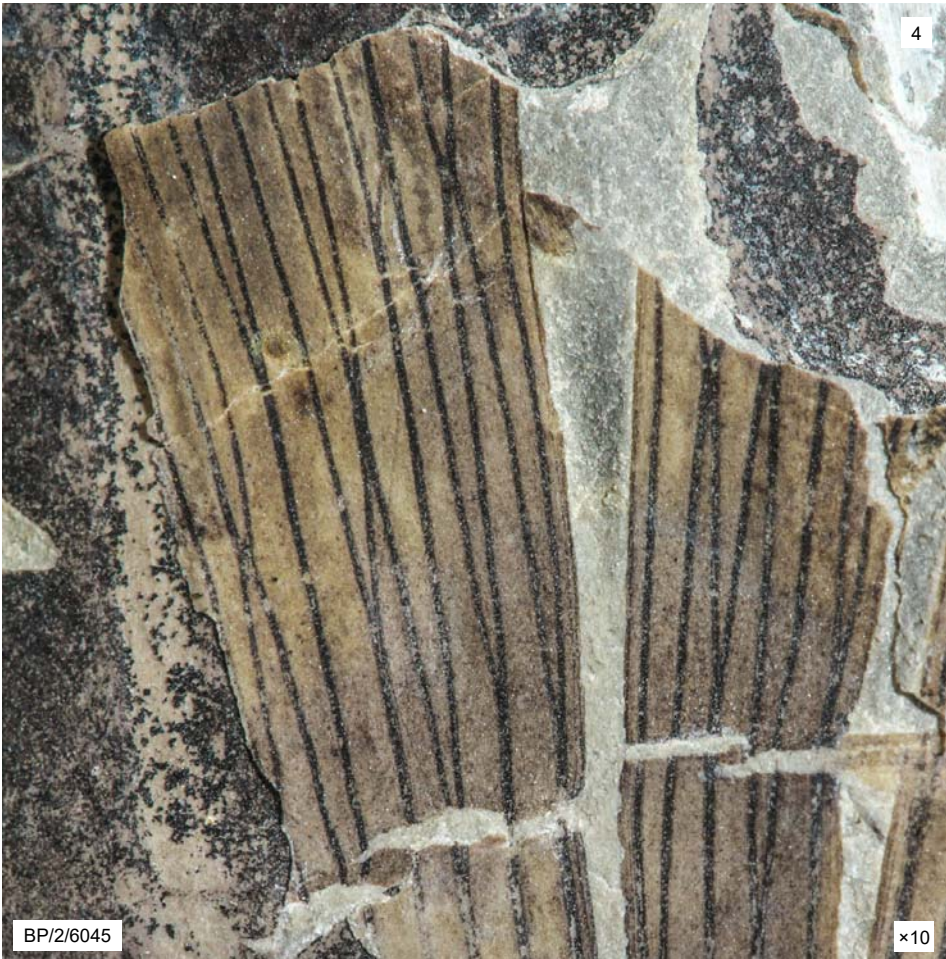
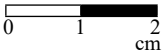




Rochipteris vincularis



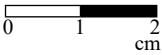
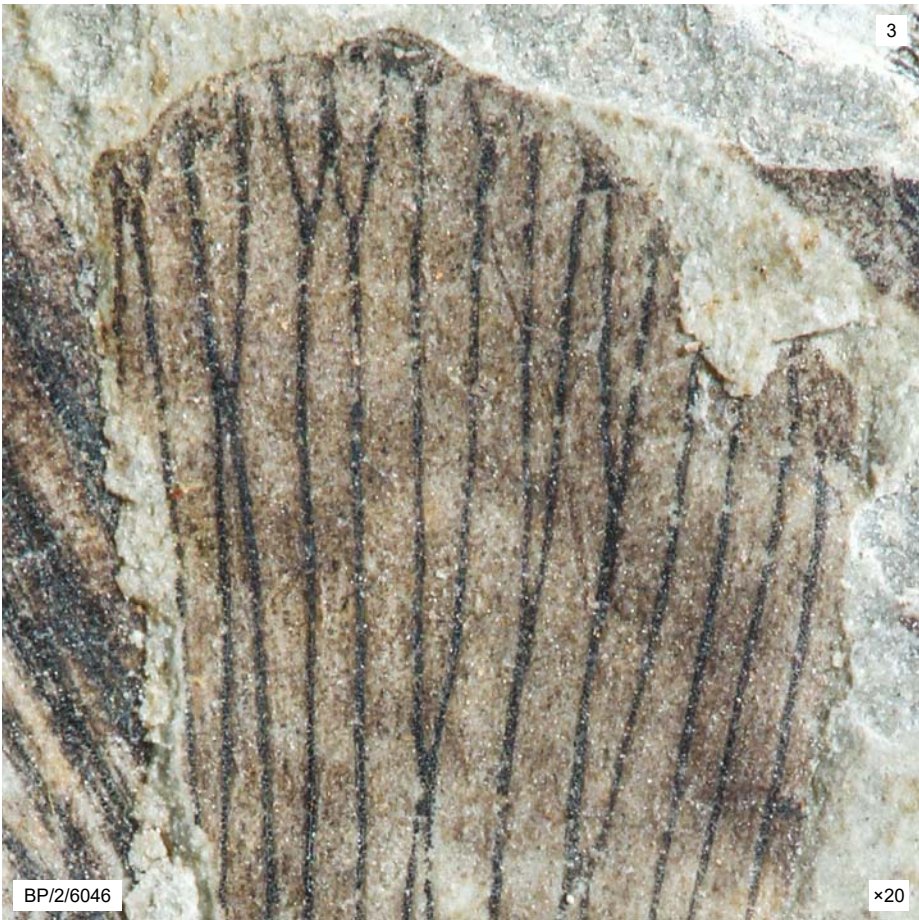
Vin 111 Dic odo



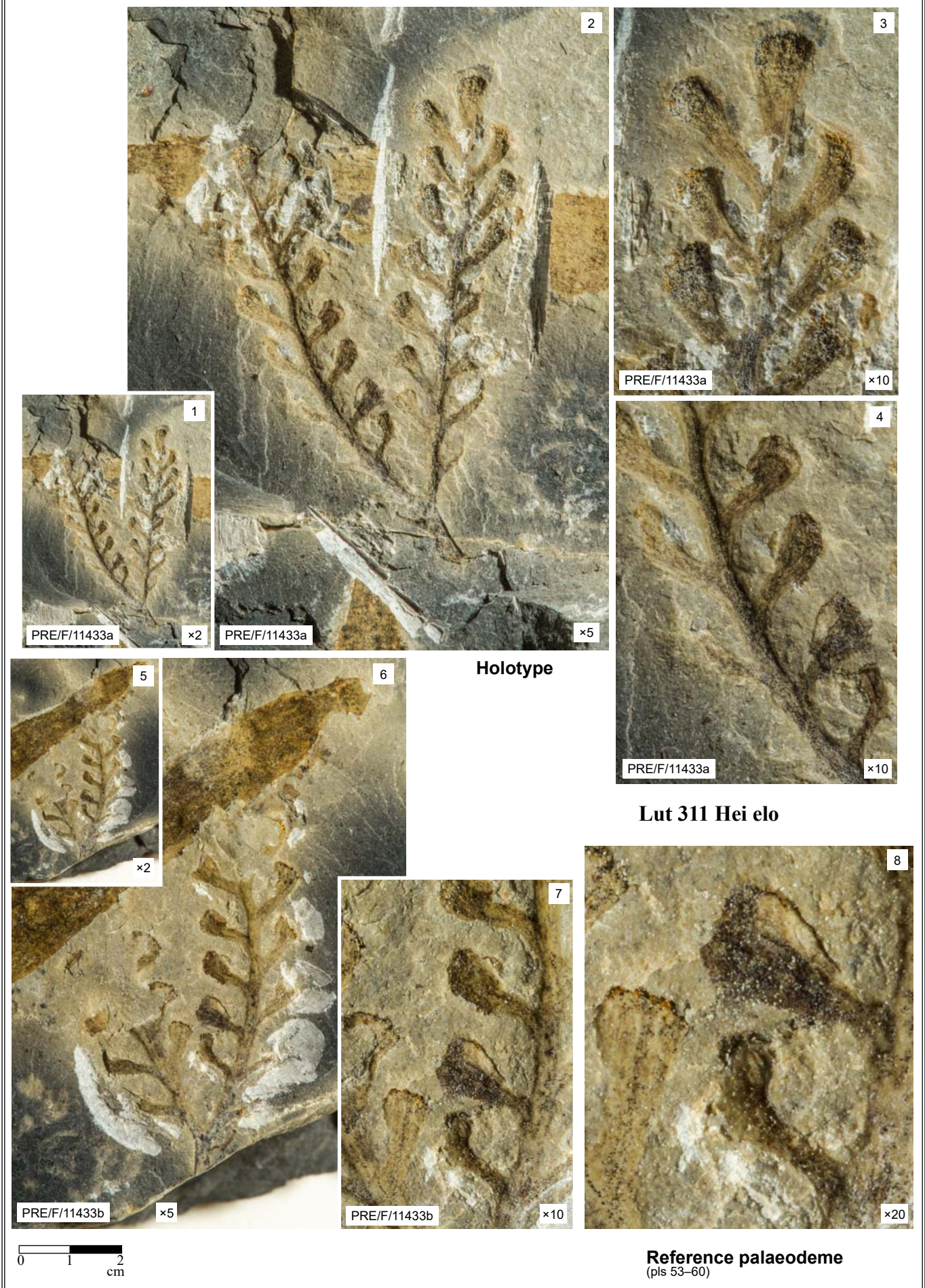
Rochipteris vincularis

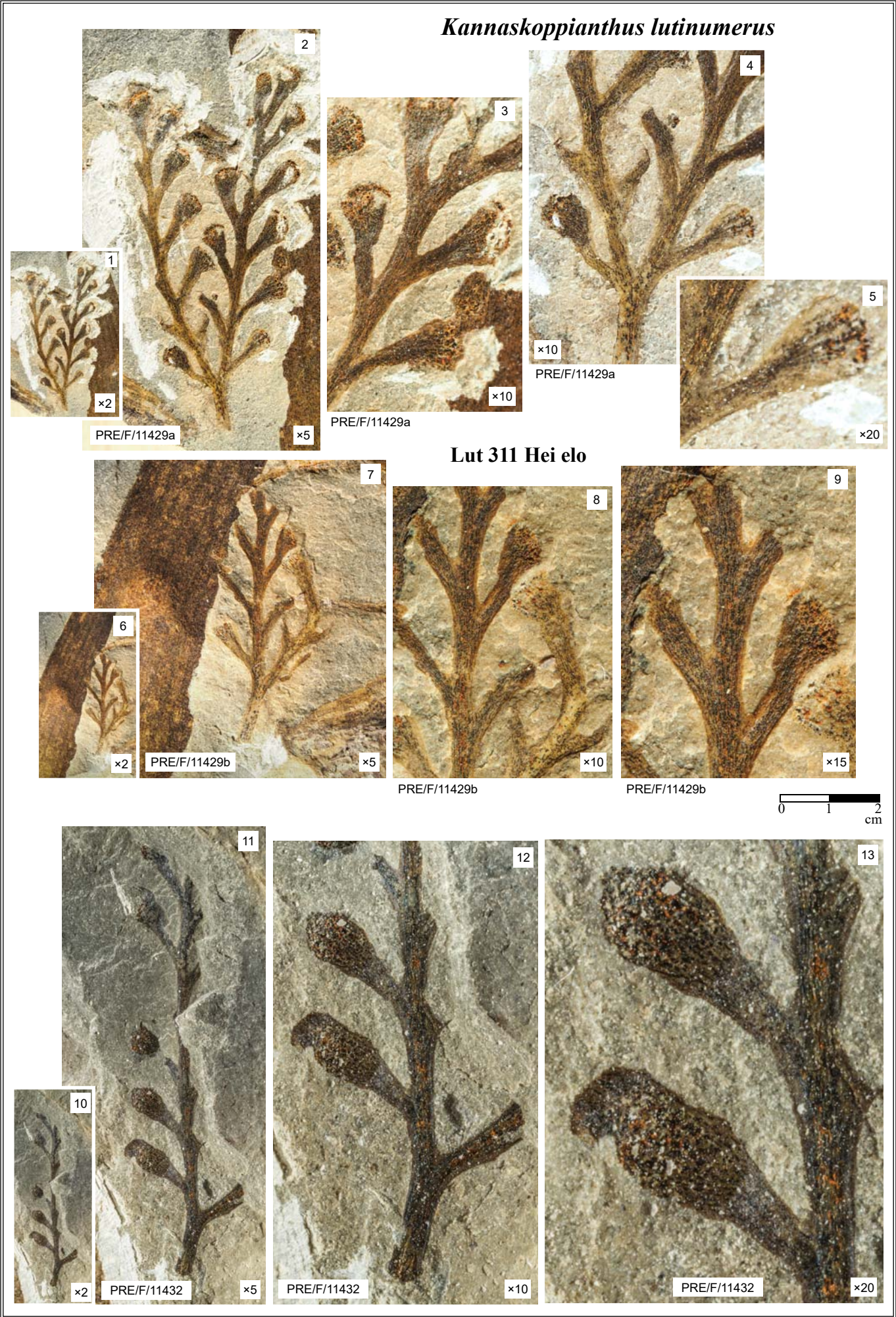


Vin 111 Dic odo

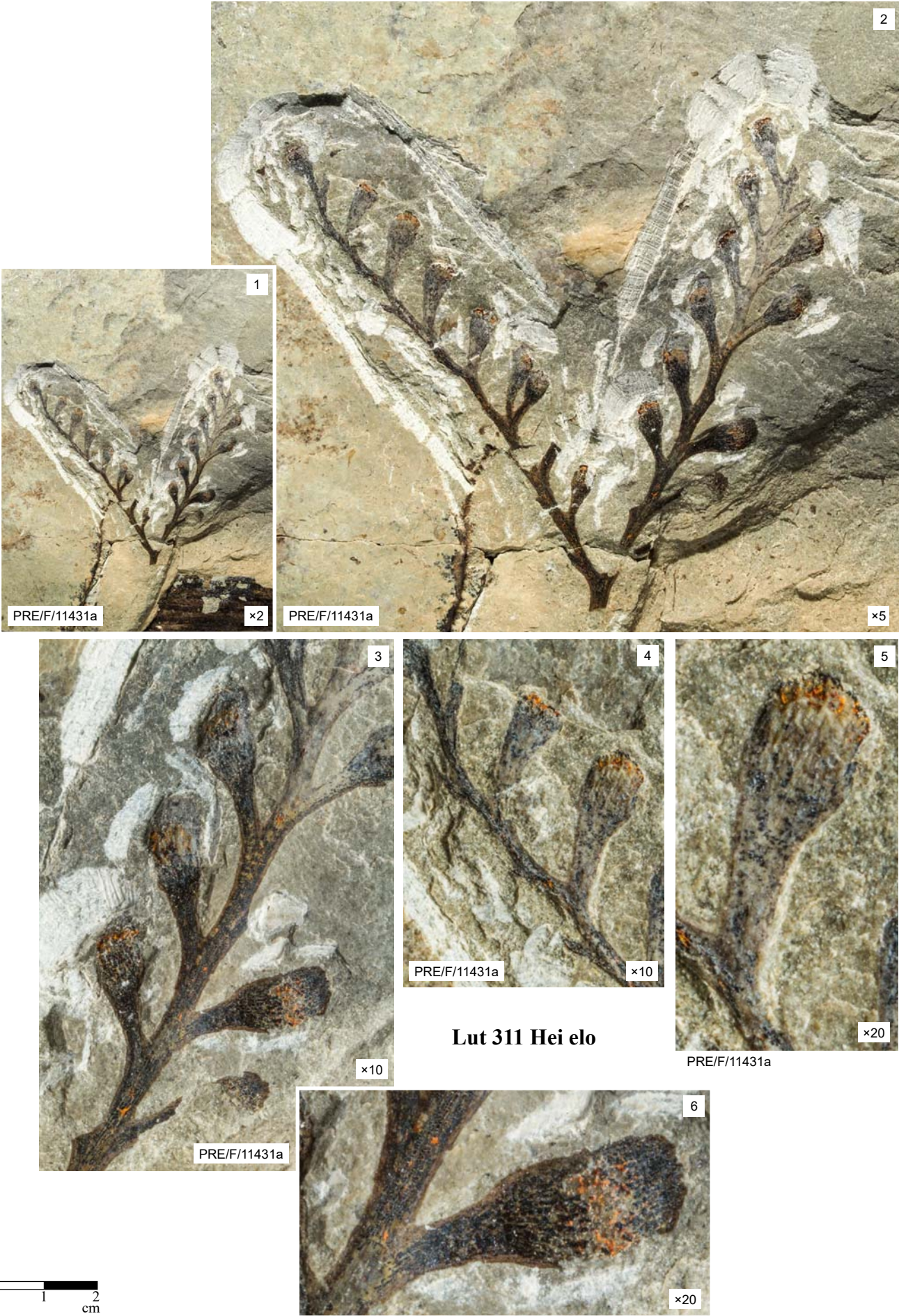


Kannaskoppianthus luti *numeris*





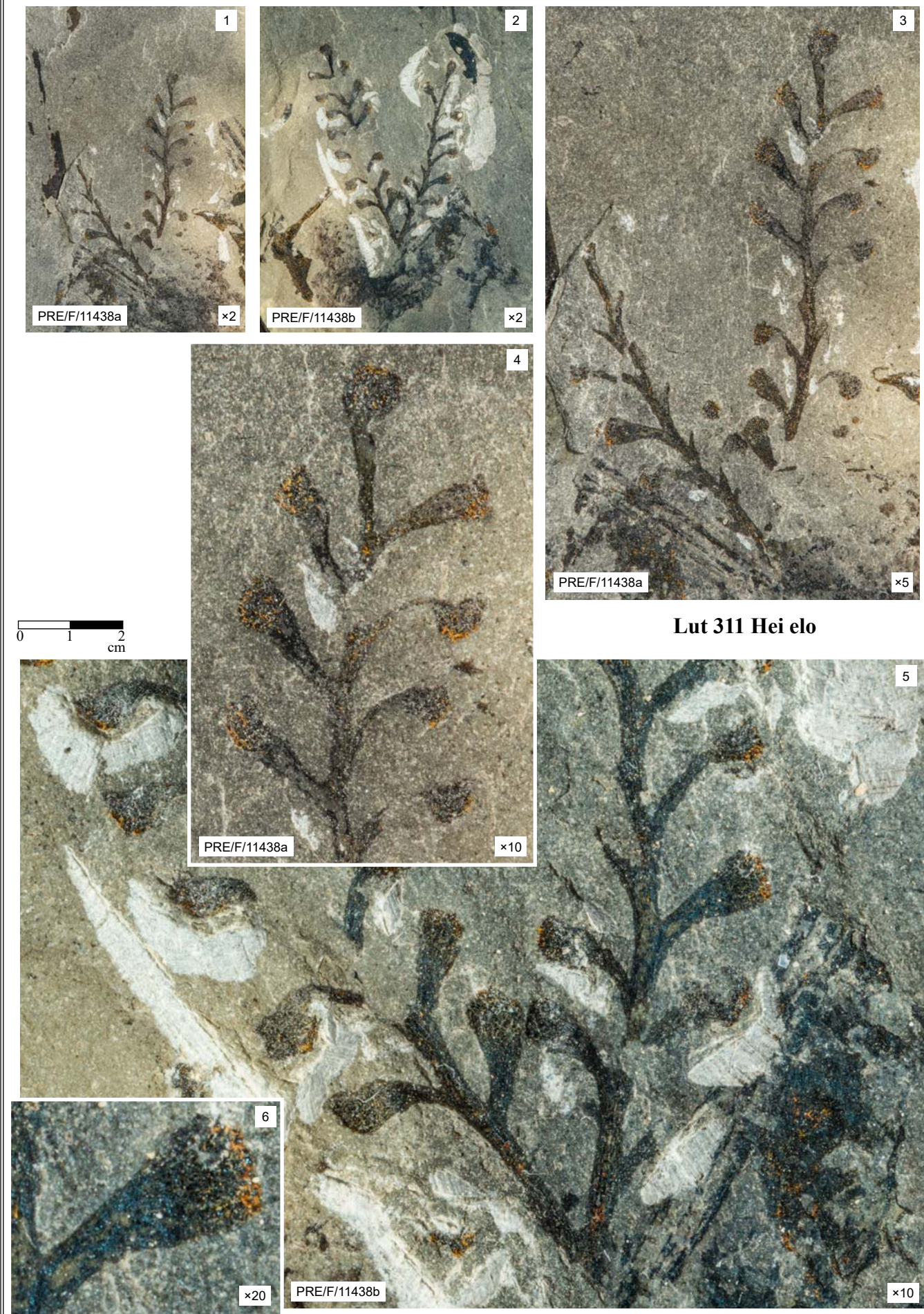
Kannaskoppianthus lutinumerus

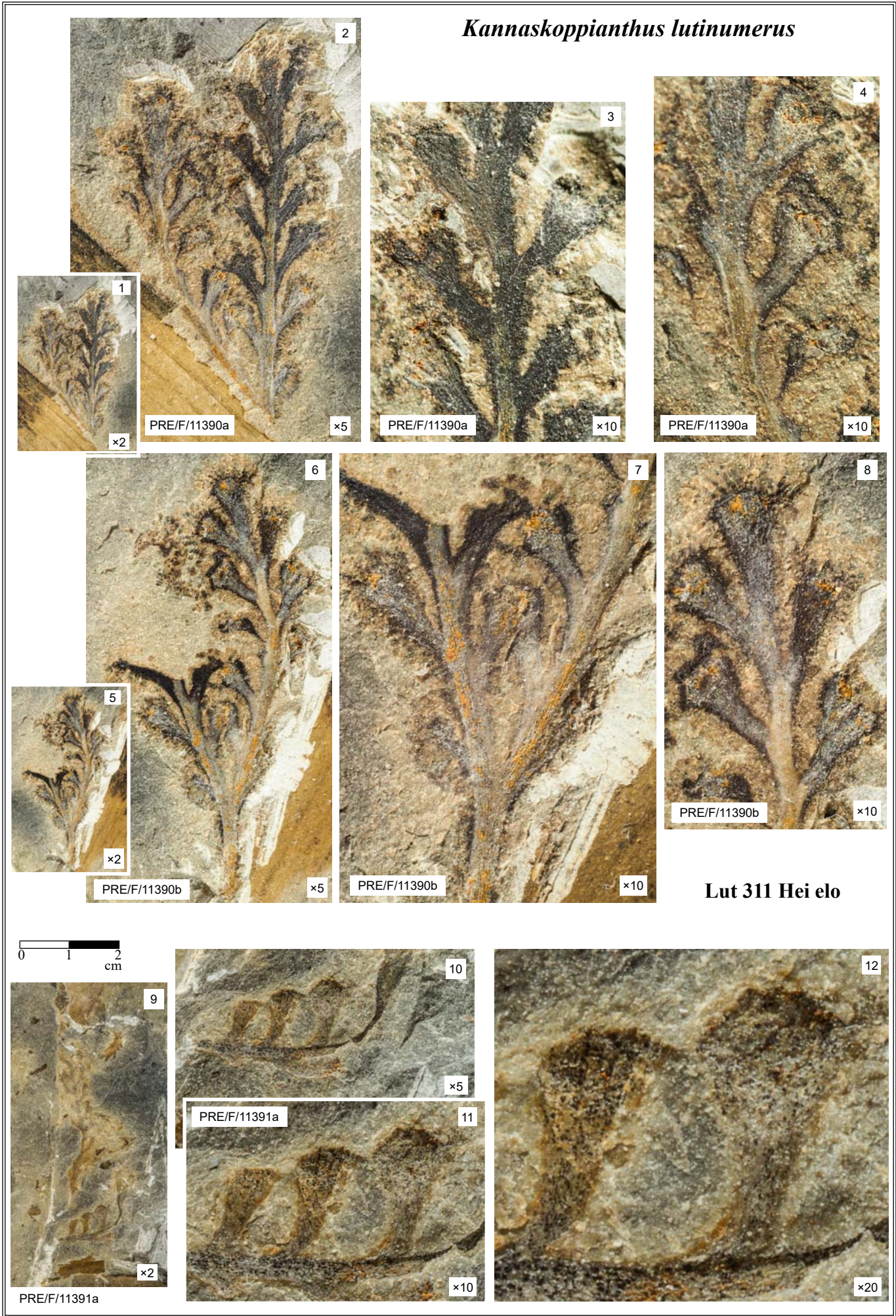


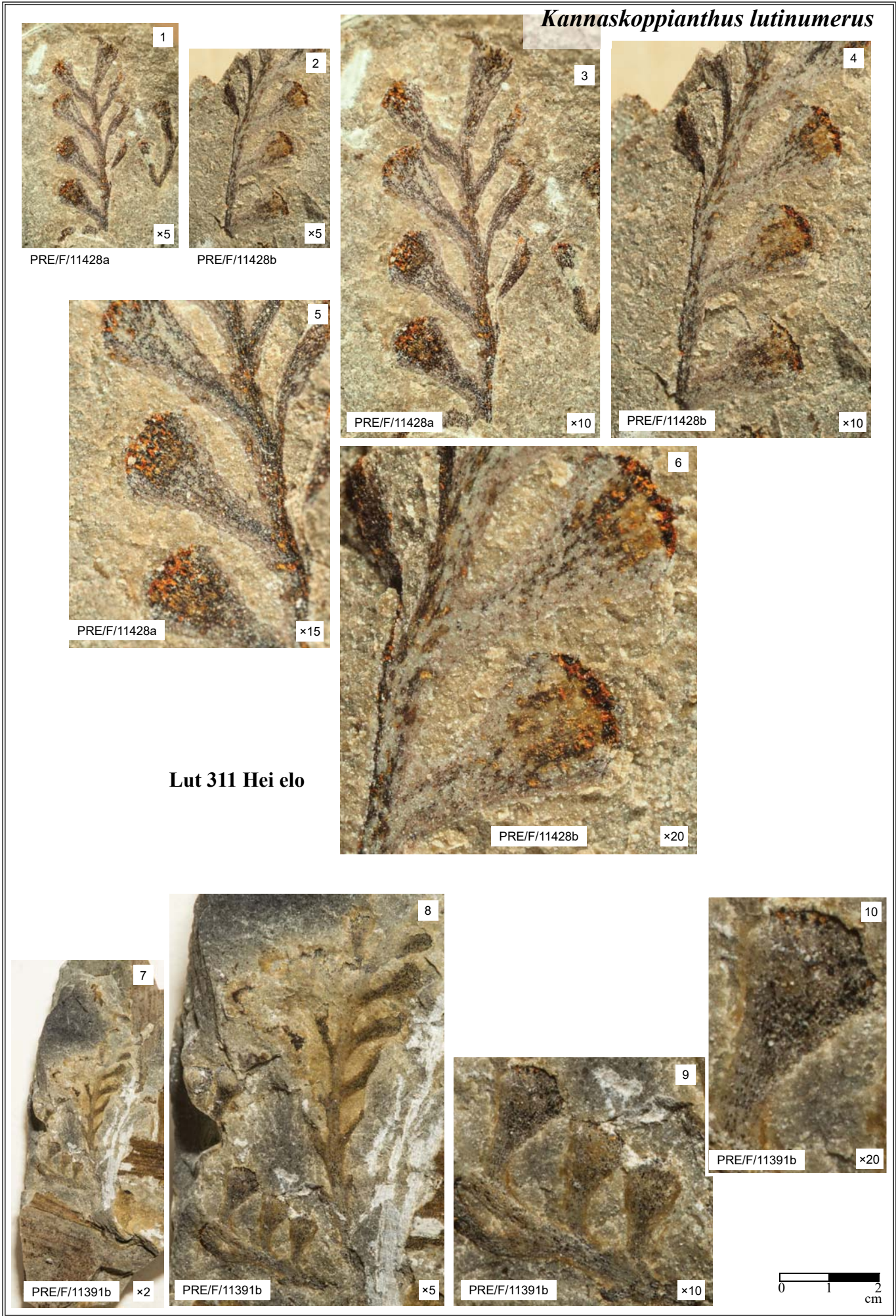
Lut 311 Hei elo

PRE/F/11431a

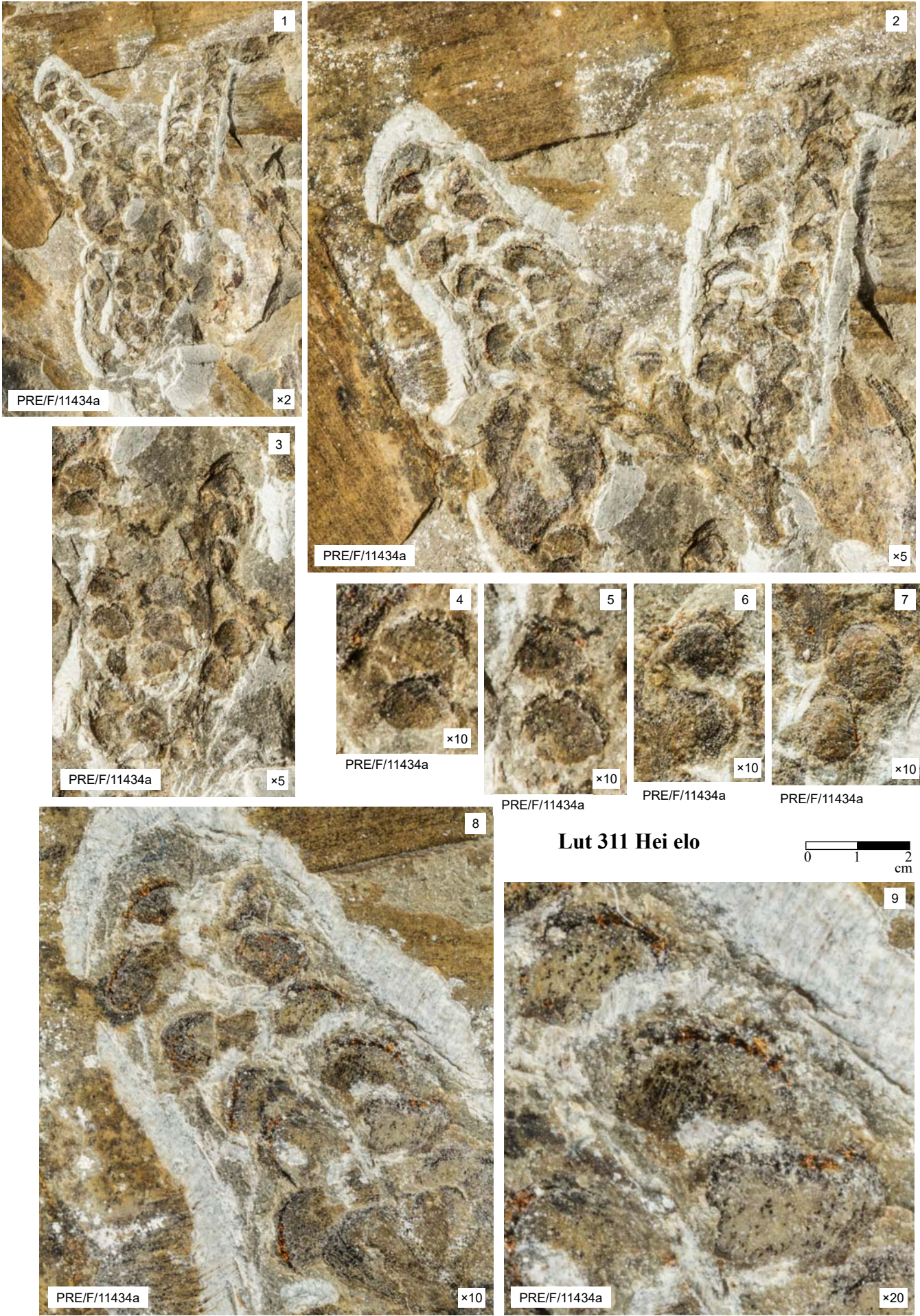
Kannaskoppianthus lutinumerus



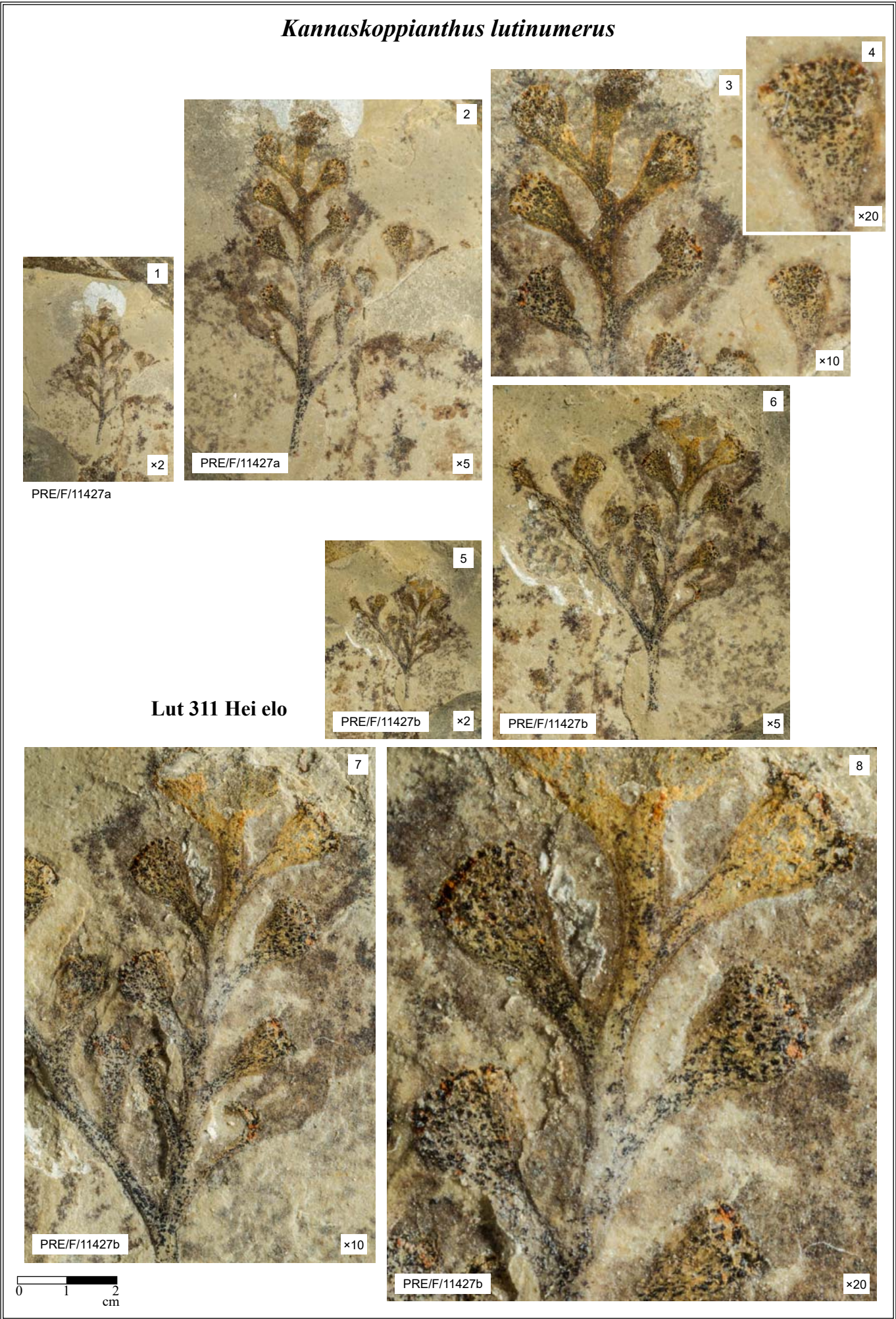




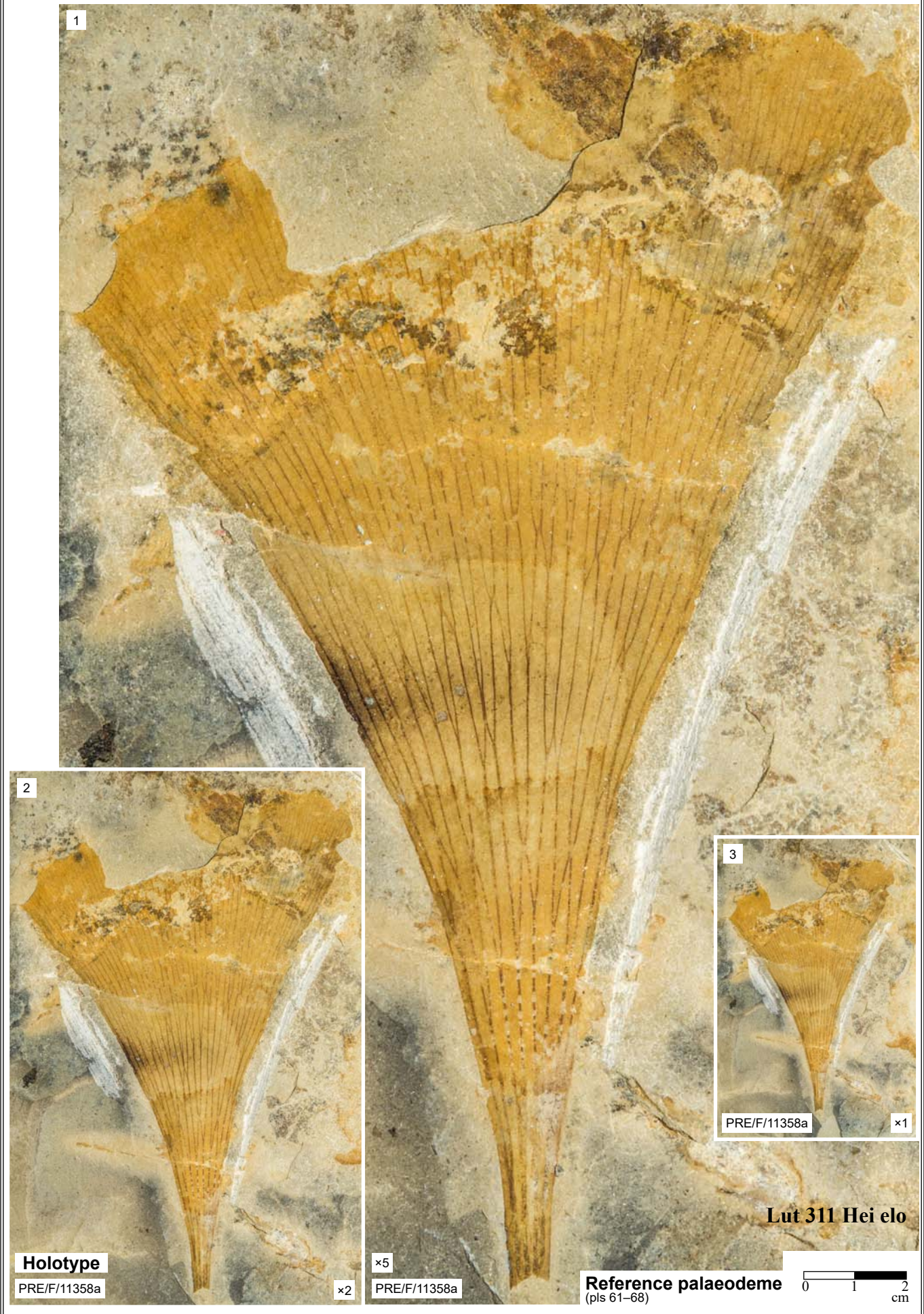
Kannaskoppianthus luti



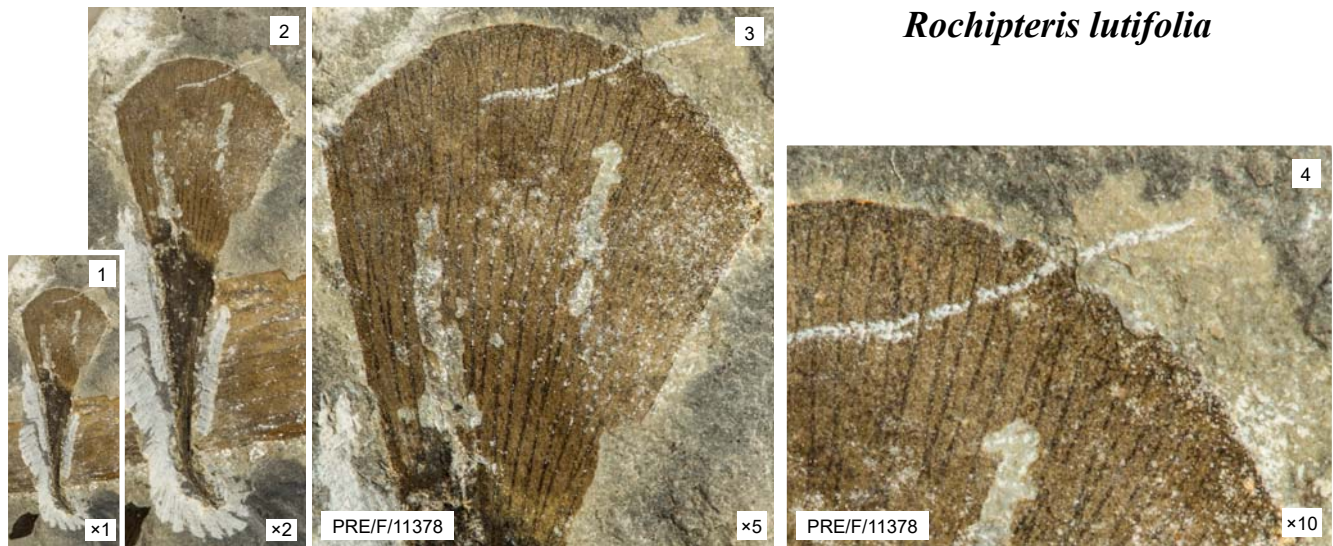
Kannaskoppianthus lutinumerus



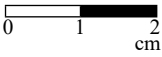
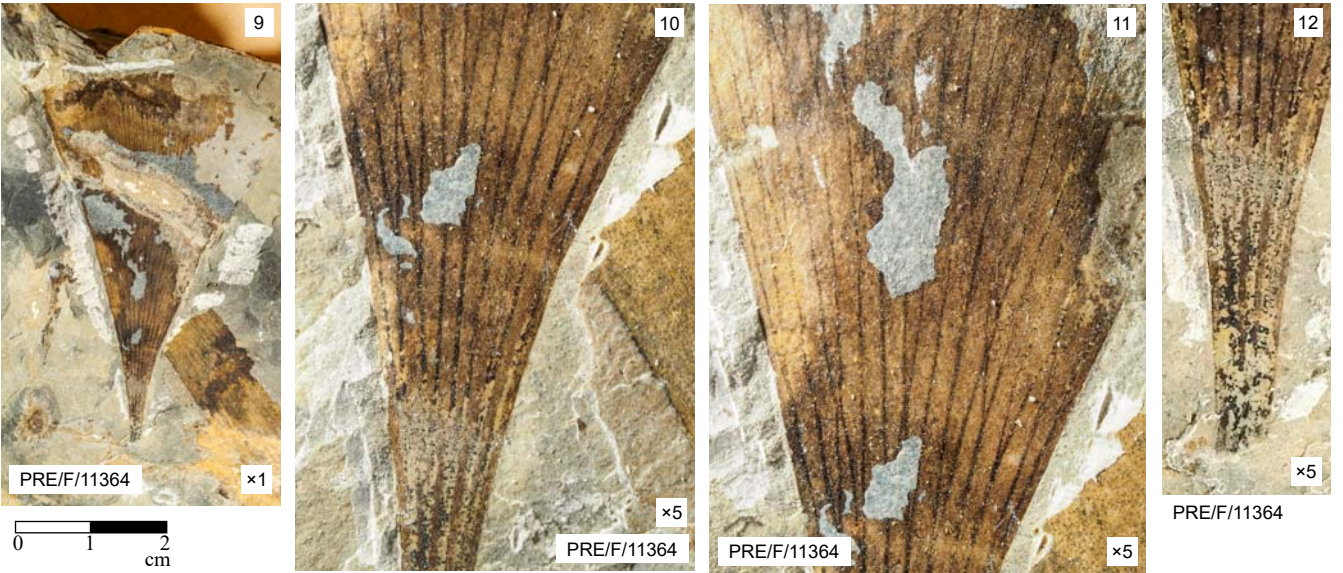
Rochipteris lutifolia



Rochipteris lutifolia



Lut 311 Hei elo



Rochipteris lutifolia



PRE/F/11350b
p.94(1)



PRE/F/11351
p.94(2)



PRE/F/11361



PRE/F/11360



PRE/F/11374a



PRE/F/11359

Lut 311 Hei elo



PRE/F/11389a



PRE/F/11397



PRE/F/11412



PRE/F/11394



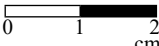
PRE/F/11418



PRE/F/11404



PRE/F/11377b



Rochipteris lutifolia



PRE/F/11351



PRE/F/11361



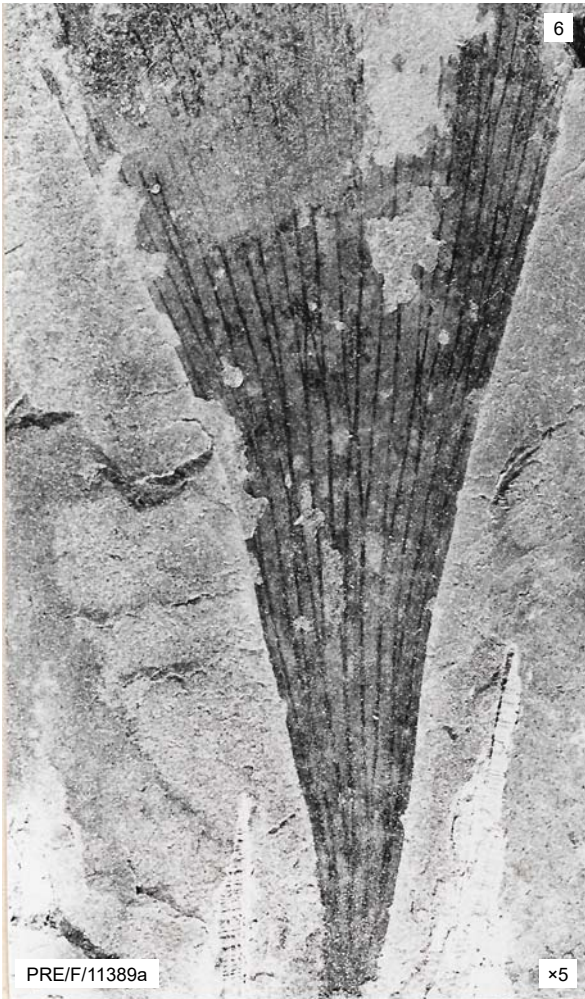
PRE/F/11360



PRE/F/11374a

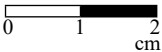


PRE/F/11359

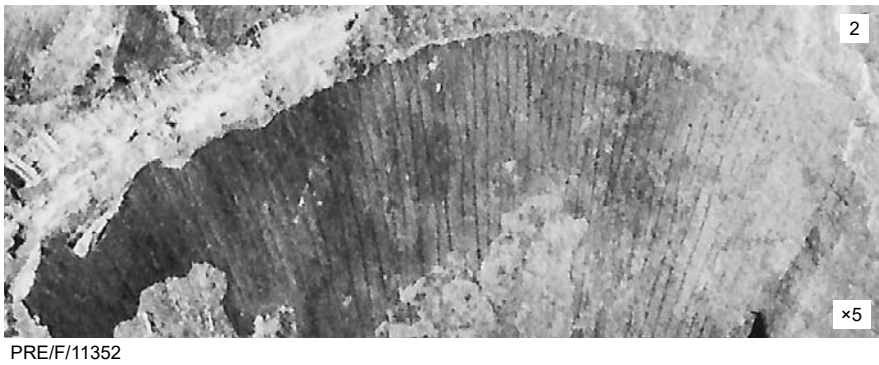


PRE/F/11389a

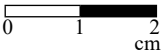
Lut 311 Hei elo



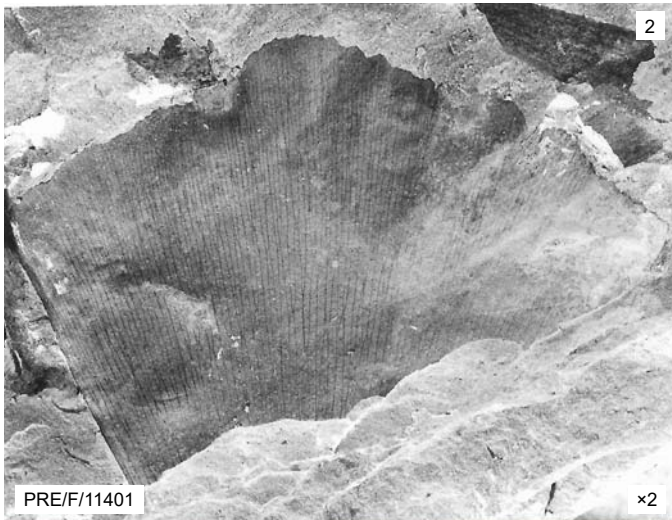
Rochipteris lutifolia



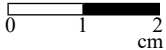
Lut 311 Hei elo



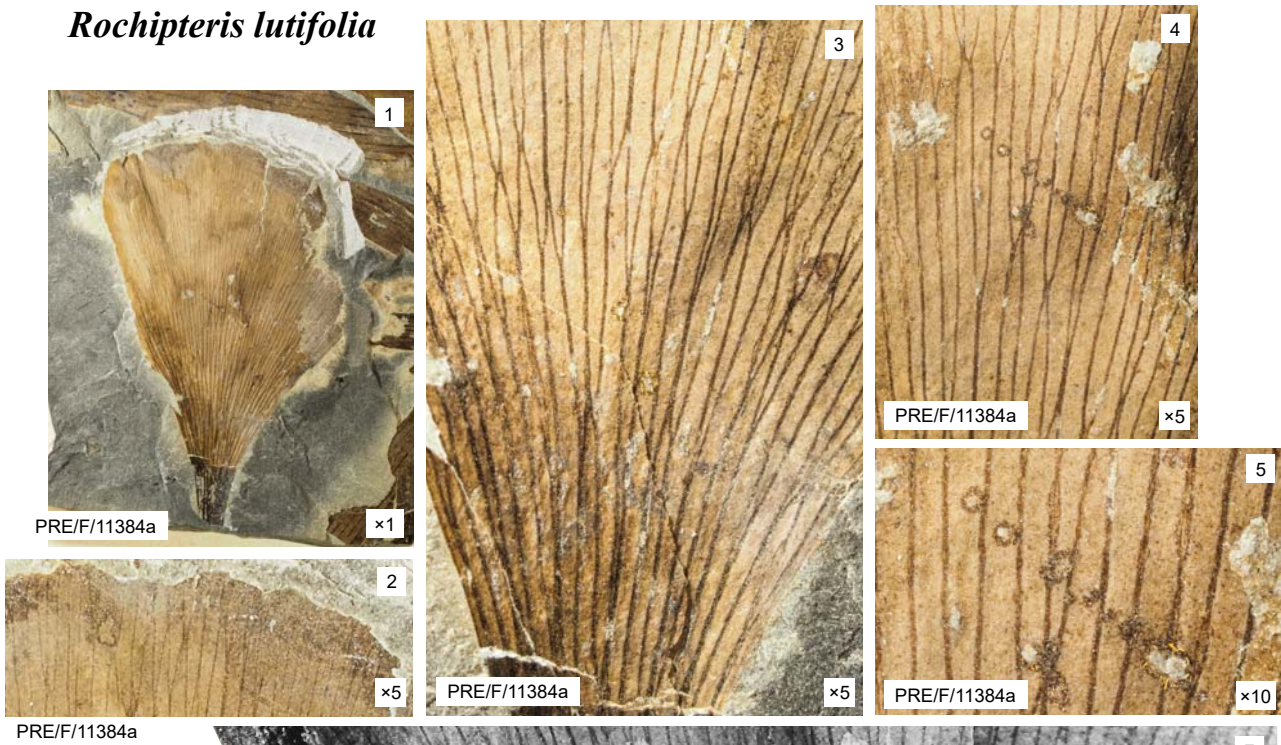
Rochipteris lutifolia



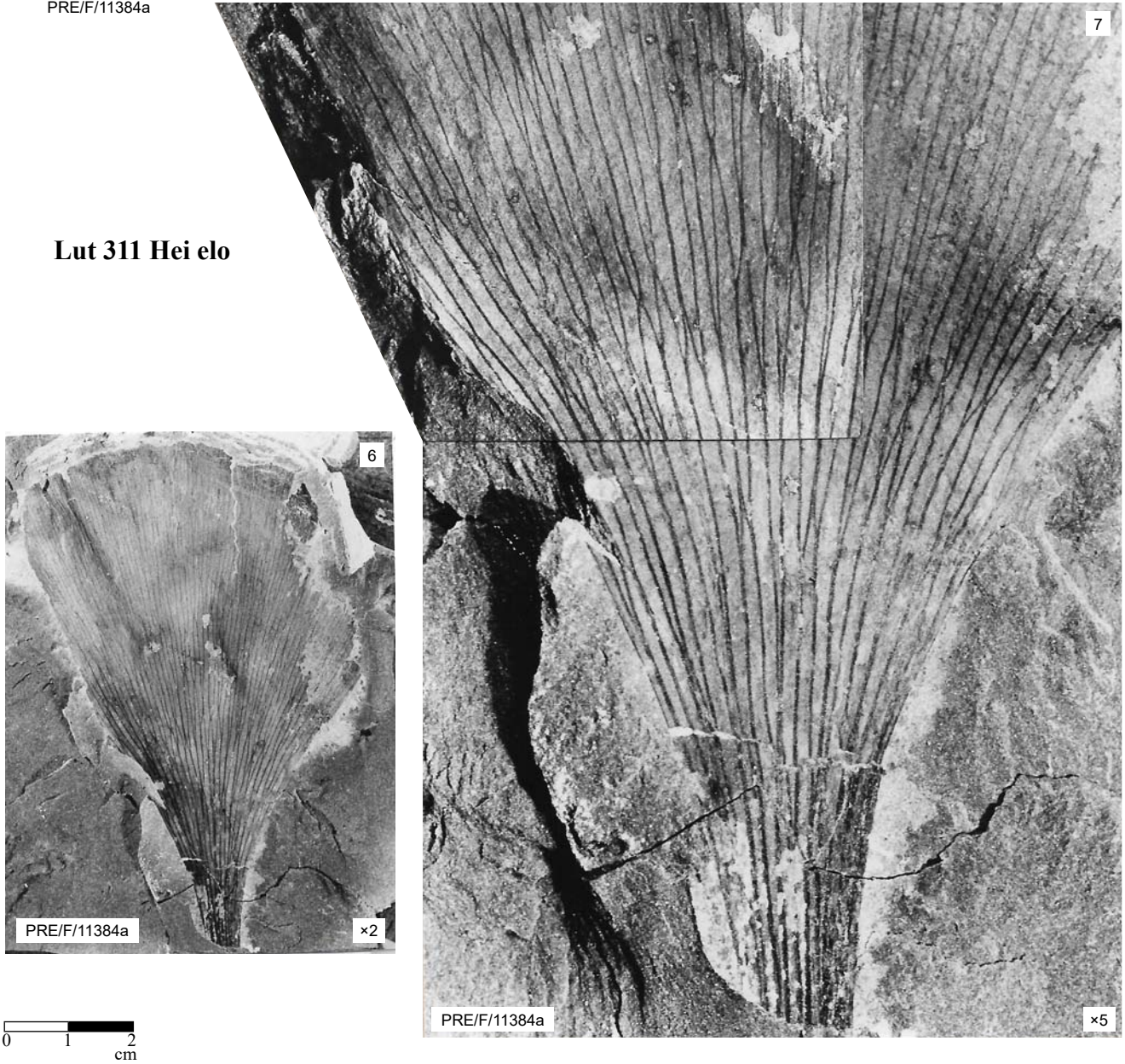
Lut 311 Hei elo



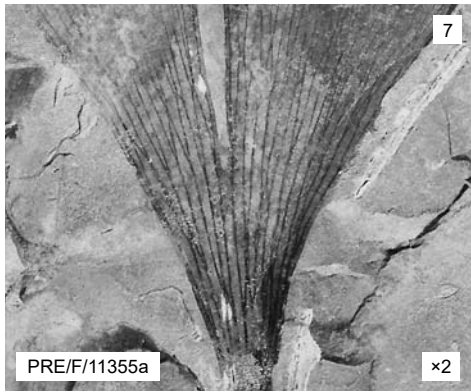
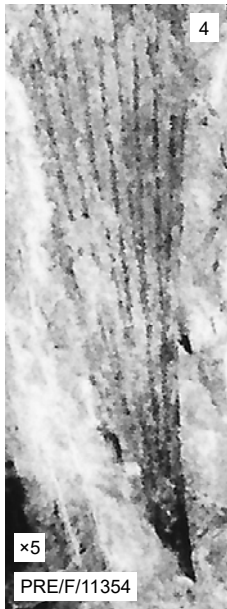
Rochipteris lutifolia



