(SS33) Southern Hemisphere floras: unique insights into the biology and ecology of Southern Hemisphere ecosystems

Date: August 29, 30
Place: Room 5334 (oral), Room 6317 (poster)
Organizers: David Cantrill & Stephen McLoughin
Contact email address: David.Cantrill@rbg.vic.gov.au
Purpose: Palaeobotanical research has largely been focused on Northern Hemisphere sequences resulting in an unequal distribution in our knowledge of fossil biotas. Within the Southern Hemisphere are several key deposits, some better known than others, which reveal exquisitely preserved plants. With detailed investigation these deposits provide the opportunity to reveal information about the biology and ecology of Southern Hemisphere ecosystems through geological time. This symposium aims to raise awareness in particular to these deposits in order to stimulate further research.

Oral Presentation

Aug. 29 [AM1] Room: 5334

Chair: David Cantrill

9:00-9:20 **Archaeopterid root anatomy and architecture: Evidence from permineralized specimens of Famennian age from Morocco** SS33-O01 (333)

Brigitte Meyer-Berthaud, Anne-Laure Decombeix

9:20-9:40 **Diversity of Late Devonian plants in Australia: contribution of the permineralized assemblage of Barraba, NSW** SS33-O02 (93)

Anne-Laure Decombeix, Brigitte Meyer-Berthaud, Mathilde Evreinoff

9:40-10:00 **Cryptic diversity of a *Glossopteris* forest: Permian silicified peats of the Prince Charles Mountains, Antarctica** SS33-O03 (483)

Ben J. Slater, Stephen McLoughlin, Jason Hilton

10:00-10:20 **Mycorrhizal-like associations in the Permian seed fern *Glossopteris* from Antarctica** SS33-O04 (170)

Carla J. Harper, Thomas N. Taylor, Michael Krings

Aug. 29 [AM2] Room: 5334

Chair: Stephen McLoughlin

10:50-11:10 **Well-preserved impression/compressions of *Trizygia speciosa*, including the first cones and spores of this widespread Gondwanan sphenophyte, from the latest Permian of South Africa** SS33-O05 (414)

Rose Prevec, Lara Sciscio, Cindy Looy, Robert A. Gastaldo

11:10-11:30 **How productive were the polar forests of the Permian and Triassic of Antarctica?** SS33-O06 (439)

Patricia E. Ryberg, Edith L. Taylor

11:30-11:50 **Micro and megaspore bearing equisetalean fertile shoots in the late Early Permian**

***Glossopteris* assemblage of Indian Gondwana** SS33-O07 (109)

Ashalata D'Rozario, Manju Banerjee

11:50-12:10 **Early Cretaceous angiosperms of southeastern Australia- no longer early** SS33-O08 (529)

Anne-Marie P. Tosolini, Barbara E. Wagstaff, David J. Cantrill, Robert A.E. Hills, Stephen J. Gallagher

Aug. 29 [PM2] Room: 5334

Chair: David Cantrill

14:30-15:10 **[Keynote] Southern Hemisphere hot spring floras: Devonian to recent** SS33-O09 (67)

Alan Channing, Alba Zamuner, Hong-He Xu, Dianne Edwards

15:10-15:30 **A spore-pollen record of Early Cretaceous southern high palaeolatitude climate and vegetation variability** SS33-O10 (551)

Barbara E. Wagstaff, Stephen J. Gallagher, Jessica K. Trainor

15:30-15:50 **The opalized mid-Cretaceous ecosystem of Lightning Ridge, eastern Australia** SS33-O11 (325)

Stephen McLoughlin, Christian Pott

Aug. 29 [PM3] Room: 5334

Chair: Alan Channing

16:20-16:40 **Mid-Cretaceous south polar palynology & floristic trends of the Tupuangi Formation, Chatham Islands, New Zealand** SS33-O12 (323)

Chris Mays, Jeffrey D. Stilwell

16:40-17:00 **Aquatic plant communities from the Upper Cretaceous La Colonia Formation, Patagonia, Argentina** SS33-O13 (143)

María A. Gandolfo, N. Ruben Cúneo, Elizabeth J. Hermsen, Julieta Gallego

17:00-17:20 **Cretaceous plant mega- and meso- fossils from James Ross Island, Antarctica** SS33-O14 (262)

Jiří Kvaček

Aug. 30 [AM1] Room: 5334

Chair: Stephen McLoughlin

9:00-9:20 **The palynology and megaspores of Cretaceous (Aptian) high latitude, vertebrate-bearing fluvial sediments from the Gippsland Basin, south-eastern Australia** SS33-O15 (68)

Katherine E. Charlton, Barbara E. Wagstaff, Doris Seegets-Villiers, Anne-Marie P. Tosolini, Stephen J. Gallagher