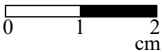
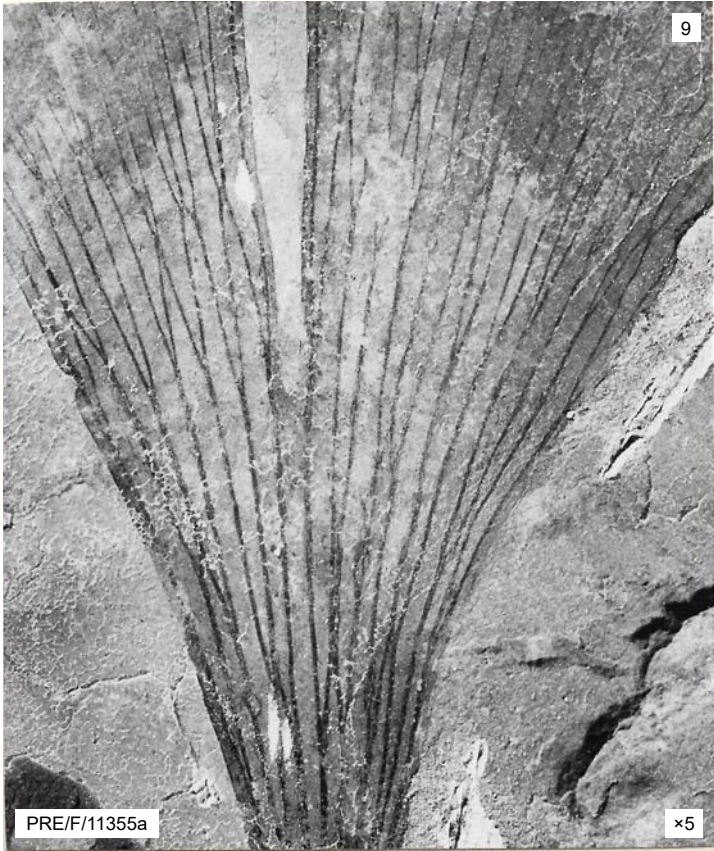
Lut 311 Hei elo



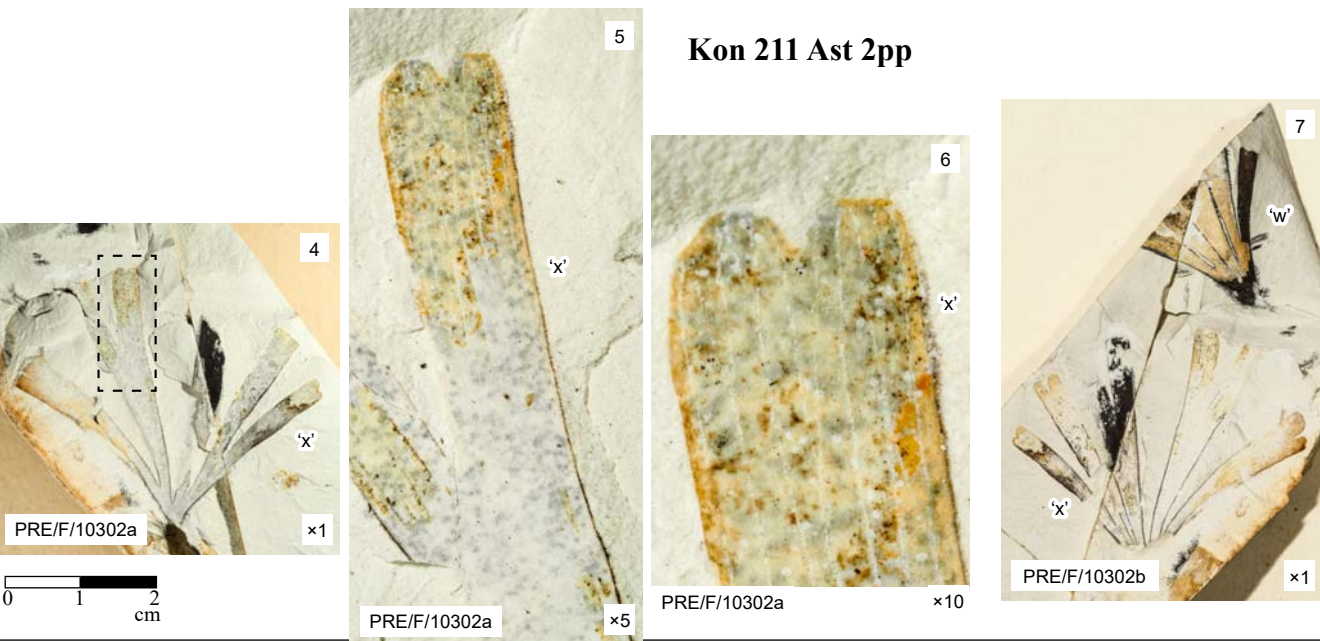
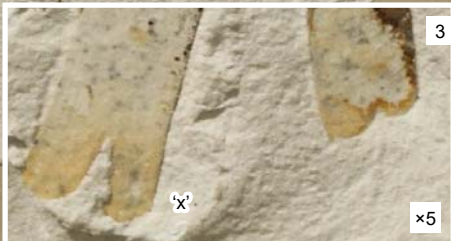
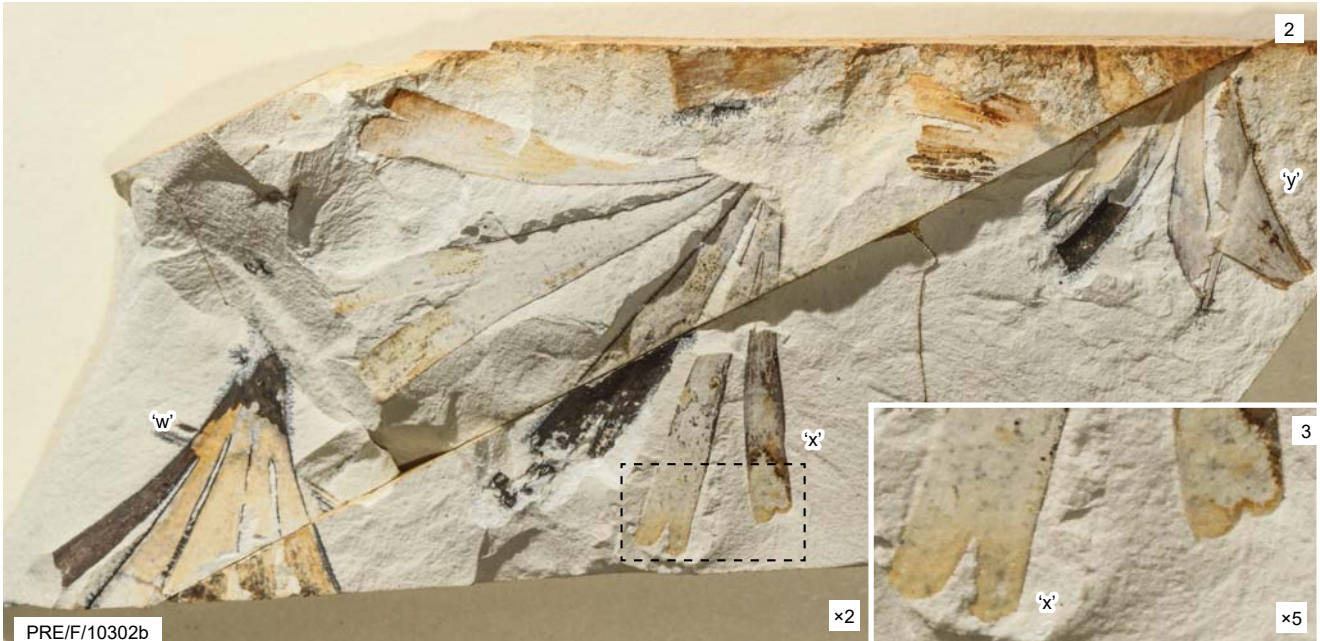
Rochipteris lutifolia



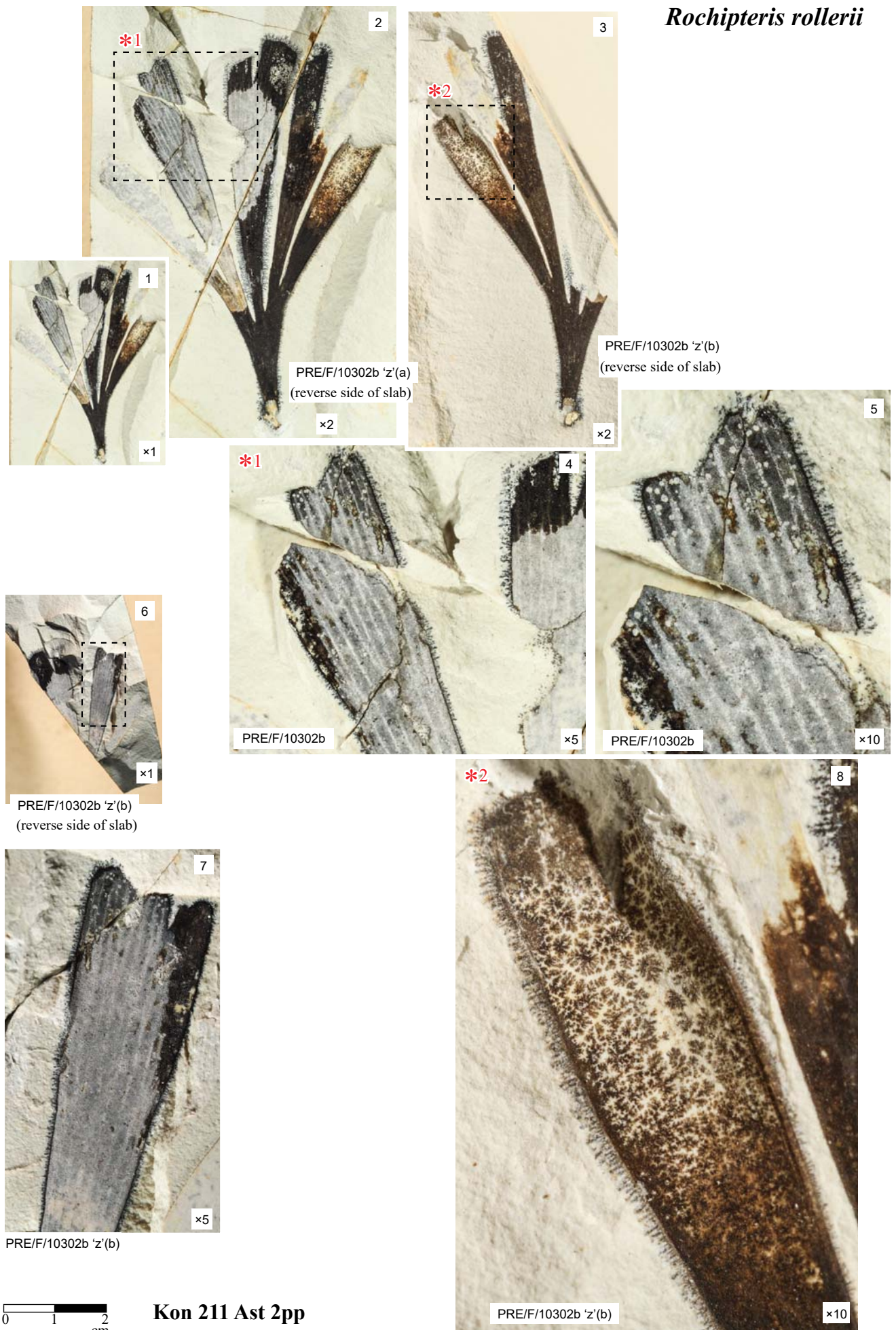
Lut 311 Hei elo



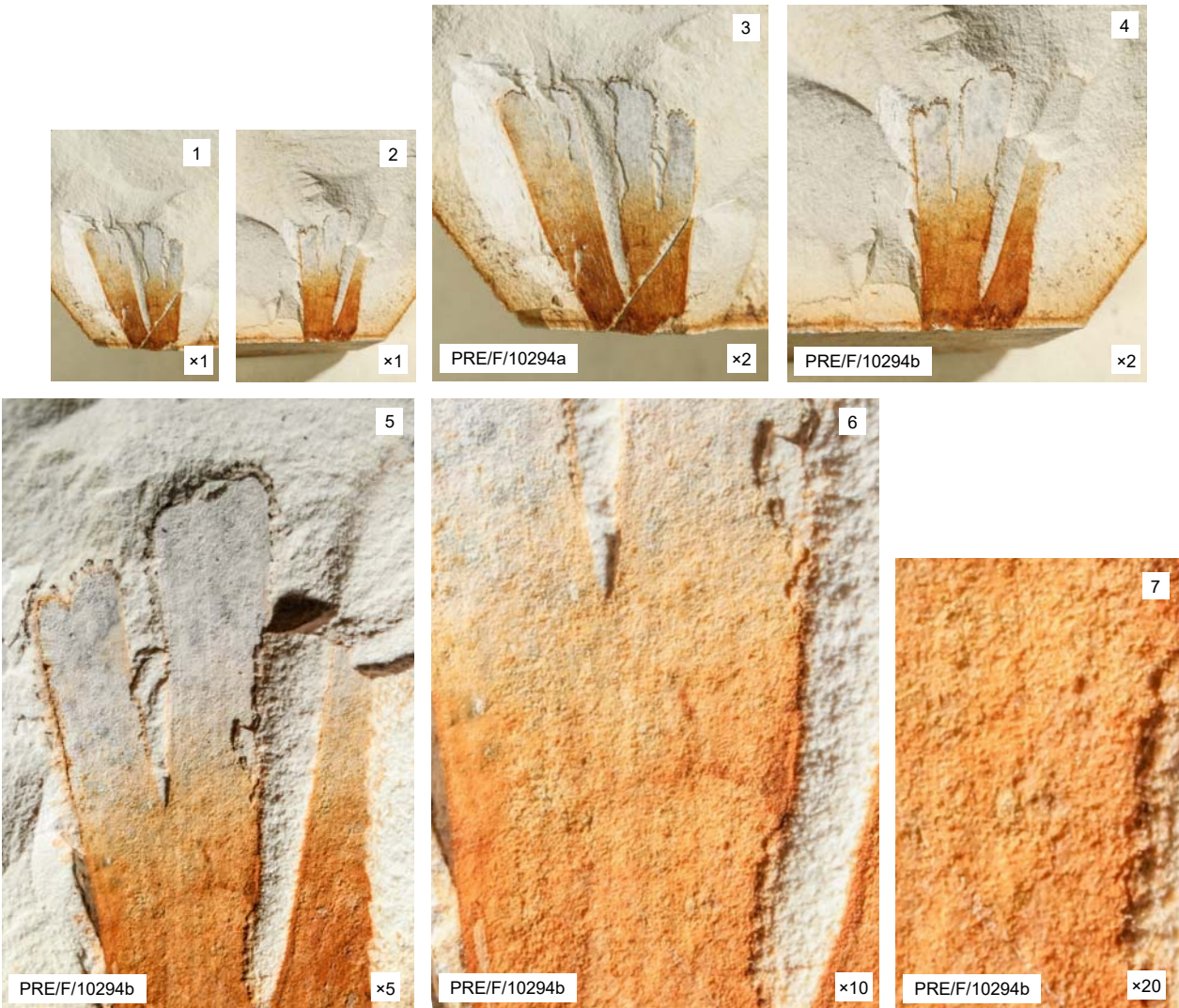
Rochipteris rollerii



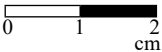
Rochipteris rollerii



Rochipteris rollerii



Kon 211 Ast 2pp

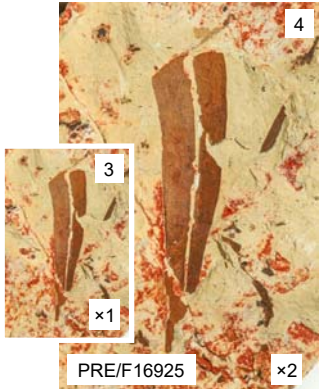


Rochipteris rollerii

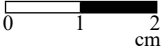
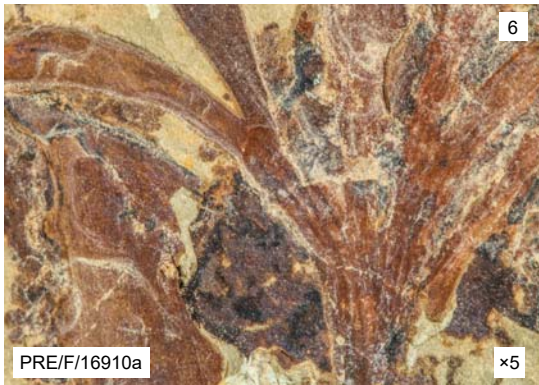




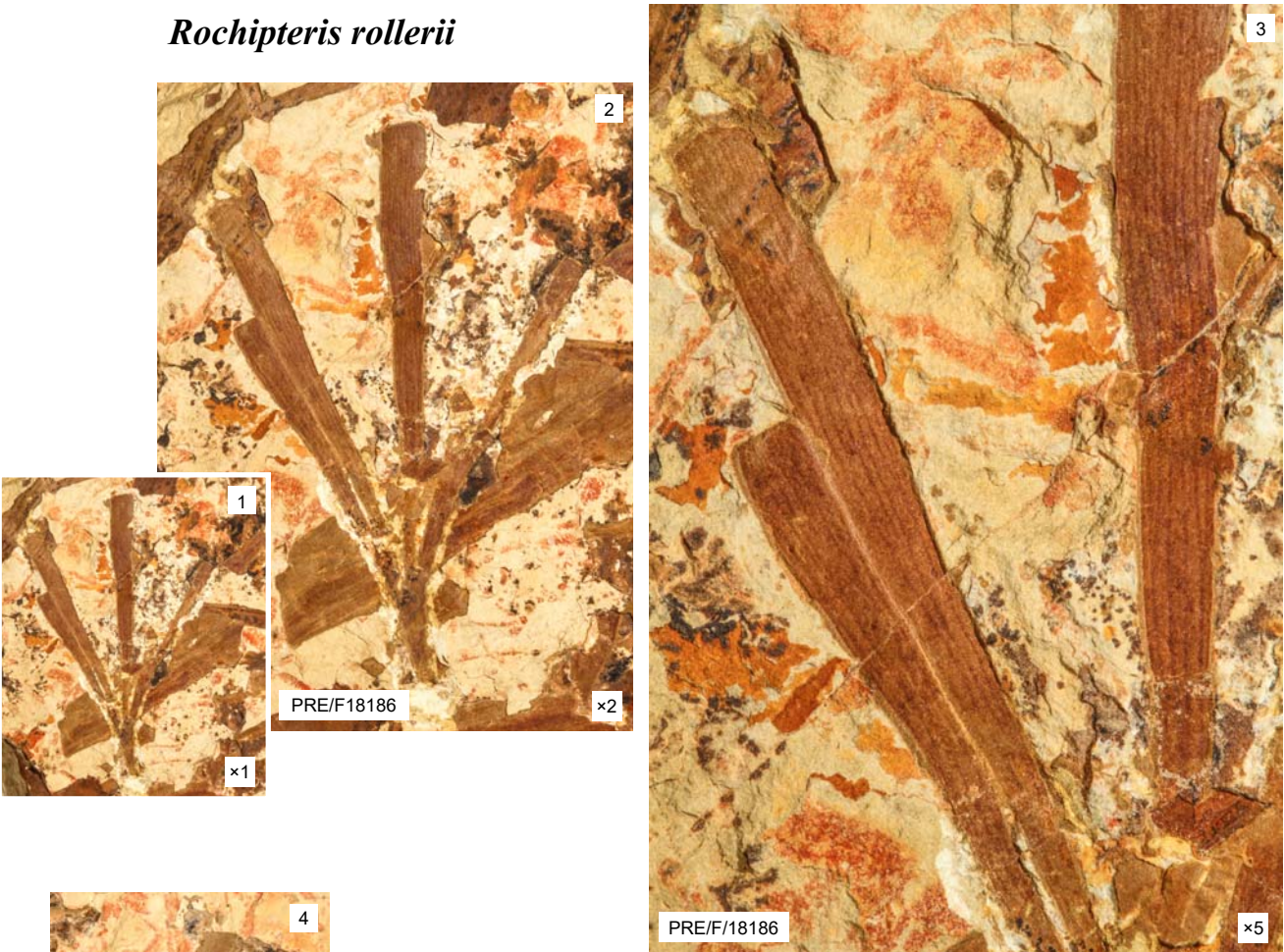
Rochipteris rollerii



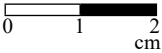
Pen 311 Hei elo



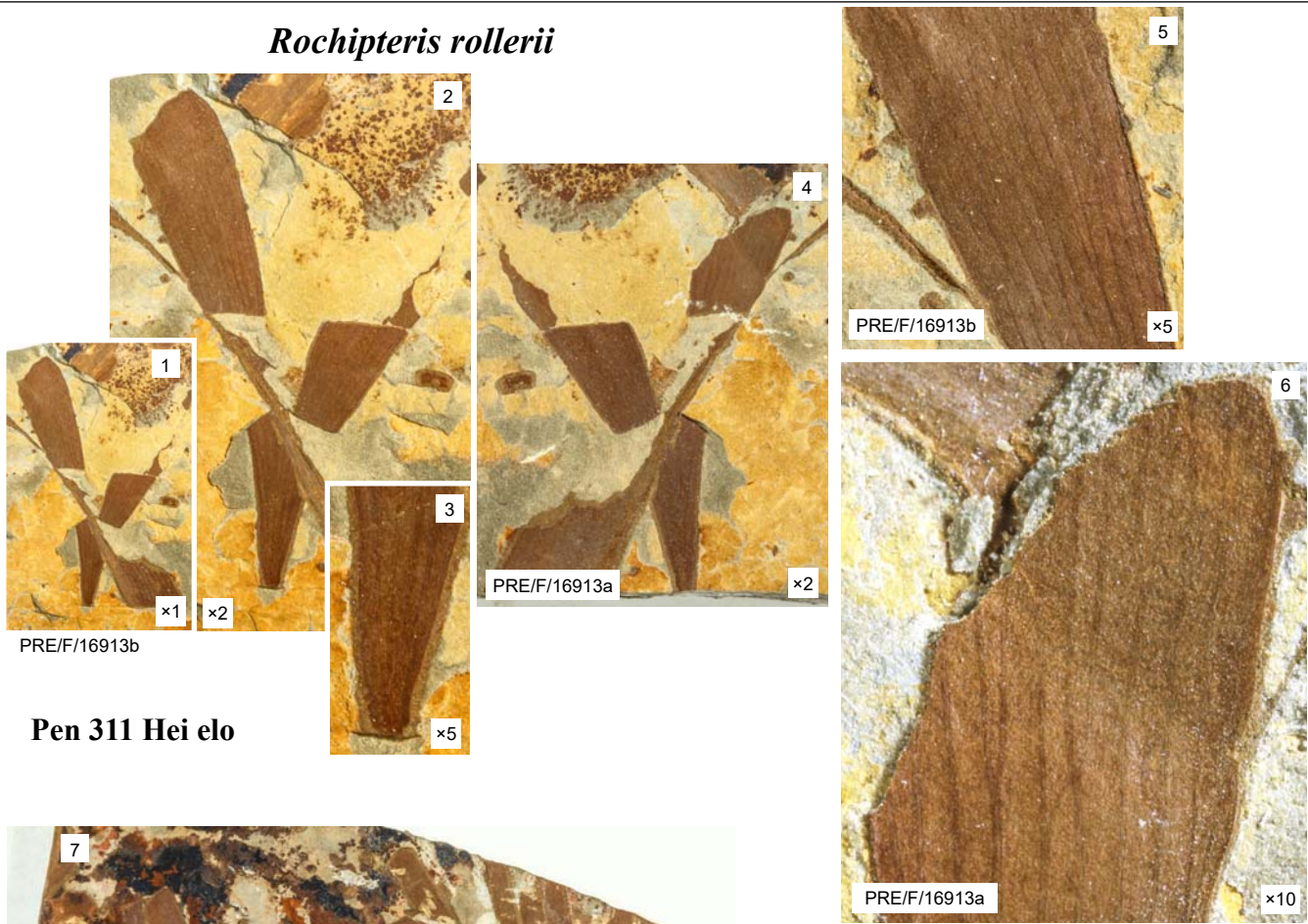
Rochipteris rollerii



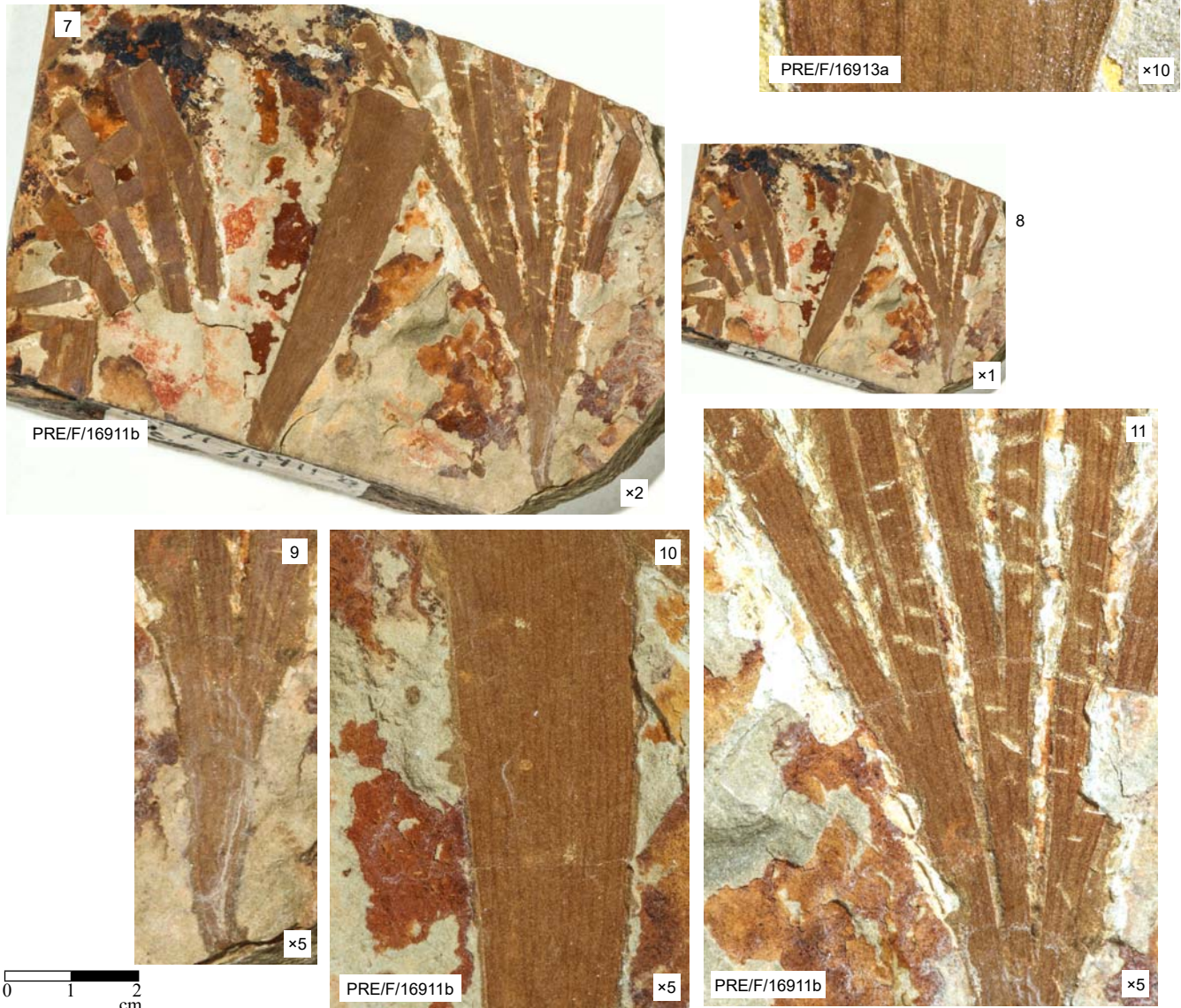
Pen 311 Hei elo



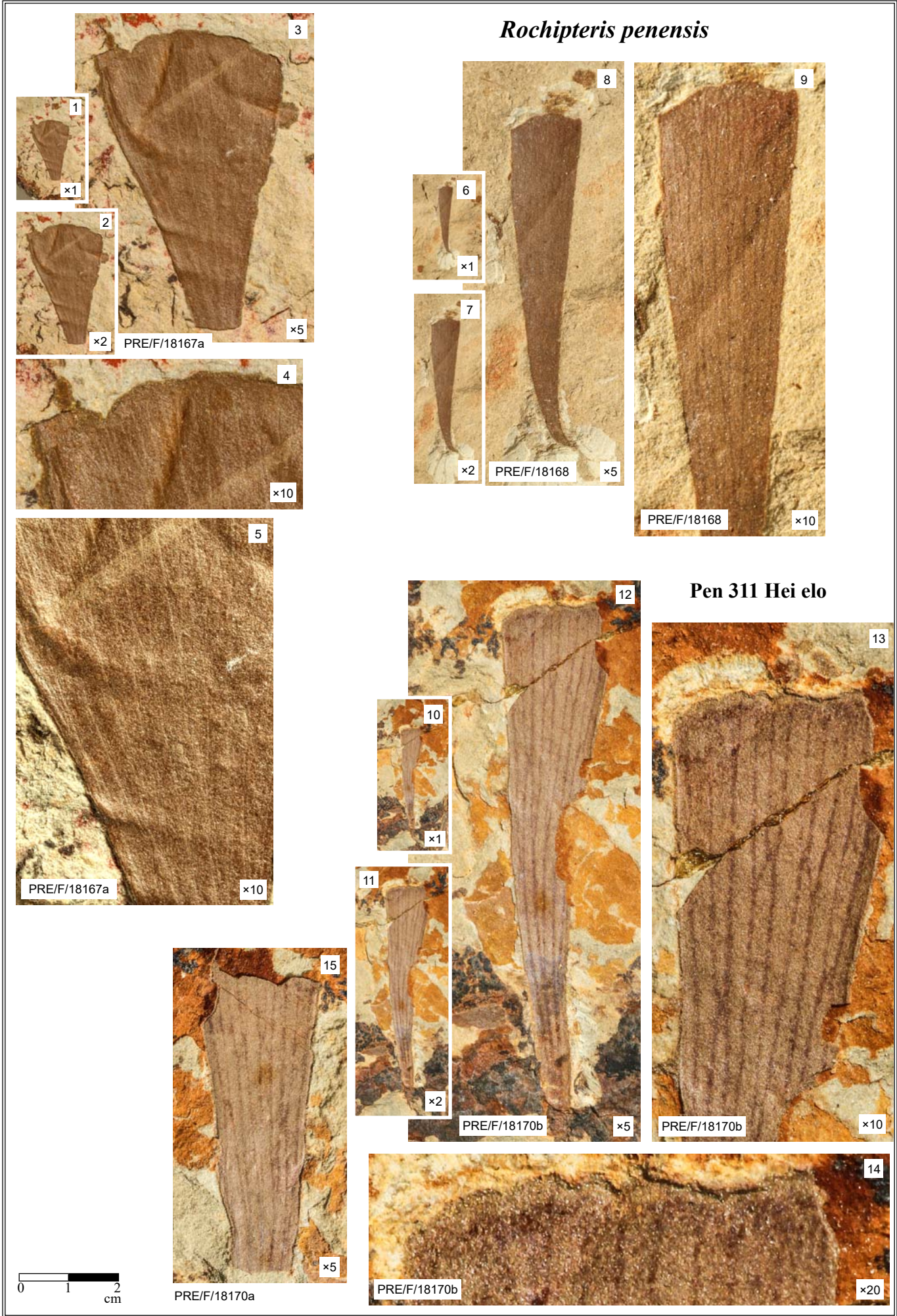
Rochipteris rollerii



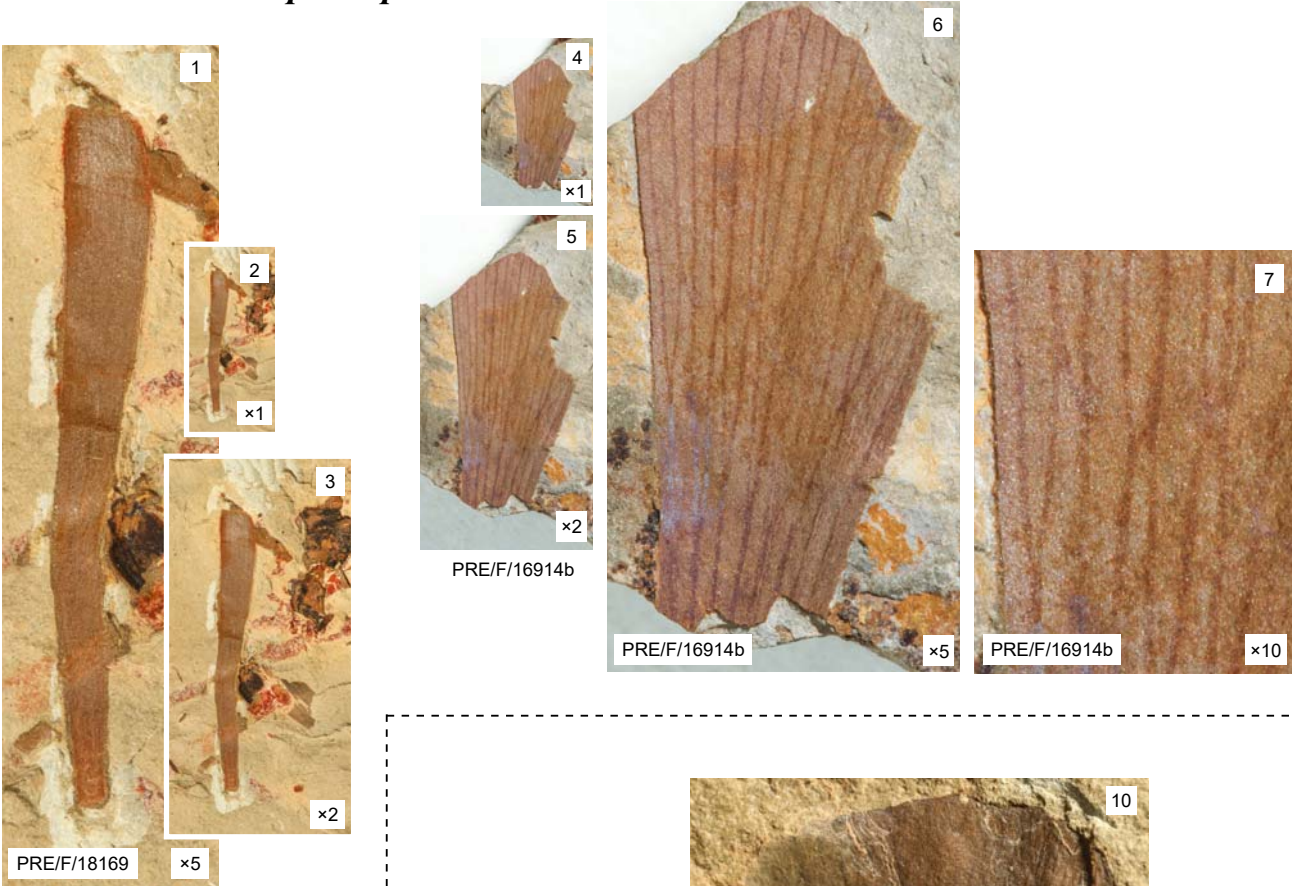
Pen 311 Hei elo



0 1 2
cm



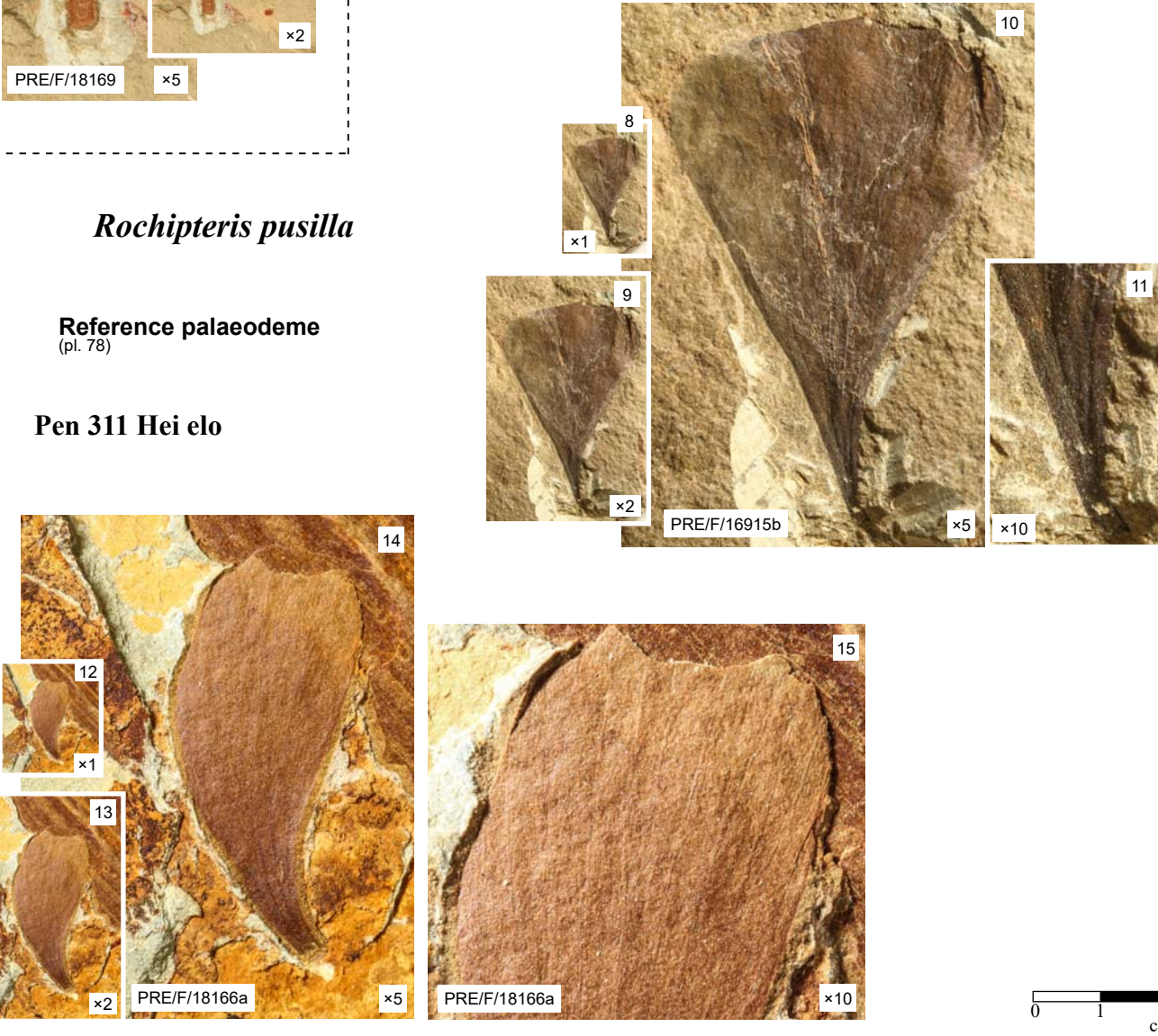
Rochipteris penensis

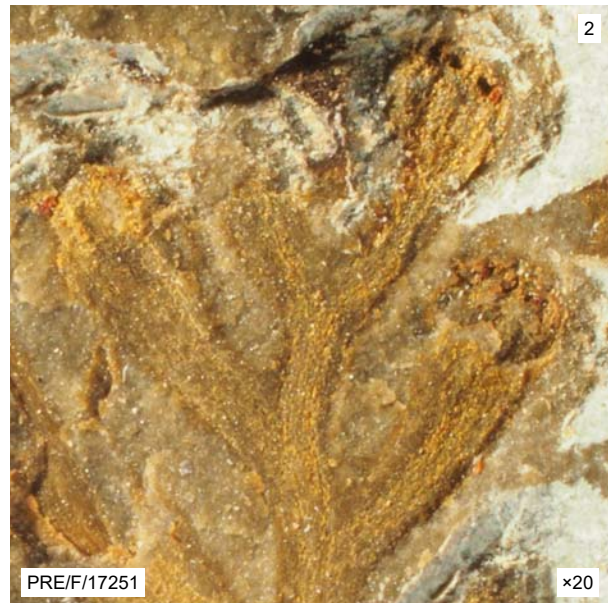


Rochipteris pusilla

Reference palaeodeme
(pl. 78)

Pen 311 Hei elo



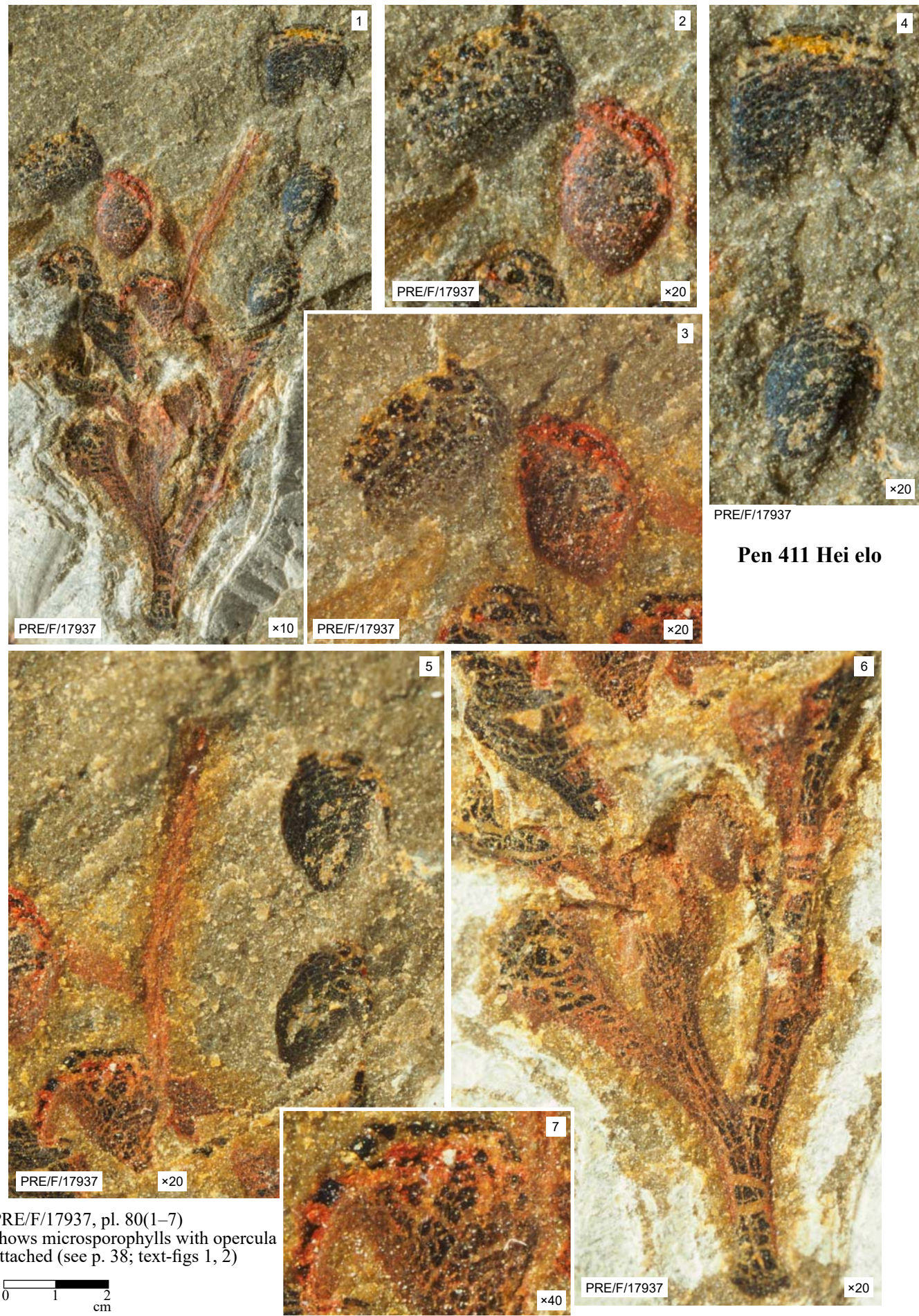
Kannaskoppianthus aasvoelensis**Pen 411 Hei elo**

0 1 2
cm

PRE/F/17938, pl. 79(6–8)
shows microsporophylls with opercula
attached (see p. 38; text-figs 1, 2)