9:20-9:40 **An early Eocene macrofossil flora from the Mwadui kimberlite pipe, Tanzania** SS33-O16 (16)

Marion K. Bamford, David J. Cantrill

9:40-10:00 **Is southern Africa different? An investigation of the relationship between leaf: physiognomy and climate in southern African mesic vegetation** SS33-O17 (495)

David C. Steart, Marion K. Bamford, Robert A. Spicer

Poster Presentation

Aug. 29 [PM1] Room: 6318

13:30-14:30 **Palynofacies analyses of Lachman Crags Member, Santa Marta Formation (Santonian-Campanian) of the north-west James Ross Island, Antarctica** SS33-P01 (63)

Marcelo de Araujo Carvalho, Renato Rodrigues Cabral Ramos

SS33-O01 (333)

Archaeopterid root anatomy and architecture: Evidence from permineralized specimens of Famennian age from Morocco

Brigitte Meyer-Berthaud, Anne-Laure Decombeix

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It is generally agreed that evolution of the root systems paralleled that of aerial shoots in the Devonian, and that the increase in size leading to the advent of trees had a considerable impact on terrestrial landscapes, geochemical cycles and global climate during the Middle and Late Devonian. Among early lignophytes, direct evidence of the size and complexity of the root systems is, however, scant. Recent discoveries showed that Middle Devonian aneurophytalean progymnnosperms possessed rhizomatous stems bearing superficial or shallow, narrow roots attached in clusters (Stein et al. 2012. Nature 483: 78–81). The root systems of the closely related archaeopteridalean progymnosperms trees, are expected to be much more extended and complex. Current evidence, limited to fragmentary specimens of small size and two specimens at the stem-root transition, has not provided yet sufficient information for substantiating these expectations and for validating the root cast identifications realized in paleosol studies (i.e. Mintz et al. 2010. PALAIOS 25:85–96). Five anatomically preserved root specimens, corresponding to the *Trifilievii* and *Erianum* types of *Callixylon* wood sensu Orlova and Iurina (2011, Paleontological Journal 45: 580–589) are described from a marine deposit of Famennian age in southeastern Morocco. They are 25 to 80 mm in diameter and show abundant secondary xylem. These specimens provide new information on the anatomy of archeopterid roots, in particular on the secondary phloem, which contains fibers, and on the stele. The latter is represented by four- and five-lobed protosteles, the number of lobes being unrelated to the size of the stele or of the root. The Moroccan material also documents new elements of the architectural complexity of the archaeopterid root system which involves: (1) at least three orders of large roots and one order of rootlets, (2) the endogenous origin of most roots including those of large diameters, (3) the indeterminate growth of large roots, (4) a probable separation of functions between large roots devoted to anchorage and rootlets for absorption of water and nutrients. The archaeopterid root system, however, also retained dichotomy as an alternative branching process for large roots. Within the early lignophytes, the complex and extensive root system of archaeopteridalean progymnosperms thus represents a significant improvement in terms of exploration and exploitation of the underground space compared to that of the aneurophytales, which may explain in part their ability to evolve/acquire a tree habit and be successful in a wide range of

habitats during the Late Devonian.

Keywords: Late Devonian, Gondwana, progymnosperm, root system complexity, endogenous roots.

SS33-O02 (93)

Diversity of Late Devonian plants in Australia: contribution of the permineralized assemblage of Barraba, NSW

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Most Late Devonian plant assemblages from Australia described to date are preserved as compressions/impressions. They document a low diversity flora dominated by the arborescent lycopsid *Leptophloeum*. A notable exception is the small assemblage of permineralized plants from the late Famennian locality of Barraba, in New South Wales. These specimens document the presence of taxa not represented in the compression/impression assemblages and show that the Late Devonian floras of Australia were more diverse than traditionally thought. After the initial description of the cladoxylopsid *Polyxylon* by Chambers and Regan (1986), further work on the Barraba locality was initiated during recent years based on museum specimens (Museum Victoria, Melbourne) and new material collected in 2004. Additional evidence of the presence of the cladoxylopsids in Australia is provided by a *Hierogramma*-like axis, and possibly by a small axis that represents a new taxon. The presence of the cosmopolitan progymnosperm genus *Archaeopteris*, which was only represented in Australia by rare compressions/impressions of foliage resembling *A. halliana*, is supported by the occurrence of *Callixylon* wood of the *Trifilievi* type. A *Kalymma* rachis (Calamopityales) represents the oldest evidence of seed plants in Australia. Altogether, the ferns s.l. and lignophytes from Barraba reveal important similarities at the generic level with contemporaneous floras from Laurussia but also some degree of endemicity. Our most recent work has focused on the lycopsids, which are represented in the assemblage by 2 specimens: (1) a bisporangiate cone about 5 cm wide and 7.5 cm long, and (2) a small leafy axis 8 mm in diameter. The cone, a unique museum specimen, was imaged using High Resolution X-ray Computed Tomography at the European Synchrotron Radiation Facility in Grenoble, France. This allowed for a non-destructive study of the specimen and provided an extremely detailed 3D reconstruction of its morphology and anatomy. In addition, micro- and megaspores were isolated from the specimen and observed using SEM. All the gathered data suggests that the cone represents a new morphotaxon. The small leafy axis, studied with serial peels and thin-sections, shows significant differences from *Leptophloeum* axes that occur as compressions/impressions at the locality. Its anatomy is very similar to that of the cone axis and it is likely that these two specimens correspond to the vegetative and fertile parts of a same plant. They demonstrate the presence in the Late Devonian of Australia of a new lycopsid taxon that was probably growing in a different environment than *Leptophloeum*.