Kannaskoppianthus aasvoelensis



Pen 411 Hei elo

Rochipteris rollerii

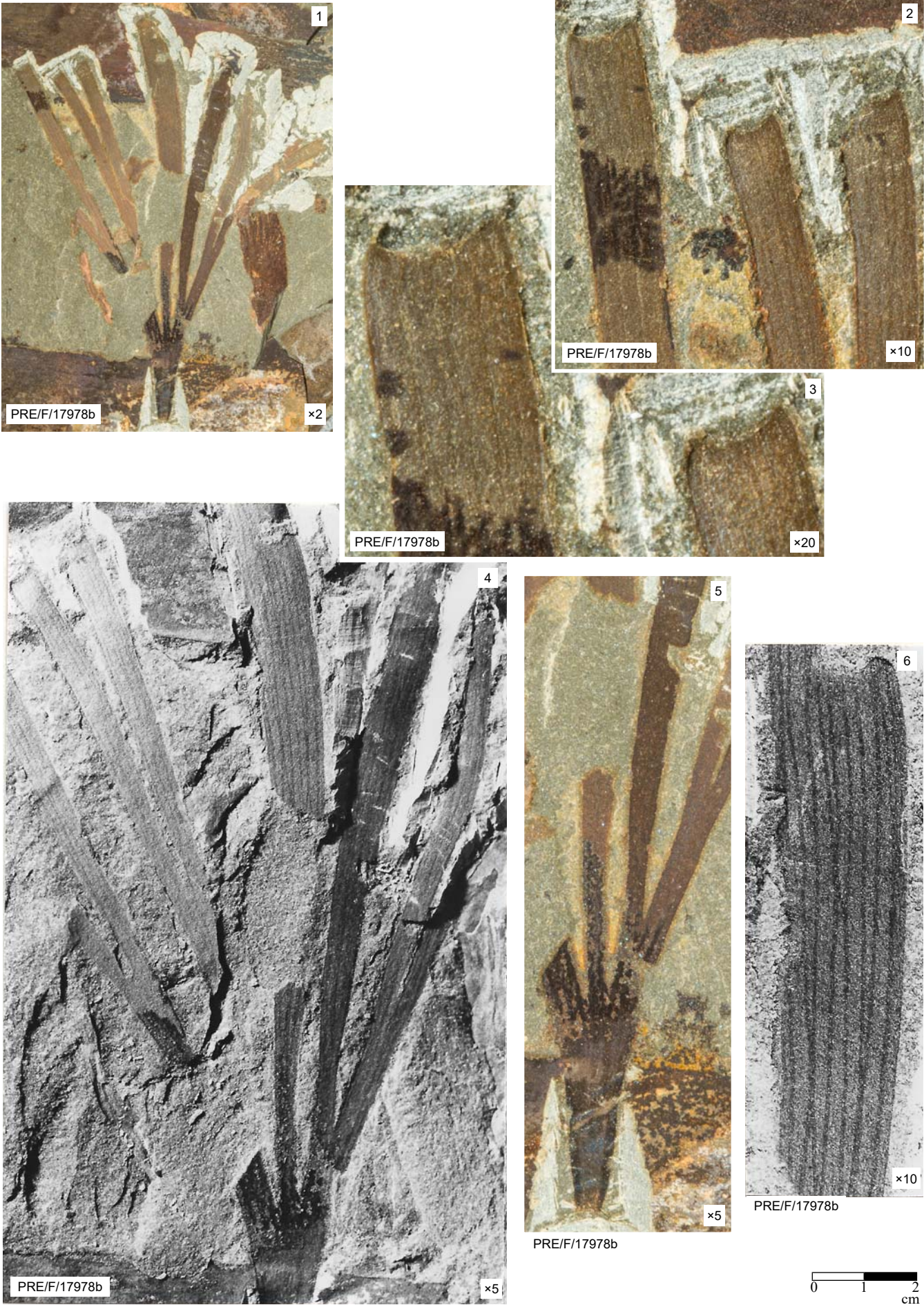


Pen 411 Hei elo

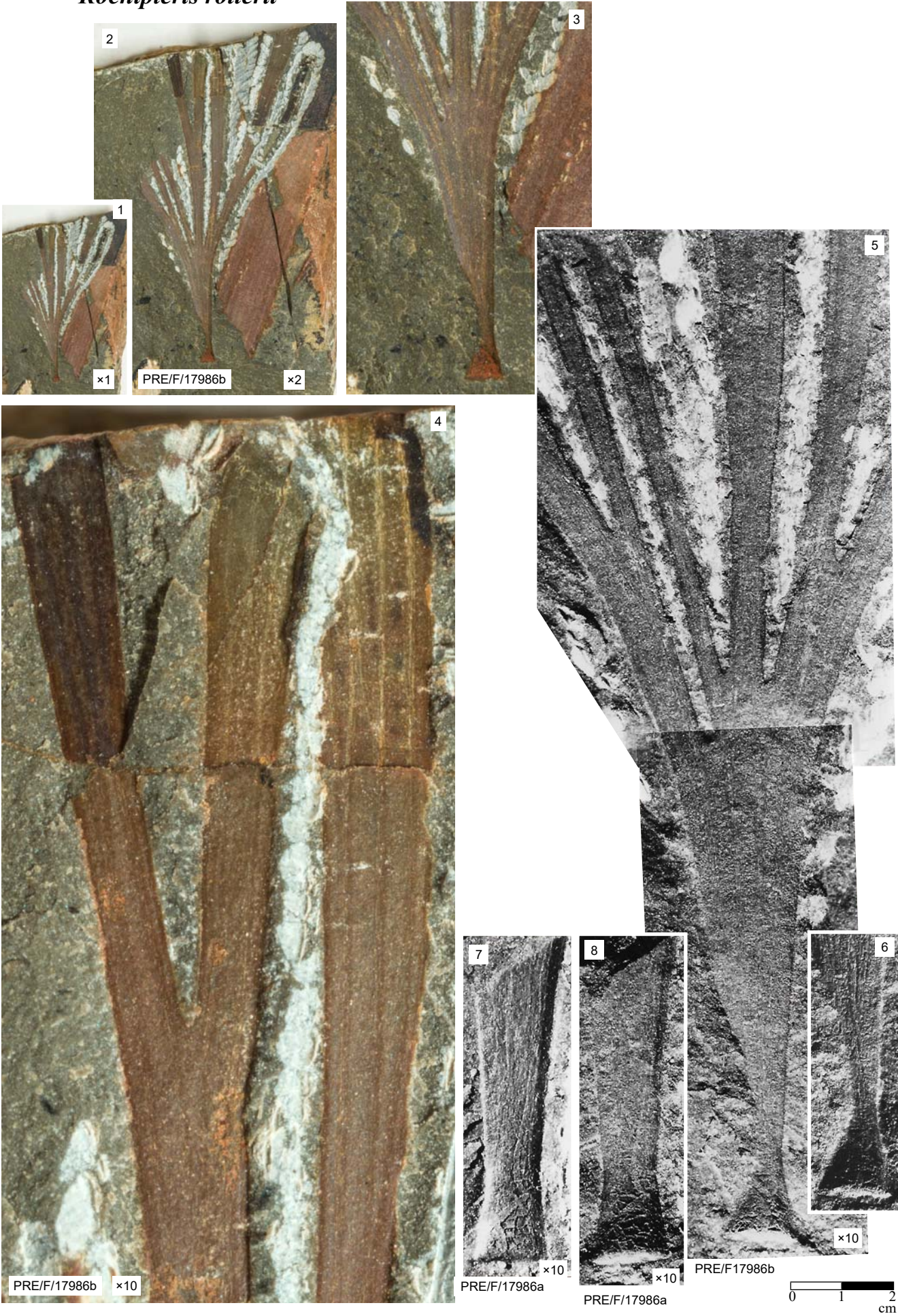


0 1 2
cm

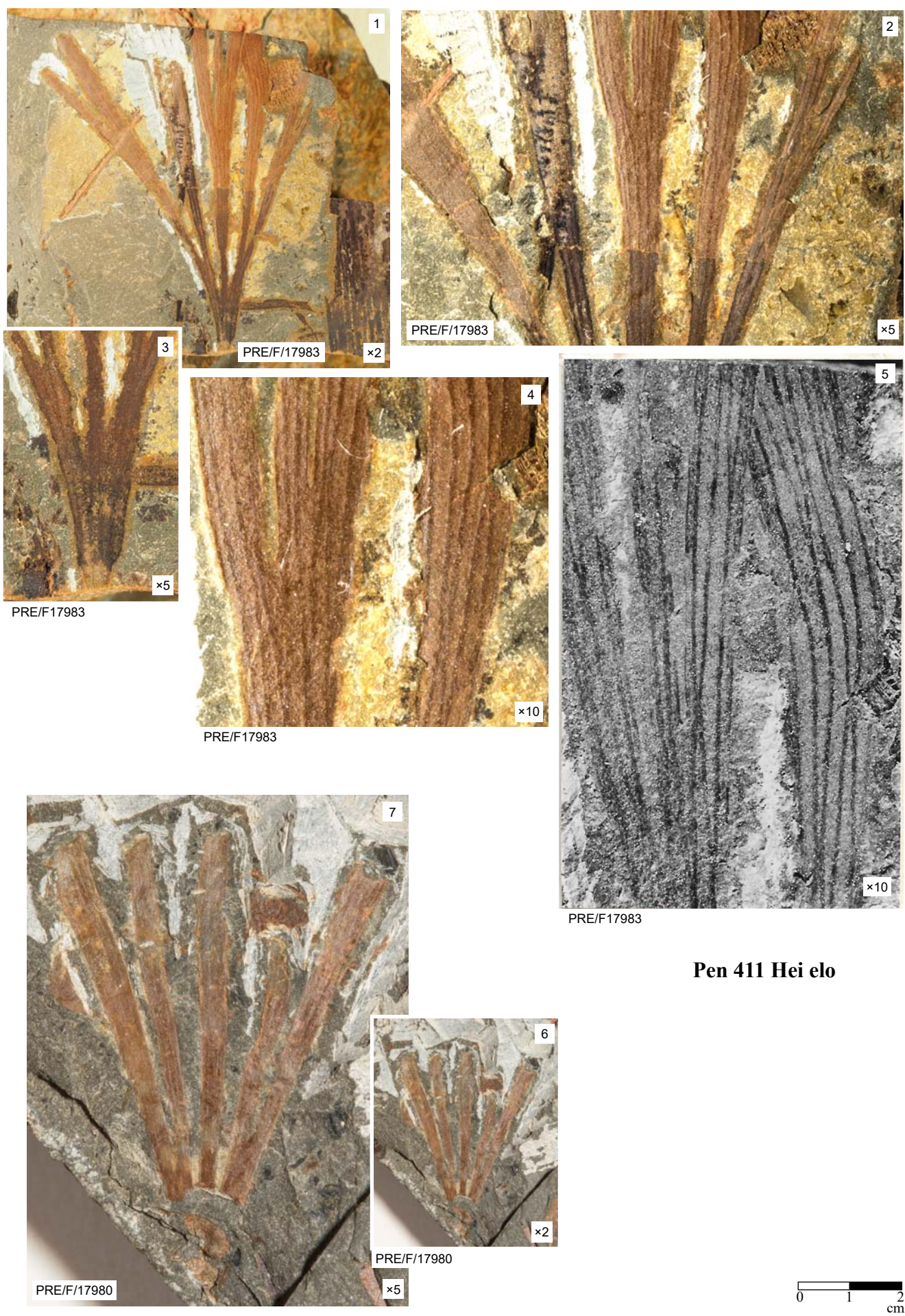
Rochipteris rollerii



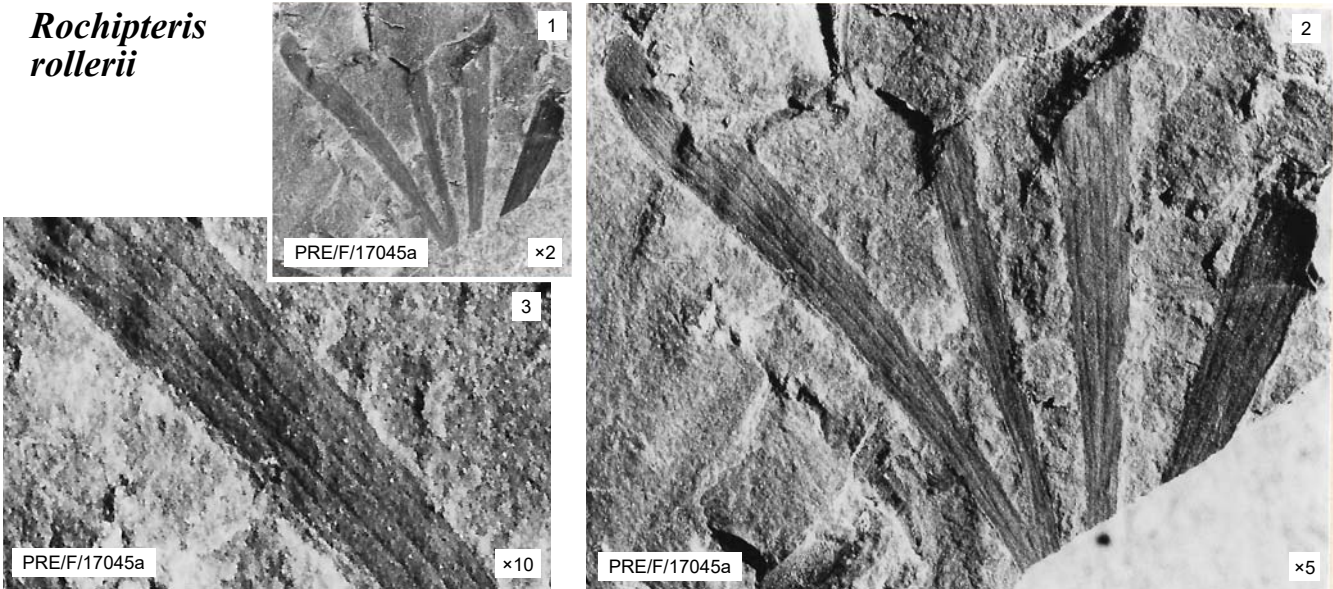
Rochipteris rollerii



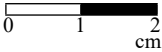
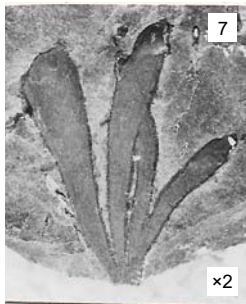
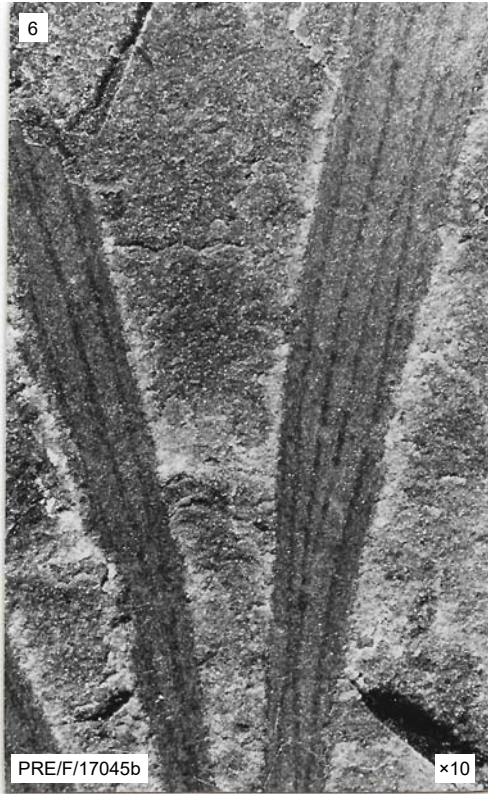
Rochipteris rollerii



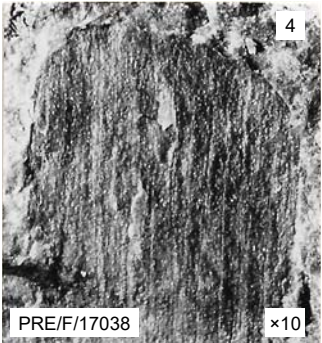
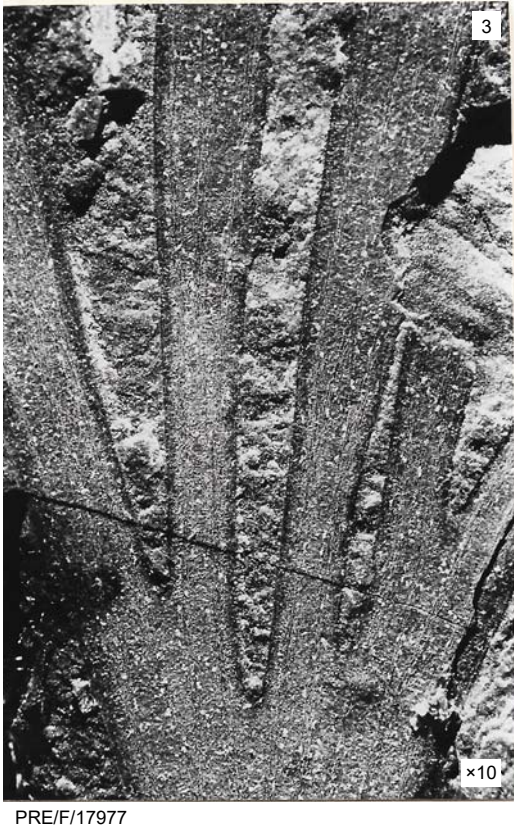
*Rochipteris
rollerii*



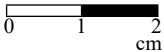
Pen 411 Hei elo

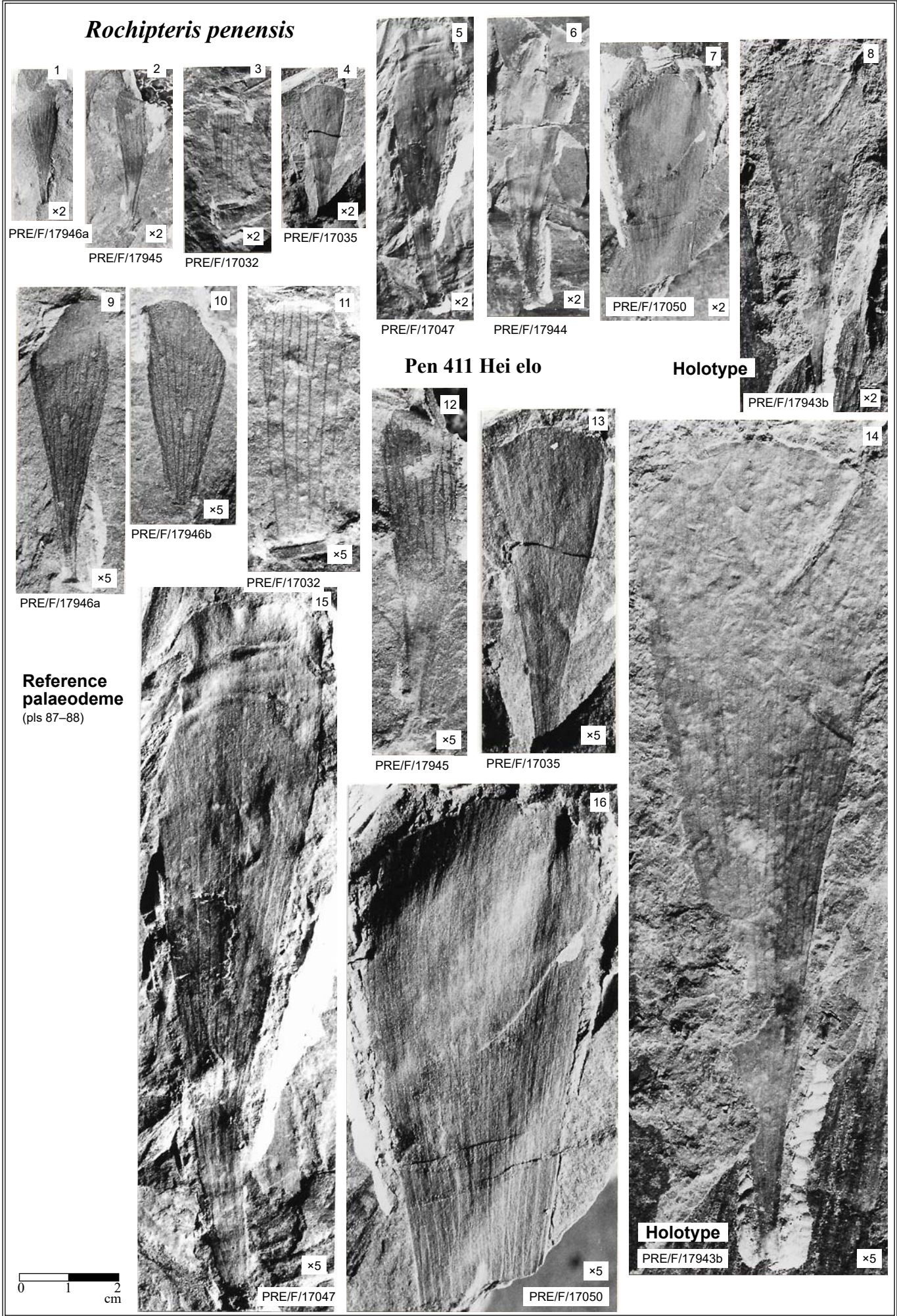


Rochipteris rollerii



Pen 411 Hei elo





Rochipteris penensis



PRE/F/17946a



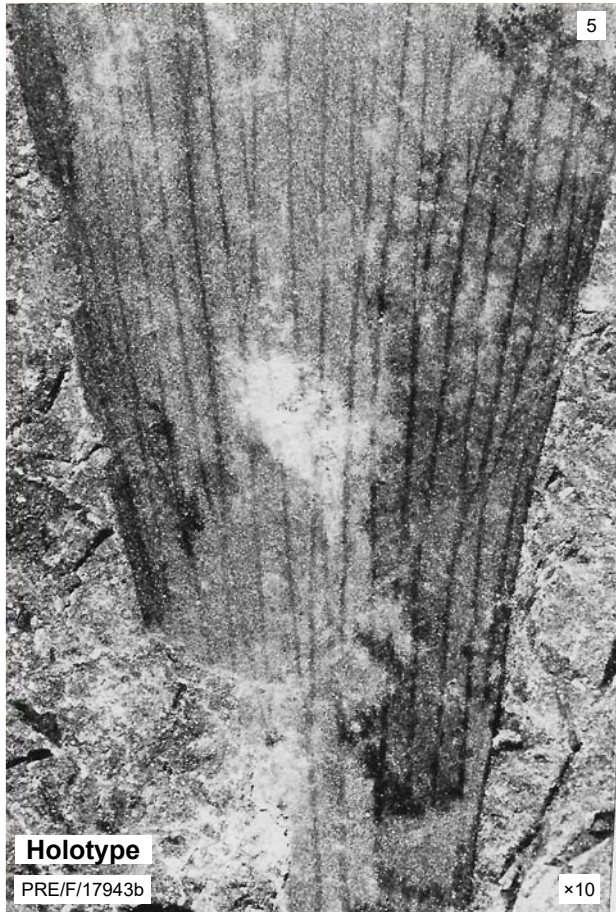
PRE/F/17032



PRE/F/17035

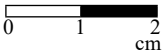


PRE/F/17945



Holotype

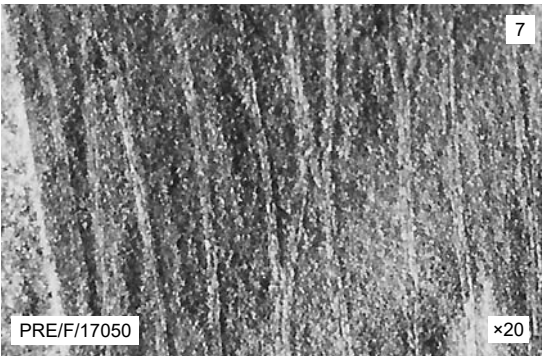
PRE/F/17943b



Pen 411 Hei elo

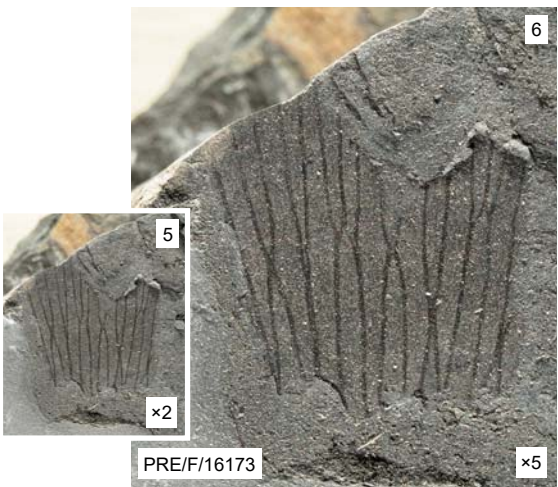
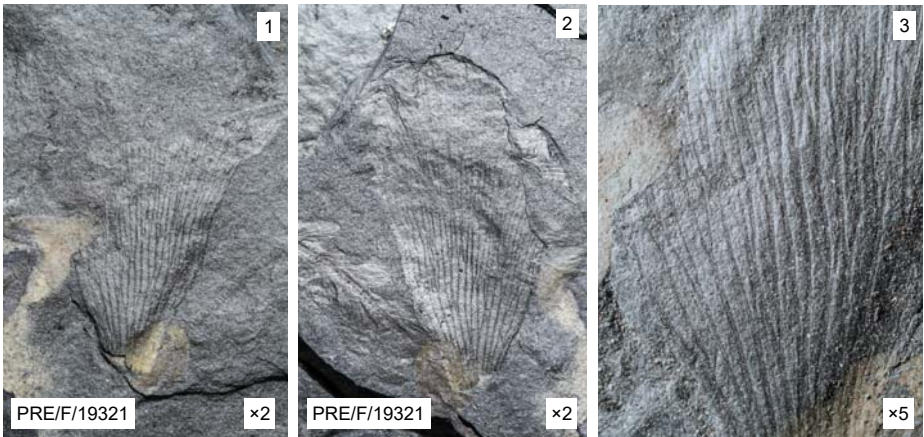


PRE/F/17050

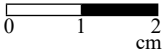


PRE/F/17050

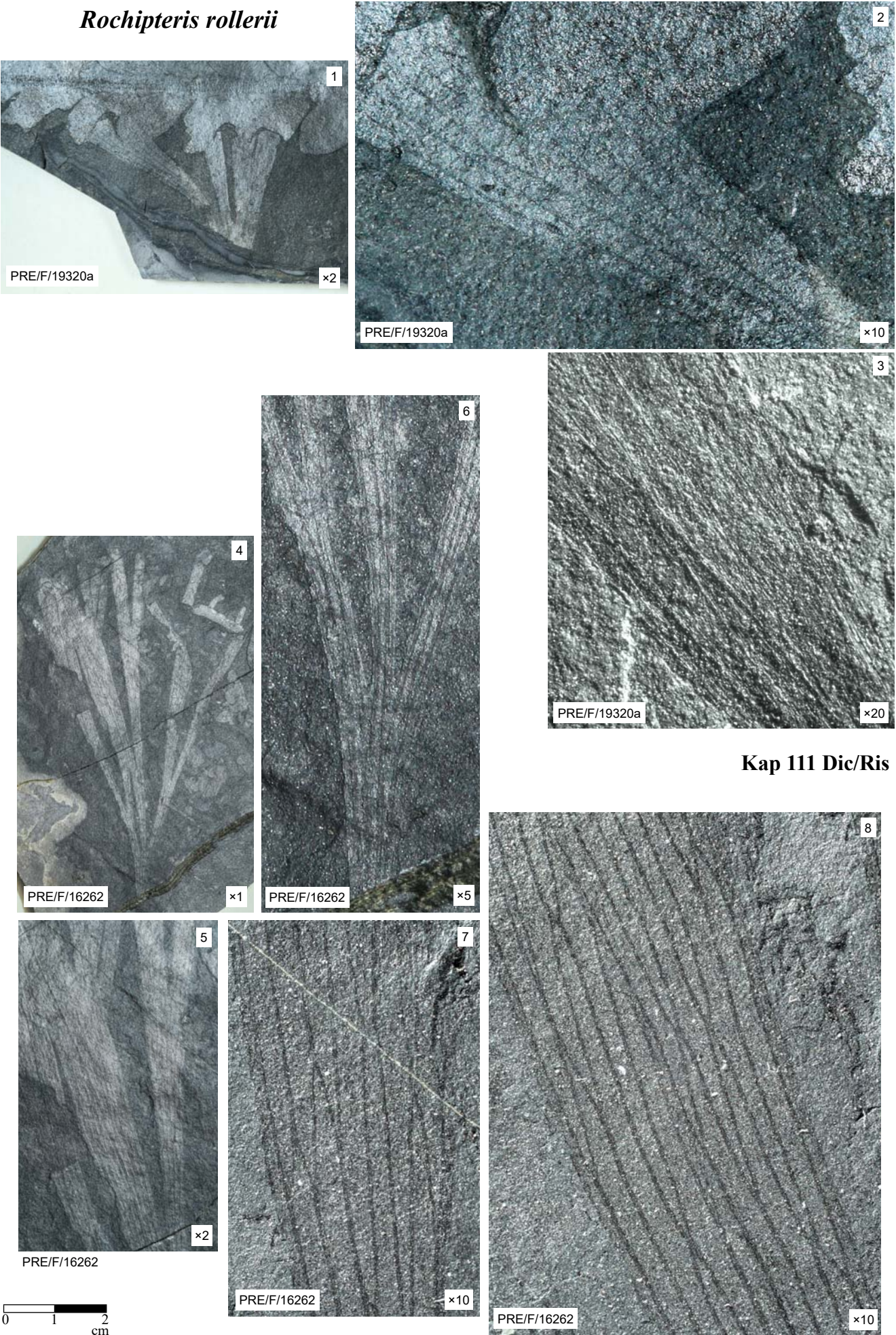
Rochipteris cf. distivena



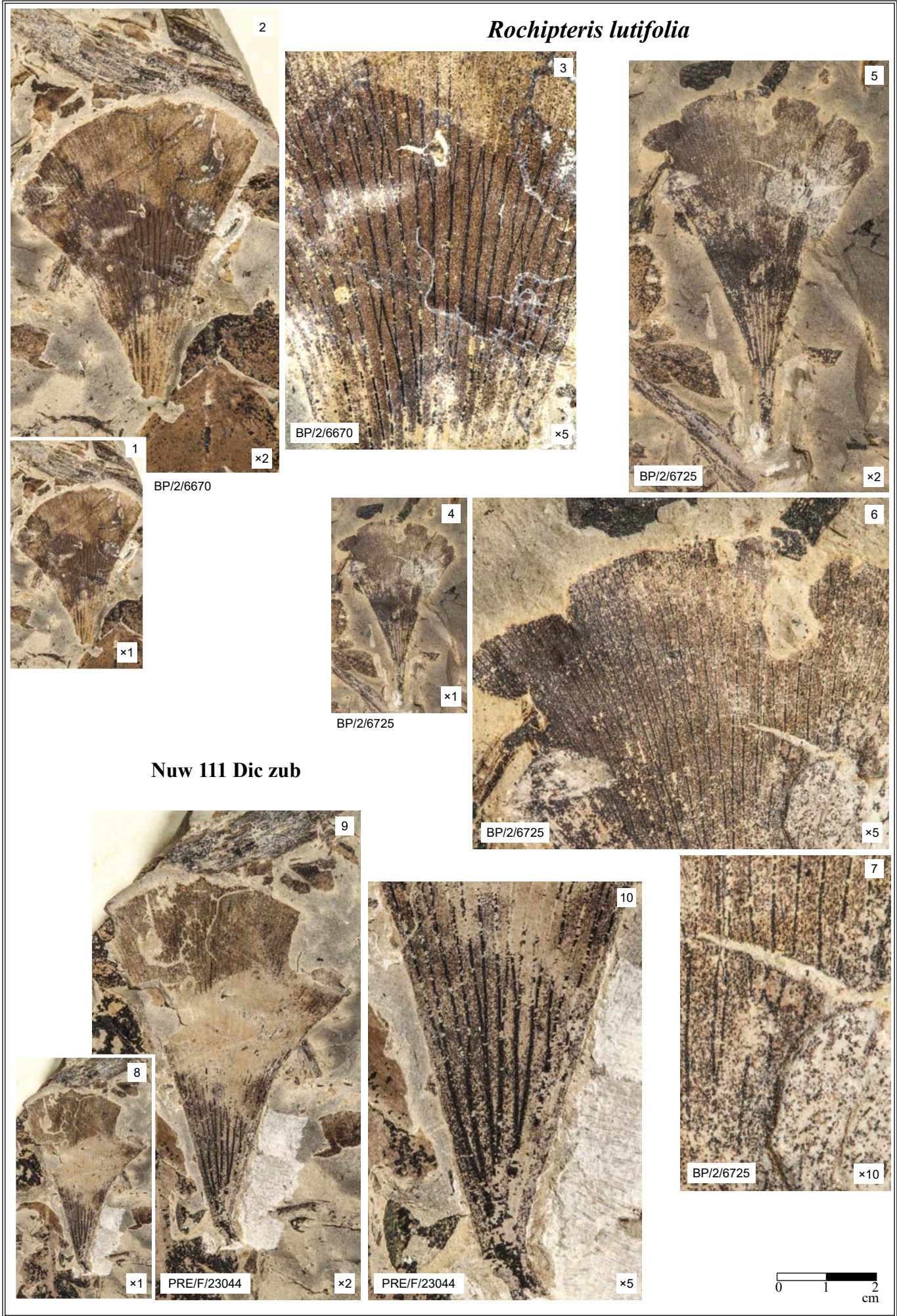
Kap 111 Dic/Ris



Rochipteris rollerii



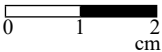
Kap 111 Dic/Ris



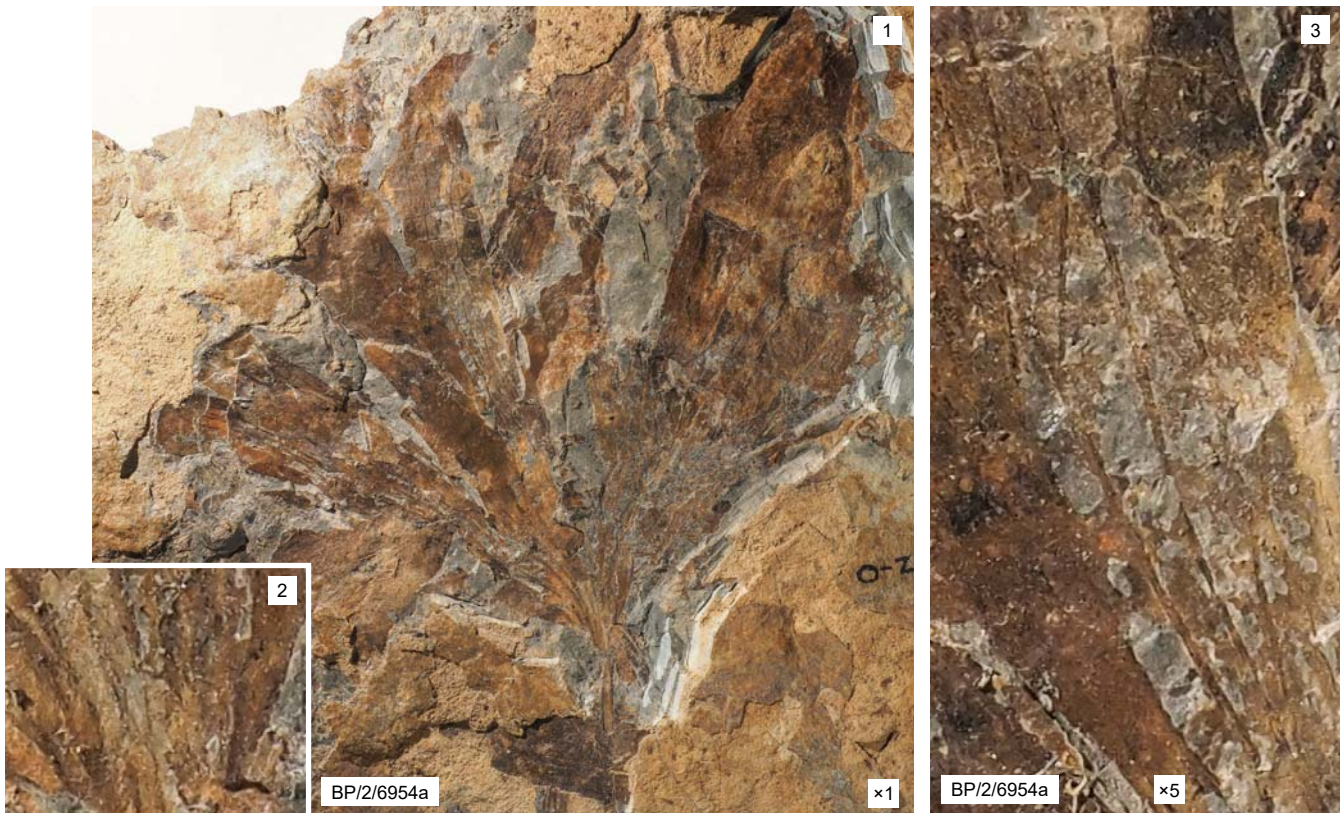
Rochipteris rollerii



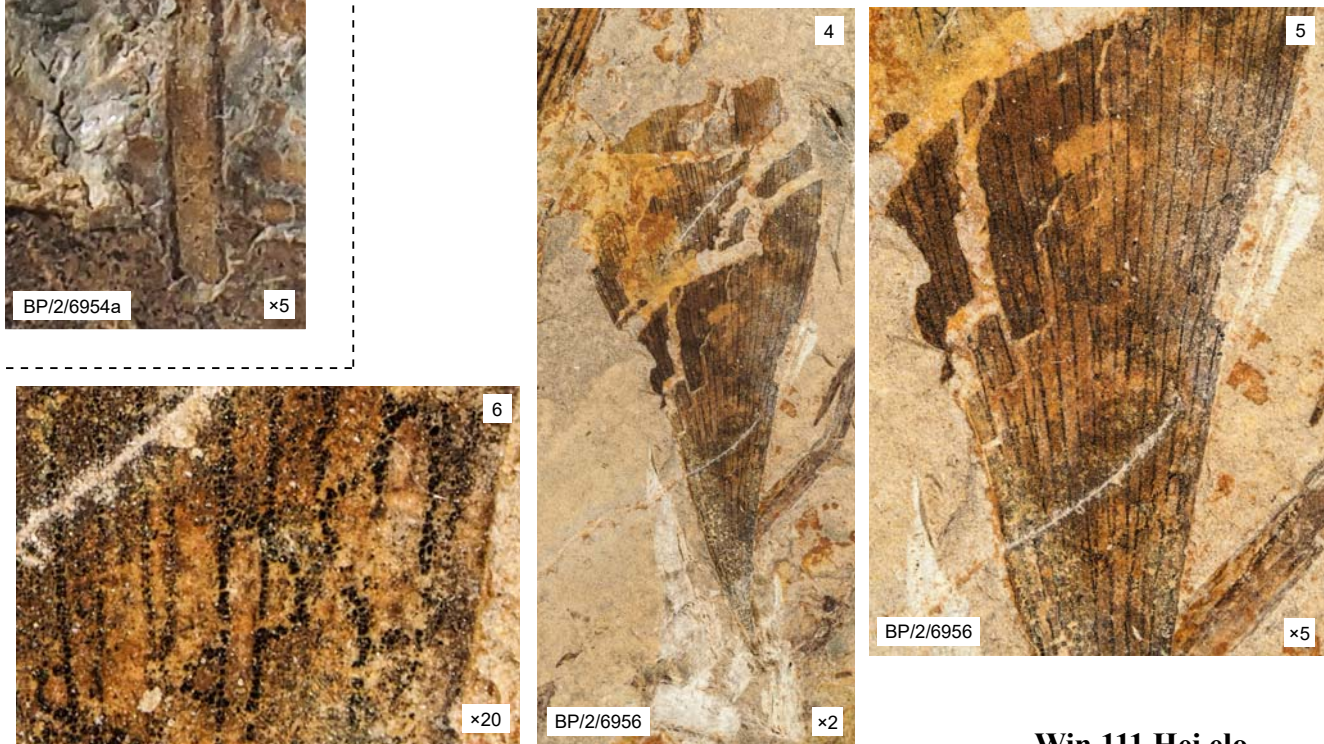
Win 111 Hei elo



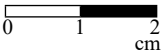
Rochipteris cf. sinuosa



Rochipteris lutifolia

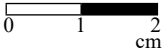


Win 111 Hei elo



Rochipteris switzifolia

Hla 213 Dic elo

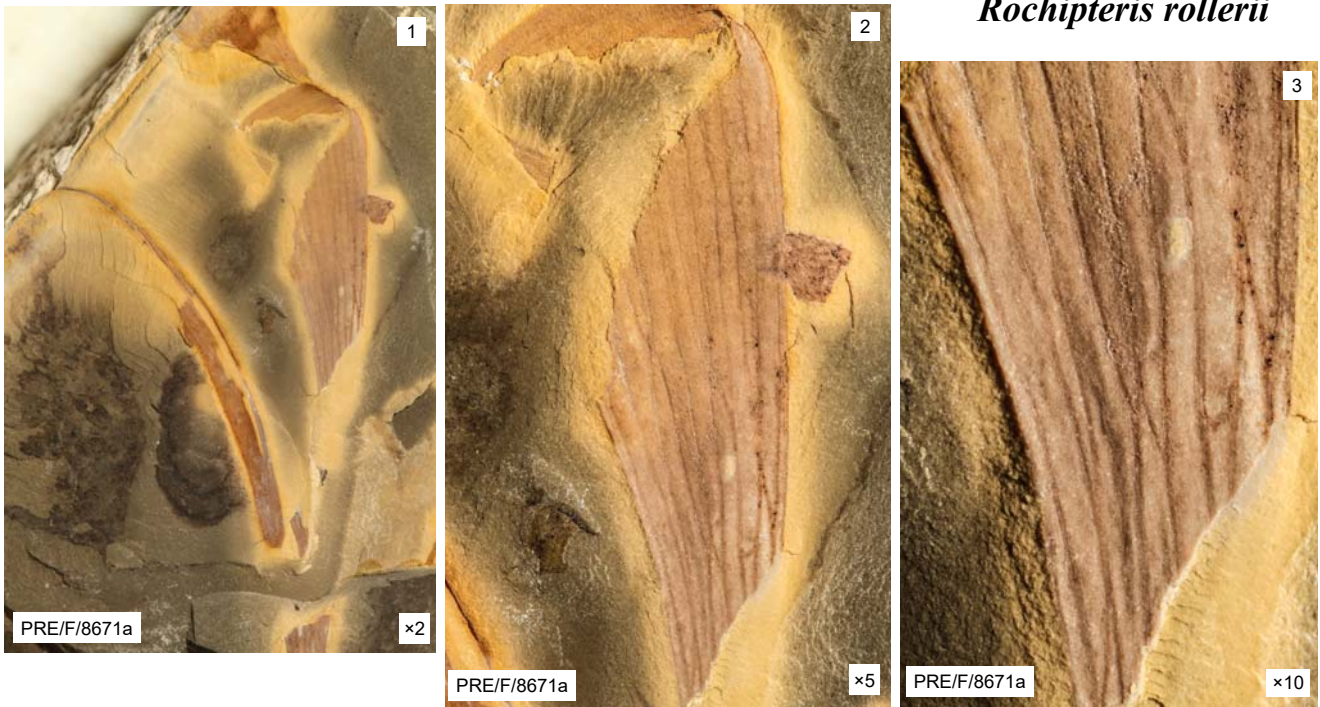


Rochipteris switzifolia*Rochipteris rollerii*

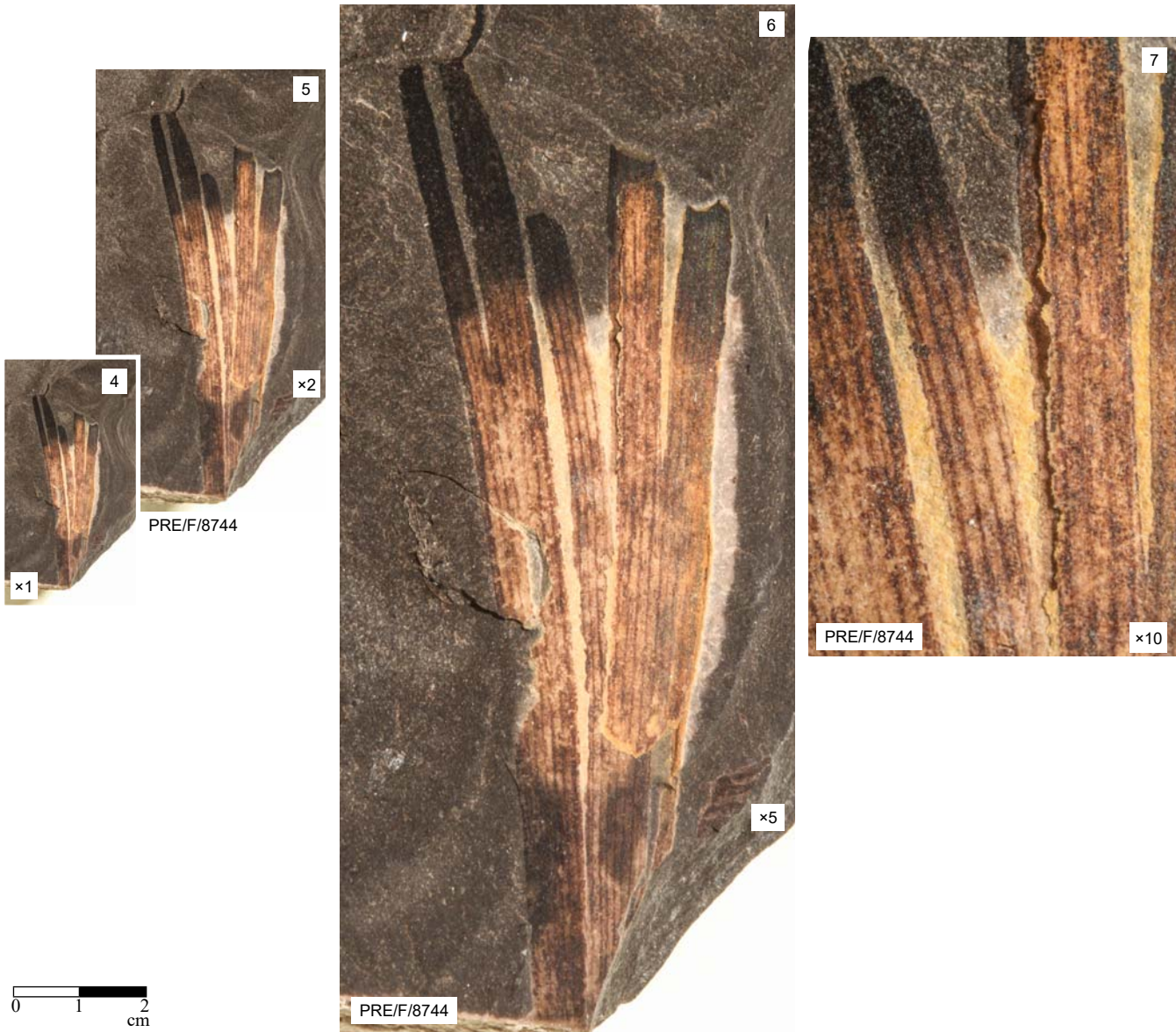
Hla 213 Dic elo

0 1 2
cm

Rochipteris rollerii



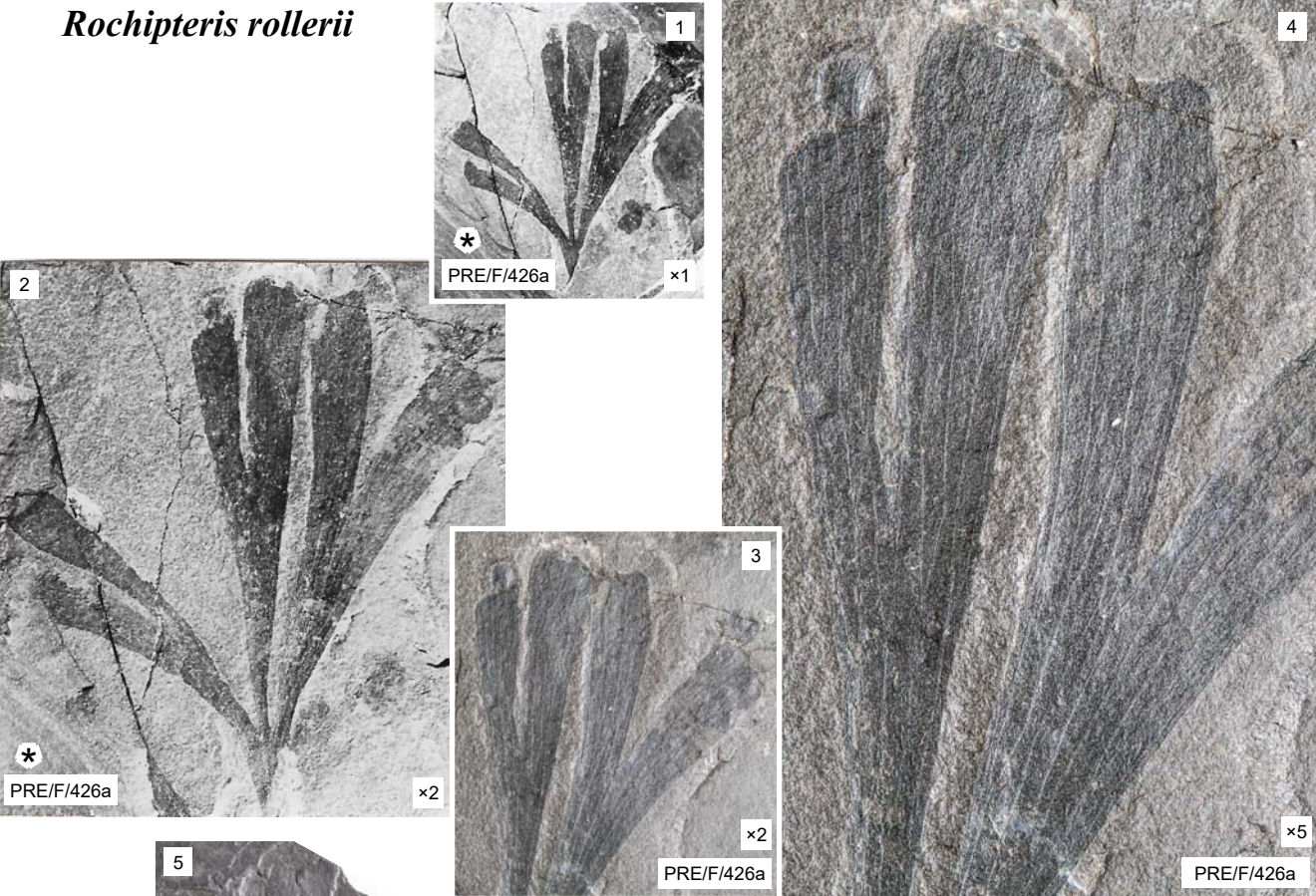
Hla 213 Dic elo



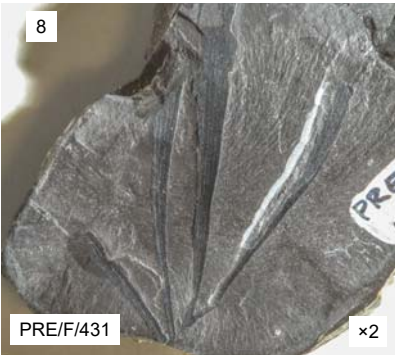
*Rochipteris
rollerii*



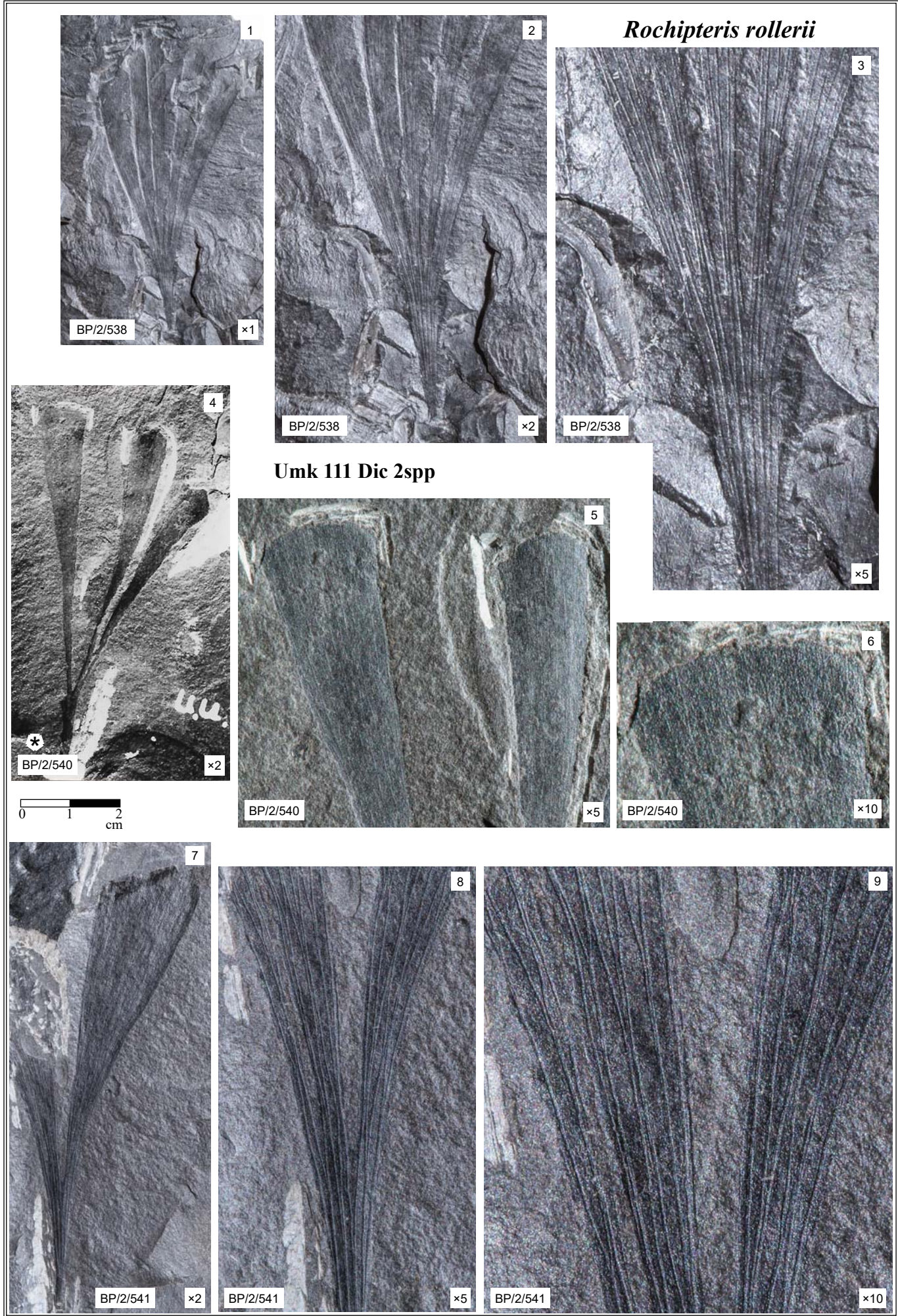
Rochipteris rollerii



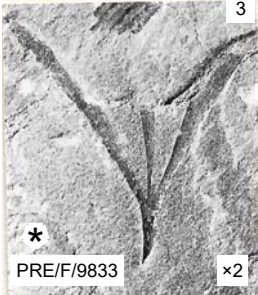
0 1 2
cm



Umk 111 Dic 2spp

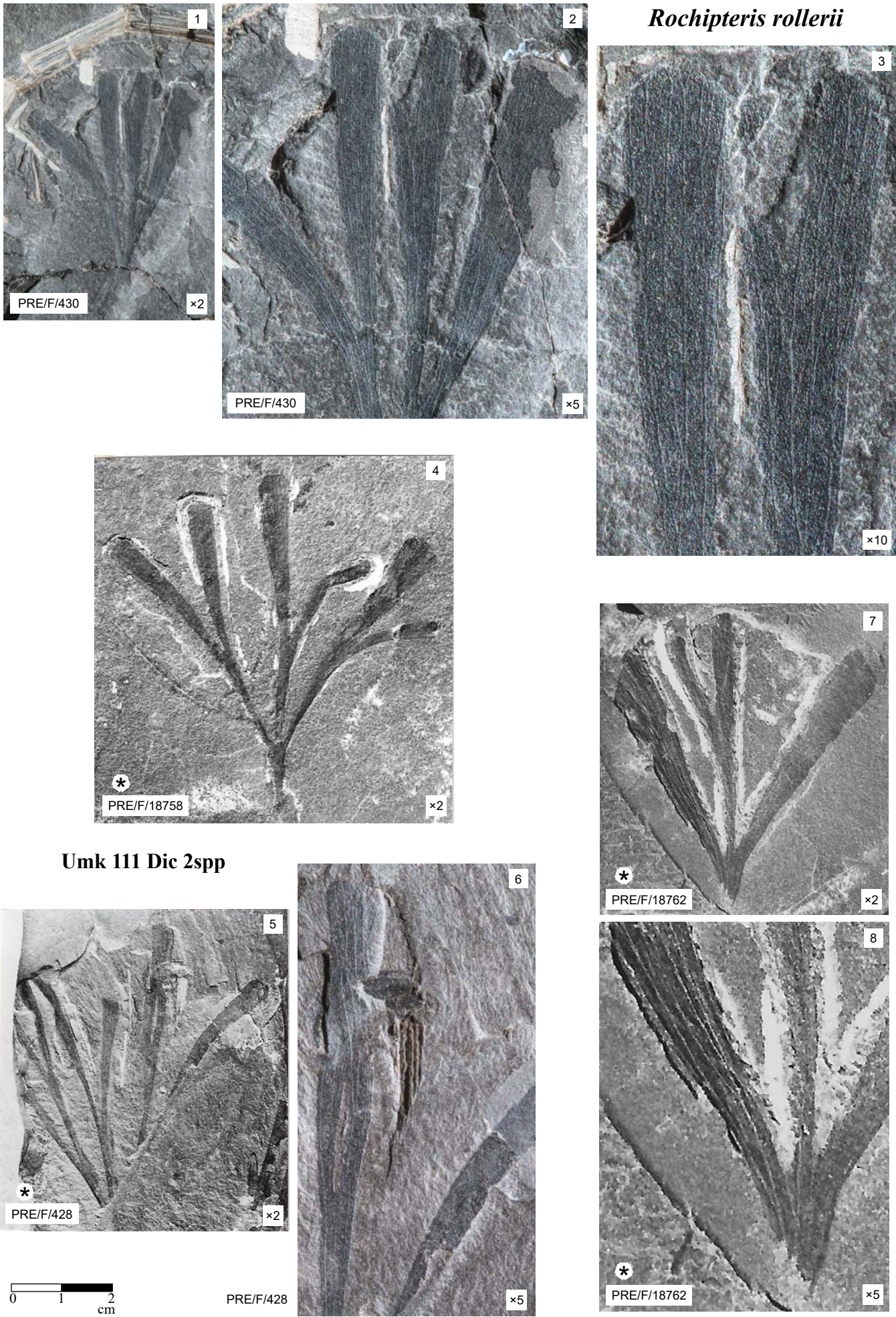


Rochipteris rollerii



Umk 111 Dic 2spp

Rochipteris rollerii



Rochipteris rollerii



PRE/F/6384b



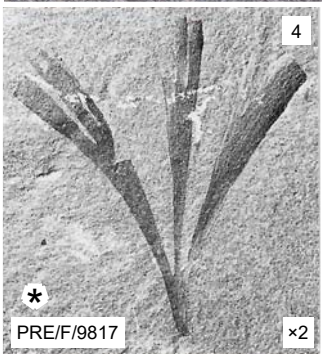
PRE/F/6384b



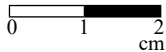
PRE/F/6384b



PRE/F/9817



PRE/F/9817



PRE/F/9816



PRE/F/9816

Umk 111 Dic 2spp

Rochipteris obtriangulata



PRE/F/422



PRE/F/422

Reference palaeodeme
(pls 103–106)

Umk 111 Dic 2spp



PRE/F/422



PRE/F/423



PRE/F/423



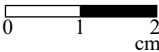
PRE/F/423

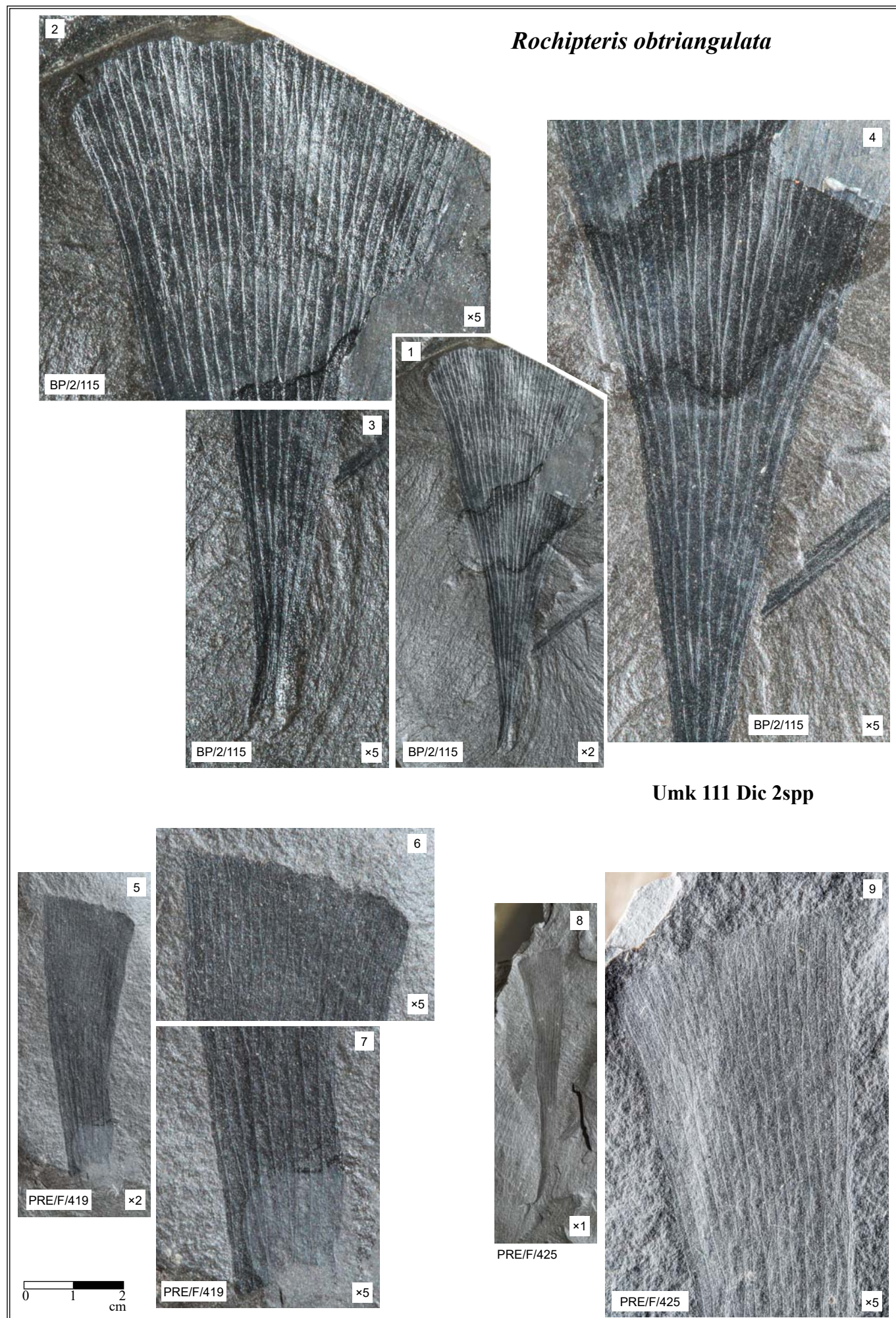


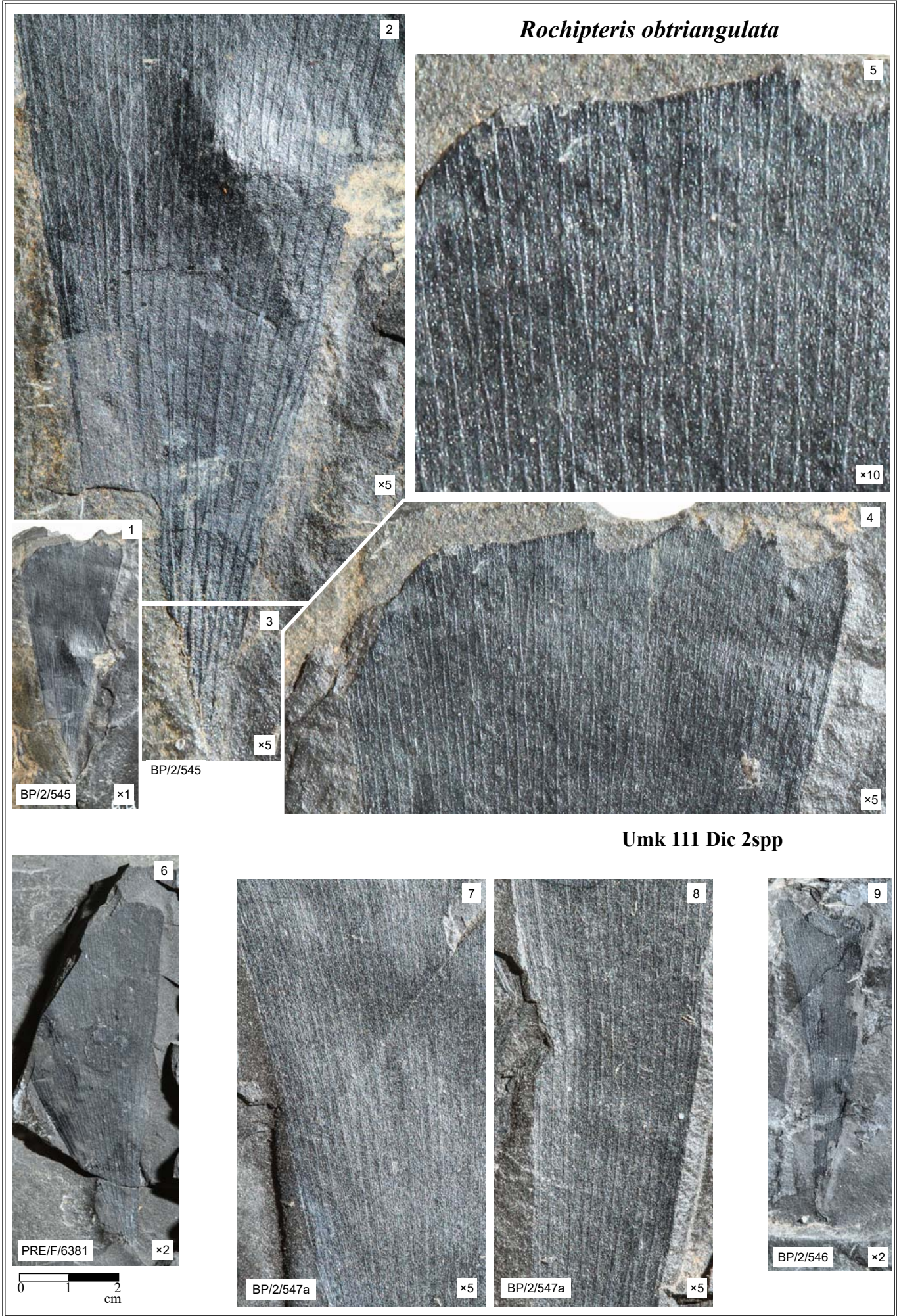
PRE/F/423



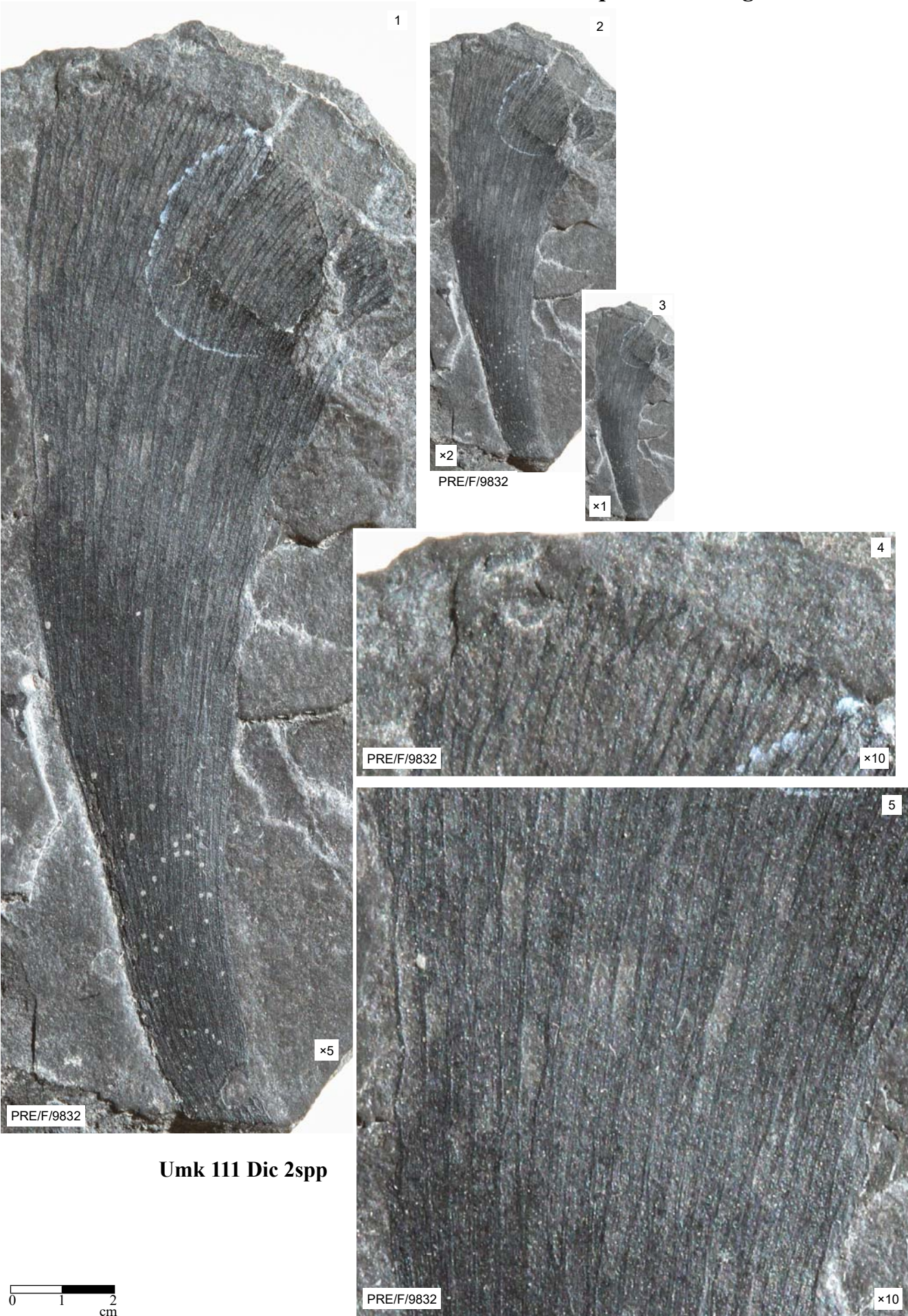
PRE/F/423



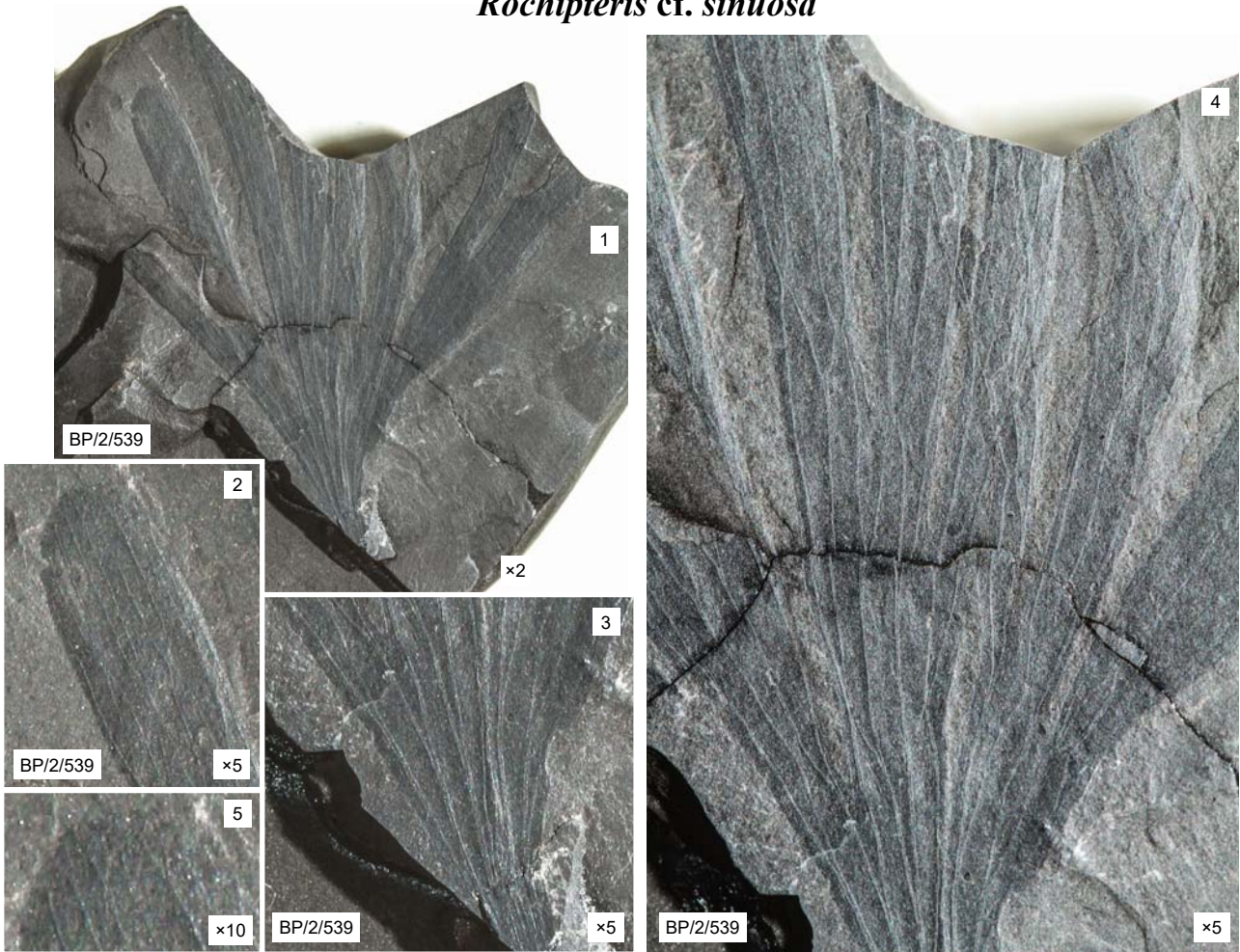




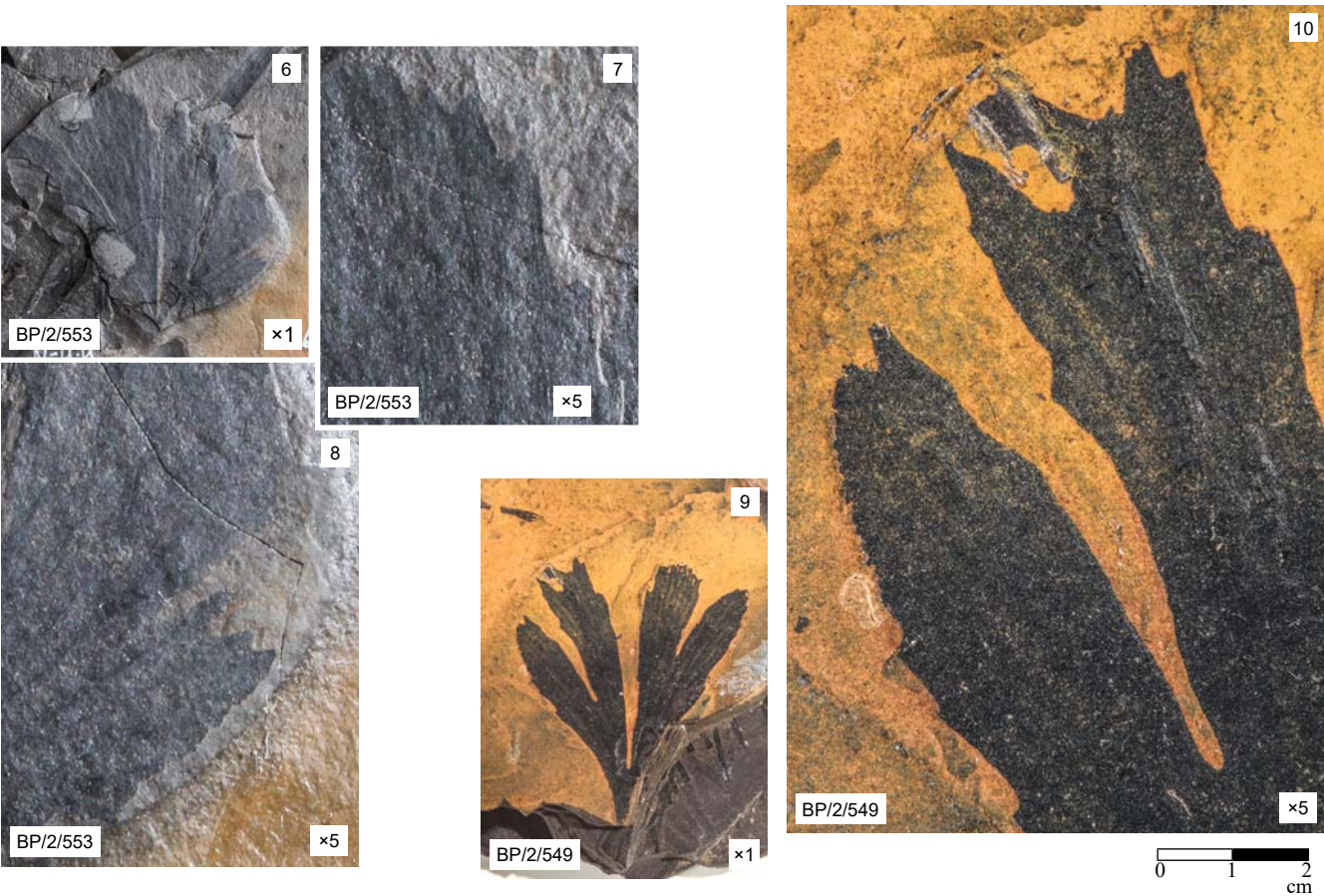
Rochipteris obtriangulata



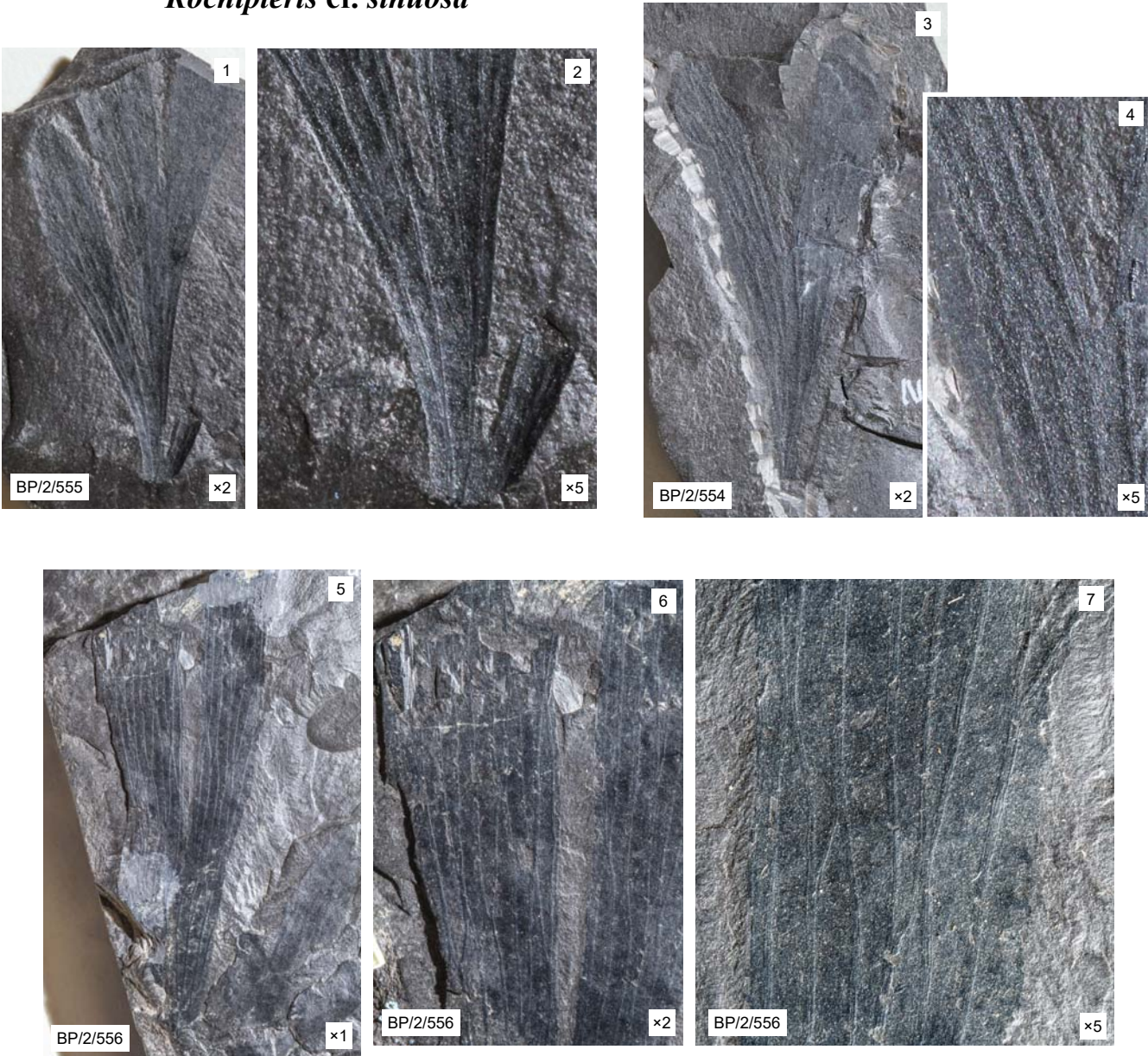
Rochipteris cf. sinuosa



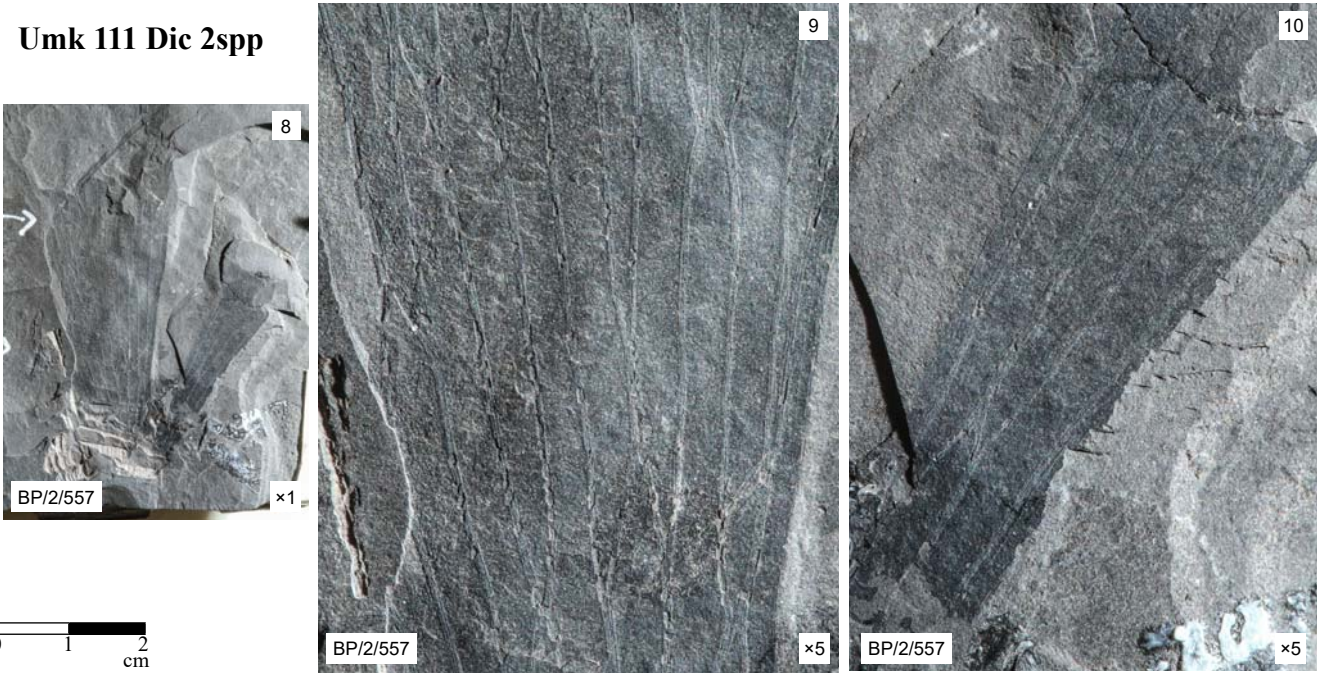
Umk 111 Dic 2spp



Rochipteris cf. sinuosa



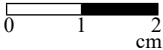
Umk 111 Dic 2spp



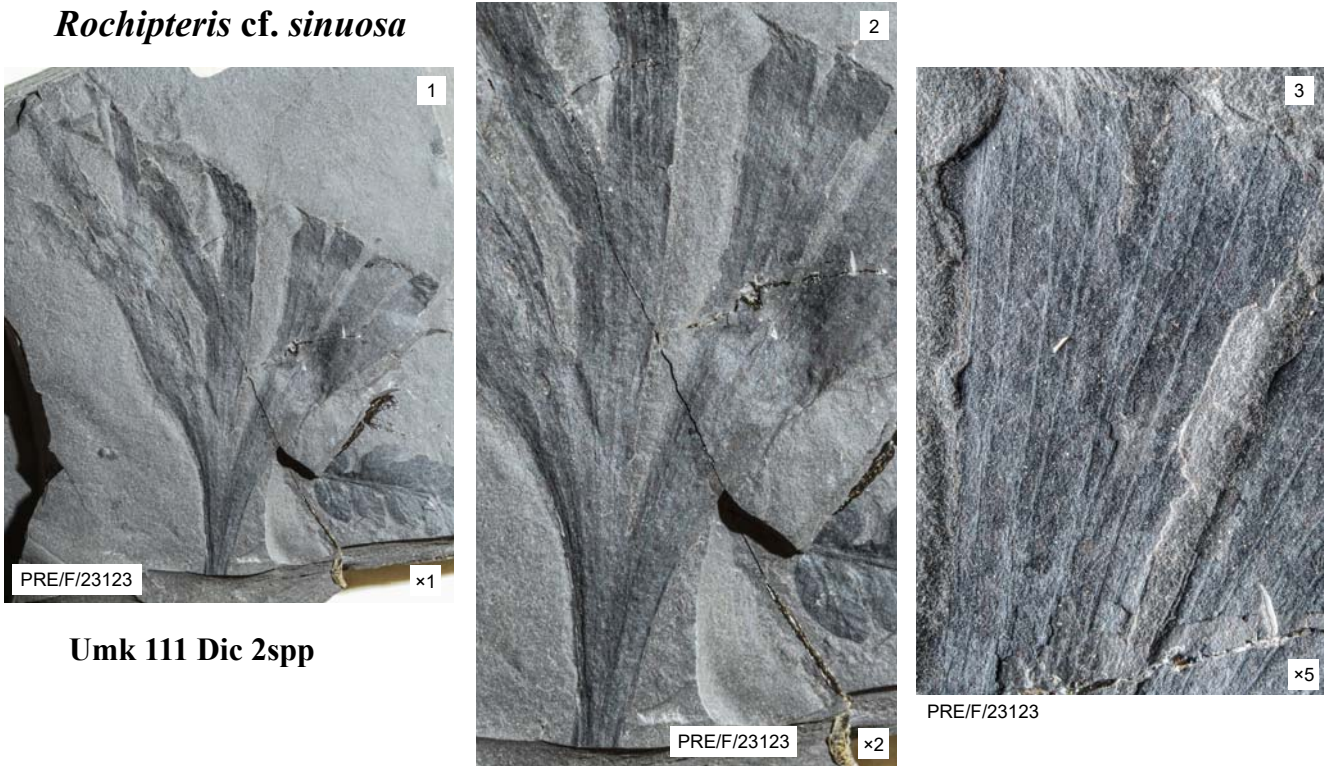
Rochipteris
cf. sinuosa



Umk 111 Dic 2spp



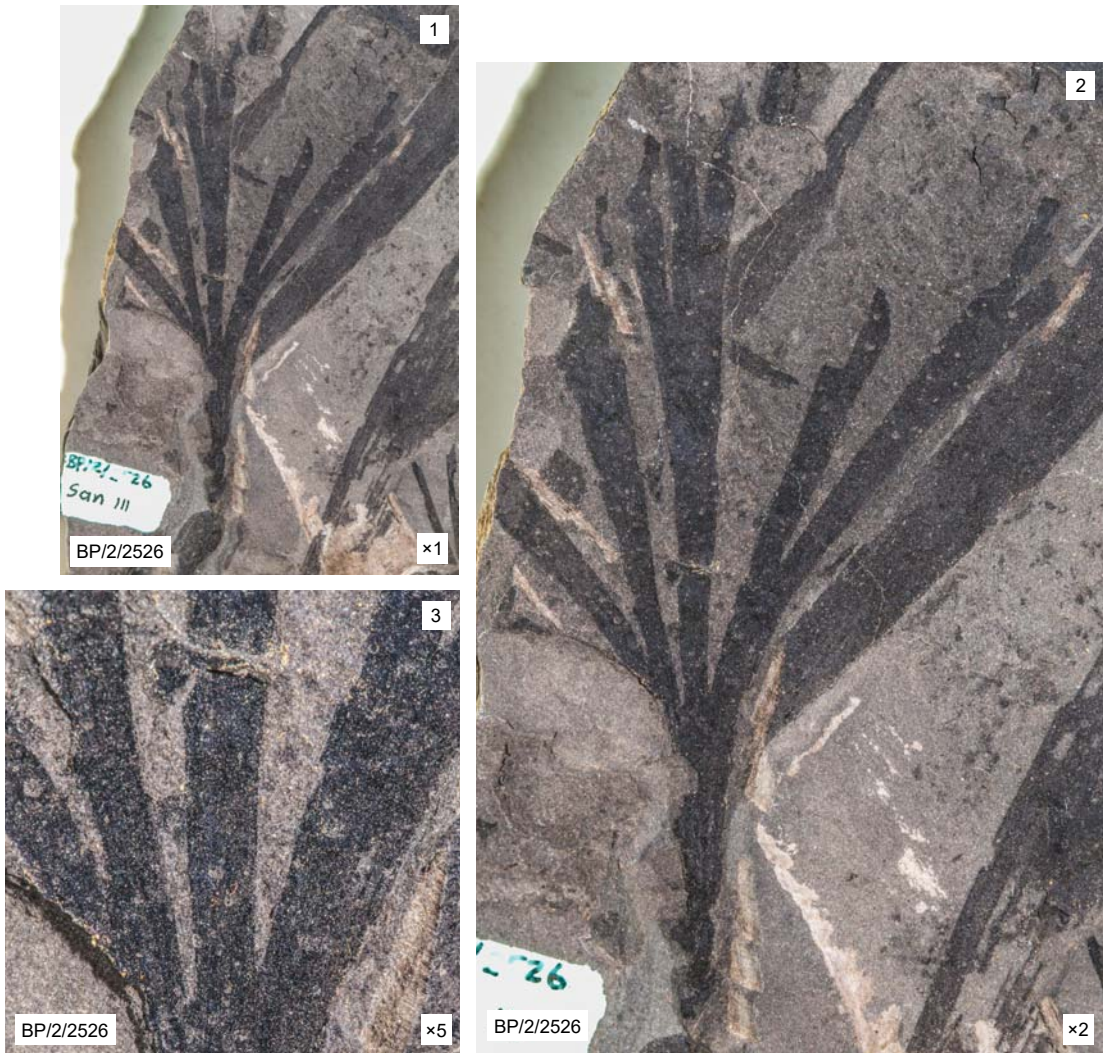
Rochipteris cf. sinuosa



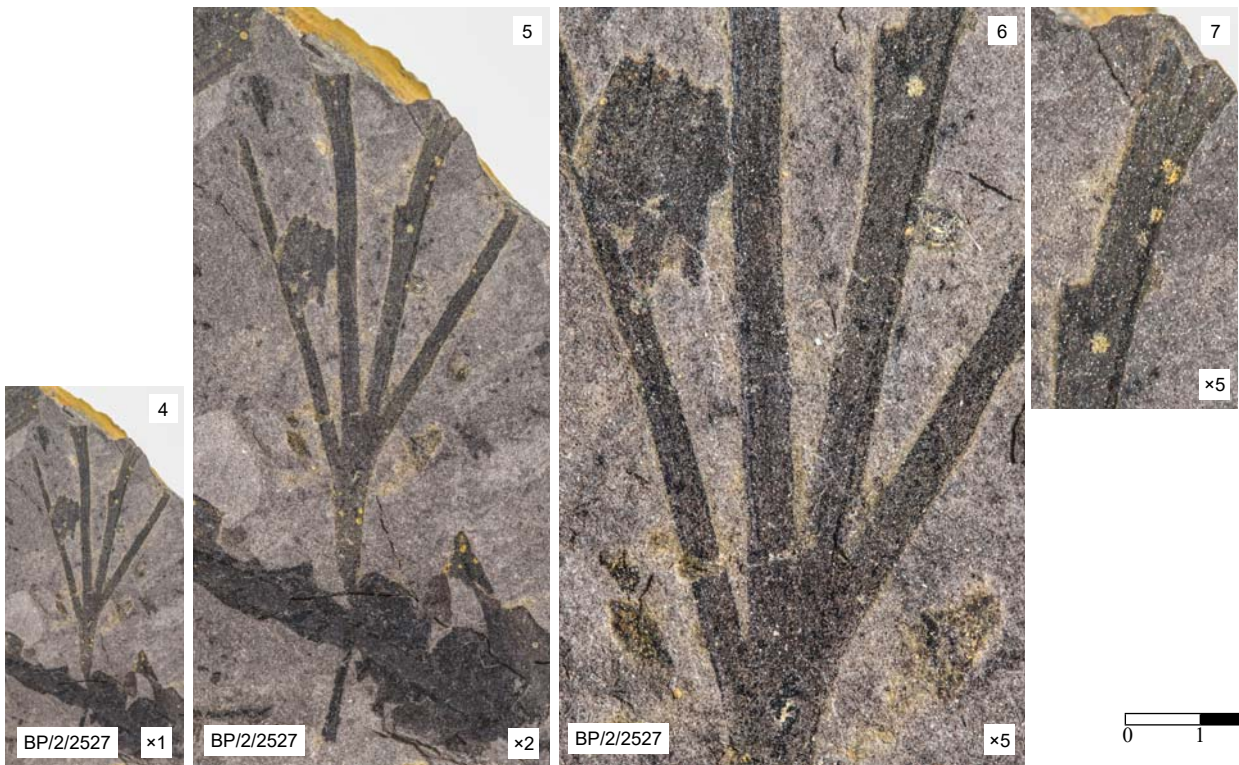
Rochipteris lutifolia



Rochipteris rollerii

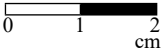


San 111 Dic cra

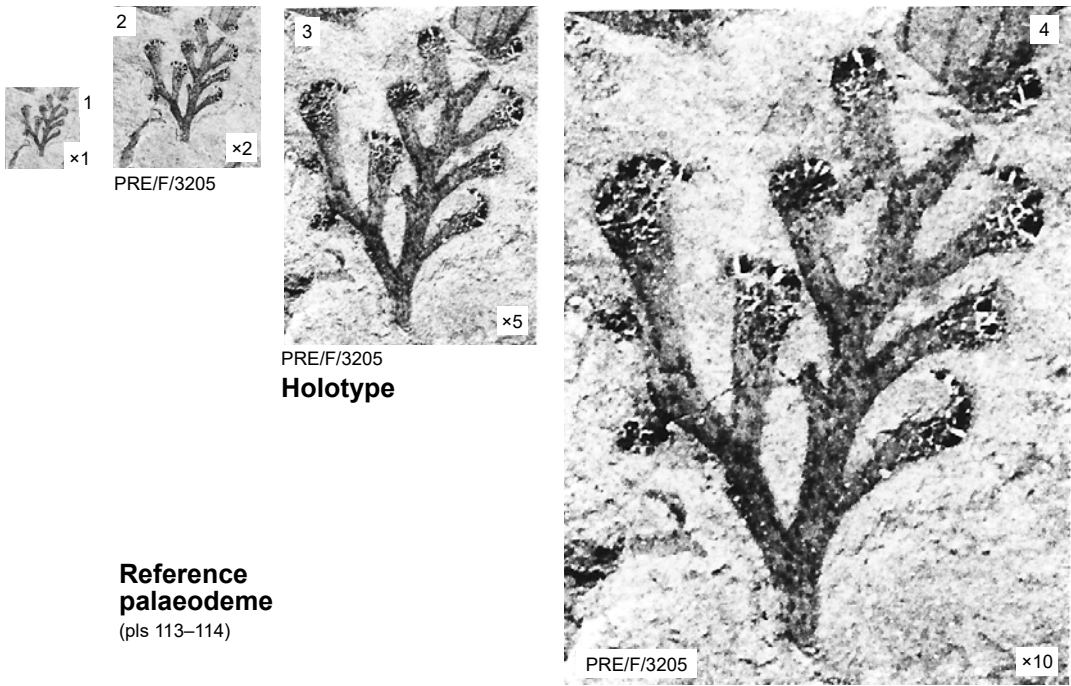


Rochipteris rollerii

San 111 Dic cra

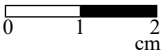
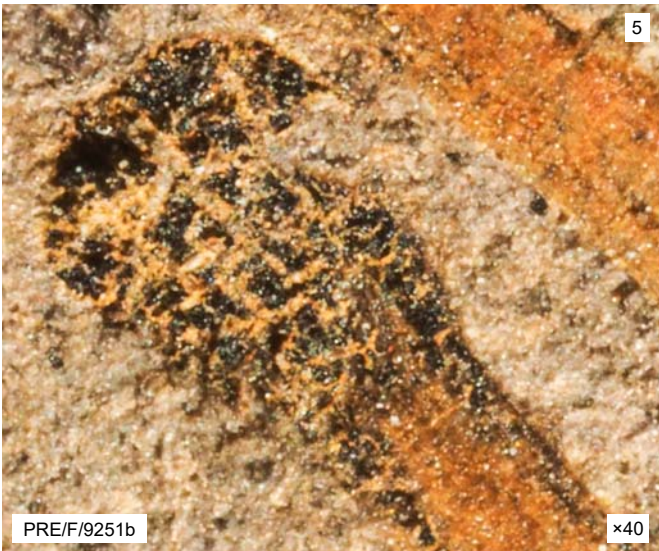
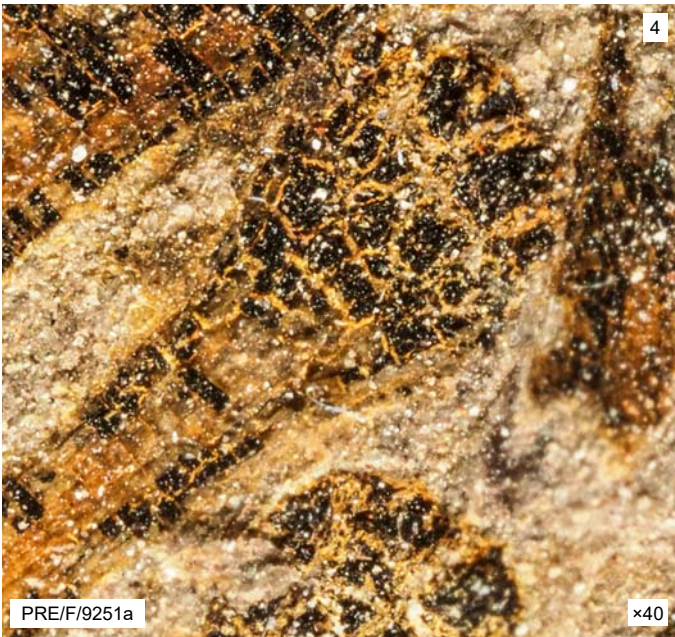


Kannaskoppianthus matatiparvus



Kannaskoppianthus matatiparvus

Mat 111 Dic dub

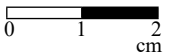


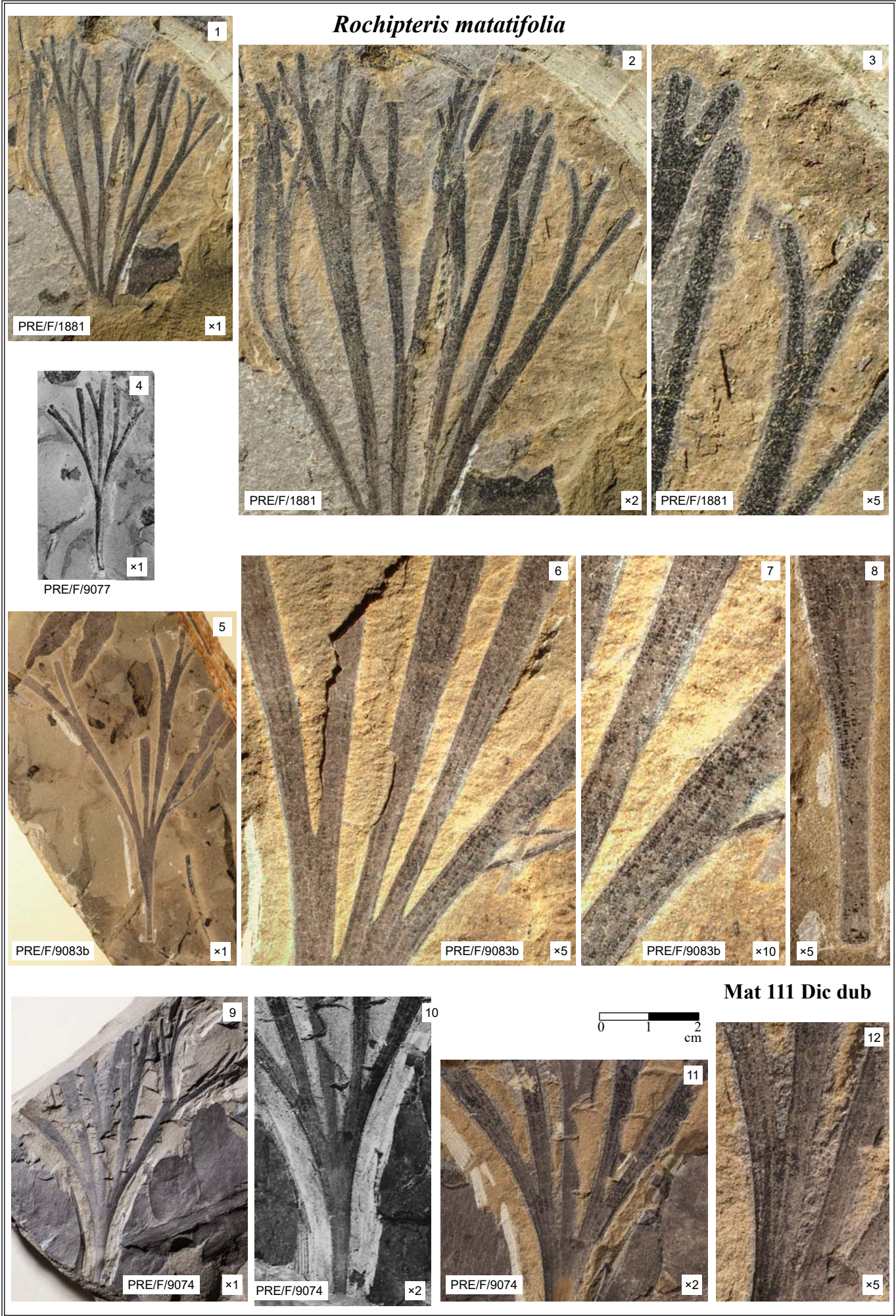
Rochipteris matatifolia



Mat 111 Dic dub

Holotype

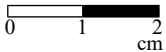




Rochipteris telefolia



Mat 111 Dic dub

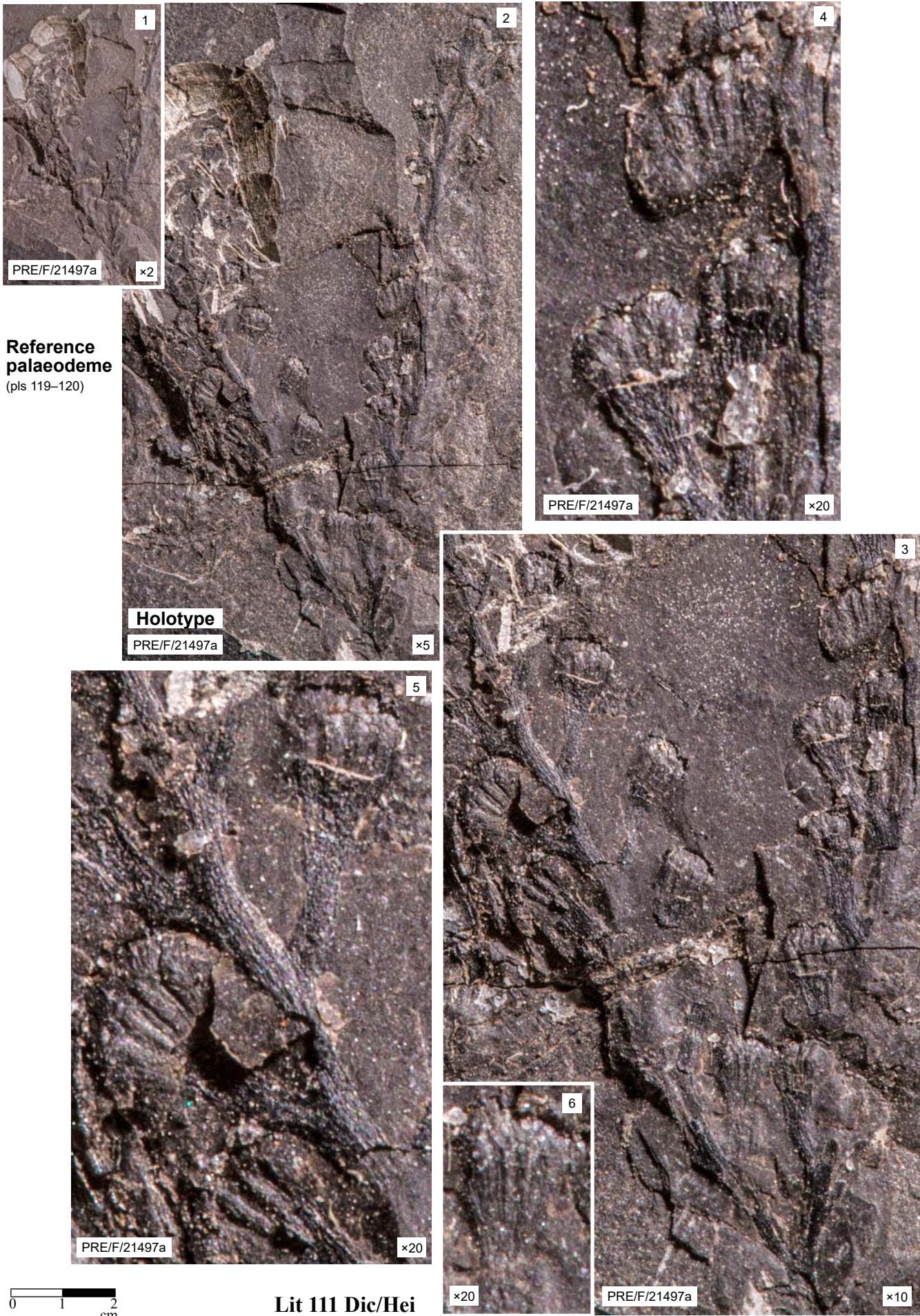


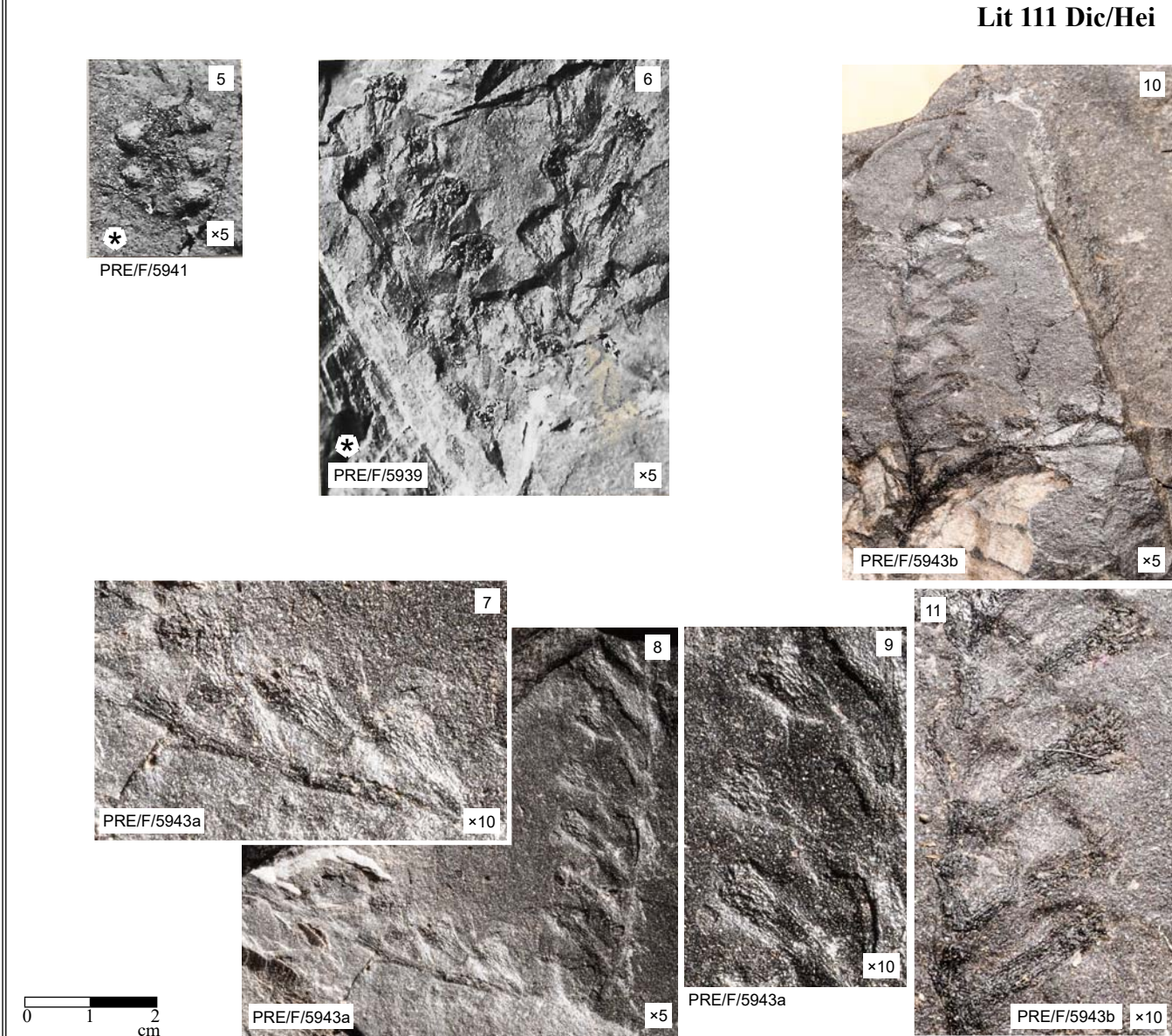
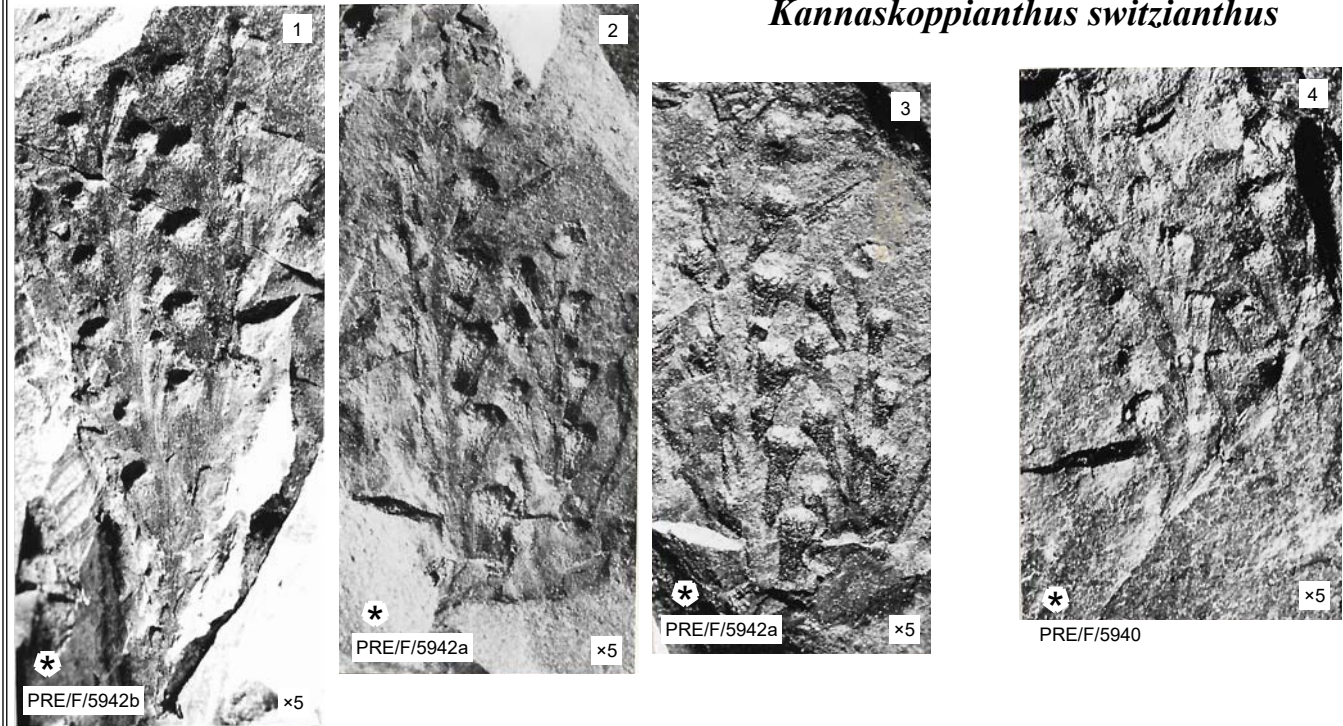
Rochipteris telefolia

Mat 111 Dic dub

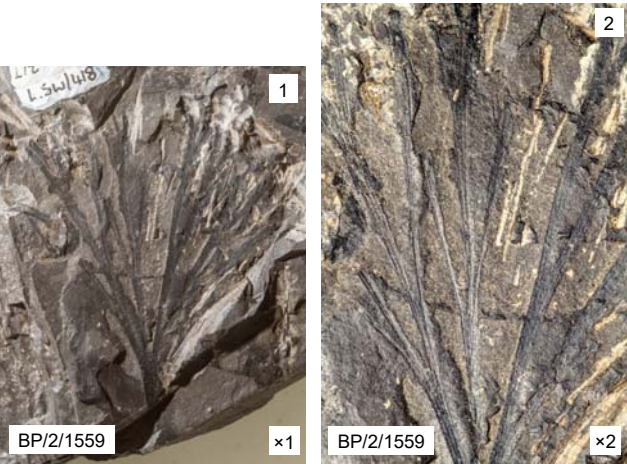


Kannaskoppianthus switzianthus

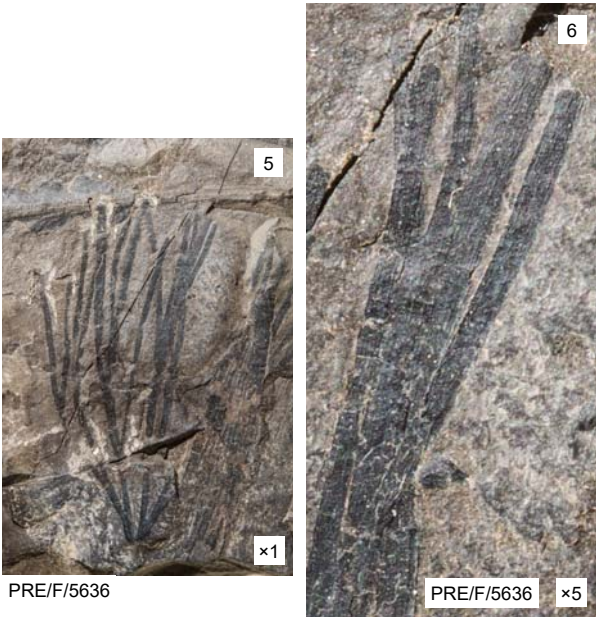




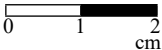
Rochipteris switzifolia



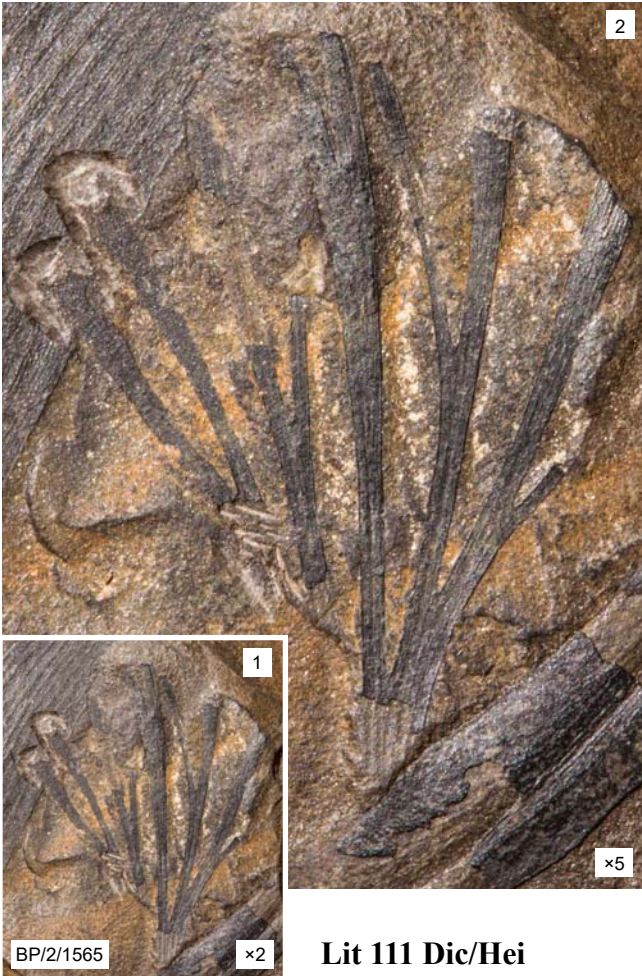
Lit 111 Dic/Hei



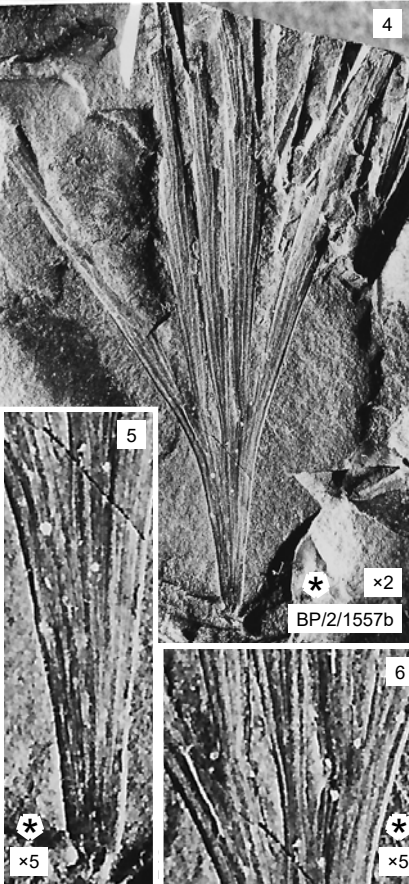
Reference
palaeodeme
(pls 121–124)



Rochipteris switzifolia



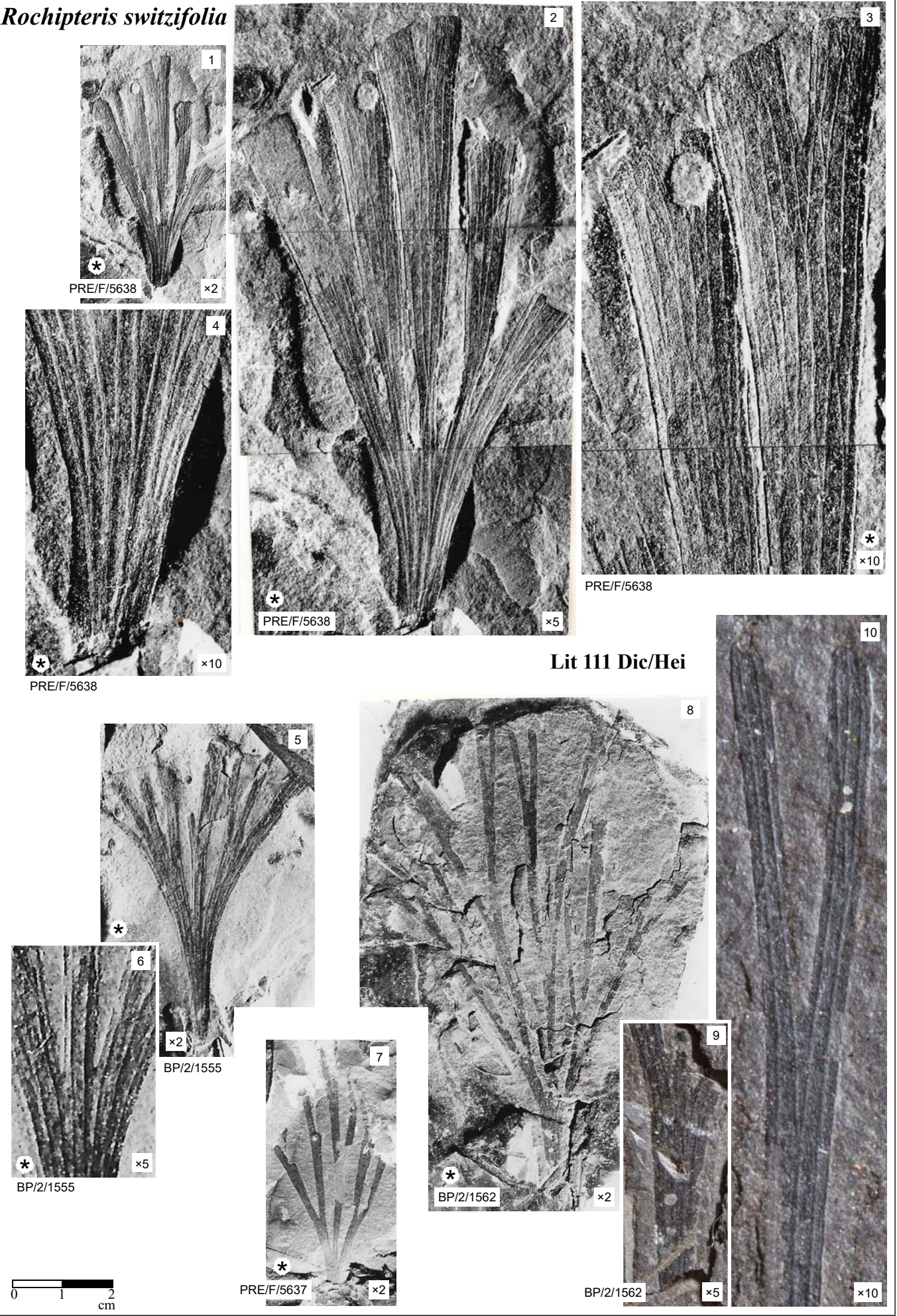
Lit 111 Dic/Hei



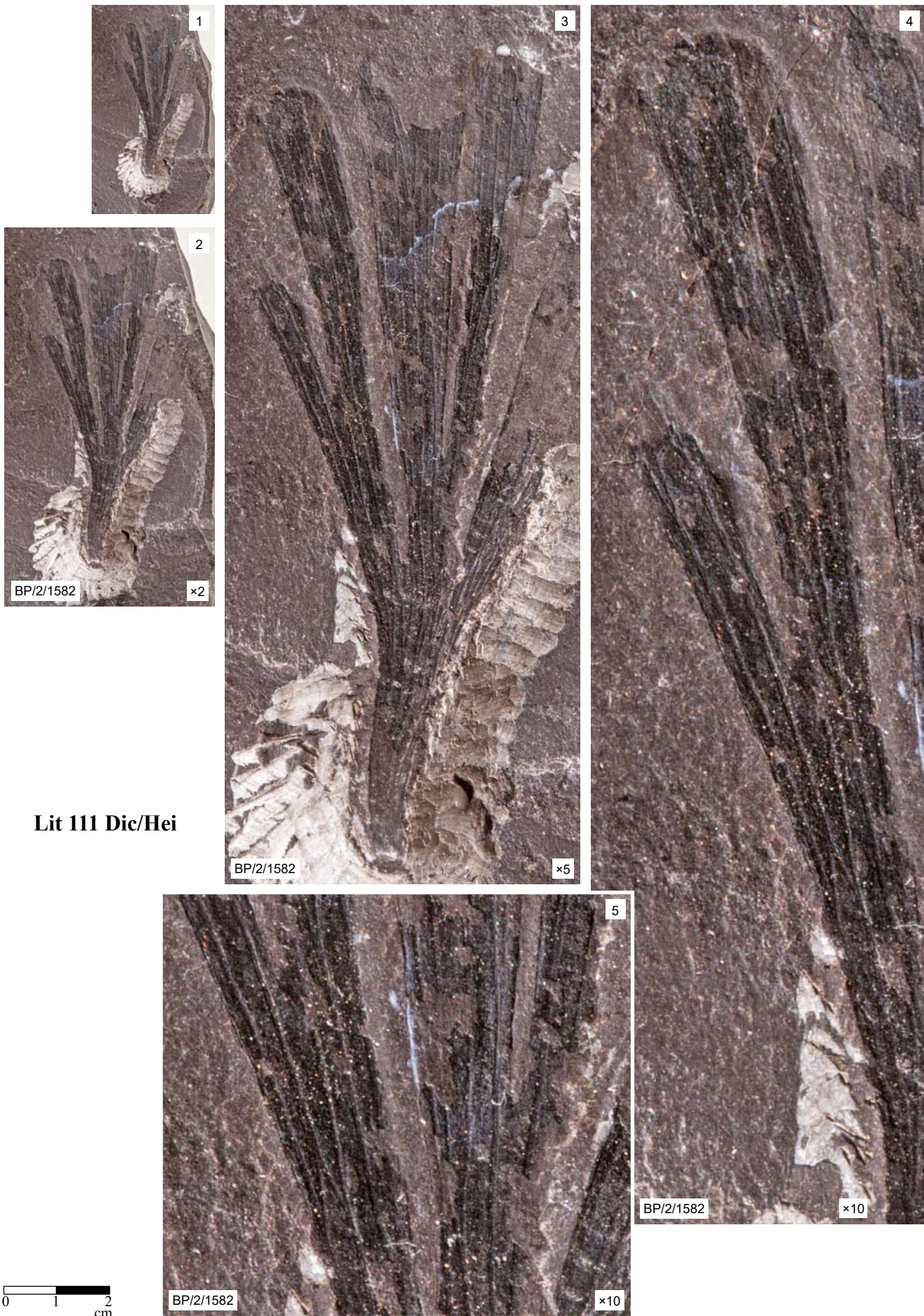
0 1 2 cm



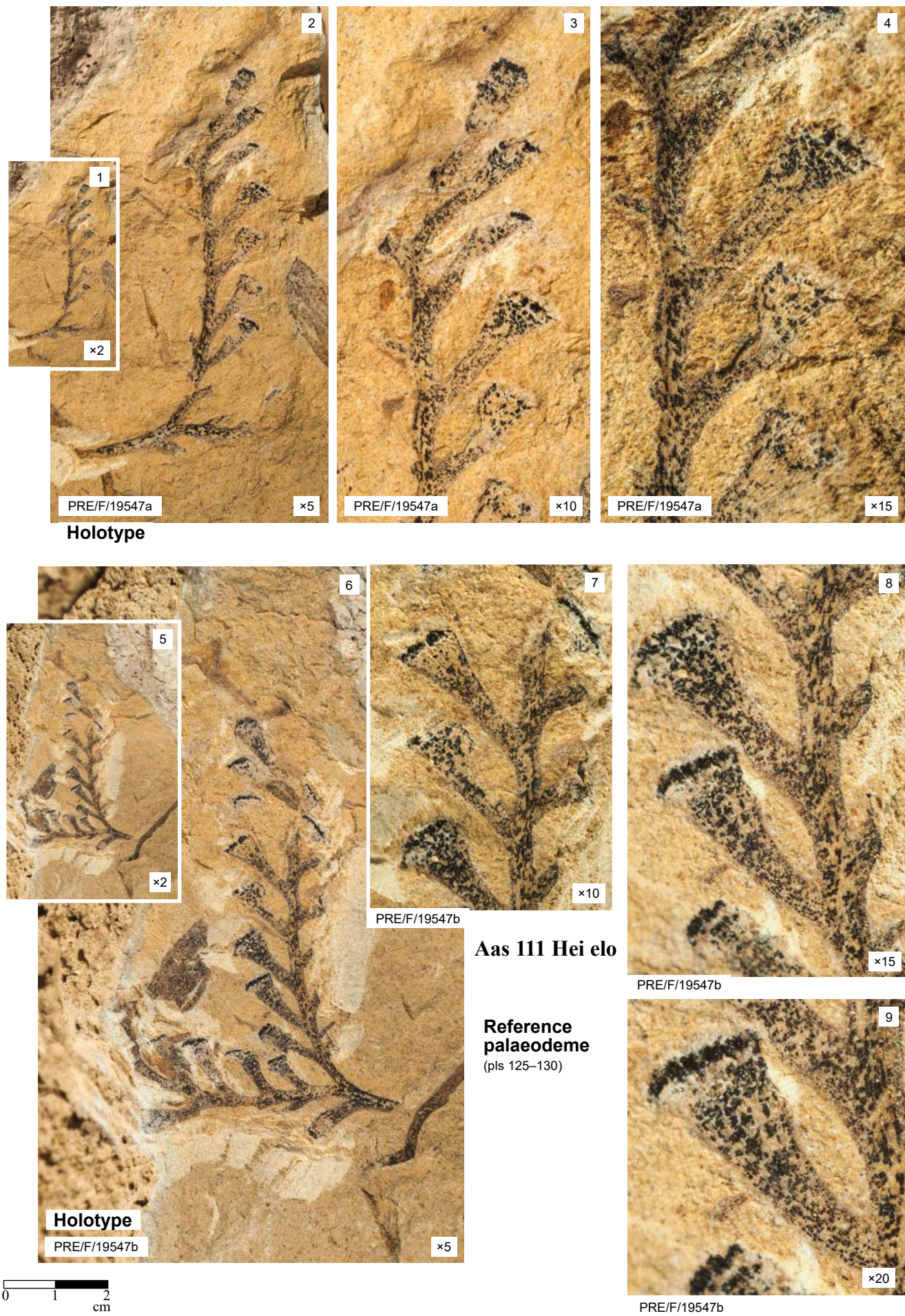
Rochipteris switzifolia



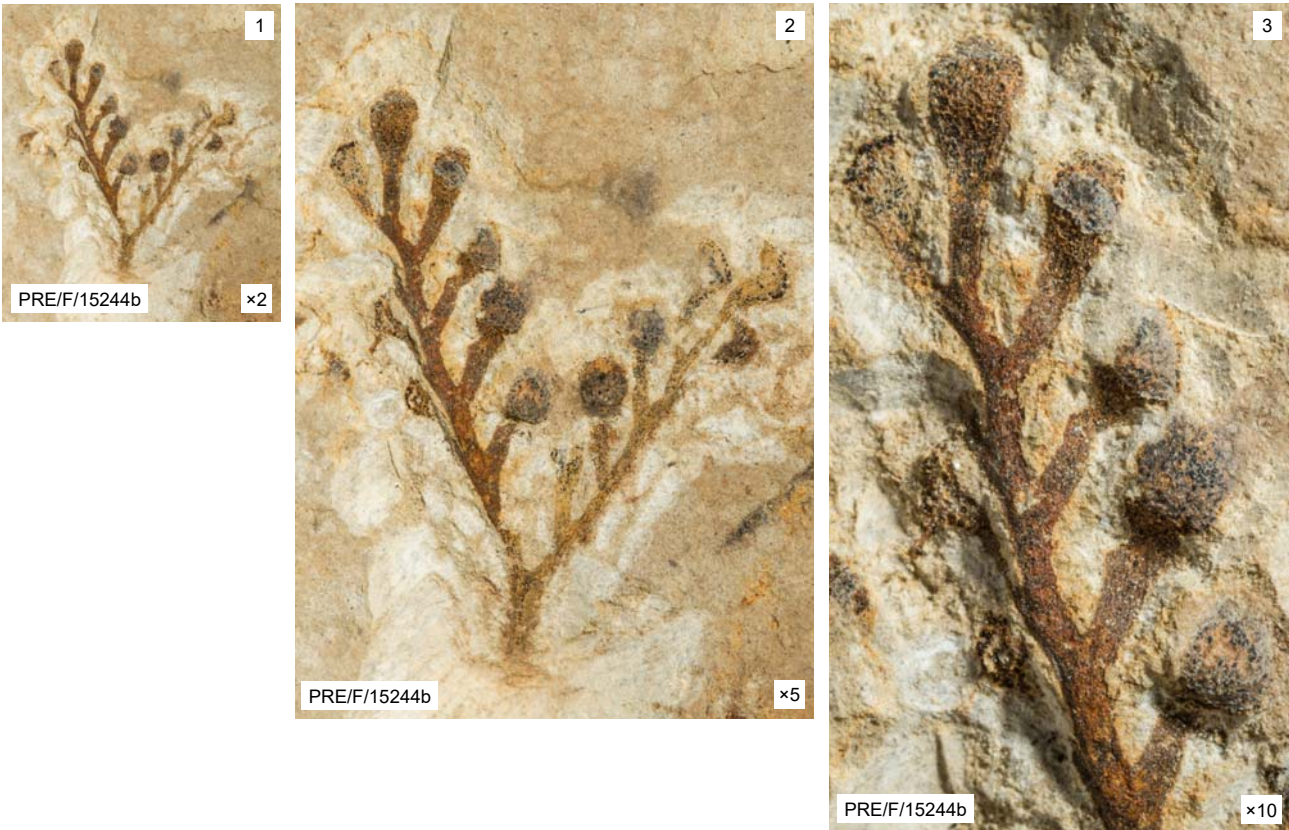
Rochipteris switzifolia



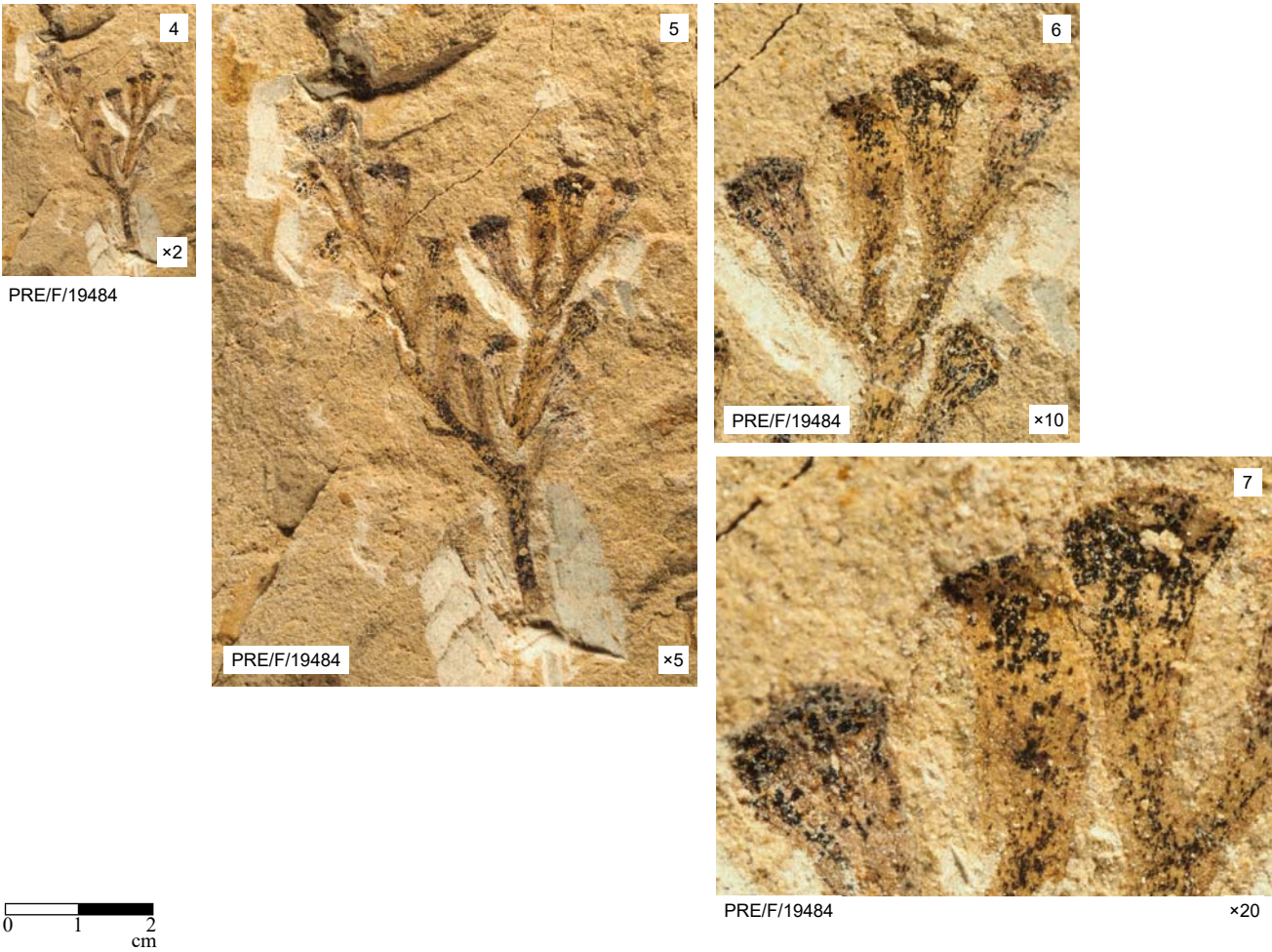
Kannaskoppianthus aasvoelensis



Kannaskoppianthus aasvoelensis



Aas 111 Hei elo



Kannaskoppianthus aasvoelensis



PRE/F/15203a



PRE/F/15203a



PRE/F/15203a



PRE/F/15203a

Aas 111 Hei elo



PRE/F/15203b



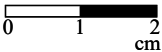
PRE/F/15203b



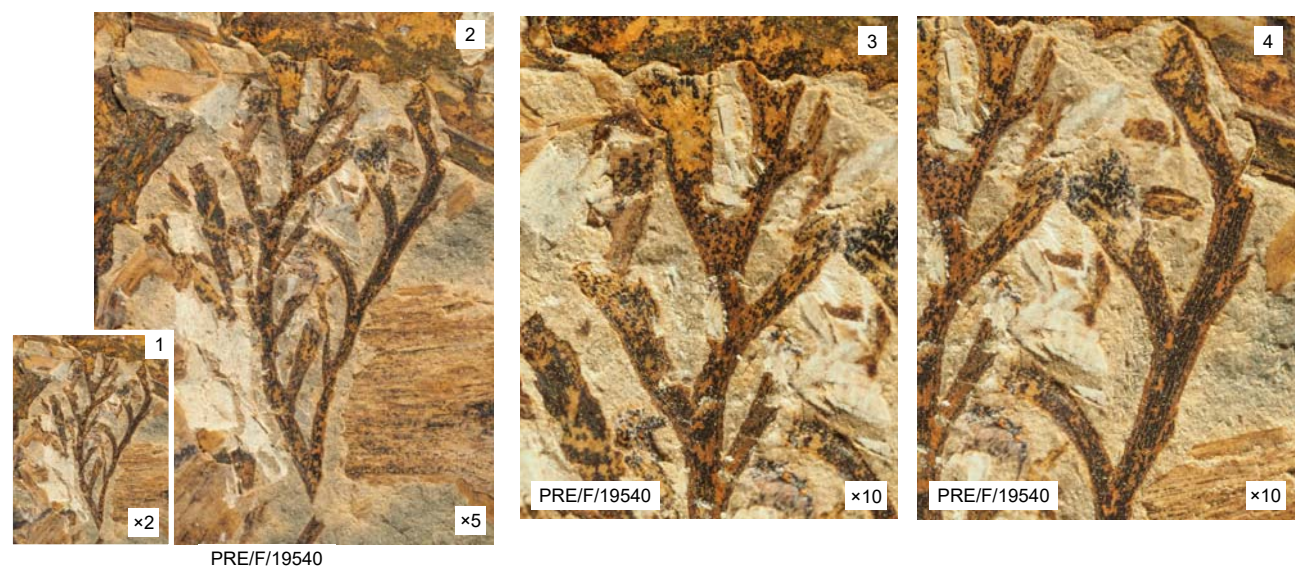
PRE/F/15203b



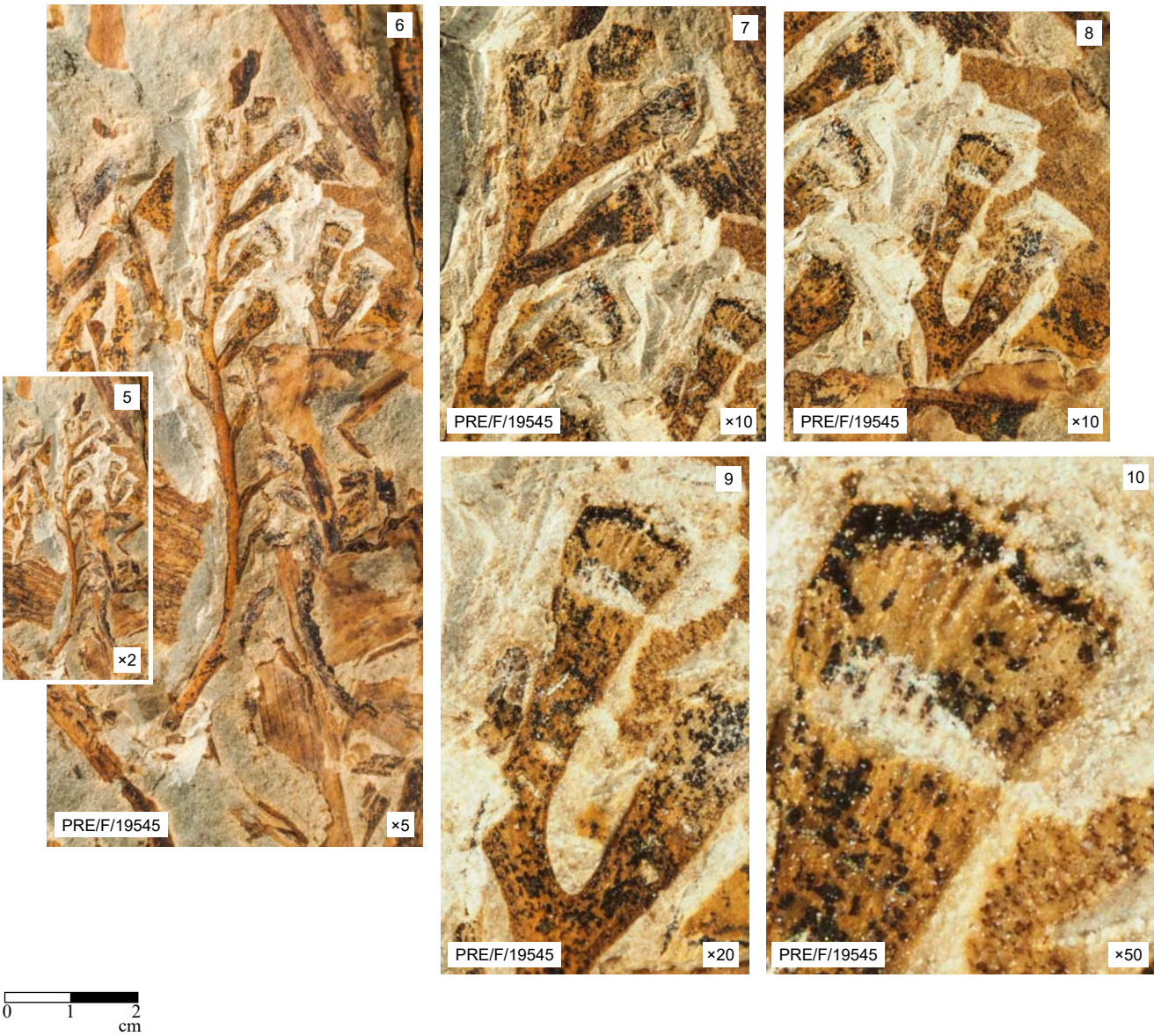
x20



Kannaskoppianthus aasvoelensis



Aas 111 Hei elo



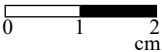
Kannaskoppianthus aasvoelensis



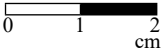
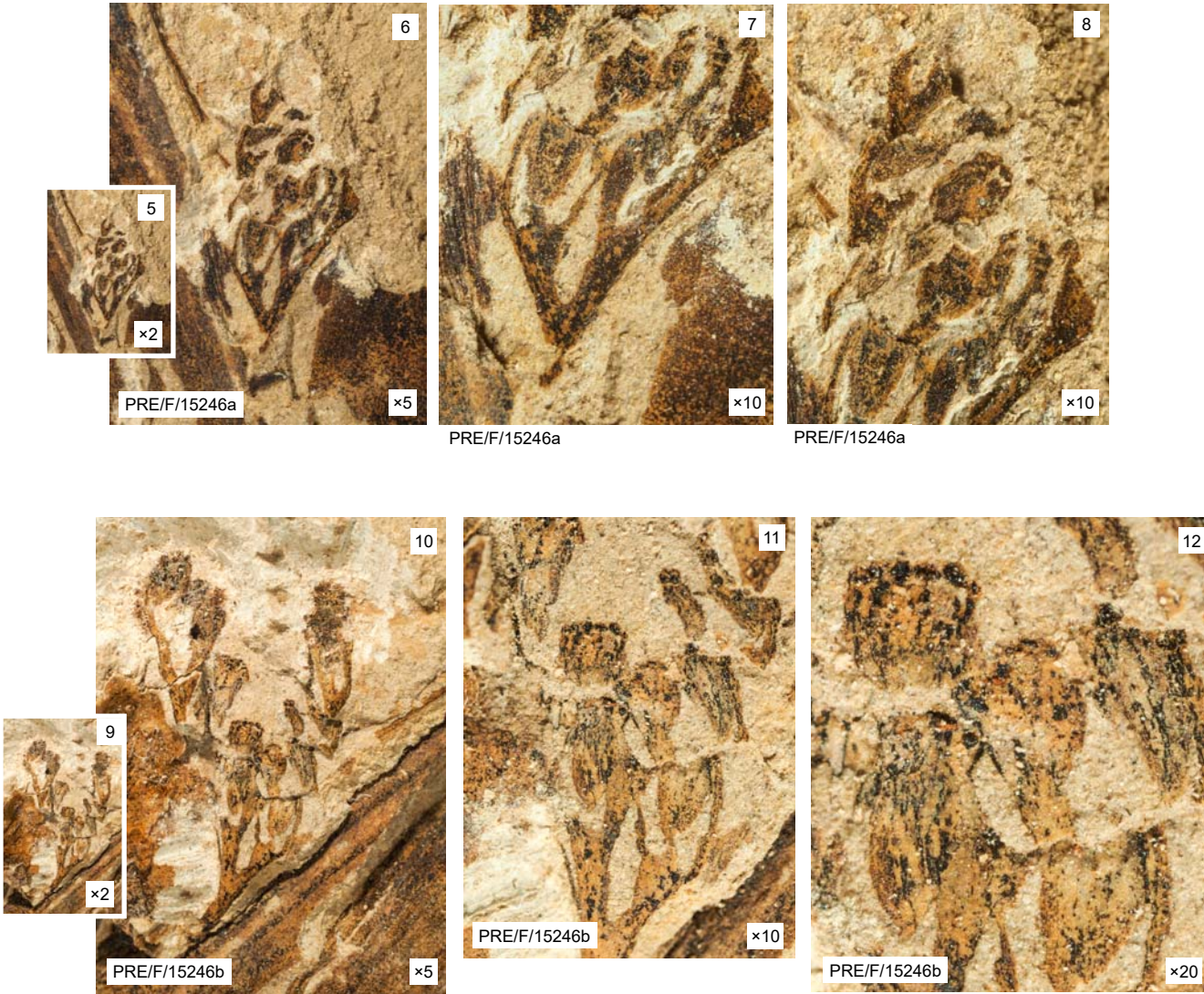
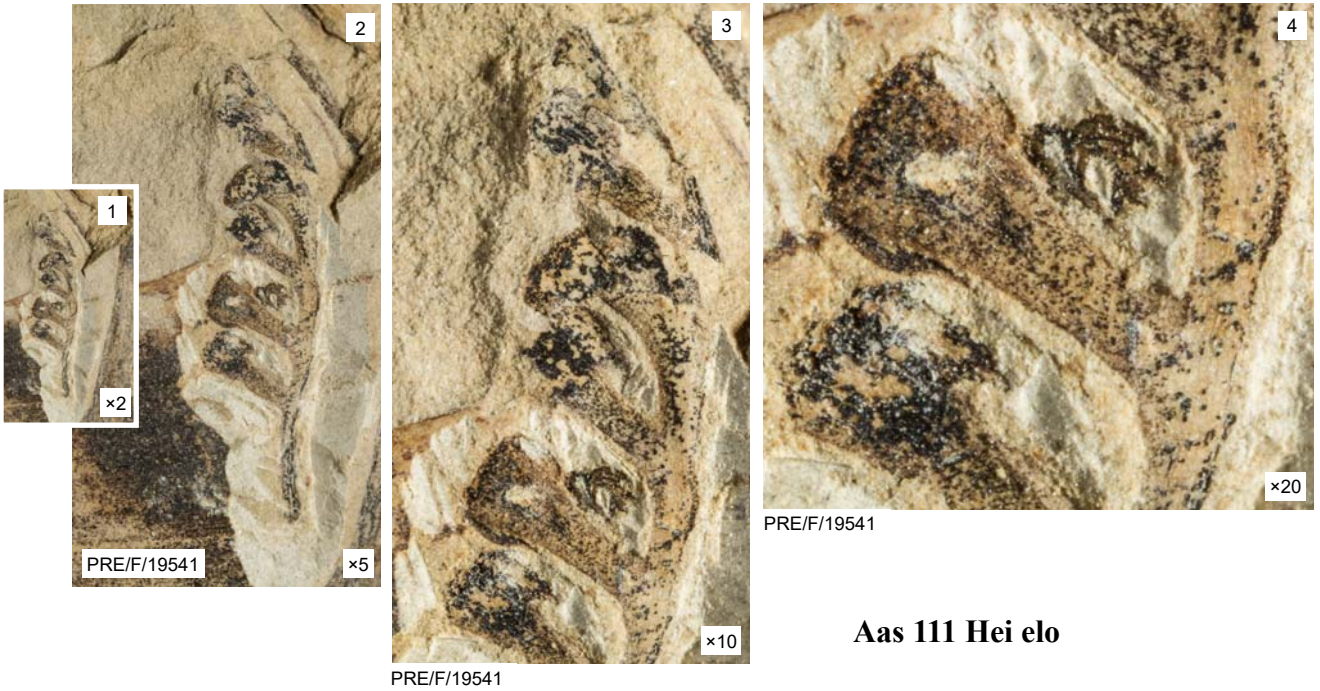
BP/2/4336a



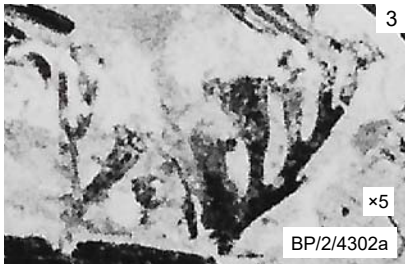
Aas 111 Hei elo



Kannaskoppianthus aasvoelensis



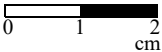
Rochipteris rollerii



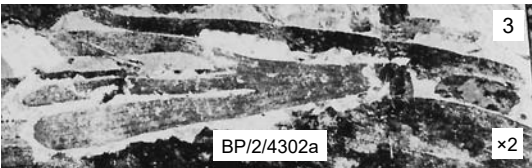
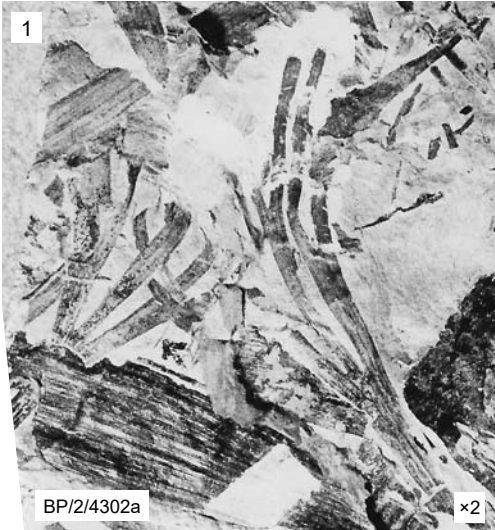
Cluster of 6 intact leaves
& at least 15 fragmentary indivs;
& 1 *Kannaskoppianthus* strobilus.

Aas 111 Hei elo

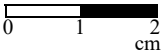
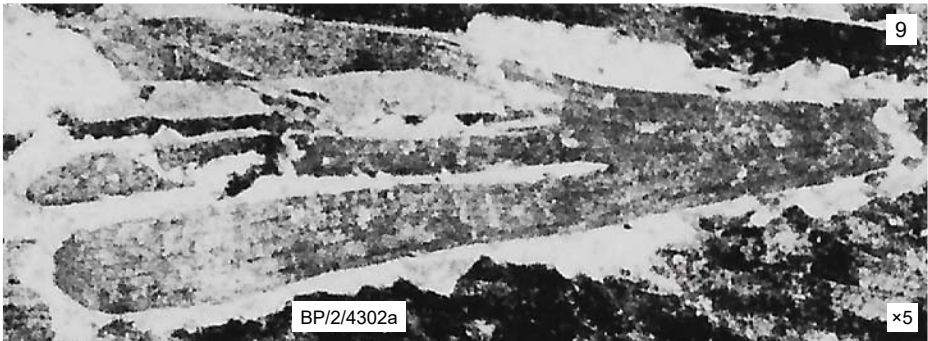
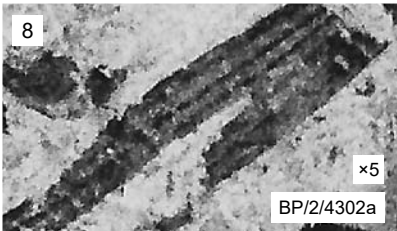
Reference
palaeodeme
(pls 131–142)



Rochipteris rollerii



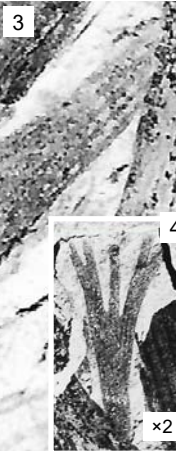
Aas 111 Hei elo



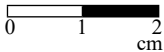
Rochipteris rollerii



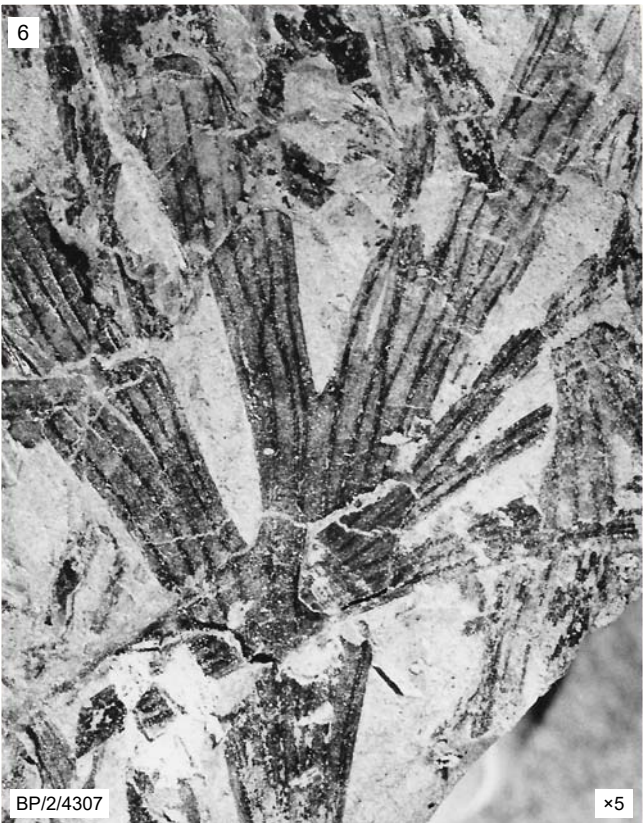
Cluster of 5 intact leaves



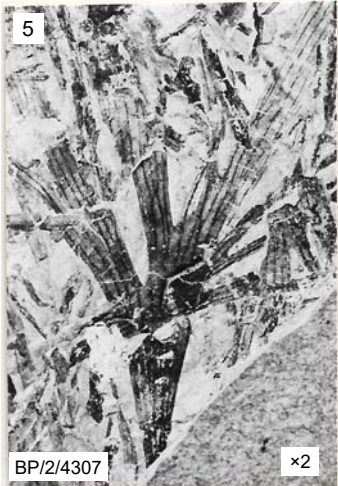
Aas 111 Hei elo



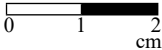
Rochipteris rollerii



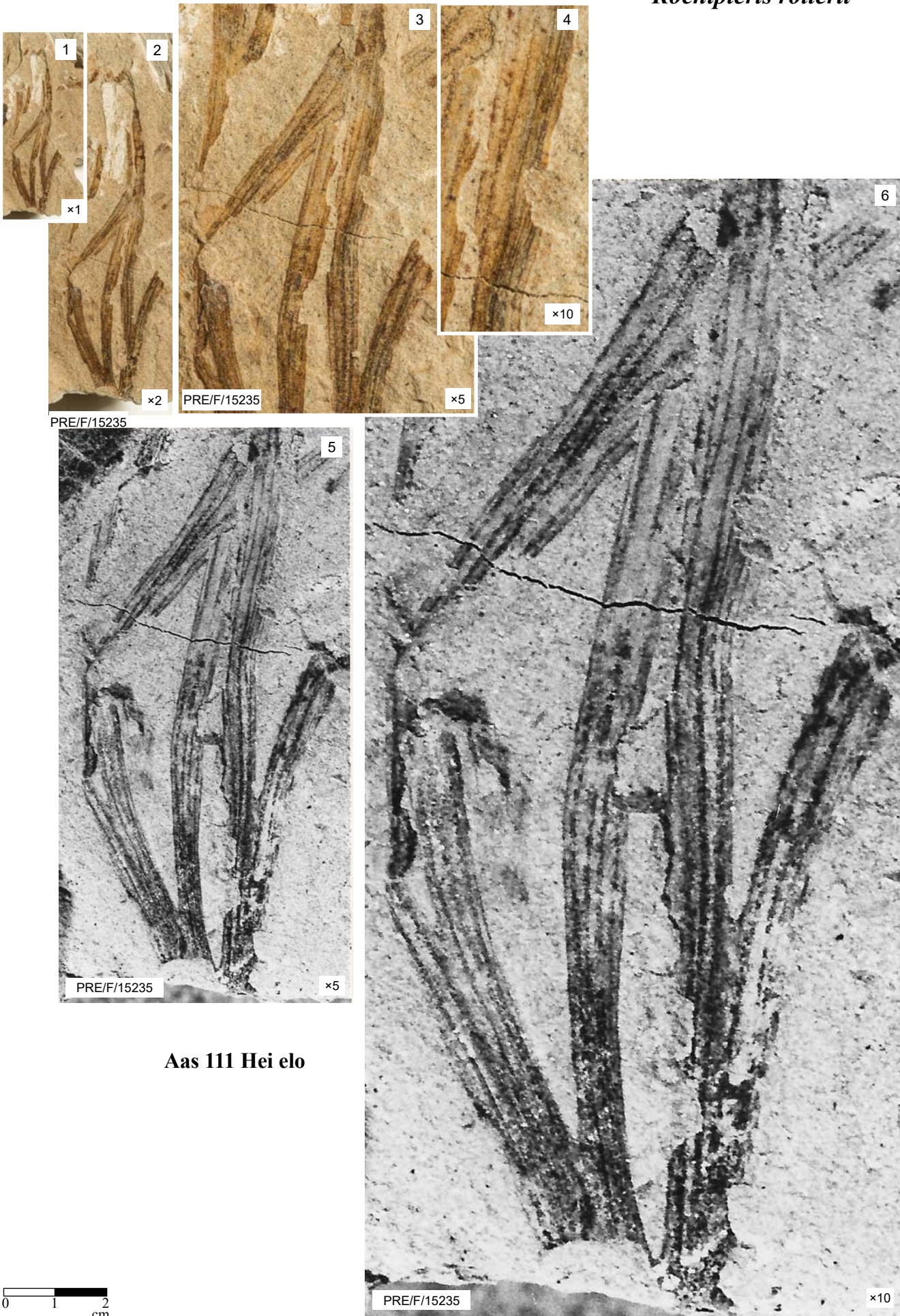
Cluster of 3 intact leaves



Aas 111 Hei elo



Rochipteris rollerii

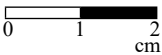


Aas 111 Hei elo

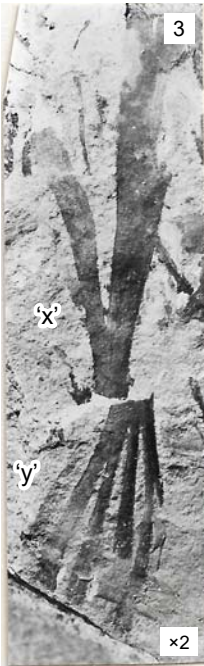
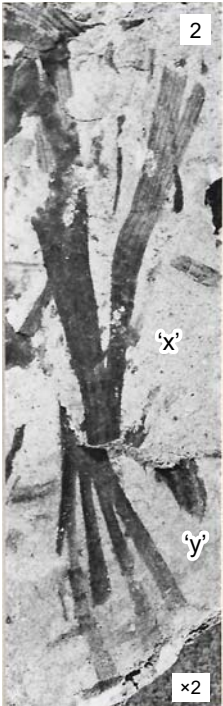
Rochipteris rollerii



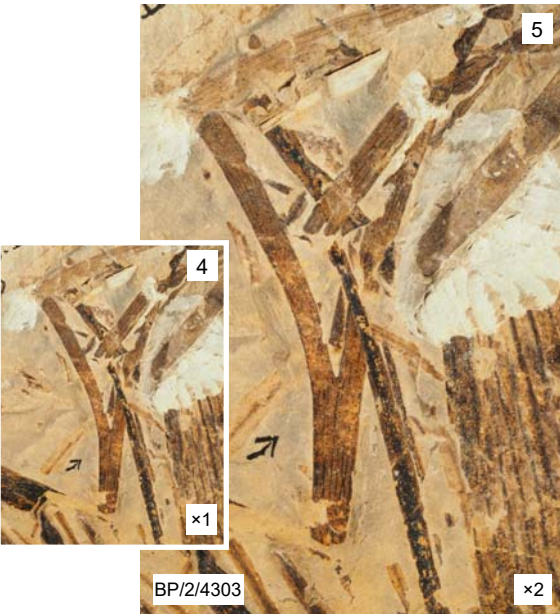
Aas 111 Hei elo



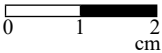
Rochipteris rollerii



PRE/F/15237a, 'x', 'y' PRE/F/15237b, 'x', 'y'
Cluster of 2 intact leaves



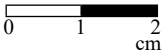
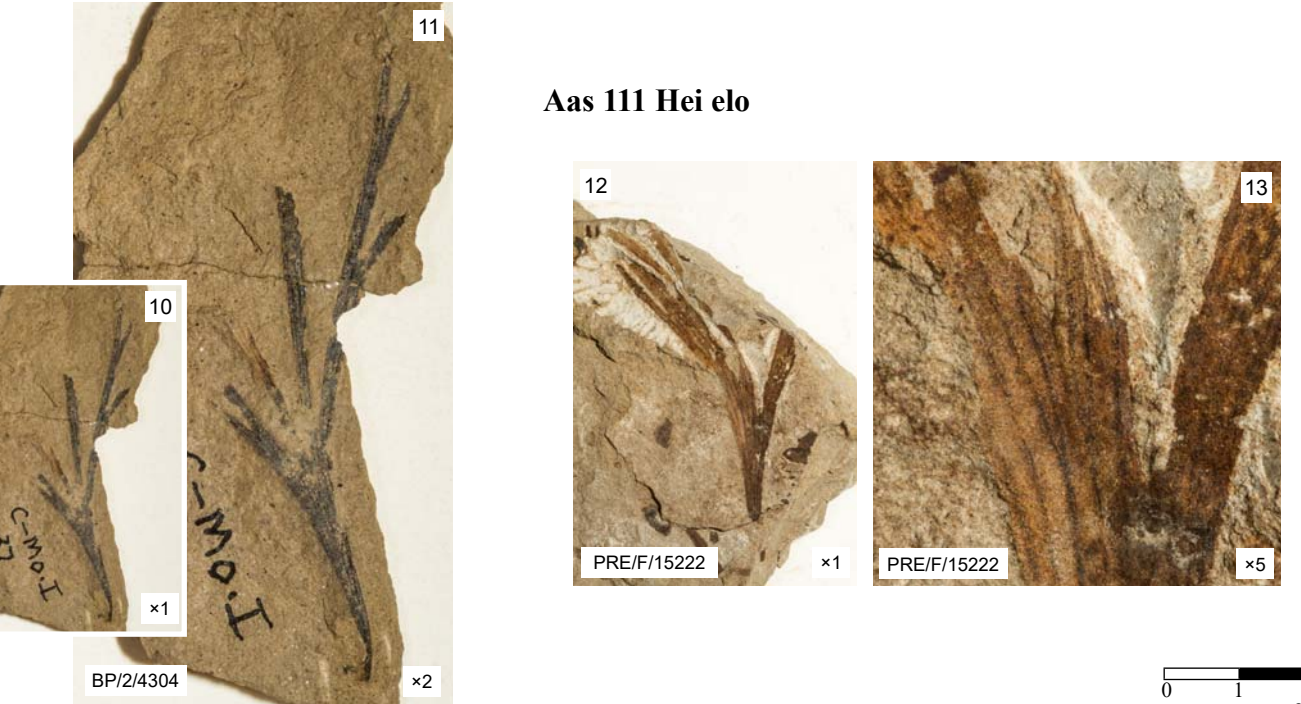
Aas 111 Hei elo



Rochipteris rollerii



Aas 111 Hei elo



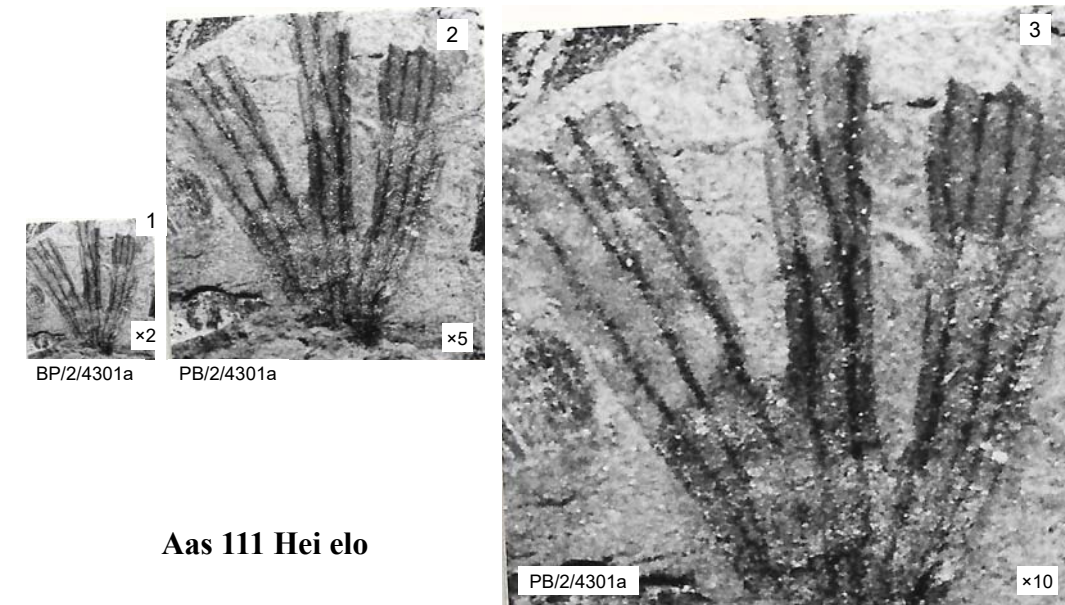
Rochipteris rollerii



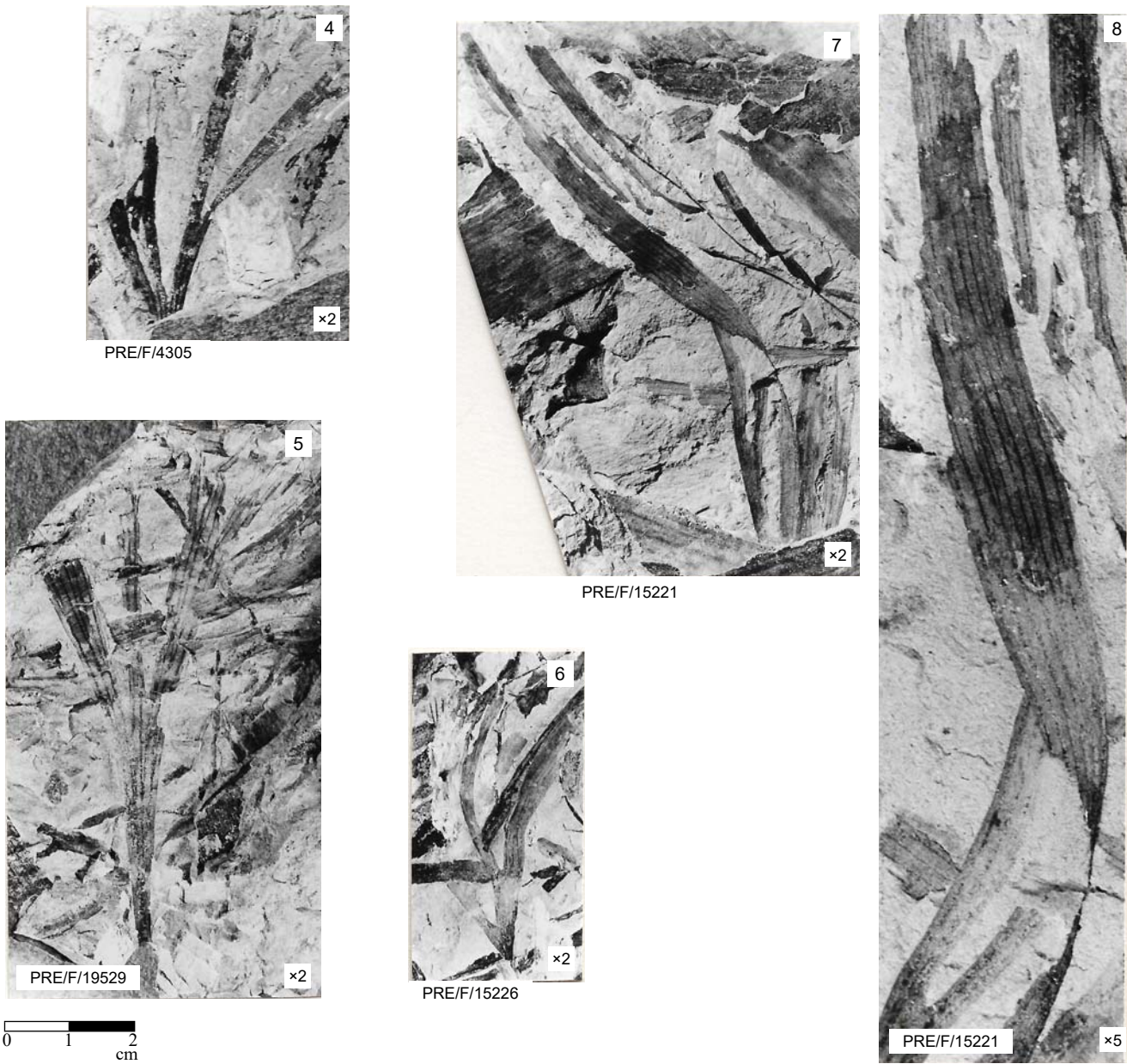
Rochipteris rollerii



Rochipteris rollerii



Aas 111 Hei elo



Rochipteris rollerii



PRE/F/15236



PRE/F/15236

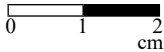


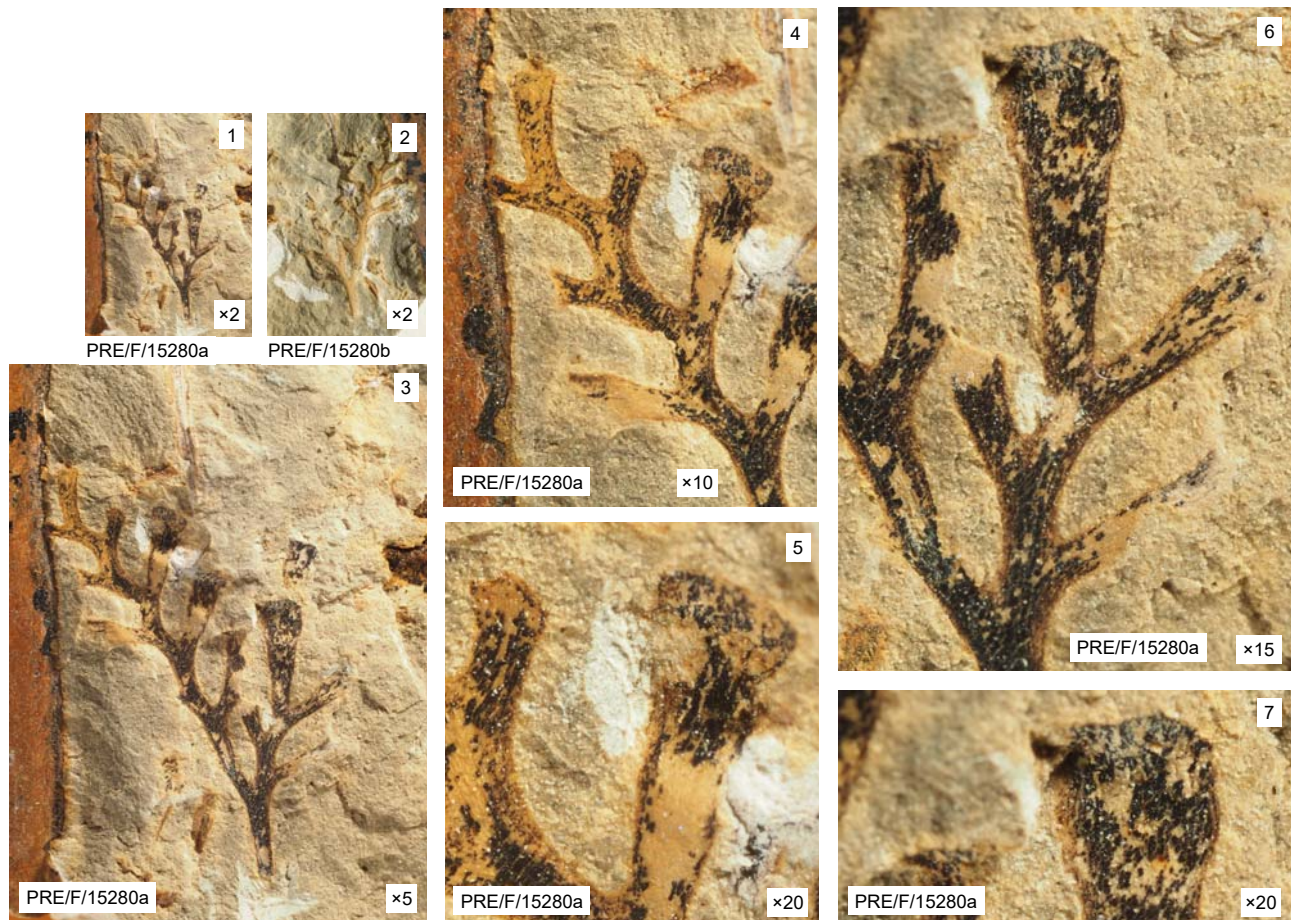
PRE/F/15236



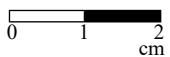
PRE/F/15236

Aas 111 Hei elo

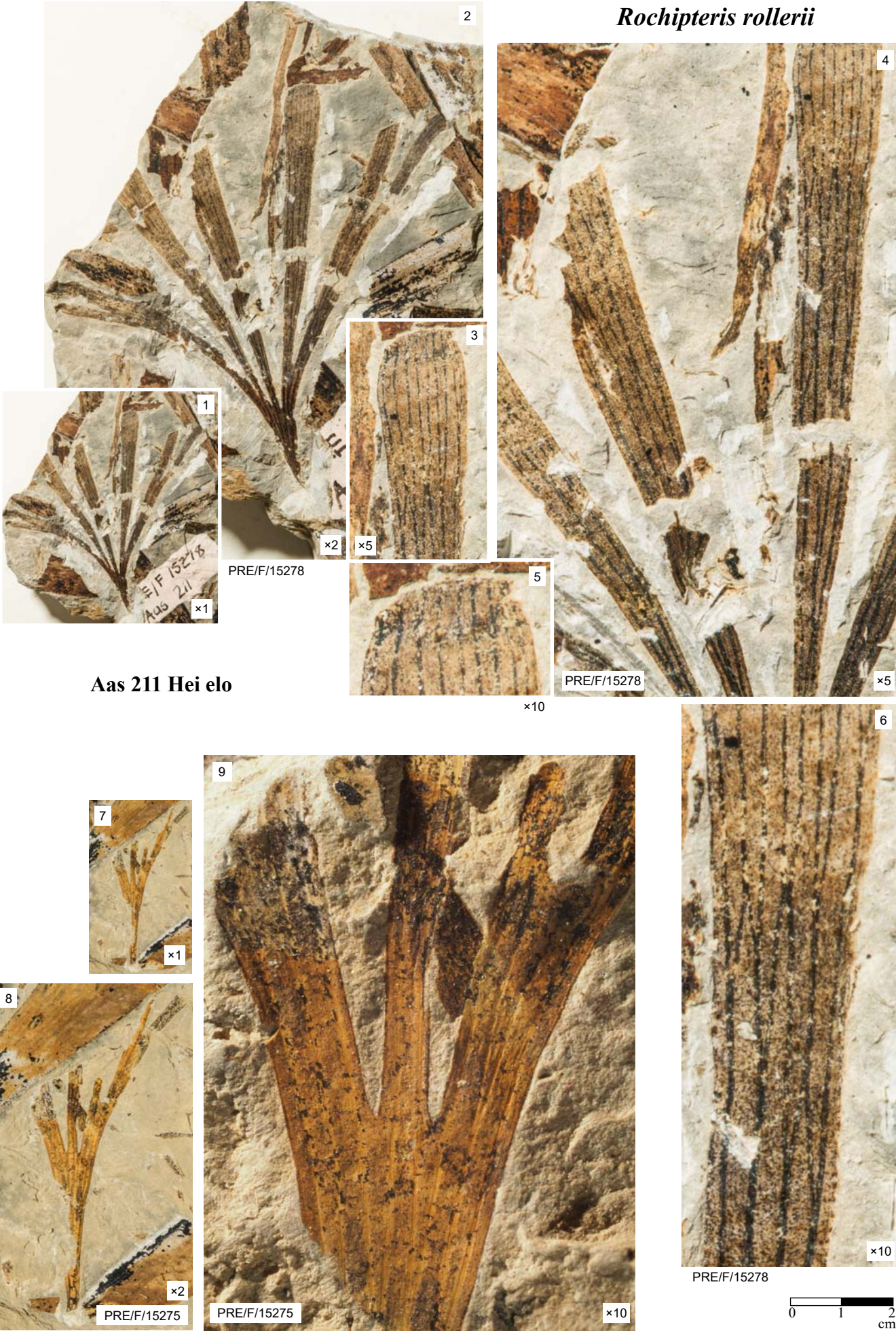


Kannaskoppianthus aasvoelensis

Aas 211 Hei elo



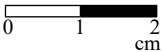
Rochipteris rollerii



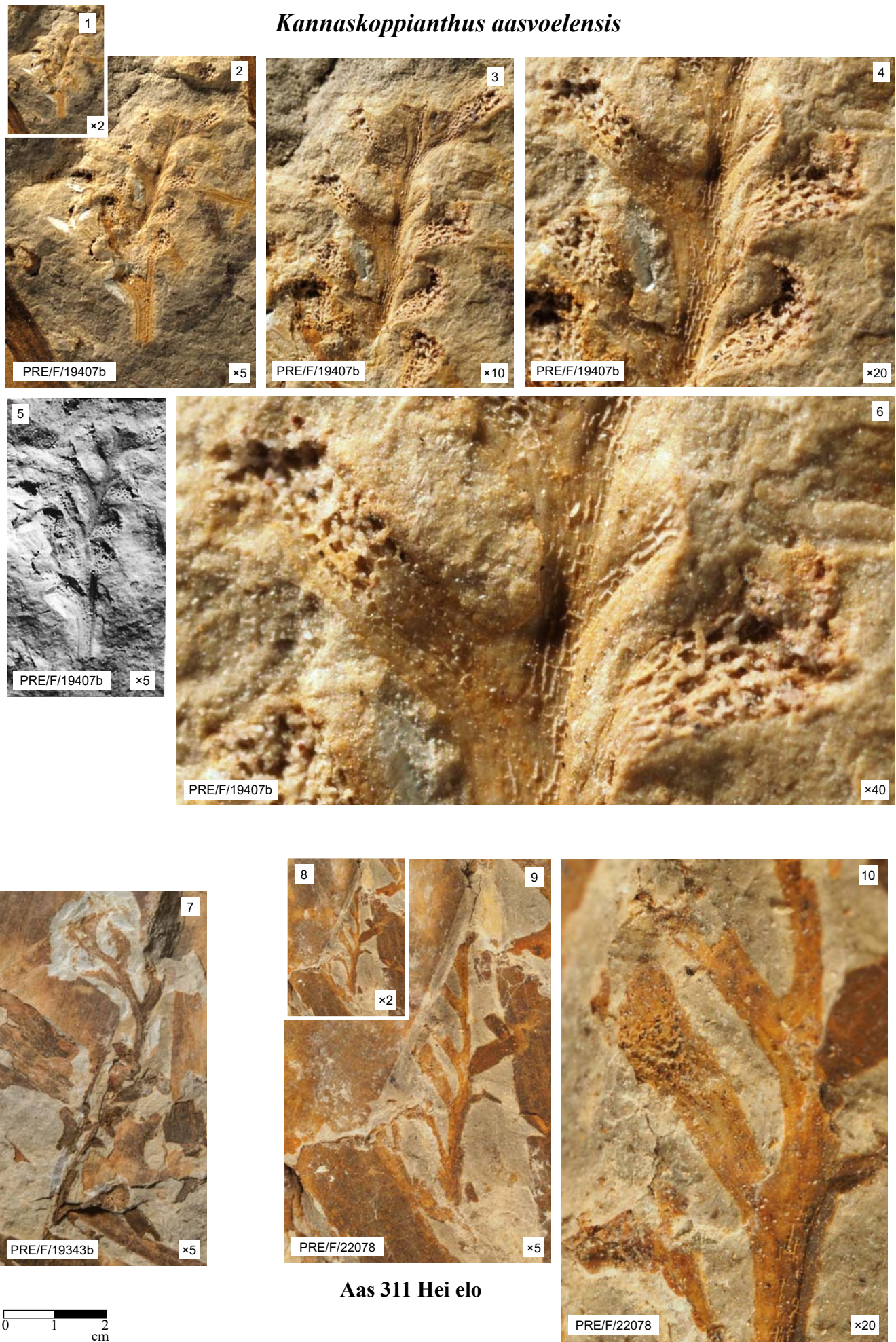
Kannaskoppianthus aasvoelensis



Aas 311 Hei elo



Kannaskoppianthus aasvoelensis

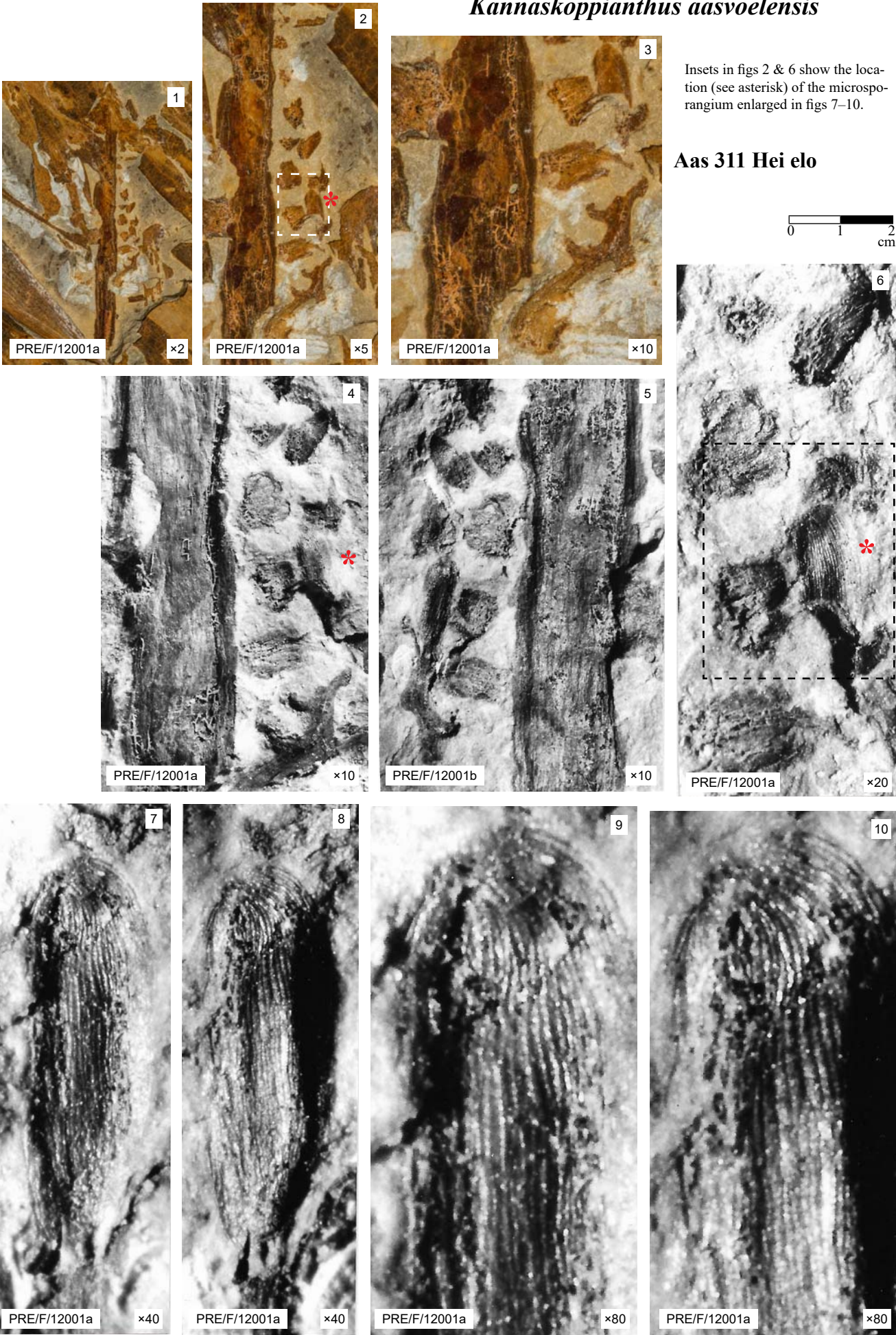
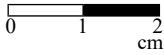


Aas 311 Hei elo

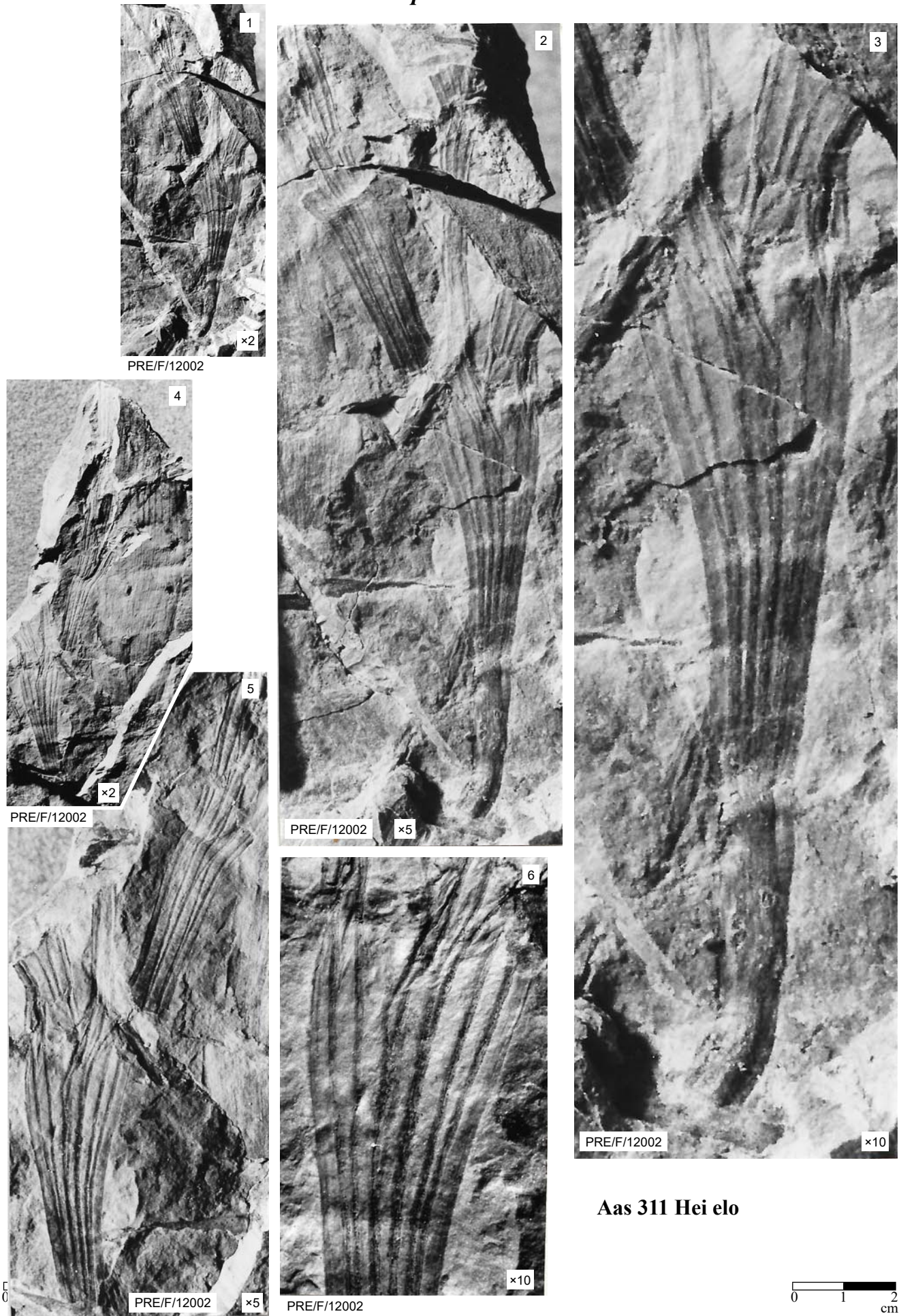
Kannaskoppianthus aasvoelensis

Insets in figs 2 & 6 show the location (see asterisk) of the microsporangium enlarged in figs 7–10.

Aas 311 Hei elo

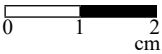
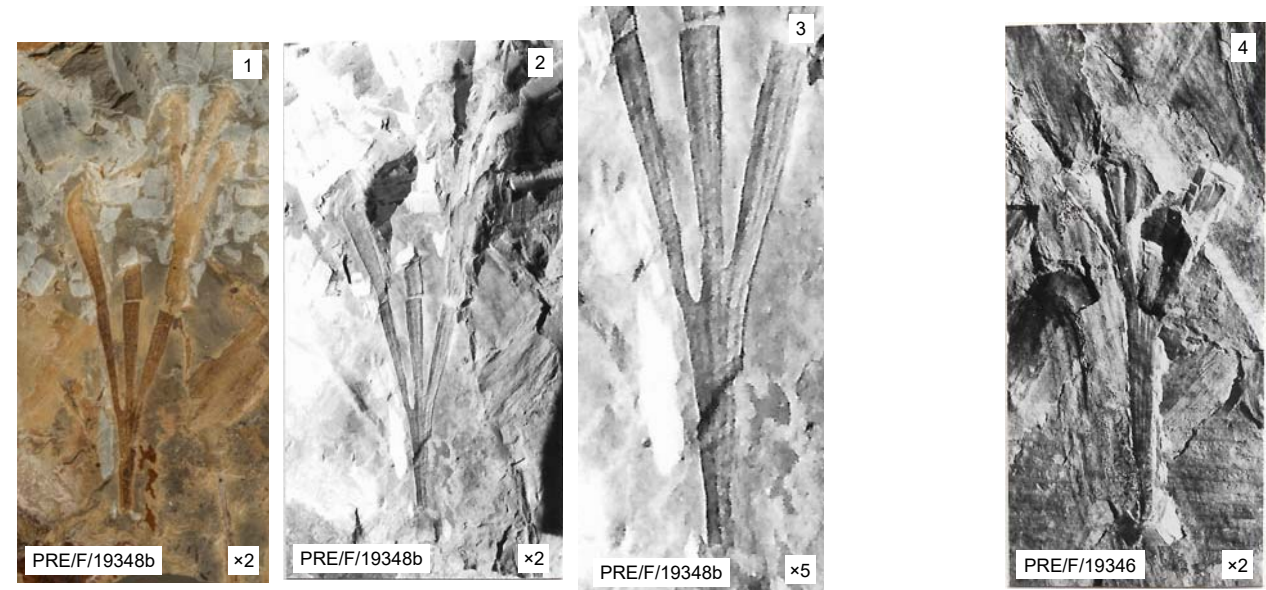


Rochipteris rollerii



Aas 311 Hei elo

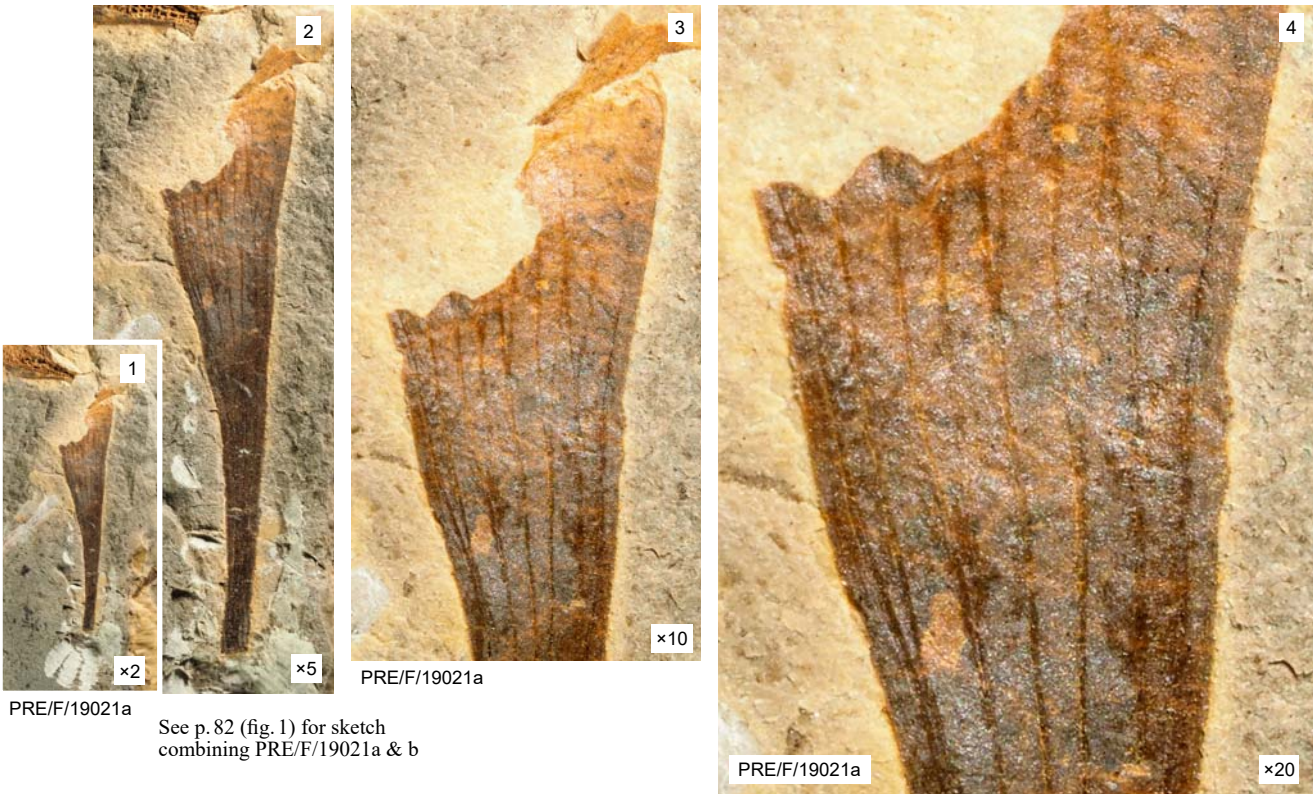
Rochipteris rollerii



Aas 311 Hei elo



Rochipteris rollerii



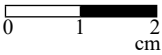
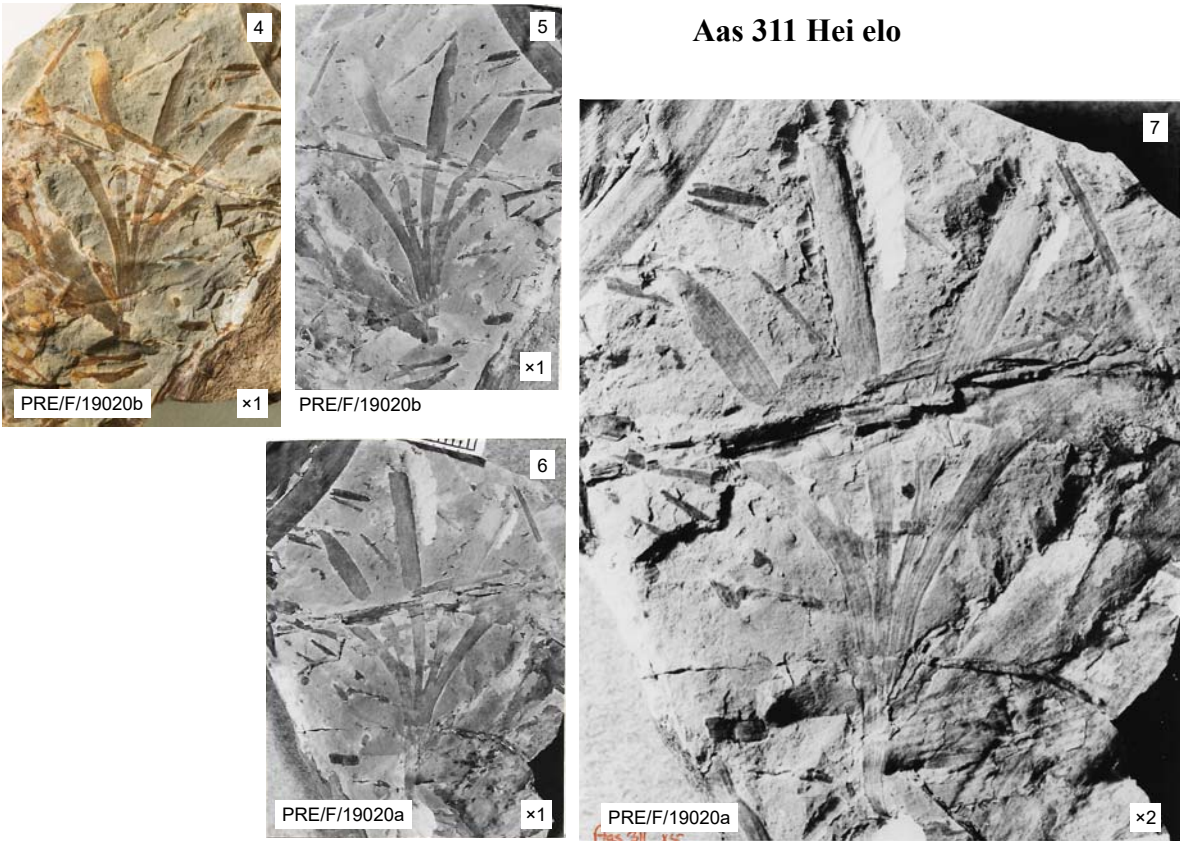
Aas 311 Hei elo



Rochipteris rollerii



Aas 311 Hei elo



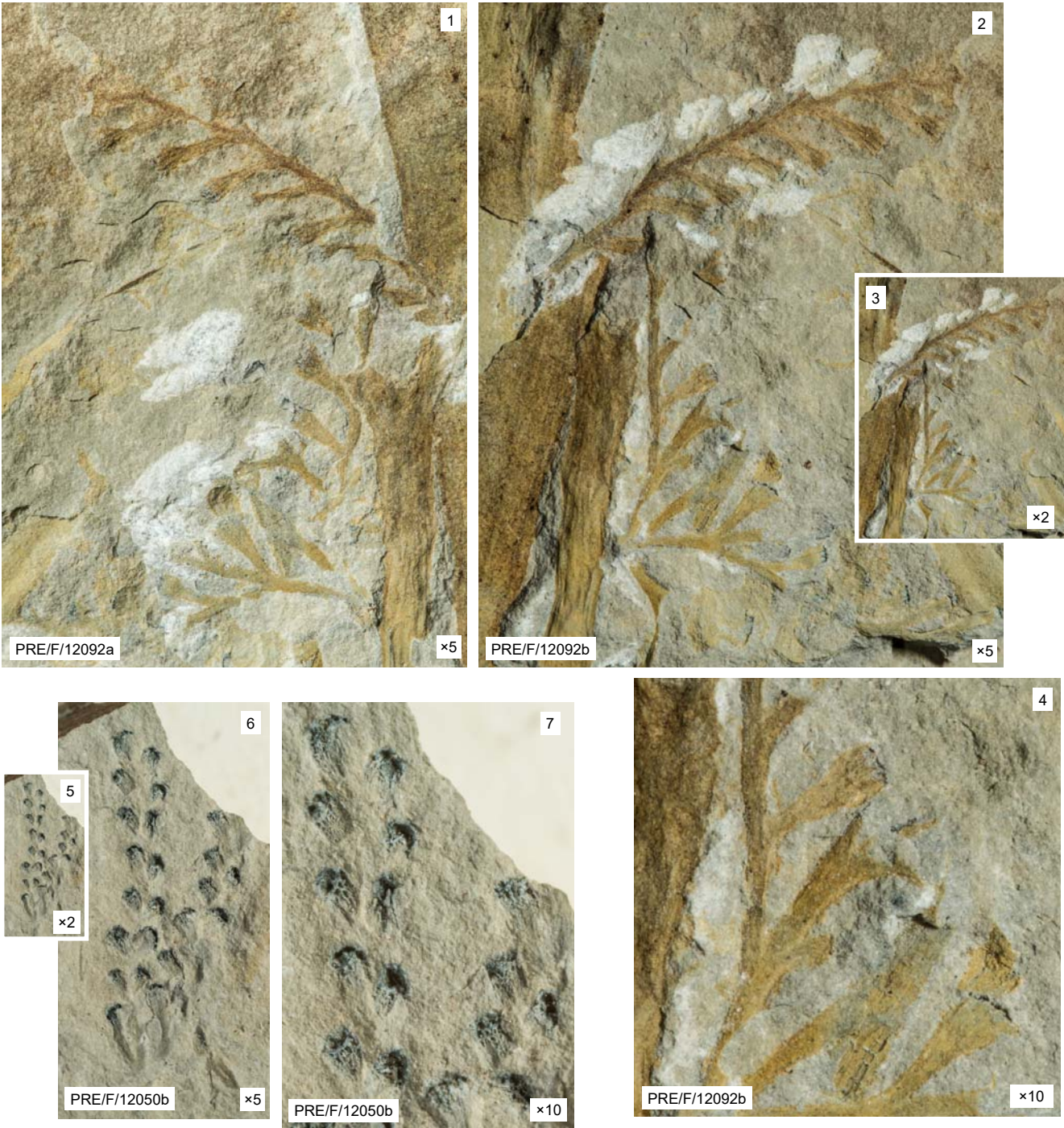
Rochipteris rollerii

1



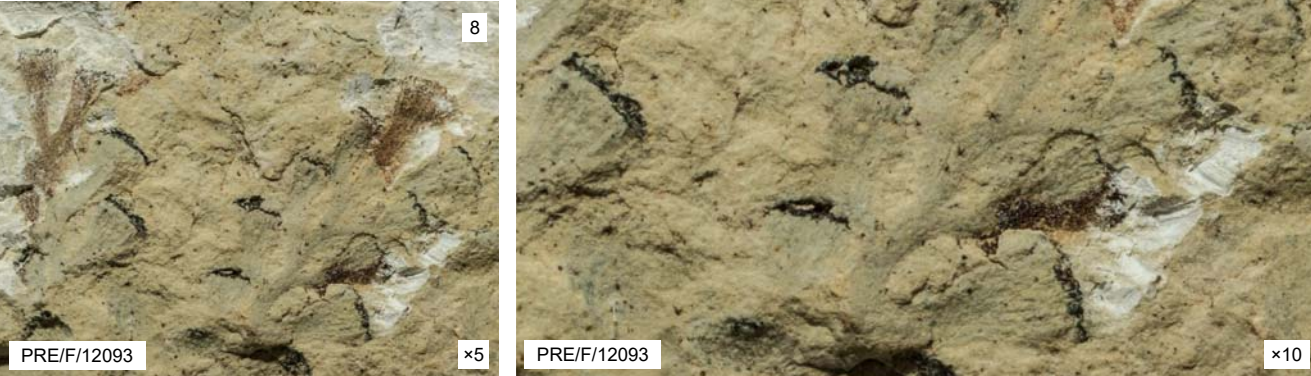
Fabiany Herrera (photo, Sept. 2022)

Kannaskoppianthus aasvoelensis



Aas 411 Dic/Sph

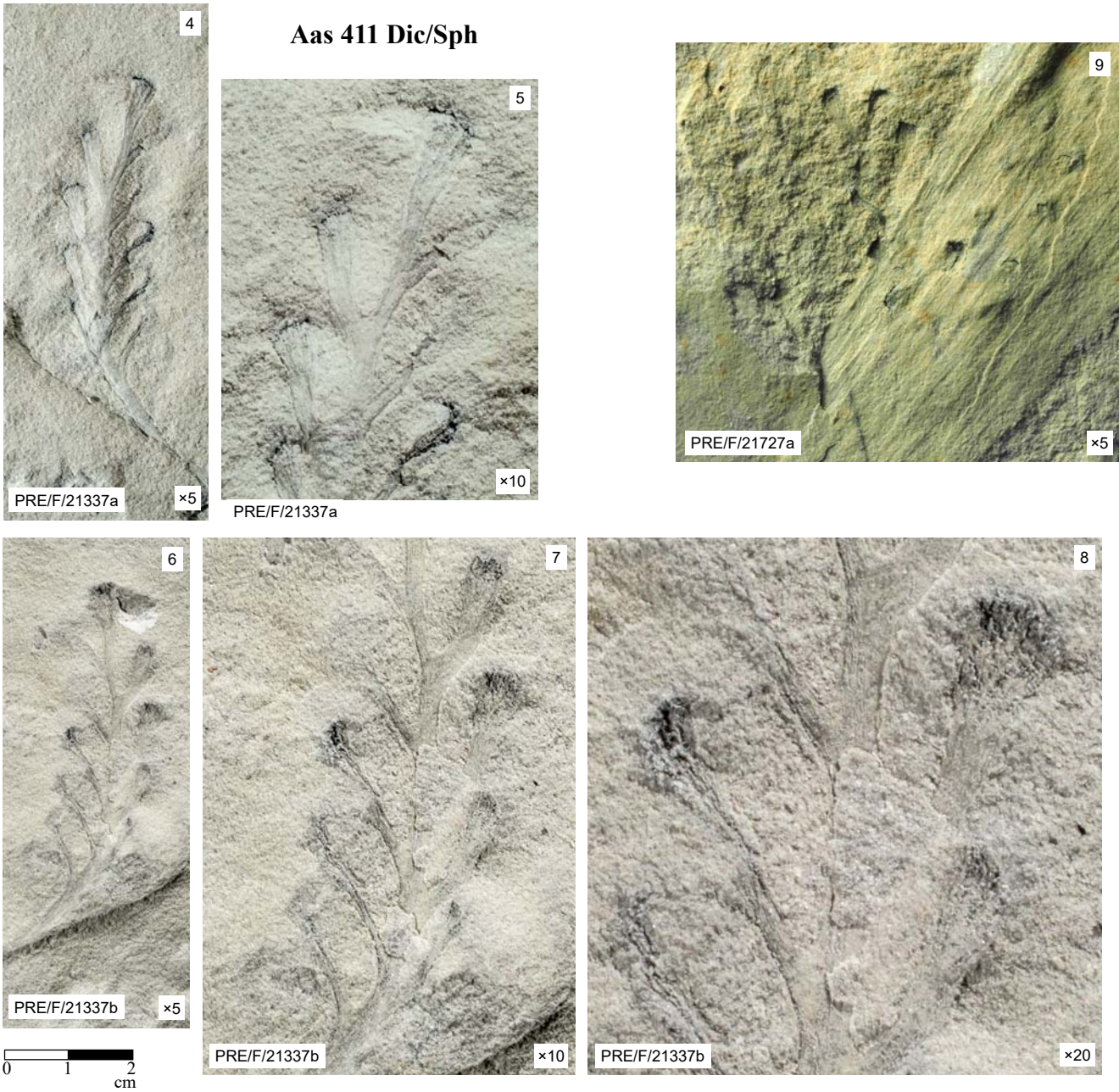
0 1 2
cm



Kannaskoppianthus aasvoelensis



Aas 411 Dic/Sph



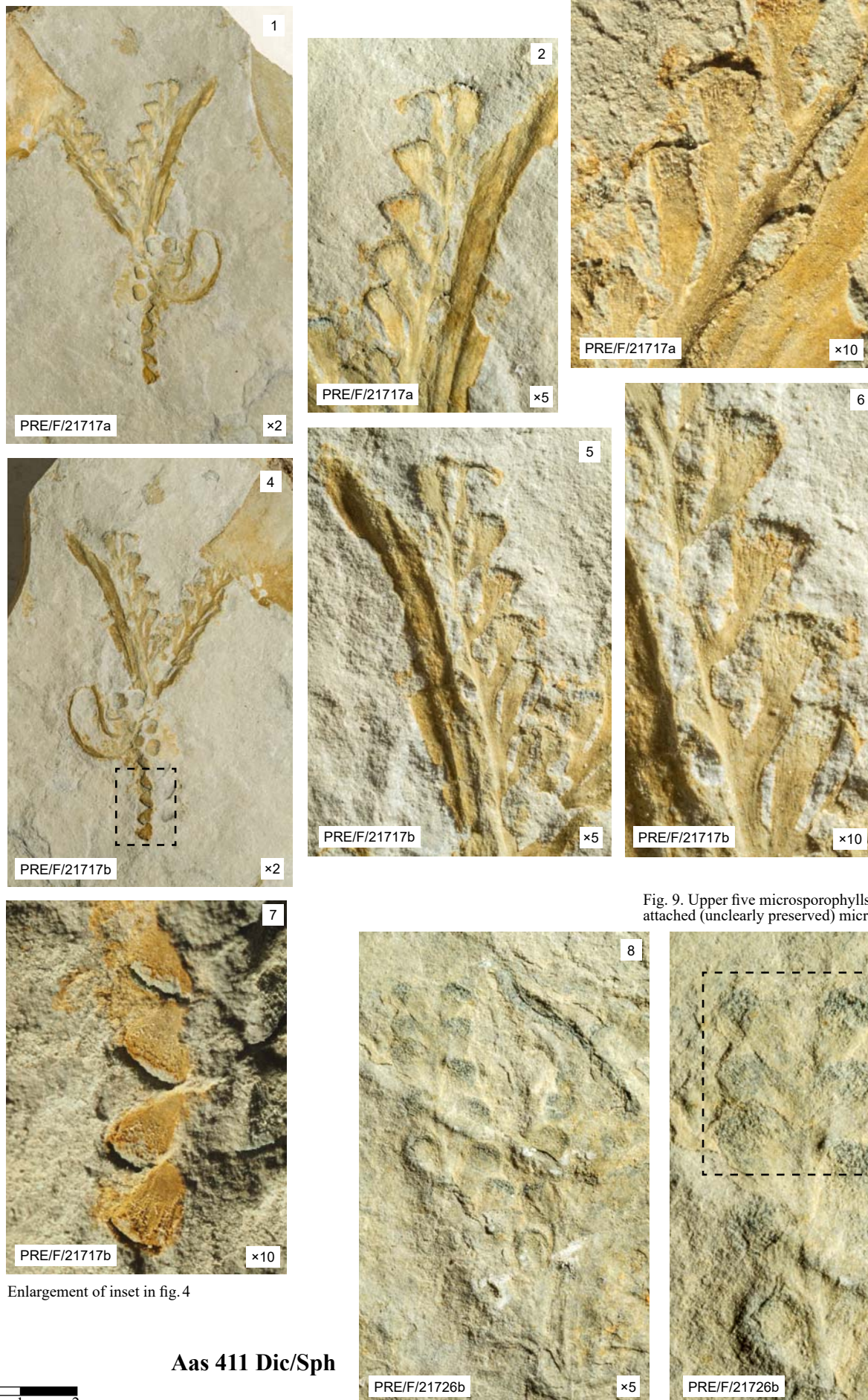
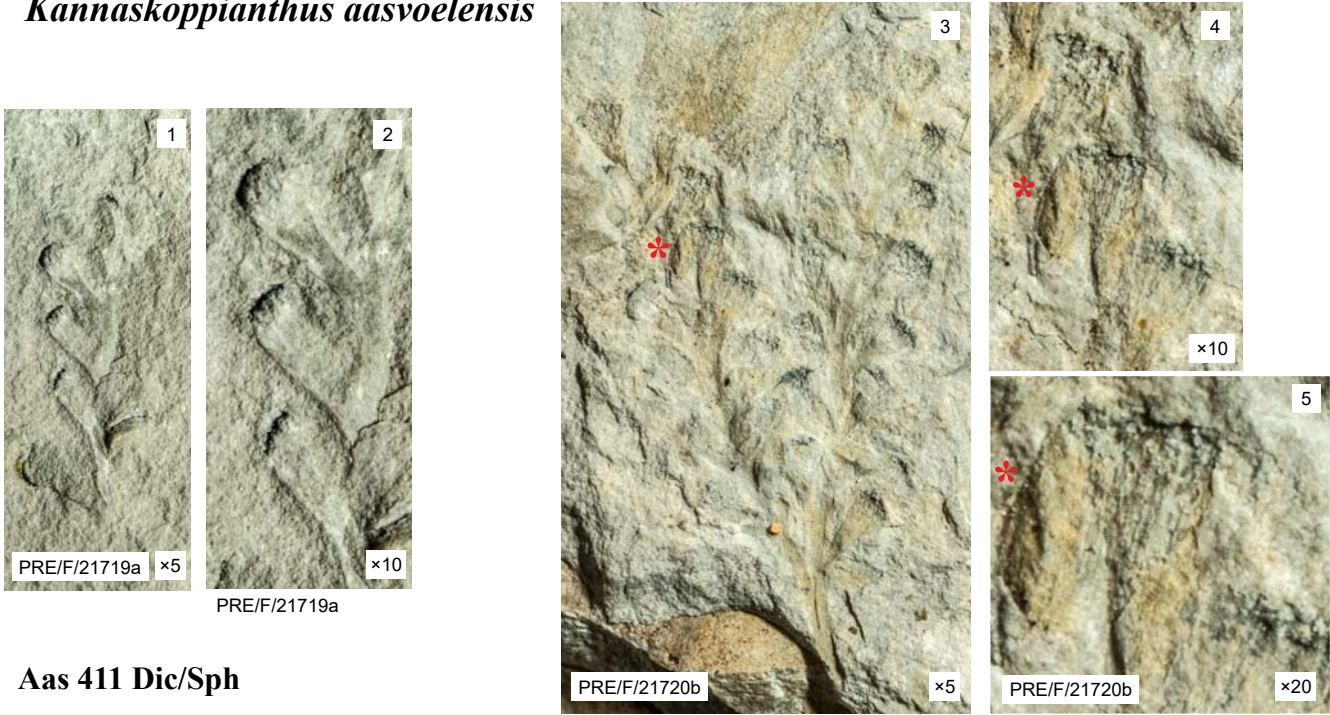
Kannaskoppianthus aasvoelensis

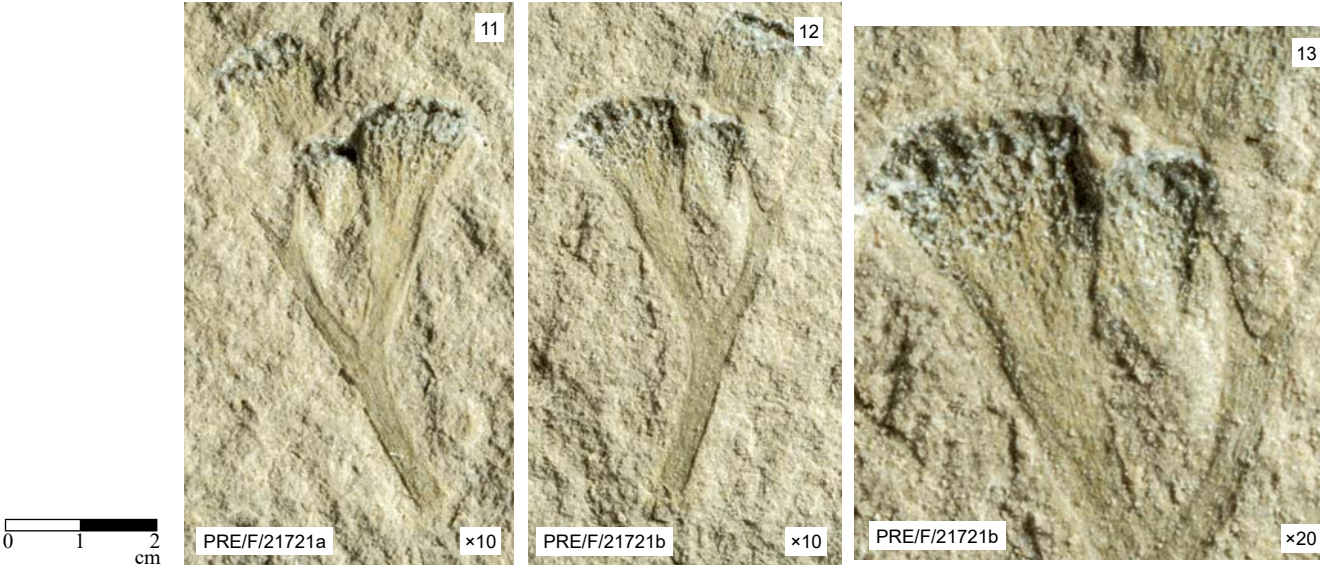
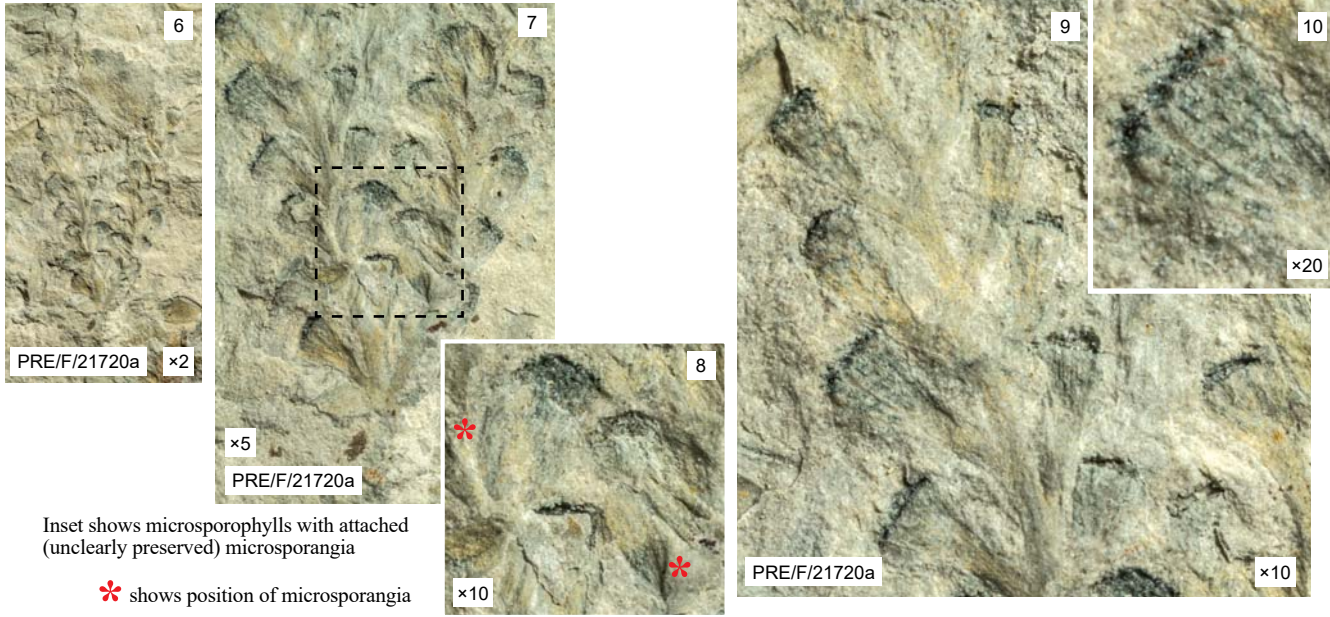
Fig. 9. Upper five microsporophylls show attached (unclearly preserved) microsporangia

Aas 411 Dic/Sph

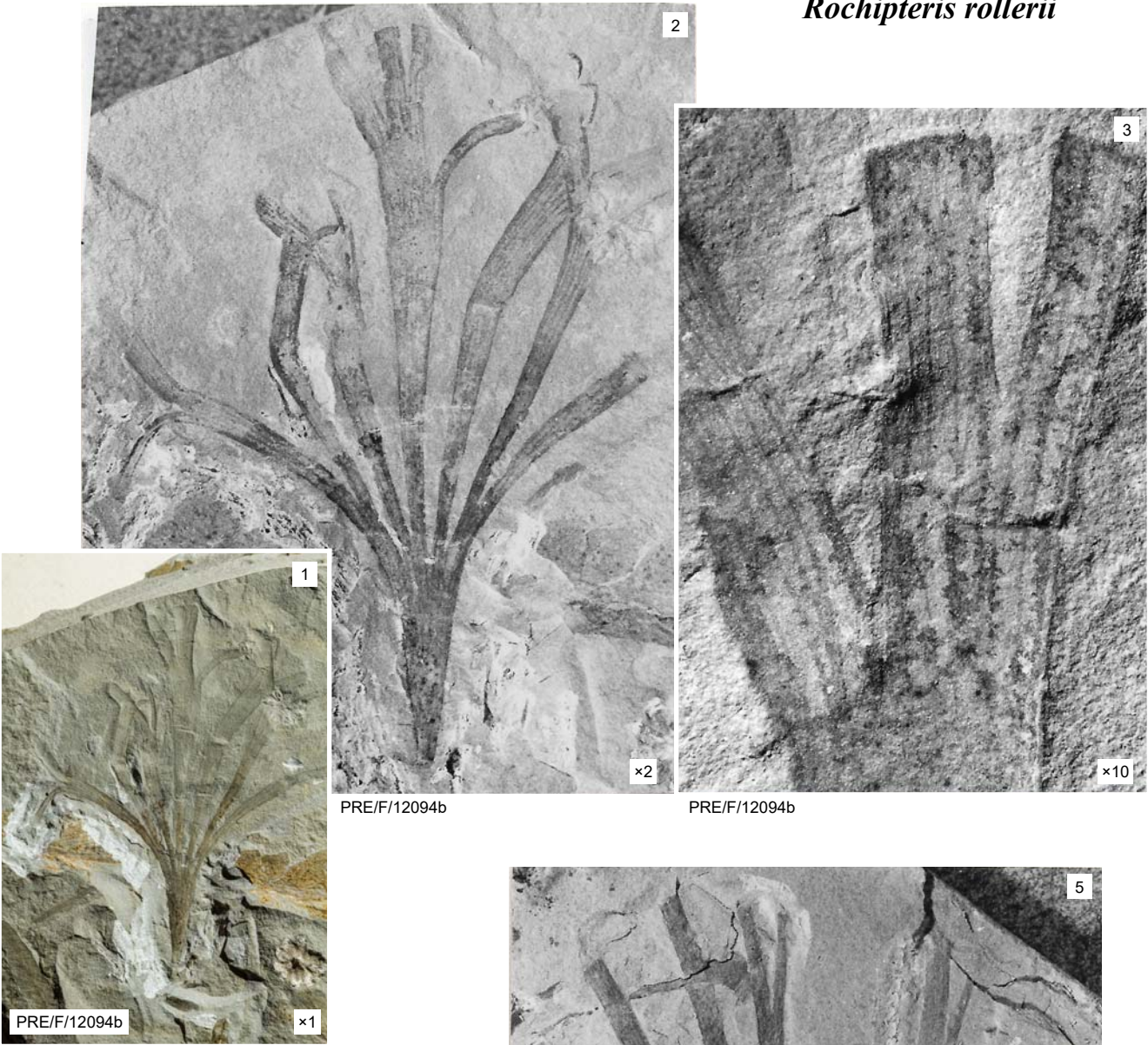
Kannaskoppianthus aasvoelensis



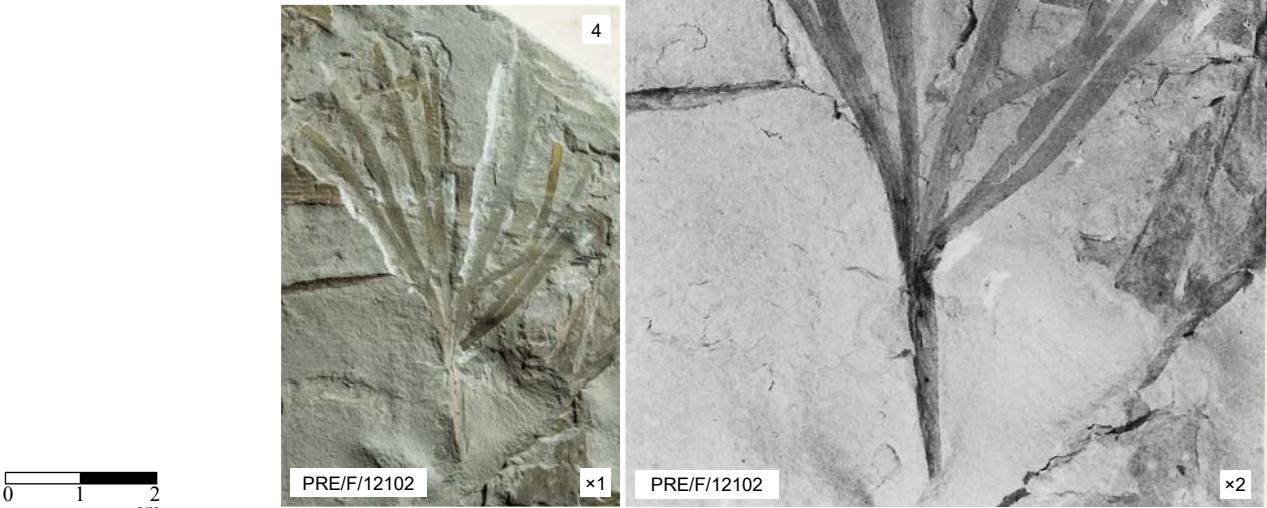
Aas 411 Dic/Sph



Rochipteris rollerii



Aas 411 Dic/Sph



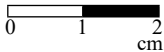
0 1 2
cm



Rochipteris rollerii



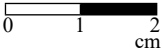
Aas 411 Dic/Sph



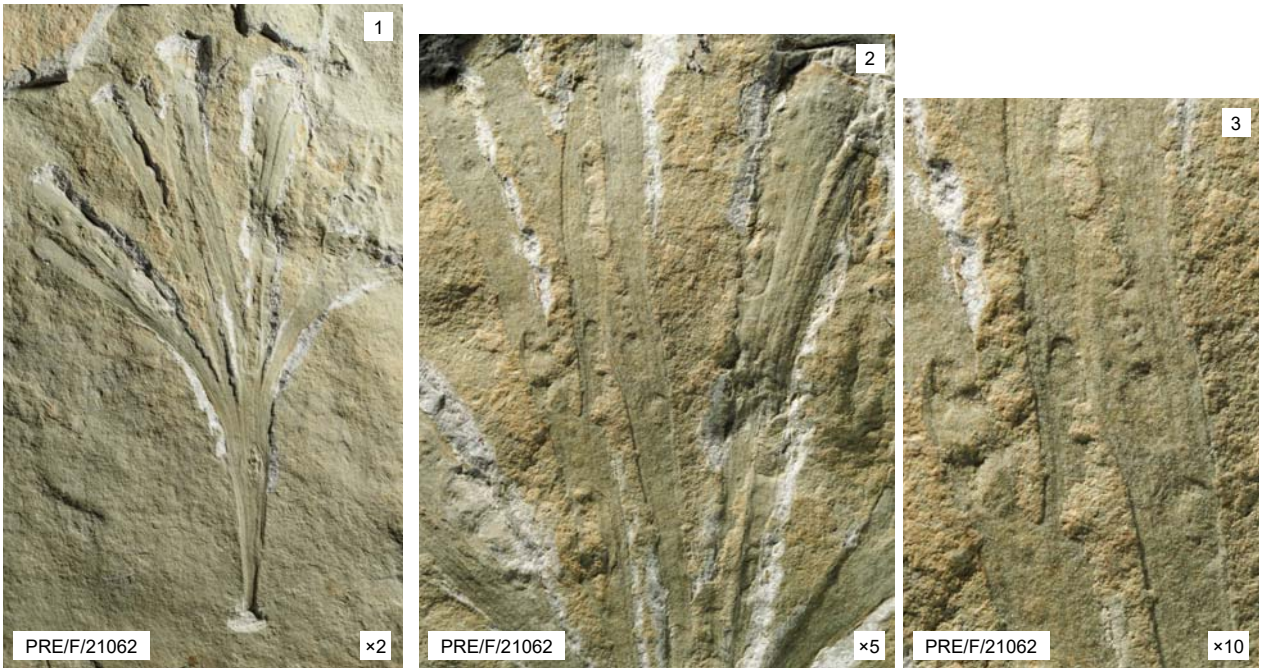
Rochipteris rollerii



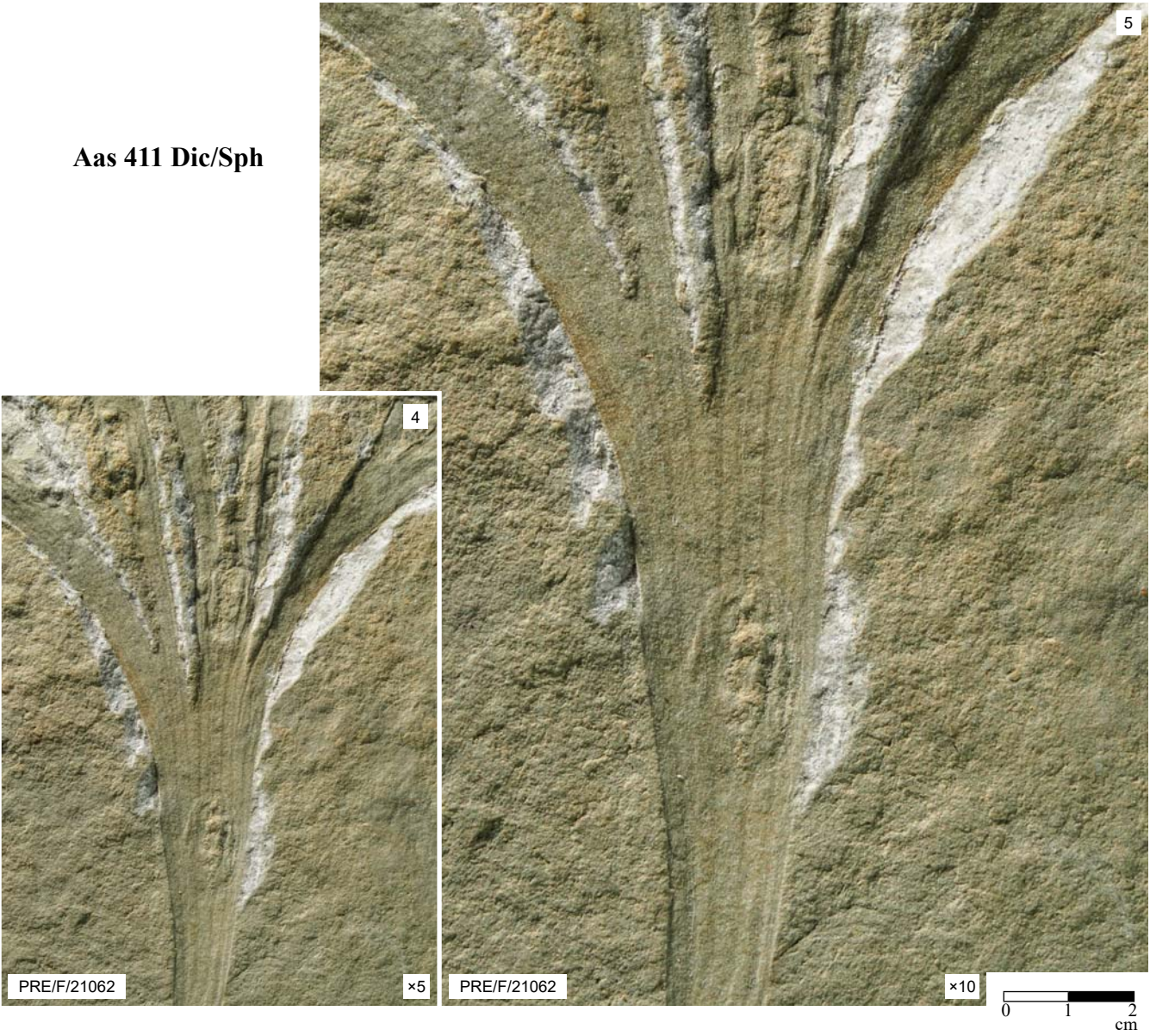
Aas 411 Dic/Sph

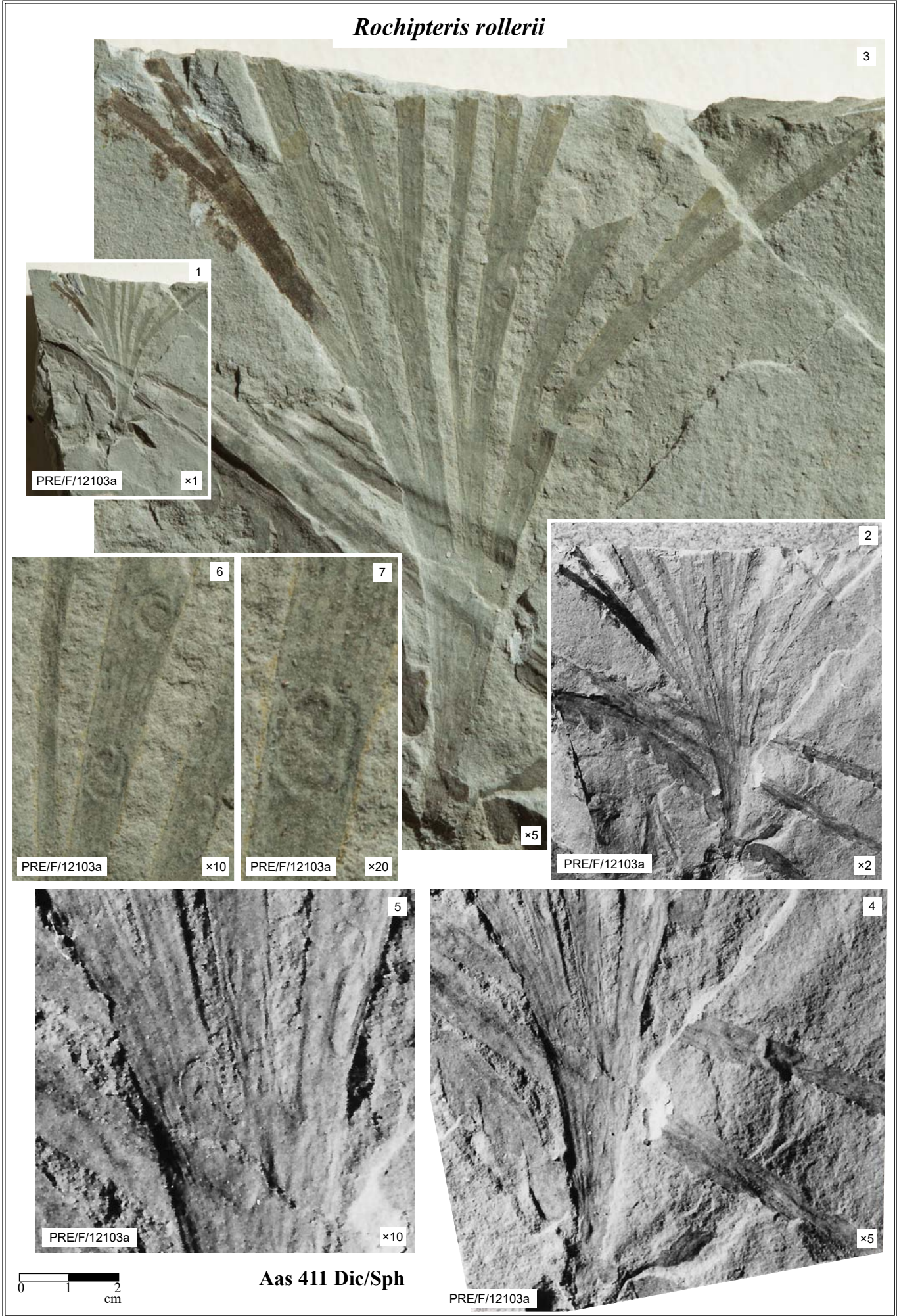


Rochipteris rollerii

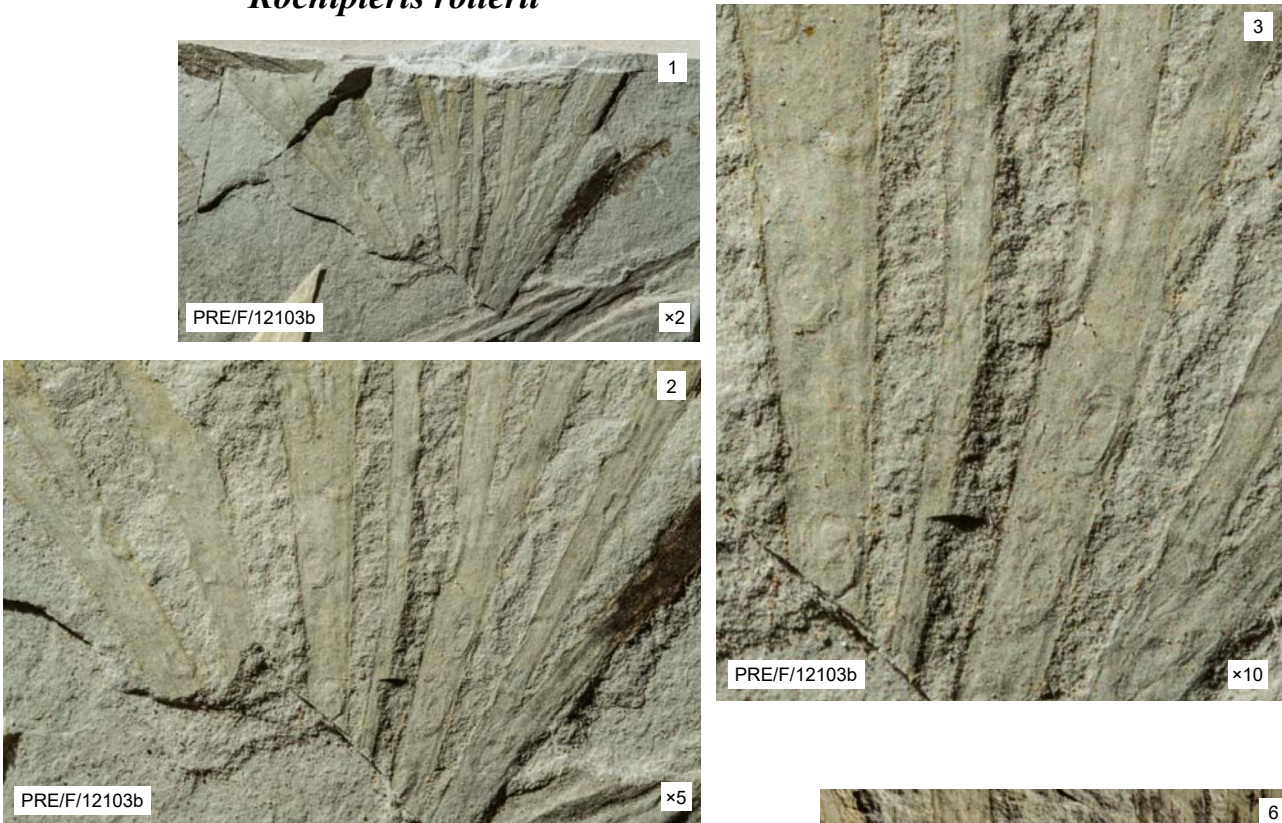


Aas 411 Dic/Sph

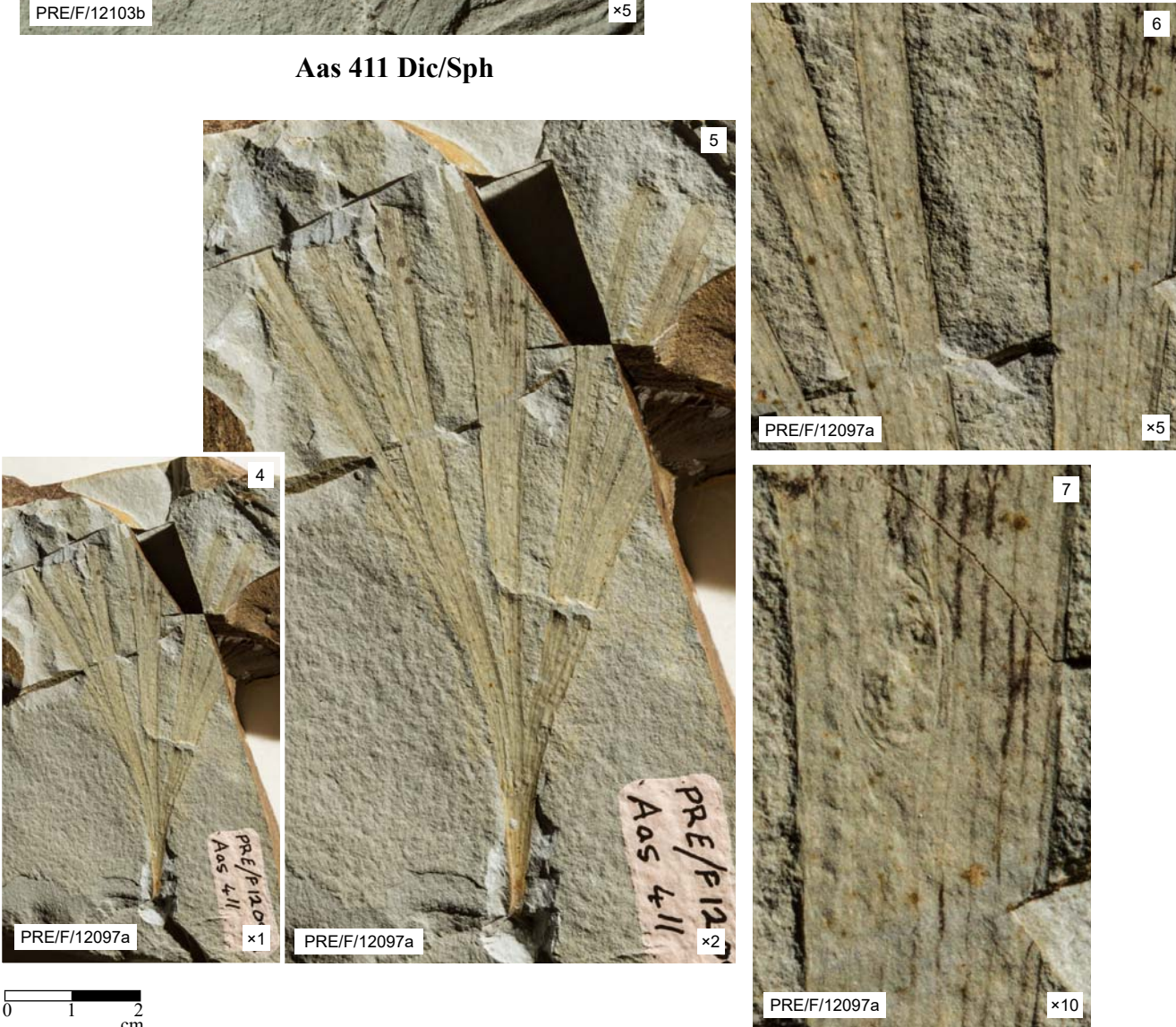


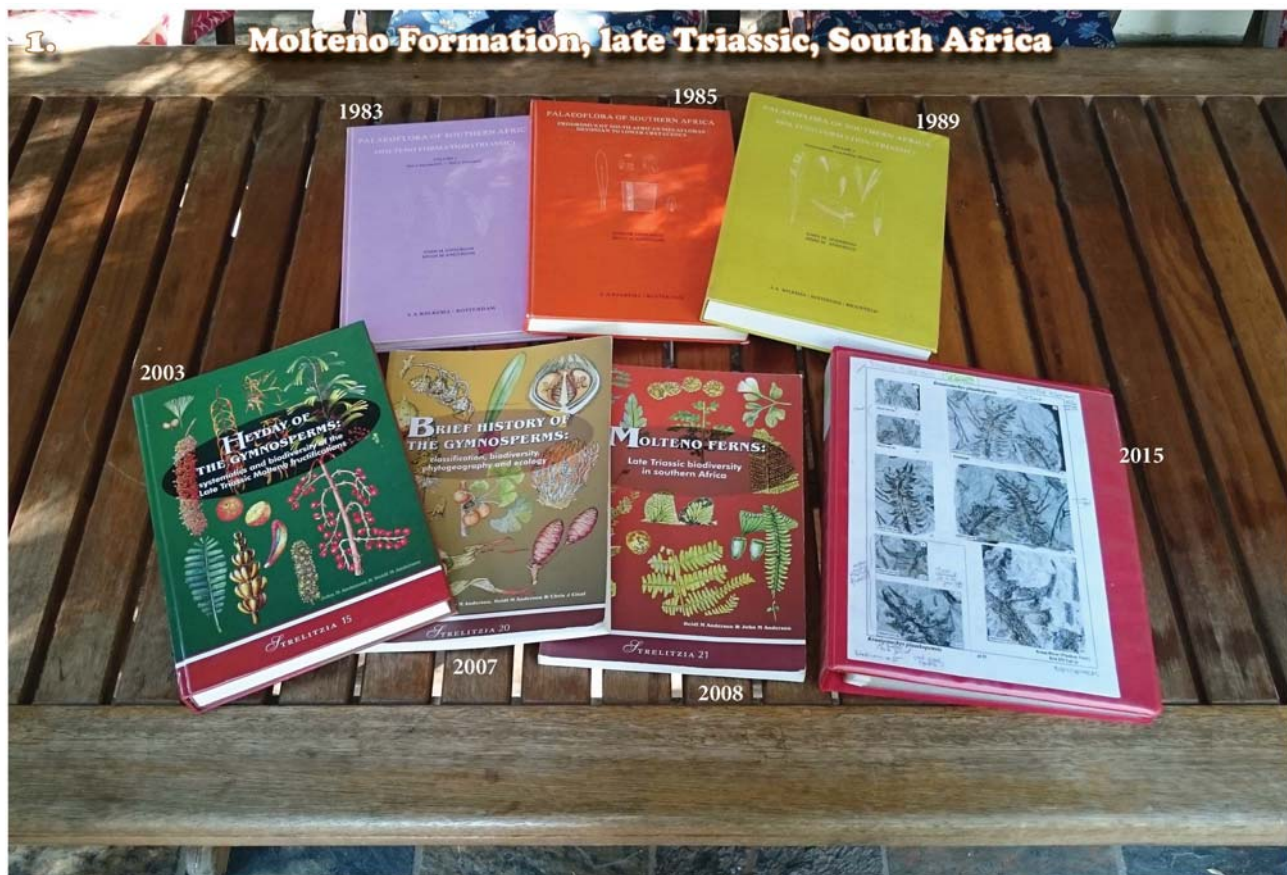


Rochipteris rollerii



Aas 411 Dic/Sph





JMA 2015 (with text adaptation since)

Our previous 7 Molteno Palaeoflora volumes (with a draft of the Sphenophyte volume)

- 1983 – ‘*Dicroidium*’ (Molteno, vegetative)
- 1985 – ‘*Prodromus of South African megaflores*’, Devonian to Lower Cretaceous
- 1989 – ‘*Gymnosperms*’, (excluding *Dicroidium*)
- 2003 – ‘*Heyday of the gymnosperms*’ (‘Molteno, fructifications’)
- 2007 – ‘*Brief history of the gymnosperms*’ (global review, Late Devonian to Present)
- 2008 – ‘*Molteno ferns*’
- 2018 – ‘*Molteno sphenophytes*’

BIBLIOGRAPHY,
GLOSSARY, INDEX

BIBLIOGRAPHY

- AMTSBERG, H. 1969. A contribution to the mesophytic flora of South Australia (Springfield and Leigh Creek). *Transactions of the Royal Society of South Australia* **93**, 79–85.
- ANDERSON, J.M. (ed.) 1999. *Towards Gondwana Alive; Promoting Biodiversity and Stemming the 6th Extinction*. Gondwana Alive Society, 140 pp.
- ANDERSON, J.M. & ANDERSON, H.M. 1983. *Palaeoflora of Southern Africa: Molteno Formation (Triassic)*, Vol. 1: Part 1, Introduction, Part 2. *Dicroidium*. Rotterdam, Balkema. 227 pp.
- ANDERSON, J.M. & ANDERSON, H.M. 1985. *Palaeoflora of Southern Africa: Prodrum of South African Megaflores, Devonian to Lower Cretaceous*. Rotterdam, Balkema. 423 pp.
- ANDERSON, J.M. & ANDERSON, H.M. 1989. *Palaeoflora of southern Africa: Molteno Formation (Triassic)*, Vol. 2: *Gymnosperms (excluding Dicroidium)*. Rotterdam, Balkema. 567 pp.
- ANDERSON, H.M. & ANDERSON, J.M. 1997. Why not look for pro-angiosperms in the Molteno Formation? *Proceedings of the 4th European Palaeobotanical and Palynological Conference, Heerlen, Netherlands* **58**, 73–80.
- ANDERSON, J.M. & ANDERSON, H.M. 2003. *Heyday of the Gymnosperms: Systematics and Biodiversity of the Late Triassic Molteno Fructifications*. Strelitzia **15**. Pretoria, National Botanical Institute. 398 pp.
- ANDERSON, H.M. & ANDERSON, J.M. 2008. *Molteno Ferns: Late Triassic Biodiversity in Southern Africa*. Strelitzia **21**. Pretoria, South African National Biodiversity Institute, 258 pp.
- ANDERSON, H.M., & ANDERSON, J.M. 2018. *Molteno Sphenophytes: Late Triassic Biodiversity in Southern Africa*. *Palaeontologia africana*, **53** (Special Issue), 1–391. Johannesburg, Evolutionary Studies Institute, Witwatersrand University.
<http://wiredspace.wits.ac.za/handle/10539/24672>
- ANDERSON, H.M., BARBACKA, M., BAMFORD, M., HOLMES, W.B.K. & ANDERSON, J.M. 2019a. *Umkomasia* (megasporophyll): Part 1 of a reassessment of Gondwana Triassic plant genera and a reclassification of some previously attributed. *Alcheringa* **43**, 43–70.
- ANDERSON, H.M., BARBACKA, M., BAMFORD, M., HOLMES, W.B.K. & ANDERSON, J.M. 2019b. *Pteruchus* (microsporophyll): Part 2 of a reassessment of Gondwana Triassic plant genera and a reclassification of some previously attributed. *Alcheringa* **43**, 511–533.
- ANDERSON, H.M., BARBACKA, M., BAMFORD, M., HOLMES, W.B.K. & ANDERSON, J.M. 2020. *Dicroidium* (foliage) and affiliated wood: Part 3 of a reassessment of Gondwana Triassic plant genera and a reclassification of some previously attributed. *Alcheringa* **44**, 64–92.
- ANDERSON, J.M., ANDERSON, H.M. & CLEAL, C.J. 2007. *Brief History of the Gymnosperms: Classification, Biodiversity, Phyto-geography and ecology*. Strelitzia **20**. Pretoria, National Botanical Institute. 280 pp.
- ANDERSON, J.M., ANDERSON, H.M. & CRUICKSHANK, A.R.I. 1998. Late Triassic ecosystems of the Molteno/Elliott biome of southern Africa. *Palaeontology* **41**, 387–421.
- ANDERSON, J.M., ANDERSON, H.M., FATTI, L.P. & SICHEL, H. 1996. The Triassic explosion (?): a statistical model for extrapolating biodiversity based on the terrestrial Molteno Formation. *Palaeobiology* **22**, 318–328.
- ANDERSON, J.M., ANDERSON, H.M. & MACRAE, C.S. 1999. Freezing cold to searing heat. Plant and insect life of the Karoo Basin, pp. 140–166. In: MacRae, C.S., *Life Etched in stone*. Johannesburg, The Geological Society of South Africa.
- ANDERSON, J.M., KOHRING, R. & SCHLÜTER, T. 1998. Was insect biodiversity in the Triassic akin to today?—a case study from the Molteno Formation (South Africa). *Entomologia Generalis—Journal of General and Applied Entomology*. **23**(1–2), 15–26.
- ANDERSON, J.M., SCHOLTZ, C., EARDLEY, C. & BONNER, H. 2016. Biodiversity & extinction, Part 5, Insects. *Supernova* **5**(3), 34–35.
- ANDERSON, J.M., THACKERAY, F. & VISSER, K. 2016. Biodiversity & Extinction, Part 7, Hominins. *Supernova* **5**(5), 34–35.
- ARBER, E.A.N. 1913. A preliminary note on the fossil plants of the Mount Potts Beds, New Zealand. *Proceedings of the Royal Society of New Zealand* **86B**, 344–347.
- ARBER, E.A.N. 1917. The earlier Mesozoic floras of New Zealand. *New Zealand Geological Survey. Palaeontological Bulletin* **6**, 81 pp.
- ARCHANGELSKY & CUNEO. 1990. *Polyspermophyllum*, a new Permian gymnosperm from Argentina, with considerations about the Dicranophyllales. *Review of Palaeobotany and Palynology* **63**, 117–135.
- ARTABE, A., MOREL, E.M., GANUZA, D.G., ZAVATTIERI, A.M. & SPALLETTI, L.A. 2007. La paleoflora Triásica de Potrerillos, provincia de Mendoza, Argentina. *Ameghiniana* **44**(2), 279–301.
- ARTABE, A.E., MOREL, E.M., SPALLETTI, L.A. & BREA, M. 1998. Paleoambientes sedimentarios y paleoflora asociada en el Triásico tardío de Malargüe, Mendoza. *Revista de la Asociacion Geologica Argentina* **53**(4), 526–548.
- ASH, S.R. 1976. The systematic position of *Eoginkgoites*. *American Journal of Botany* **63**, 1327–1331.
- ASH, S.R. 1977. An unusual bennettitalean leaf from the Upper Triassic of the south-western United States. *Palaeontology* **20**, 77–79.
- AZCÁRATE, V. & FASOLA, A. 1970. Sobre formas nuevas para la flora triásica de Los Molles. *Museo Nacional de Historia Natural, Chile, Boletín* **29**, 249–269.
- BARONE-NUGENT, E.D., McLOUGHLIN, S. & DRINNAN, A.N. 2003. New species of *Rochipteris* from the Upper Triassic of Australia. *Review of Palaeontology and Palynology* **123**, 273–287.
- BEHRENSMEYER, A.K., DAMUTH, J.K., DIMICHELLE, W.A., POTTS, R., SUES, H.D. & WING, S.L. 1992. *Terrestrial Ecosystems through Time: Evolutionary Paleocology of Terrestrial Plants and Animals*. Chicago, University of Chicago Press. 568 pp.
- BELL, S., HARRINGTON, H.J. & McKELLAR, I.C. 1956. Lower Mesozoic fossils from the Black Jacks, Waitaki River, South Canterbury. *Transactions of the Royal Society of New Zealand* **83**(4), 663–672.
- BODNAR, J., MOREL, E.M., COTUREL, E.P. & GANUZA, D.G. 2020. New plant fossil records and biostratigraphic analysis from the Uspallata Group (Late Triassic) at Cacheuta Hill, Cuyo Basin, west-central Argentina. *Geobios* **60**, 3–27.
- BOMFLEUR, B., DECOMBEIX, A.-L., ESCAPA, I.H., SCHWENDEMANN, A.B., AXSMITH, B. 2013. Whole-plant concept and environment reconstruction of a *Telemachus* conifer (Voltziales) from the Triassic of Antarctica. *International Journal of Plant Sciences* **174**, 425–444.
- BOMFLEUR, B., DECOMBEIX, A.-L., SCHWENDEMANN, A.B., ESCAPA, I.H., TAYLOR, E.L., TAYLOR, T.N. & McLOUGHLIN, S. 2014. Habit and ecology of the Petriellales, an unusual group of seed plants from the Triassic of Gondwana. *International Journal of Plant Science* **175**(9), 1062–1075.
- BONNER, H. 2016. The insect timetree, pp. 34–35. In: Anderson, J.M., Scholtz, C. & Eardley, C., *Biodiversity & extinction, Part 5 Insects. Supernova, The Mag for Curious Kids* **5**(3).
- BONNER, H., JOVERO, S., & ANDERSON, J.M. 2018. *Plant & Insect Timetrees* (Posters). Helsinki Botanical Garden, Finland.
- BORDY, E., ABRAHAMS, M., SHARMAN, G.R., VIGLIETTI, P.A., BENSON, R.B.J., McPHEE, B.W., BARRETT, P.M., SCISCIO, L., CONDON, D., MUNDIL, R., RADEMAM, Z., JINNAH, Z. CLARK, J.M., SUAREZ, C.A., CHAPPELLE, K.E.J. & CHOINIERE, J.N. 2020. A chronostratigraphic framework for the upper Stormberg Group: implications for the Triassic–Jurassic boundary in southern Africa. *Earth-Science Reviews* **203**, 1–24.
- CAIRNCROSS, B., ANDERSON, J.M. & ANDERSON, H.M. 1995. Palaeoecology of the Triassic Molteno Formation, Karoo Basin, South Africa—sedimentological and palaeoecological evidence. *South African Journal of Geology* **98**, 452–478.
- CARRUTHERS, W. 1872. Notes on fossil plants from Queensland, Australia. *Quarterly Journal of the Geological Society of London* **28**, 350–359.
- CHAPMAN, F. & COOKSON, I.C. 1926. A revision of the ‘Sweet’ collection of Triassic plant remains from Leigh’s Creek, South Australia. *Transactions of the Royal Society of South Australia* **1**, 163–178.

- CHAPMAN, F. 1927. Monograph on the Triassic flora of Bald Hill, Bacchus Marsh, Victoria. *Memoirs of the National Museum, Melbourne* 7, 121–155.
- CLIFFORD, H.T. & CAMILLERI, N. 1998. A mature cupule of *Leptostrobus* (Czekanowskiales) from the Late Triassic of Queensland. *Memoirs of the Queensland Museum* 42, 445–447.
- CRANE, P.R. 1985. Phylogenetic analysis of seed plants and the origin of angiosperms. *Annals of the Missouri Botanical Garden* 72, 716–793.
- CRANE, P.R. 1986. The morphology and relationships of Bennettitales. In: Spicer, R.A. & Thomas, B.A. (eds), *Systematic and Taxonomic Approaches in Palaeobotany*, 163–175. Oxford, Clarendon Press.
- CRANE, P.R. 1988. Major clades and relationships in the “higher” gymnosperms. In: Beck, C.B. (ed.), *Origins and Evolution of Gymnosperms*, 218–272. New York, Columbia University Press.
- CUNEO, N.R., ISBELL, J., TAYLOR, E.L. & TAYLOR, T.N. 1993. The *Glossopteris* flora from Antarctica: taphonomy and paleoecology. *Proceedings of the IXth International Congress on Carboniferous/Permian Stratigraphy and Geology*, Buenos Aires. Vol. 2, 13–40.
- DiMICHELE, W.A. & GASTALDO, R. A. 2008. Plant paleoecology in deep time. *Annals Missouri Botanical Garden* 95, 144–198.
- DOYLE, J.A. 2008. Integrating molecular phylogenetic and paleobotanical evidence on origin of the flower. *International Journal of Plant Sciences* 169(7), 816–843.
- DU TOIT, A.L. 1927. The fossil flora of the Upper Karroo beds. *Annals of the South African Museum* 22, 289–420.
- ELGORRIAGA, A., ESCAPA, I.H. & CÚNEO, N.R. 2019. Southern hemisphere Caytoniales: vegetative and reproductive remains from the Lonco Trapial Formation (Lower Jurassic), Patagonia. *Journal of Systematic Palaeontology* 17(17), 1477–1495.
- ENGLER, A. 1897. *Die natürlichen pflanzenfamilien Nachthäge zum II–IV Teil*. Leipzig, Engelmann. 380 pp.
- ETHERIDGE, R. Jr. 1894. Occasional descriptions of New South Wales fossils, No. 1: 1. Further traces of *Schizoneura*. *Records of the Geological Survey of New South Wales* 4(1), 32–33.
- ETHERIDGE, R. Jr. 1895. Additional plant remains from the Leigh Creek Coal-field, central Australia. *Transactions Royal Society South Australia* 19, 138–145.
- FEISTMANTEL, O. 1889. Übersichtliche Darstellung der geologisch-palaeontologischen Verhältnisse Süd-Afrikas. Th 1: Die Karroo Formation und die dieselbe unterlagernden Schichten. *Abhandlungen der Königlichen böhmischen Gesellschaft der Wissenschaften. (Rozprawy třídy matematiko-přirodové české spol. ečnosti nauk)*. Prague 7(3), 1–89.
- FERGUSON, D.K. 1992. Understanding plant taphonomic processes, or how to turn information losses into gains. In: Gall, J.C. & Grauvogel-Stamm, L. (eds), *Taphonomy: Processes and Products*, 2–4. Strasbourg, European Palaeontological Association (workshop).
- FRENGUELLI, J. 1942. Contribuciones al conocimiento de la flora del Gondwana superior en la Argentina. I–X *Notas del Museo de la Plata, Paleontología* 7(42–51), 265–353.
- FRENGUELLI, J. 1946. Contribuciones al conocimiento de la flora del Gondwana superior en la Argentina, XXXIII. *Notas del Museo la Plata II, Paleontología* 87, 100–127.
- GNAEDINGER, S.C. & ZAVATTIERI, A.M. 2017. Nuevos registros paleobotánicos de la Formación Nestares (Jurásico Temprano), extremo austral de la Cuenca Neuquina, Argentino. *Revista Museo Argentino Ciencias Naturales, n.s.* 19(2), 101–112.
- GRESHKO, M. 2020. Reimagining dinosaurs: from rainbow feathers to river monsters, prehistoric icons get a modern reboot. *National Geographic* 10(2020), 38–89.
- HANCOX, P.J., NEVELING, J. & RUBIDGE, B.S. 2020. Biostratigraphy of the *Cynognathus* Assemblage Zone (Beaufort Group, Karoo Supergroup), South Africa. *South African Journal of Geology* 123(2), 217–238.
- HANLON, V.C.T., OTTO, S.P. & AITKEN, S.N. 2019a. Somatic mutations substantially increase the per-generation mutation rate in the conifer *Picea sitchensis*. *Evolution Letters* 3(4), 348–358.
- HANLON, V.C.T., OTTO, S.P. & AITKEN, S.N. 2019b. Surprising genetic diversity in old growth trees. www.indefenseofplants.com/blog, 23 July 2019 (researchers at University of British Colombia).
- HARRIS, T.M. 1933. A new member of the Caytoniales. *The New Phytologist* 32, 97–173.
- HARRIS, T.M. 1940. *Caytonia*. *Annals of Botany* 4, 713–734.
- HARRIS, T.M. 1958. The seed of *Caytonia*. *The Palaeobotanist* 7, 93–106.
- HARRIS, T.M. 1964. *The Yorkshire Jurassic Flora. 2. Caytoniales, Cycadales and Pteridosperms*. London, British Museum of Natural History. 191 pp.
- HERBST, R., TRONCOSO, A. & GNAEDINGER, S.C. 2001. *Rochipteris* nov. gen., hojas *incertae sedis* (= *Chiropteris pro parte*) del Triásico Superior de Argentina y Chile. *Ameghiniana* 38(3), 257–269.
- HERBST, R. & TRONCOSO, A. 2012. La flora Triásica de la Quebrada Doña Inés Chica, Región de Atacama, Chile. *GAEA, Journal of Geoscience* 8(2), 55–66.
- HILGER, H.H. 2014. *Angiosperm Phylogeny Poster*. Freie Universität Berlin.
- HOEG, O.A. 1967. Psilophyta. In: Boureau, E. (ed.), *Traité de Paléobotanique*, Vol. 2, 193–433. Paris, Masson et Cie.
- HOLMES, W.B.K. & ANDERSON, H.M. 2005. The Middle Triassic megafossil flora of the Basin Creek Formation, Nymboida Coal Measures, New South Wales, Australia. Part 5. The genera *Lepidopteris*, *Kurtzia*, *Rochipteris* and *Walkomiopteris*. *Proceedings of the Linnaean Society of New South Wales* 126, 39–79.
- IMBLER, S. 2019. Found: pollen on a 99-million-year old beetle, in amber. <https://www.atlasobscura.com/articles/found-ancient-beetle-pollen-amber>
- IRMIS, R.B., MUNDIL, R., MARTZ, J.W. & PARKER, W.G., 2011. High resolution U-Pb ages from the Upper Triassic Chinle Formation (New Mexico, USA) support a diachronous rise of dinosaurs. *Earth and Planetary Science Letters* 309, 258–267.
- IUGS, 2018. *International Chrono Stratigraphic Chart*. International Commission on Stratigraphy (July 2018). www.stratigraphy.org
- JACK, R.L. & ETHERIDGE, R., Jr. 1892. The geology and palaeontology of Queensland and New Guinea. *Queensland Department of Mines, Geological Survey of Queensland Publications* 92, 1–768.
- JOHNSTON, R.M. 1888. *A Systematic Account of the Geology of Tasmania*. Hobart, Government Printer. 408 pp.
- JONES, O.A. & DE JERSEY, N.J. 1947. The flora of the Ipswich Coal Measures—morphology and floral succession. *Papers from the Department of Geology, University of Queensland* 3, 1–88.
- JONES, T.P. & ROWE, N.P. (eds) 1999. *Fossil Plants and Spores: Modern Techniques*. London, The Geological Society. 396 pp.
- KOHRING, R.R. 1998. Conchostraca (Arthropoda: Crustacea) from the Molteno Formation (Upper Triassic, South Africa): palaeoecological suggestions. *Journal of African Earth Sciences, Special Abstracts Issue*. 27(1A), 124–125.
- KOHRING, R.R. & HÖRNIG, A.C.F. 1998. The earliest freshwater Bryozoa: evidence from the Upper Triassic Molteno Formation (South Africa). *Journal of African Earth Sciences, Special Abstracts Issue*. 27(1A), 125.
- KRASSILOV, V.A. 1977. Contributions to the knowledge of the Caytoniales. *Review of Palaeobotany and Palynology* 24, 155–178.
- KUSTATSCHER, E., & VAN KONIJENBURG-VAN CITTERT, H.A., 2011. The ferns of the Middle Triassic flora from Thale (Germany). *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie* 261, 209–248.
- LABANDEIRA, C.C. 2006. Silurian to Triassic plant and hexapod clades and their associations: new data, a review, and interpretations. *Arthropod Systematics & Phylogeny* 64(1), 53–94.
- LABANDEIRA, C.C. 2018. Faunal ecology of the Molteno: towards an integrated ecology. In: Anderson, H.M., Anderson, J.M. *Molteno Sphenophytes: Late Triassic Biodiversity in Southern Africa*, 14–15. Johannesburg, Evolutionary Studies Institute, Witwatersrand University. <http://wiredspace.wits.ac.za/handle/10539/24672>

- LABANDEIRA, C.C., ANDERSON, J.M. & ANDERSON, H.M. 2018. Expansion of arthropod herbivory in Late Triassic South Africa: the Molteno biota, Aasvoëlberg 411 site and developmental biology of a gall. In: Tanner, L.H. (ed.), *The Late Triassic World, Topics in Geobiology* (Ch. 14), 623–719. Springer International Publishing AG
- LABANDEIRA, C.C., CURRANO, E.D. 2013. The fossil record of plant–insect dynamics. *Annual Review of Earth and Planetary Sciences* **41**, 287–311.
- LABANDEIRA, C.C., WILF, P., JOHNSON, K.R. & MARSH, F. 2007. *Guide to Insect (and other) Damage Types on Compressed Plant Fossils* (Version 3.0–Spring 2007), Washington, D.C., Smithsonian Institution, 26 pp. <http://paleobiology.si.edu/insects/index.html>
- LEDFORD, H. 2017. Massive database of 182,000 leaves is helping predict plant family trees. <https://www.scientificamerican.com/article/>
- LUCAS, S.G., TANNER, L.H., KOZUR, H.W., WEEMS, R.E. & HECKERT, A.B. 2012. The Late Triassic timescale: age and correlation of the Carnian–Norian boundary. *Earth-Science Reviews* **114**, 1–18.
- LUTZ, A., GNAEDINGER, S., MANCUSO, A. & CRISAFULLI, A. 2011. Paleoflora de la Formación Los Rastros (Triásico Medio), Provincia de San Juan, Argentina, consideraciones taxonómicas y tafonómicas. *Ameghiniana* **48**(4), 568–588.
- MANCUSO, A.C., BENAVENTE, C.A., IRMIS, R.B. & MUNDIL, R., 2020. Evidence for the Carnian pluvial episode in Gondwana: new multiproxy climate records and their bearing on early dinosaur diversification. *Gondwana Research* **86**, 104–125.
- MARSICANO, C.A., IRMIS, R.B., MANCUSO, A.C., MUNDIL, R. & CHEMALE, F., 2016. The precise temporal calibration of dinosaur origins. *PNAS* **113**(3), 509–513.
- MCCOY, F. 1847. On the fossil botany and zoology of the rocks associated with the coal of Australia. *Annals and Magazine of Natural History* **20**, 145–157.
- McLOUGHLIN, S., TOSOLINI, A.P. & DRINNAN, A.N. 2000. Revision of an Early Cretaceous macroflora from the Maryborough Formation, Maryborough Basin, Queensland, Australia. *Memoirs of the Queensland Museum* **45**, 483–503.
- MENENDEZ, C.A. 1951. La flora Mesozoica de la Formación Llantenes (Provincia de Mendoza). *Revista del Instituto Nacional de Investigaciones de las Ciencias Naturales (Botánica)* **2**(3), 147–261.
- MEYEN, S.V. 1987. *Fundamentals of Palaeobotany*. London, Chapman & Hall. 432 pp.
- MOREL, E.M., ARTABE, A.E., GANUZA, D.G. & ZÚÑIGA, A. 2011. La paleoflora Triásica del Cerro Cacheuta, Provincia de Mendoza, Argentina. Petriellales, Cycadales, Ginkgoales, Voltziales, Coniferales, Gnetales y gimnospermas incertae sedis. *Ameghiniana* **48**(4), 520–540.
- MORRIS, J. 1845. Fossil flora. In P.E. de Strezelecki, *Physical Description of New South Wales and van Diemens Land*, 245–254. London, Longman, Brown & Green.
- OGG, J.G., HUANG, C. & HINNOV, L. 2014. Triassic timescale status: a brief overview. *Albertiana* **41**, 3–30.
- OPLUŠTIL, S., PŠENIČKA, J., BEK, J., WANG, J., FENG, Z., LIBERTÍN, M., ŠIMŮNEK, Z., BUREŠ, J. & DRÁBKOVÁ, J. 2014. T^o peat-forming plant assemblage preserved in growth position by volcanic ash-fall: a case study from the Middle Pennsylvanian of the Czech Republic. *Bulletin of Geosciences* **89**(4), 773–818.
- PENNISI, E. 2016. Shaking up the tree of life; species were once thought to keep to themselves. Now hybrids are turning up everywhere, challenging evolutionary theory. *Science* **354**, 817–821
- POLE, M.S. & RAINE, J.I. 1994. Triassic plant fossils from Pollock Road, Southland, New Zealand. *Alcheringa* **18**, 147–159.
- RASMUSSEN, C., MUNDIL, R., IRMIS, R.B. *et al.* 2020. U–Pb zircon geochronology and depositional age models for the Upper Triassic Chinle Formation (Petrified Forest National Park, Arizona, USA): Implications for Late Triassic paleoecological and paleoenvironmental change. *The Geological Society of America Bulletin* **133**(3–4), 539–558.
- REYMANÓWNA, M. 1973. The Jurassic flora from Grojec near Kraków in Poland. Part II—Caytoniales and anatomy of *Caytonia*. *Acta Palaeobotanica Polonica* **14**, 46–87.
- RETALLACK, G.J. 1980. Middle Triassic megafossil plants and trace fossils from Tank Gully, Canterbury, New Zealand. *Journal of the Royal Society of New Zealand* **10**, 31–63.
- RETALLACK, G.J. 1981. Middle Triassic megafossil plants from Long Gully, near Otematata, north Otago, New Zealand. *Journal of the Royal Society of New Zealand* **13**(3), 107–127.
- RETALLACK, G.J. 1983. Middle Triassic megafossil marine algae and land plants from near Benmore Dam, southern Canterbury, New Zealand. *Journal of the Royal Society of New Zealand* **13**, 129–154.
- RETALLACK, G.J. 1985. Triassic fossil plant fragments from shallow marine rocks of the Murihiku Supergroup, New Zealand. *Journal of the Royal Society of New Zealand* **15**, 1–26.
- ROTHWELL, G.R. & STOCKEY, R.U. 2016. Phylogenetic diversification of Early Cretaceous seed plants: the compound seed cone of *Doylea tetrahedrasperma*. *American Journal of Botany* **103**(5), 923–937.
- ROZEFELDS, A.C., 1986. Type, figured and mentioned fossil plants in the Queensland Museum. *Memoirs of the Queensland Museum* **22**, 141–153.
- RUFFELL, A., DAL CORSO, J.A. & BENTON, M. 2018. Triassic extinctions & explosions. *Geoscientist* **28**(8), 10–15.
- SCOTSESE, C.R. 1997. *Palaeogeographic Atlas: Paleomap Project. Report 900497*. Arlington, U.S.A., University of Texas.
- SEWARD, A.C. 1903. Fossil floras of the Cape Colony. *Annals of the South African Museum* **4**(1), 1–122.
- SHIRLEY, J. 1898. Additions to the fossil flora of Queensland, mainly from the Ipswich Formation, Trias–Jura System. *Bulletin of the Geological Survey of Queensland* **7**, 1–25.
- SMITH, R.M.H., RUBIDGE, B.S., DAY, M.O. & BOTHA, J. 2020. Introduction to the tetrapod biozonation of the Karoo Supergroup. *South African Journal of Geology* **123**(2), 131–140.
- SMITH, T., NICOLL, R., LAURIE, J.R., CROWLEY, J., McKELLAR, J., CAMPBELL, H.J., RAINE, I. & MANTLE, D.J. 2018. Recalibrating Australian Triassic palynostratigraphy to the International Geologic Timescale using high resolution CA-IDTIMS dating. *ASEG Extended Abstracts* **1**(1).
- SOLMS-LAUBACH, H. & STEINMANN, G. 1899. Das Auftreten und die Flora der rhätischen Kohlschichten von La Ternera (Chile) In: Steinmann, G., Beiträge zur Geologie und Palaeontologie von Südamerika, VII, 581–609. *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie* **12**.
- STANLEY, S.M. 1979. *Macroevolution. Pattern and Process*. San Francisco, Freeman & Co. 332 pp.
- SQUIRES, D. 2012. *Type and figured Palaeontological Specimens in the Tasmanian Museum and Art Gallery: a Catalogue*. Hobart, Tasmanian Museum and Art Gallery. 164 pp.
- SYLVESTER-BRADLEY, P.C. 1977. Biostratigraphical tests of evolutionary theory. In: Kauffman, E.G. & Hazel, J.E. (eds), *Concepts and Methods of Biostratigraphy*, 41–63. Stroudsburg, Pennsylvania Dowden, Hutchinson & Ross Inc..
- TAYLOR, E.L. 1996. Enigmatic gymnosperms? Structurally preserved Permian and Triassic seed ferns from Antarctica. *Review of Palaeobotany and Palynology* **90**, 303–318.
- TAYLOR, E.L. & TAYLOR, T.N. 2009. Seed ferns from the late Paleozoic and Mesozoic: any angiosperm ancestors lurking there? *American Journal of Botany* **96**, 237–251.
- TAYLOR, T.N., DEL FUEYO, G.M. & TAYLOR, E.L. 1994. Permineralised seed fern cupules from the Triassic of Antarctica: implications for cupule and carpel evolution. *American Journal of Botany* **81**, 666–777.
- THACKERAY, J.F. 2007. Approximation of a biological species constant? *South African Journal of Science* **103**, 489.
- THACKERAY, J.F. 2018. Alpha and sigma taxonomy of *Pan* (chimpanzees) and Plio–Pleistocene hominin species. *South African Journal of Science* **114**(11/12), 1–2.
- THACKERAY, J.F. 2019. Alpha and sigma taxonomy of *Lystrosaurus murrayi* and *L. declivis*, Triassic dicynodonts (Therapsida) from the Karoo Basin, South Africa. *South African Journal of Science* **115** (3/4), 1–3.

- THACKERAY, J.F., BELLANY, C.L., BELLARS, D. *et al.* 1997. Probabilities of conspecificity: application of a morphometric technique to modern taxa and fossil specimens attributed to *Australopithecus* and *Homo*. *South African Journal of Science* **93**, 195–196.
- THACKERAY, J.F., DURAND, J.F. & MEYER, L. 1998. Morphometric analysis of South African dicynodonts attributed to *Lystrosaurus murrayi* (Huxley, 1859) and *L. declivis* (Owen, 1860): probabilities of conspecificity. *Annals of the Transvaal Museum* **36**, 413–420.
- THACKERAY, J.F. & DYKES, S. 2016. Morphometric analyses of hominoid crania, probabilities of conspecificity and an approximation of a biological species constant. *Homo - Journal of Comparative Human Biology* **67**(1), 1–10.
- THACKERAY, J.F., MAUREILLE, B., VANDERMEERSCH, B., BRAGA, J. & CHAIX, R. 2005. Morphometric comparisons between Neanderthals and ‘anatomically modern’ *Homo sapiens* from Europe and the Near East. *Annals of the Transvaal Museum* **42**, 47–51.
- THACKERAY, J.F. & ODES, E. 2013. Morphometric analysis of early Pleistocene African hominin crania in the context of a statistical (probabilistic) definition of a species. *Antiquity*, 87. <http://antiquity.ac.uk/projgall/thackeray335/>
- THACKERAY, J.F. & SCHREIN, C.M. 2017. A probabilistic definition of a species, fuzzy boundaries and ‘sigma taxonomy’. *South African Journal of Science* **113**(5/6), 1–2.
- WALKOM, A.B. 1924. On fossil plants from Bellevue, near Esk. *Memoirs of the Queensland Museum* **8**, 77–92.
- WALKOM, A.B. 1925a. Fossil plants from the Narrabeen Stage of the Hawkesbury Series. *Proceedings of the Linnean Society of New South Wales* **50**, 214–224.
- WALKOM, A.B. 1925b. Notes on some Tasmanian Mesozoic plants. Part 1. *Papers and Proceedings of the Royal Society of Tasmania*, **1924**, 73–89.
- WALKOM, A.B. 1926. Notes on some Tasmanian Mesozoic plants. Part 1. *Papers and Proceedings of the Royal Society of Tasmania*, **1925**, 63–74.
- WANG, J., PFEFFERKORN, H.W., SUN, B. & LIU, L. 2003. Discovery of organic connection of *Chiropteris* Kurr and *Nystroemia* Halle from Early Permian of western Henan, China. *Chinese Science Bulletin* **48**(20), 2248–2252.
- WANG, J., PFEFFERKORN, H.W., ZHANG, Y. & FENG Z. 2012. Permian vegetational Pompeii from Inner Mongolia and its implications for landscape paleoecology and paleobiogeography of Cathaysia. www.pnas.org/cgi/doi/10.1073/pnas.1115076109
- WEBB, J.A. & MITCHELL, M.M. 2006. Stratigraphy and palaeoflora of the Triassic Council Trench Formation, central Victoria. *Proceedings of the Royal Society of Victoria* **118**(1), 113–127.
- WILSON, E.O. 1992. *The Diversity of Life*. London, Penguin Books. 406 pp.
- WOOD, B. 2014. Where we came from. *Scientific American* **311**(3), 44–41.

GLOSSARY

The terms included here are those considered most relevant to our general study of Molteno and Gondwana Triassic floristics and biodiversity. They are arranged to emphasize the significance of certain fields. Though some terms are not applied in this particular volume, they are retained for coherence of related topics.
Updated from And. & And. (2003, 2018).

** – terms introduced in our own publications on the Molteno or other fossil floras of Southern Africa.

* – usage as followed in our own works.

SAMPLING

Optimal sampling of fossiliferous strata – and there are many criteria that might be considered in defining optimal – is critical to reliable tracking of diversity patterns through time.

Frequency – The measure of frequency of a fossil taxon within a formation is the number of taphocoenoses (TCs) or assemblages, out of the total sampled, in which it has been found. Through the Gondwana Triassic, for instance, it might be the number of degree squares (out of the total sampled) in which it has been found.* (This differs from the usual definition of frequency, where the proportional specimen count of a taxon with a single taphocoenosis is referred to.)

Abundance – The abundance of a fossil taxon is a measure of the absolute or relative number of individuals collected from or encountered in an assemblage, formation, region or continent.*

Assemblage – The full suite of fossil individuals or palaeodemes collected from a distinct lithological unit (lithosome) of limited geographic and stratigraphic extent. A megaplant assemblage will generally represent a localized mosaic of plant associations, less often a single association, through several generations.*

Locality – An area to about 1 km in diameter, which may include continuous fossiliferous exposure, but will generally include one or more productive exposures of lesser rank.*

Extensive sampling – Concerns the number and spread of localities sampled in a fossiliferous horizon.*

Intensive sampling – Concerns the comprehensiveness of collecting from a particular fossiliferous deposit.*

Singletons – Those species recorded from a particular geological horizon (member, formation or biozone) that are known from only a single locality (more specifically an assemblage). The number of singletons (and doubletons) is critical in projecting biodiversity from the observed record.

Doubletons – Those species recorded from a particular geological horizon that are known from only two localities. (Note that these definitions of singletons and doubletons differ from those referring to specimens occurring within an assemblage.)

SAMPLING HIERARCHY (geographic subdivisions)** (see And. & And., 1983)

	Upper limit to areas (max. diam.)	Name codes (examples)
Superregion	10 000 km	SAf
Region	1000 km	SAf (Ka)
Subregion	100 km	SAf (Ka 4)
Superlocality	10 km	Hla
Locality	1 km	Hla 2
Sublocality	100 m	Hla 21
Supersite	10 m	Hla 213
Site	1 m	Hla 2131
Subsite	10 cm	Hla 21311

Superregion

Area: (a) To 10 000 km diam.
(b) Continents or sub-continents; e.g. SAf (Southern Africa).

Region

Area: (a) To 1000 km diam.
(b) Geological basins (or major portions thereof), or coherent clusters of smaller basins or erosional remnants; e.g. Ka (Karoo Basin).

Subregion

Area: (a) To 100 km diam.
(b) Degree squares (applying the global long./lat. grid); e.g. SAf (Ka 4), the grid that includes Umk 111.

Superlocality

Area: (a) To 10 km diam.
(b) Incorporates clusters of localities that fall reasonably into areas of topographic or geological unity, such as a section of river valley or the slopes of a mountain; e.g. Hla (Hlatimbe).

Locality

Area: (a) To 1 km diam.
(b) May include continuous fossiliferous exposure over the full km, but will generally include one or more productive exposures of lesser rank; e.g. Hla 2 (Hlatimbe).

Sublocality

Area: (a) To 100 m diam.
(b) Such as an exposed surface or section (stream or erosion gully) of backswamp or floodplain deposit; e.g. Hla 21 (Hlatimbe).

Supersite

Area: (a) To 10 m diam.
(b) Such as a shale lens (lithosome) representing a section through an abandoned channel; e.g. Hla 213 (Hlatimbe).

Site

Area: (a) To 1 m diam.
(b) A single 1 m wide trench excavated at a supersite to expose the sequence of fossiliferous beds (not considered in this vol.).

Subsite

Area: (a) To 10 cm diam.
(b) A 10 cm² grid superimposed on an exposed bedding-plane delineating areas of this rank would be appropriate for detailed association analyses (not considered in this vol.).

TAPHONOMY

There is inevitably a reduction between the number of species making up the original flora and fauna of the region and that preserved in the fossil record. This filtering or winnowing of the original diversity occurs through the taphonomic process. Taphonomy is of vital concern in biodiversity projections. (Selected references: Ferguson 1992; Behrensmeyer *et al.* 1992; Cuneo *et al.* 1993).

Taphonomy – The conditions and processes intervening between a living species association and a fossil assemblage.

Taphonomic mode – Reflects the environmental context of the fossiliferous deposit. Examples include levee, lake, crevasse splay or abandoned channel of the floodplain (i.e. subenvironments of meandering and braided fluvial systems).

Isotaphonomic – Refers to fossiliferous assemblages of similar taphonomic mode.

Biocoenosis (BC) – Living community.

Thanatocoenosis – Death assemblage; that fraction of the original community that is preserved in the fossil deposit.

Taphocoenosis (TC) – Taphonomic assemblage; fossil assemblage resulting from the taphonomic process; the aggregate of fossil remains contained in a deposit or bed.

Phytotaphocoenosis – A fossil plant assemblage or plant taphocoenosis.

Autochthonous – Described TCs that have originated *in situ*. While such assemblages might be relatively common in the case of fossil tetrapods, they are a far more rare phenomenon in palaeobotany (e.g. horsetails entombed in growth position in a marsh).

Paraautochthonous – Describes TCs deposited close to the original site of occurrence.

Allochthonous – Describes TCs deposited at some significant distance from the original site of occurrence.

PALAEODEMES**

Terms either from And. & And. (1983) or our later works.

Palaeodeme (fossil population) – A collection of fossil specimens judged to represent a single potentially interbreeding population of plants or animals, showing a normal distribution of variation for selected diagnostic characters, and derived from a single taphocoenosis from a discrete small-scale lithological unit (lithosome) such as an abandoned channel infill or crevasse splay.**

Reference palaeodeme (Ref.pal.) – The most comprehensive, representative, photographically documented palaeodeme in the literature proposed as reference for a particular infrageneric taxon.**

Reference assemblage (RA) – That assemblage from which the reference palaeodeme derives.**

Reference specimen (RS) – The most complete, average, mature specimen selected from the reference palaeodeme.**

Home palaeodeme – The palaeodeme from which a specimen derives.**

Sister palaeodeme (Sis.pal.) – A palaeodeme belonging to the same species.**

ABUNDANCE/RARITY**

No matter how extensively (number of localities) or intensively (number of specimens) one has sampled a fossiliferous formation, there inevitably appear certain fringe taxa – those that range from *very rare* to *vanishingly rare*. This is especially the case with fruiting material – in the present case, sphenophyte strobili or fragments of strobili. And inevitably, amongst these there will be specimens on the borderline regarding quality of preservation – those sufficient or not regarding diagnostic characters for recognizing new taxa.

Rarity: as measured in man-hours cleaving; see And. & And. (2003, tabs 8a,b, p. 13).

Mono-dominant 70–100%

Co-dominant 70–100

Abundant 20–69%

Common 3–5%

Sparse 1–2%

Rare >1 cone per 1–5 man-hours (but <1% of TC)

Very rare 1 cone per 5–49 man-hours

Extremely rare 1 cone per 50–499 man-hours

Vanishingly rare 1 cone per 500–4999 man-hours

Infinitely rare 1 cone in over 5000 man-hours

AFFILIATED ORGANS **

Reliability grades (after And. & And. 1985, p.85)

The evidence for linking organs ranges from marginal to certain. At the lower end of the range the evidence will be slim, yet suggestive, or alternate options might be more or less equally likely, while at the upper end of the range clear organic attachment certifies linkage (see Pt 4, p.77)

Grade 1, marginal – Marginal likelihood of affiliation; mutual occurrence (weak).

Grade 2, poor – Most feasible affiliation (alternatives competitive); mutual occurrence (unclear).

Grade 3, fair – Probable affiliation (alternatives weak); mutual occurrence (fairly clear), little other supportive data.

Grade 4, good – Virtually exclusive likelihood of affiliation; mutual occurrence (particularly clear), cuticle correspondence and/or kindred reinforcement, and/or possible organic attachment.

Grade 5, certain – Certain affiliation; organic attachment undoubted.

FOSSIL TAXA

For form-genera and organ-genera, we follow standard usage. Further terms in this field are introduced, or used in a particular sense, to meet the specific needs of our Molteno research. The concepts can equally be applied to species. Note that this piece on ‘Fossil taxa’ was compiled for our work on the Molteno gymnosperms (And. & And., 2003).

Form-genus – “a genus of fossil plants based on a detached organ which, because of the limited characters shown, cannot be assigned to a family, although it may be possible to assign it to a higher taxonomic level. The “artificial” nature of such a genus is illustrated by the several instances where we have one form-genus in which different species may closely resemble members of two or more different families” (Jones & Rowe, 1999).

Organ-genus – “a genus based on only part (an organ or organs) of a fossil plant, showing a sufficient range of distinctive characters that it may reasonably be assigned to a family. An organ-genus is regarded as “natural”, in the sense that its constituent species are believed to have the same close relationship as those of a living genus. However, an organ-genus differs from a genus of living plants in that only fossils of

the same organ, showing the same type of characters, can be assigned to it (e.g. fossil lauraceous leaves cannot be assigned to *Laurocarpum*, an organ-genus of fossil lauraceous fruit)” (Jones & Rowe, 1999).

Whole-plant genus – A fossil plant genus considered ‘natural’ that includes one or more organ-genera. The term is applied here only after comprehensive and systematic affiliation studies for the group (e.g. gymnosperms) and formation (e.g. Molteno) have been completed. In the Molteno (see And. & And., 2003, tab. 15, p. 21), we recognized 38 gymnosperm whole-plant genera, i.e. 38 genera known from at least one of the three organs – ovulate, foliage or microsporangiata (*ibid.*, p. 43) and And. & And. (2018, pt 4, tab. 4, p. 76).*

Whole-plant species – as for above, but referring to a species.*

Fossil-plant genus (or simply plant-genus) – A generalized term usually referring to a ‘natural’ whole-plant or multi-organ genus.*

Multi-organ genus – A fossil-plant genus considered ‘natural’ that includes more than one organ-genus. In the Molteno (And. & And., 2003, tab. 15, p. 21), we recognize 16 gymnosperm multi-organ genera, i.e. 16 genera known from at least two of the three organs – ovulate, foliage or microsporangiata (*ibid.*, p. 43).*

Multi-plant genus – The original living-plant genus occurring in the Molteno Biome. (The relationship between the living and fossil genus is akin to that between the phytocoenosis and taphocoenosis, i.e. between the living assemblage and the fossil assemblage.)*

Sister genera – Those organ-genera or whole-plant genera included in the same family or order (e.g. the three male-cone genera *Fredianthus*, *Lutanthus* and *Odyssianthus*, from the Molteno placed in the order Voltziales, And. & And., 2003, pp 70, 74).*

Sister specimen – A specimen of the same species from the same palaeodeme (e.g. as for *Lutanthus hemidiscus* and *L. ornatus*, And. & And., 2003, p. 76).*

SPECIES CONFIDENCE LEVEL**

This we have applied specifically for the nine Molteno species of *Equisetostachys* (see And. & And., 2018, pt 5, panorama 1, pp 156–157). We reiterate that core to the overall study of the Molteno is aiming to reconstruct the biota (plants, insects, plant–insect interactions, paleoecology) of the Molteno Biome through its duration as faithfully as can be achieved. Hence considering biodiversity, especially of the rarest elements such as strobili, from all viewpoints: morphology, affiliated organs and their morphology, habitat, stratigraphy and duration of Molteno deposition.

51%, marginal

60%, fair

75%, good

90%, virtually certain

100%, certain

BIODIVERSITY

“The variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; includes the variety of ecosystems, which comprise both the communities of organisms within particular habitats and the physical conditions under which they live” (Wilson 1992).

Observed diversity – The actual tally of taxa of a particular rank (e.g. species, families, orders) collected (curated and/or described) from a particular geological horizon (e.g. formation, assemblage zone).*

Preserved diversity – The projected tally of taxa of a particular rank representing the full potential sample (assuming comprehensive sampling of all preserved taphocoenoses) from a particular geological horizon.*

Existed diversity – The projected tally of taxa of a particular rank representing the full flora and fauna that actually inhabited the various habitats of the biome existing at the time of deposition of a particular geological horizon.*

Alpha diversity – The number of species occupying a particular habitat at a particular locality, e.g. the 73 foliage species recorded from the riparian forest at the Umkomaas locality, Molteno Formation.*

Beta diversity – The rate at which the species number increase along a transect through adjacent ecozones (habitats).*

Gamma diversity – The totality of species, considering all habitats over a broad area; e.g. the full extent of the Molteno Biome.*

MNS – (*Minimum number of species*) *Sub-heading* The minimum tally of observed whole-plant species in a taphocoenosis, formation or other defined body of sediment. In the Molteno (And. & And., 2003, tab. 15, p. 21), we recognized 143 gymnosperm whole-plant species: this is the sum of MNSs recognized for each whole-plant genus in the formation.*

ATTRIBUTES OF SUCCESS (Gondwana Triassic) **
And. & And. (2003, pp 26–29).

Frequency (F): measure of repetitiveness of occurrence.

The number of subregions (degree squares), of the 85 across Gondwana yielding Triassic megaplants, from which the genus has been recorded. The tally is derived directly from the distribution maps published here, most being reproduced unchanged from our previous Molteno volumes (And. & And., 1983, 1989); see this vol., Pt. 1, pp 4–6.

Ubiquity (U): measure of general range of occurrence.

The number of superregions (continents), of the five making up Gondwana, from which the genus has been recorded.

Diversity (D): measure of speciation, radiation, variability.

The number of species recognized in the genus for the Gondwana Triassic (as documented in this volume).

Abundance (A): measure of quantity.

The average of the abundance figures (where 1% or greater) for the genus in those assemblages in which it occurs. The data are based exclusively on the Molteno, as clear abundance figures are rarely available for other formations.

Longevity (L): measure of duration of the lineage.

In our earlier Molteno works, duration was based on the number of international standard ammonite biozones between first and last recorded appearances. For the sphenophyte study, the duration in millions of years from first to last appearance in the Gondwana Triassic is recorded (the conversion is the number of ammonites biozones spanned, multiplied by 1.46 myrs per zone (And. & And., 2018, pt 2, p. 23)).

Evolutionary success (or prominence) – Can be measured in many ways, but is taken here as a combination of frequency, ubiquity, diversity, abundance and longevity – giving a **FUDAL** rating (And. & And., 2003, 2018).

Frequency – measure of repetitiveness of occurrence.

Ubiquity – measure of general range of occurrence.

Diversity – measure of speciation, radiation, variability.

Abundance – measure of quantity.

Longevity – measure of duration of the lineage.

In the Molteno Formation, for instance, *Dicroidium*, with a FUDAL rating of 188, was clearly the most successful plant genus, as it was throughout the Gondwana Triassic (And. & And., 2003, pp 26–29).*

EVOLUTION & GENETICS

“Evolution proceeds mostly by the accidental substitution of one or more of the letters (of the genetic code), followed by the winnowing of these mutations and their combinations through natural selection” (Wilson, 1992). The immense diversity of species derives from the astronomic number of rearrangements possible within the hugely lengthy sequence of nucleotide letters of the genetic code.

Evolutionary biology – Covers the broad array of disciplines – palaeontology, ecology, population biology, systematics, biogeography, ethology, cladistics, molecular evolution, etc. – focused on the evolutionary process and consequently the building of biodiversity.

Hox genes – Those genes that control (encode) the body plans of embryos of all animals, apparently from the first multicellular animals some 700 Ma back to fruit flies, elephants and human beings today. All mammals, for instance, have 38 different Hox genes. (Plants also have Hox genes, such as the MADS.box genes.)

Genetic code – The code contains *c.* 1 million nucleotide pairs in bacteria and 1 to 10 billion pairs in higher plants and animals (Wilson, 1992).

Macroevolution – “Evolution above the species level” (Stanley, 1979).

Microevolution – Evolutionary change within the species (Stanley, 1979).

Allopatric speciation (*geographic speciation*) – “The divergence to species level by populations that originally belonged to the same species but were isolated by a physical barrier such as a sea strait, river valley, or mountain range” (Wilson, 1992).

Parapatric speciation – The divergence to species level by a local population while remaining in genetic contact with other populations of the original species (Stanley, 1979).

Phyletic gradualism – Sympatric speciation. The evolution of one species into another through time. One species replaces another through a series of subspecies in an evolutionary lineage. Modification occurs through geological time in a single phyletic line (phylogenesis).

(This and the next two terms from And. & And., 1983, after Sylvester-Bradley, 1977).

Punctuated equilibria – Allopatric (geographic) speciation. A single species becomes ancestral to two or more descendant species through the splitting of the phyletic line (cladogenesis). Speciation occurs relatively rapidly such that transitional forms will rarely be preserved in the fossil record.

Reticulate speciation – Combines aspects of the previous two, involving both phylogenesis and cladogenesis. The central characteristic is the complex alternating isolation and hybridization of races.

Extinction – The termination of any lineage of organisms, from subspecies and species to classes and phyla (Wilson, 1992).

Renewal – Refers here to the re-establishment of diversity after a mass global extinction.

Adaptive radiation – “The rapid proliferation of new taxa from a single ancestral group” (Stanley, 1979).

RECONSTRUCTION GRADES (pen/pencil sketches) **

We follow, again, the methodology established in the earlier Molteno volumes. The system of grades was introduced in And. & And. (1989, p. 22) and reiterated in And. & And. (2003, p. 44).

RS was introduced in And. & And. (2018, pt 4, p. 84).

R1 – no intended reconstruction (catalogue number of individual given).

R2 – minor intended reconstruction; correcting and cleaning unnecessary or ambiguous noise (minor irregularities, distortions, breaks in detail) due to imperfections of preservation or incomplete preparation; based on a single specimen (catalogue number given).

R3 – intermediate reconstruction; completing or adding leaflets; based primarily on a single specimen (catalogue number given) but other members of the home palaeodeme may be consulted (assemblage code given).

R4 – extensive reconstruction (composite for palaeodeme); full frond, or other organ, reconstructed from a composite of specimens from a single palaeodeme (assemblage code given).

R5 – extensive reconstruction (composite for formation); as in R4 but based on a composite of specimens from sister palaeodemes (assemblage codes given).

RS – Reconstruction Schematic; where the sketch is no longer life-like, but is introduced to demonstrate comparative morphology.

ECOLOGY & PALEOECOLOGY

Biome – “A major category of habitat in a particular region of the world, such as the tundra of northern Canada or the rainforest of the Amazon basin” (Wilson, 1992).

Ecosystem – “The organisms living in a particular environment, such as a lake or a forest (or, in increasing scale, an ocean or the whole planet), and the physical part of the environment that impinges on them. The organisms alone are called the community” (Wilson, 1992).

Ecozone (habitat) – A physical or vegetational environment of a particular restricted kind, such as the riparian forests, braided-river sandbar meadows or floodplain woodlands of the Molteno Biome.*

Guild – “A set of species that live within a community in the same area and harvest the same food by similar means” (Wilson, 1992).

CLADISTICS

Aside from its rigour in revealing phylogenetic relationships, cladistics has a major role to play in biodiversity studies. Consider current knowledge of mammalian and lepidopteran phylogeny: the cladogram, in each case, brings into focus a considerable hidden diversity during the earlier phases of adaptive radiation of the group.

Cladistics – Phylogenetic taxonomy; a rigorous attempt – with each step subject to Popperian falsification – to construct phylogenetic trees based on a selection of morphological and/or molecular characters with polarized (primitive or derived) states.

Phylogeny – The evolutionary history of a specified group of organisms of any rank, with particular focus on the genealogical tree of lineages comprising the group.

Cladogram – Figure or phylogenetic tree showing the branching pattern of the group under study.

Lineage – “A single line of descent” (Stanley, 1979).

Clade – A cluster of lineages deriving from a common ancestor.

Monophyletic – Pertaining to a group of taxa sharing a common ancestor.

Polyphyletic – Pertaining to a group of diverse taxa not sharing a common ancestor.

Paraphyletic – Pertaining to a group of taxa including the last common ancestor and all descendants except for a few (usually only one or two) monophyletic subgroups.

Crown group – Includes the cluster of lineages expected to show all apomorphies (derived/advanced characters) of the extant taxa.

Stem group – Includes those forms (directly on the line to the extant group or on extinct side-branches) showing only some of the apomorphies of the extant taxa.

Sister group – That taxon or clade judge to share an immediate common ancestor with the group in question.

Plesiomorphic – Pertaining to the primitive state of a character.

Apomorphic – Pertaining to the derived state of a character.

INSECT DAMAGE (plant–insect interaction) **

See Part 1 (pp 14–27), Sampling & Occurrence, locality spreads

1. ✓ 1 indiv.
2. ✓✓ 2 or 3 indivs
3. ✓✓✓ common
4. ✓✓✓✓ widespread, >50% indivs
5. ✓✓✓✓✓ frequent (infestation), a high proportion of indivs

FOSSIL SLABS & SPECIMENS

Examples (see plates) given below in brackets.

Individuals – referring to particular, isolated (or attached), foliage or fruit specimens; see Aas 211 (pls 143, 144).

PRE/F/13487‘x’, ‘y’ (indicating separate individuals on a single surface on a single slab); see Kan 111 (pls 23–26).

Part & Counterpart – concerning the same individual, as seen/exposed on the two surfaces of a cleaved slab; see Lut 311 (pl. 53).

PRE/13506a,b (part & counterpart); see Kan 111 (pl. 31).

Flake – a smaller piece cleaved from the relevant surface of the slab to show further features of the individual embedded in the slab; see Kan 111 (pls 25, 26).

Reverse – the other side of the same slab.

PRE/F/3227 ‘z’ (indiv. on reverse of slab); see Kom 111 (pl. 48).

ABBREVIATIONS

TEXT (general & taxonomic)

indiv(s) – individual(s)

Org. att. – Organic attachment

2 m, 3 mm (with space, no full stops)

80–140 mm (n-dash in general text and on figures)

Pt 3 – Part 3

Fig. 3 – Figure 3, e.g. when noting a holotype for a taxon

fig. 3 – figure 3, when associated with a reference in brackets

t-fig. – text-figure

p. 14 – space after p.

pp – pages, with no full stop

Examples in cross-references:

(Pt 1, Chart 4, Fig. 1, p. 8); simplified to (Fig. 1, p. 8)

(Pt 3, Chart 2, pp 126(1), 127(1)); simplified to (pp 126–127)

When giving tallies of genera and species:

gen – genus, genera (with no full stop)

spp – more than one species (with no full stop)

sp – a single species (with no full stop)

When referring to new taxa:

sp. nov.

gen. et sp. nov.

Chart 2 (not Ch. 2, which could be confused with Chapter) in the current volume; Ch. 2 when referring to other works.

HYPODIGM CHART (Part 2, pp 102–115)

For the sake of brevity & space, we further abbreviate in special cases such as the Hypodigm charts.

pl, fig, t-fig – with no full stops;

figs 10(4,6,9), 11(15,16), 13(43,48) – with no spaces

MOLTENO LOCALITY CODES

The first three letters of the superlocality are followed by assemblage numerals and horizon abbreviation (e.g. for ‘Little Switzerland’, our code is Lit 111 Dic odo). See Part 1, Tab. 1, p. 7, for the full set of codes for the 100 Molteno TCs.

PLATES

Examples given below in square brackets

Umk 111 Dic 2spp – locality & taphocoenosis [see Part 4, pls 97–110]

Ref. pal. – Reference palaeodeme.

COLLECTIONS

BP/2 – Bernard Price/fossil plants; our earlier Molteno collections were made whilst doing our doctorates and working at the Bernard Price Institute for Palaeontology, Witwatersrand University, Johannesburg; now named Evolutionary Studies Institute (ESI).

PRE/F – Pretoria/Fossil, South African National Biodiversity Institute (SANBI); previously named National Botanical Institute (NBI).

The collection (as of March–July 2010) has been moved on loan to ESI.

SAM – South African Museum, Cape Town, which now falls under the Iziko Museums of South Africa.

REFERENCES & AUTHORS

And. & And. 1985 – Anderson, J.M. & Anderson, H.M. 1985 (as in previous volumes, we have abbreviated our names throughout in this way).

HMA – Heidi Marguerite Anderson

JMA – John Malcolm Anderson

ICN – International Code of Nomenclature for algae, fungi and plants (Melbourne Code 2011)

ICBN – International Code of Botanical Nomenclature (replaced by ICN)

PFN – plant fossil numbers (given for each new genus or species).

The “Plant Fossil Names Registry is based and maintained by the National Museum Prague since 2014 under the auspices of the International Organisation of Palaeobotany (IOP). The present modified version is in operation since June 2018.”

INDEX

Genera and species described or discussed in this volume.

A			
<i>Acrocarpus</i>	39	<i>Kannaskoppianthus matatiparvus</i>	46, 91
B		“ <i>matatiparvus/Rochipteris matati-</i>	134
<i>Baiera</i>	103	“ <i>folia</i>	
<i>Baiera cuyana</i>	103	“ <i>switzianthus</i>	45, 89
<i>Batiopteris</i>	50	“ <i>switzianthus/Rochipteris switzifolia</i> ..	132
C		“ <i>telemagnus</i>	42, 69
<i>Caytonia</i>	35	“ <i>telemagnus/Rochipteris telefolia</i> ..	126
<i>Caytonianthus</i>	39	“ <i>telepentatus</i>	49, 100
<i>Cetiglossa</i>	50	<i>Kannaskoppifolia</i>	50
<i>Chiropteris</i>	50, 102, 104	N	
<i>Chiropteris lacerata</i>	102	<i>Nystroemia</i>	50
“ <i>waitakiensis</i>	102	P	
“ <i>copiapensis</i>	102, 104	<i>Petriellaea</i>	34
“ <i>biloba</i>	102	<i>Polyspermophyllum</i>	35
<i>Crossotheca</i>	39	<i>Psymophyllum</i>	104
<i>Cyclopteris</i>	103	R	
<i>Cyclopteris lacerata</i>	102	<i>Rochipteris</i>	50–53, 102–104
D		<i>Rochipteris alexandriana</i>	103
<i>Dicroidium</i>	102	“ <i>copiapensis</i>	103–104
E		“ <i>chilensis</i>	104
<i>Eoginkgoites</i>	50	“ <i>cuneata</i>	103
F		“ <i>distivena</i>	56, 74
<i>Feraxotheca</i>	39	“ <i>etheridgei</i>	104
G		“ <i>ginkgoides</i>	104
<i>Ginkgo</i>	102	“ <i>incisa</i>	102–103
<i>Ginkgo digitata</i>	102	“ <i>komifolia</i>	60, 92, 93, 104
<i>Ginkgoites</i>	50, 104	“ <i>lacerata</i>	102–104
<i>Ginkgophytopsis</i>	50, 102–103	“ <i>lutifolia</i>	61, 94–97, 104
<i>Ginkgophytopsis lacerata</i>	102	“ <i>matatifolia</i>	59, 90, 91, 103
“ <i>tasmanica</i>	103	“ <i>nymboidensis</i>	103
“ <i>truncata</i>	104	“ <i>obtriangulata</i>	62, 98, 104, 140
<i>Glossopteris</i>	50	“ <i>penensis</i>	64, 100, 104, 144
<i>Gontriglossa</i>	50, 51	“ <i>pusilla</i>	65, 101, 104, 146
<i>Graciliglossa</i>	50	“ <i>rollerii</i>	57, 78–87, 103–104
K		“ <i>cf. sinuosa</i>	63, 99, 103, 142
<i>Kannaskoppia</i>	34–35, 102	“ <i>sinuosa</i>	104
<i>Kannaskoppia vincularis</i>	36, 66, 67	“ <i>switzifolia</i>	58, 88, 89, 103
“ <i>vincularis/Rochipteris vincularis</i>	124	“ <i>tasmanica</i>	103
<i>Kannaskoppianthus</i>	38–41	“ <i>telefolia</i>	55, 69–73, 102–104
<i>Kannaskoppianthus aasvoelensis</i>	44, 81, 83, 85, 87	“ <i>truncata</i>	103–104
“ <i>aasvoelensis/Rochipteris rollerii</i> ..	130	“ <i>turbata</i>	104
“ <i>irregularis</i>	43, 75	“ <i>vincularis</i>	54, 67, 68
“ <i>irregularis/Rochipteris distivena</i> ..	128	S	
“ <i>komanthus</i>	47, 92, 93	<i>Sagenopteris</i>	35, 50
“ <i>komanthus/Rochipteris komifolia</i> ..	136	<i>Sagenopteris salisburyoides</i>	103
“ <i>lutinumerus</i>	48, 95	<i>Sphenobaiera</i>	50
“ <i>lutinumerus/Rochipteris lutifolia</i> ..	138	W	
		<i>Walkomiopteris</i>	50

STYLE GUIDE FOR AUTHORS — REVISED 2019

GENERAL

Palaeontologia africana publishes papers in the field of palaeontological research and in related branches of the earth sciences. Copies are available for purchase individually or in sets. Back copies of volumes 1–48 are available electronically at the address below and in hard copy upon request at variable rates depending on shipping costs. Beginning with volume 49, *Palaeontologia africana* is available online only in pdf format at the following permanent address: <http://wiredspace.wits.ac.za/handle/10539/13253>. Direct all enquiries to:

The Editor, *Palaeontologia africana*
Evolutionary Studies Institute, University of the Witwatersrand,
Private Bag 3, WITS 2050, South Africa
Telephone: [+27-11] 717-6690/6682
Fax: [27-11] 717-6694
E-mail: jonah.choiniere@wits.ac.za

Submission of a manuscript for publication will be taken to indicate that the material is original and has not been submitted for publication elsewhere.

Authors reserve copyright for their articles. Manuscripts are published under the Creative Commons Attribution 4.0 Unported License (CC BY 4.0; <https://creativecommons.org/licenses/by/4.0/>). This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. Manuscripts and illustrations should be submitted to the following e-mail address: palaeontologia.africana@gmail.com

PREPARATION AND SUBMISSION OF MANUSCRIPTS

Manuscripts

Manuscripts must be submitted electronically, and formatted to fit on one side of A4 size paper in double spacing throughout and with margins at least 25 mm wide all around. All pages must be numbered consecutively in the centre of the top margin, beginning with page 1 on the title page.

The text should be saved in either .doc, .docx, or .rtf format, with a file name that clearly identifies at least the lead author and keywords from the title.

ORCID iDs

Corresponding authors are required to provide their ORCID iDs, which will be displayed on the first page of publications. All other authors are strongly encouraged to provide ORCID iDs.

Layout

Except in the case of short communications and technical reports, manuscripts should normally be divided into appropriate conventional sections set out in the following order: title, abstract, introduction, body of text (subdivided as appropriate), acknowledgements, references, figure legends, tables.

Title

The title should be concise and should reflect the contents clearly. Names of new biological taxa proposed in the manuscript should not be included in the title. If the title is long a suitable abbreviated running title must be provided.

The title must be followed on a separate line by the authors' name/s and institutional address/es. Institutional affiliations, mailing addresses, and e-mail addresses of all authors must be provided. In multi-authored contributions, the institutional address and e-mail of each individual must be linked to the relevant name using superscript numbers.

Abstract

An informative abstract not exceeding 300 words must be provided. Omit this section in Technical Reports.

Keywords

At least five keywords should be provided immediately after the abstract. Keywords must not appear in the title of the article.

Introduction and main text

The manuscript should be divided as appropriate into conventional sections (e.g. Introduction, Materials and Methods, Results, Discussion).

Acknowledgements

Authors should include only those acknowledgements that are truly warranted.

References

References are listed at the end of the manuscript, beginning on a new page. Under this heading, authors must list only published works that have been cited in the text.

Unpublished works, even those that are 'in press', must not be included unless full bibliographic details can be provided, including pagination. However, formal theses and dissertations, even though unpublished, may be listed provided full details are supplied; this must include reference to the institution where the master copy is lodged. Work that is 'in preparation' and 'personal communications' may be referred to in the text, but must not be included in the list of references.

The list of references must be arranged alphabetically, then chronologically, according to the layout of the examples below. **An Endnote™ style is available for authors to download at the following address:** <http://hdl.handle.net/10539/17375>. Leave one blank line between each reference, and do not indent or otherwise format each entry. The layout sequence is:

- (i) Author's name(s) and initials (in uppercase only). In the case of multi-authored manuscripts, successive authors' names should be separated by commas, with an ampersand (&) between the penultimate and last name;
- (ii) Year of publication (not in brackets). If more than one paper by the same author is listed for the same year, successive entries must be designated by placing the letters a, b, c, etc., after the year of publication;
- (iii) Full title of paper. Use capitals only for the first letter and for proper names. Generic and specific names must be italicized, unless such names themselves fall within an italicized title, in which case the names should be in regular (non-italic) script;
- (iv) Full (unabbreviated) title of journal, book or other source, in italics. Book titles should be followed by the edition (if other than the first), the place of publication and the name of the publisher.
- (v) Volume specification of journal: i.e. series (if applicable), volume number (in

bold), part number (if any) in brackets, pagination (first and last page).

Examples of reference citations (to save space, the blank line between successive entries has been omitted):

ANDERSON, H.M. 1976. *A revision of the genus Dicroidium from the Molteno Formation*. Unpublished Ph.D. thesis, University of the Witwatersrand, Johannesburg.

ANDERSON, H.M. & ANDERSON, J.M. 1970. A preliminary review of the biostratigraphy of the uppermost Permian, Triassic and lowermost Jurassic of Gondwanaland. *Palaeontologia africana* 13, 1–22.

CROMPTON, A.W. 1962. On the dentition and tooth replacement in two bauriiform reptiles. *Annals of the South African Museum* 46(9), 231–255.

HOPSON, J.A. & BARGHUSEN, H.R. 1986. An analysis of therapsid relationships. In: Hotton, N., MacLean, P.D., Roth, J.J. & Roth, E.C. (eds), *The Ecology and Biology of Mammal-like Reptiles*, 159–168. Washington, Smithsonian Institution Press.

ROMER, A.S. 1966. *Vertebrate Palaeontology* (3rd edn). Chicago, University of Chicago Press.

ROMER, A.S. 1973. Permian reptiles. In: Hallam, A. (ed.), *Atlas of Palaeobiogeography*, 159–168. Amsterdam, Elsevier.

VAN DER MERWE, N.J., LEE-THORP, J.A., THACKERAY, J.F., HALL-MARTIN, A., KRUGER, E.J., COETZEE, H., BELL, R.H.V. & LINDEQUE, M. 1990. Source-area determination of elephant ivory by isotopic analysis. *Nature* 346, 744–746.

PERIERA, L.M. 2009. The Wits Online Phytolith Database. University of the Witwatersrand, Johannesburg, South Africa. Online at: <http://web.wits.ac.za/Academic/Science/GeoSciences/BPI/Research/WOPD/> (accessed 15 February 2010).

Reference citations in the text should give the name of the author and the date on each occasion, and substitutes such as *op. cit.*, *loc. cit.* should not be used, e.g. 'Smith & Jones (1943) suggested that ...', '... extinction rates (Smith & Jones 1972) and other factors ...'. In the text, successive references by the same author should be separated by commas, and those of different authors by semi-colons: (Brain 1990, 1991; Hughes 1961; Smith & Jones 1972: 231). Please note we use the standards of the International Commission on Stratigraphy for spelling and capitalization of chronostratigraphic intervals.

Headings

Three orders of headings are used.

FIRST ORDER, printed in bold capitals and left-aligned.

Second order, printed in bold upper and lower case and left-aligned.

Third order, printed in upper and lower case italics and left-aligned.

Headed sections and paragraphs should not otherwise be numbered or lettered in the manuscript.

Tables

Tables must be set out on separate sheets, with second-order headings for each. They are numbered consecutively in arabic numerals (e.g. Table 1, Table 2). Please indicate the position of each table by notation in the text (e.g. "<<Insert Table X here>>").

When referring to Tables in the text the word 'Table' is spelt out in full and given a capital initial letter, e.g. Table 2. Table legends should be placed at the end of the body text, after the References section. Please format as follows: **Table X**. Text.

Figure legends

Figure legends should be placed at the end of the body text, after References. When referring to figures in the text the word is abbreviated with a capital initial letter, e.g. Figs 2–4. Please format as follows:

Figure X. Text. **A**, text. **B**, text. **C**, text. Scale bar(s) equal: **A**, 1 cm; etc.

Figures

All illustrations are termed Figures (the word is to be spelt out in full with a capital initial letter), and they are numbered consecutively with arabic numerals. *Palaeontologia africana* only accepts electronic figures.

Please mark the position of figures by inserting the following identifier at an appropriate position in the body text: "<<Insert Figure X here>>".

All figures should be designed for same-size printing or slight reduction in the final form. Maximum printed sizes for figures are as follows: full page, height 245 mm × width 175 mm; column width 87 mm. Tip-ins and fold-outs will require special arrangements with the editor and will incur costs.

For initial submission, .pdf, .jpeg, or .png figures with resolution of 150 dpi are acceptable. Upon acceptance, authors will be asked to provide high-resolution 300 dpi (black and white or colour photographic images) or 600dpi (mixed line and photographic images), or 1200dpi (line art). .tif, .wmf, .eps, .pdf or .png figures. A guide to preparing high-quality figures is available from the Editor. Lettering and label lines should be added in a vector editor such as Adobe Illustrator or Inkscape. Colour illustrations welcomed at no cost to the author(s).

Scale should be represented by suitably labelled scale bars of appropriate size, with the units of measurement specified in the caption; avoid reference to magnification in captions.

Graphs should preferably be in one of the vector (not bitmap) formats (.eps, .wmf, .svg, .emf, or .pdf). Diagrams prepared in Excel should be saved in one of the following formats: .wmf, .emf, .eps, .pdf, .svg.

Figures with large file sizes may be submitted on CD-ROM or via FTP sites such as Dropbox.com or Wetransfer.com.

Numerical data

The metric system (SI units) is to be used throughout for all numerical data, with standard abbreviations. If there is good reason for using units other than metric, the SI metric equivalents must be given in brackets.

ACCEPTANCE OF PAPERS

All manuscripts offered to the Editor are submitted to two or more referees for critical appraisal, and the substance of the referees' comments is forwarded to the author. The Editor will advise the author whether or not the manuscript is accepted for publication, based on the substance of the reviews.

If the manuscript is accepted, one set of proofs (usually page proofs) will be submitted to the author for careful checking and these must be returned as soon as possible. The cost of any additions or major alterations to the text at proof stage may be charged to the author. Further proofs may be submitted to the author if the Editor considers it to be necessary or desirable.

As I noted twenty years ago, in my experience there is no set of fossil plant assemblages that has been collected with the same intensity, uniformity of approach, and care that John and Heidi have lavished on the Molteno Formation. The scale and scope of their effort, which has resulted in a collection of more than 30 000 slabs from more than 40 localities and 100 different plant fossil assemblages, is unequalled. This huge effort in the field has been joined with intensive and equally methodical work in the laboratory and this volume presents John and Heidi's discoveries and observations in almost overwhelming detail. The presentation of results is also enlivened by John and Heidi's considerable artistic skills. Numerous locality sketches and reconstructions of ancient plants and vegetation are an important part of this book, and the line drawings of individual plant fossils, done with extreme care, are especially valuable. What emerges from John and Heidi's diligence and dedication to the plant fossils of the Molteno Formation is a more detailed glimpse into Triassic vegetation than that provided by any other set of localities anywhere in the world.

Through their continuing work on the plant fossils preserved in the Molteno Formation, John and Heidi are leaving a truly impactful legacy: work that is of disproportionate value for understanding the plants of the past, and what they tell us about the plants of the present.

Sir Peter Crane FRS

President Oak Spring Garden Foundation, U.S.A. (Oct. 2022)

Past Director, Royal Botanic Gardens, Kew, London, U.K.

This manuscript will form another milestone in the authors' formidable task to achieve a complete documentation and systematic treatment of the famous Triassic Molteno-biome plant fossils. The monumental efforts in successful prospection, collecting, preparing, photographing, describing and interpreting the Molteno Fm plant-fossil assemblages in general demand greatest respect, and so does this work about a particularly interesting group of gymnosperms.

Prof. Dr. Benjamin Bomfleur

Institut für Geologie und Paläontologie

University of Münster, Germany

Peer review, *Molteno Kannaskoppia* volume (May 2023)

The present *Kannaskoppia* volume will be our 8th in the Molteno series to be published; leaving a further four volumes to be completed – ending with the overall Molteno synthesis.

Having begun our Molteno journey in around mid-1967, this will then have been a 60-year marathon. A marathon exploring – through our particular window – the heyday of the gymnosperms at the heart of Gondwana midway through the Triassic. Peering through a window at a most special moment in Earth history – at the height of the Triassic explosion of life in the aftermath of the end-Permian Extinction. A marathon one would not have exchanged for anything.

John M. Anderson

Pretoria, South Africa (2020)

Extract from Preface, *Molteno Kannaskoppia*