SS33-O03 (483)

Cryptic diversity of a *Glossopteris* forest: Permian silicified peats of the Prince Charles Mountains, Antarctica

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A Middle Permian silicified peat capping a coal seam in the Bainmedart Coal Measures of the Prince Charles Mountains, East Antarctica, accumulated from the remains of a community of mire plants dominated by *Glossopteris*. Observations of the peat blocks in thin-section and scanning electron microscopy of materials extracted from the silicified peats through bulk maceration reveal several cryptic elements of the peat-forming community and demonstrate a range of biological interactions. New elements of the peat mire include diminutive herbaceous lycophytes (and their dispersed megaspores), a diversity of fern sporangia, an array of seed morphotypes and evidence for a range of invertebrate feeding strategies targeting the *Glossopteris* plant. In addition, an assortment of fungal groups in a variety of associations with other organisms are represented within the peats.

Keywords: animal-plant interaction, silicified peats, *Glossopteris*, Fungi, Antarctica, Permian.

SS33-O04 (170)
Mycorrhizal-like associations in the Permian seed fern *Glossopteris* from Antarctica

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The study of plant-fungal interactions in ancient ecosystems is an emerging area of focus in paleomycology. In extant ecosystems, one of the most significant interactions are mycorrhizal symbioses, which are estimated to occur in approximately 92% of all modern plant groups and are necessary for the uptake of multiple macronutrients. Surprisingly, there is a paucity of information regarding the occurrence of mycorrhizal symbioses in many of the extinct plant groups, including the seed ferns. The Glossopteridales, an extinct group of Gondwanan Paleozoic seed ferns that dominated the Permian, including Antarctica, are poorly understood relative to fungal interactions. Through the use of thin sectioning techniques, we report the first evidence of vesicular-arbuscular mycorrhizal-like associations in the Glossopteridales. The fungus is characterized by large septate hyphae that colonize the cortical cells of the *Vertebraria* root in a serpentine or helical pattern that closely resembles *Paris*-type arbuscules. There are numerous spheroidal to oblong vesicles present as well. The fungus is typically found 2 to 3 cell layers beneath the epidermis in roots with an intact cortex i.e., no separation between vascular cylinder and cortex. The fungus is only found in the young rootlets of *Vertebraria* and is absent in roots containing secondary xylem with characteristic air spaces. This may suggest that the mycorrhiza played an essential role during the early establishment of the roots. This find provides unequivocal evidence for the antiquity of mycorrhizal associations in the fossil record of certain seed plants in addition to providing further insight into the structure of specific Permian paleoecosystems. Moreover, this discovery adds a new perspective to the biology of the Glossopteridales and at least one of the environments in which they lived. Together with the data on the anatomy and physiology of these plants, and novel evidence of fungal associations provides new paleoecological insights that may help to explain the dominance of the glossopterid seed ferns in the Permian of Gondwana. These findings add to our increasing knowledge base of the complex interactions in ancient ecosystems and evolutionary insights between plants and fungi.

Keywords: fungi, arbuscules, *Vertebraria*, Glossopteridales, Paleozoic.

SS33-O05 (414)

Well-preserved impression/compressions of *Trizygia speciosa*, including the first cones and spores of this widespread Gondwanan sphenophyte, from the latest Permian of South Africa

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The Wapadsberg Pass plant fossil locality, Eastern Cape Province, South Africa, has produced one of the youngest *Glossopteris*-dominated floras in the world, situated 70 m below what is generally considered to be the Permian/Triassic boundary on the basis of regional vertebrate biostratigraphy. Although of unusually low diversity for a Changhsingian glossopterid flora, the quality of impression fossil preservation is high in this autochthonous deposit that is preserved in a possible reworked ash. This has resulted in the preservation of very delicate structures including over 40 cones attributed here to the sphenopsid *Trizygia speciosa*. Although this sphenophyte is widespread across Gondwana (it was first described from India by Royle in 1839), fertile organs have not been reported previously. The cones are mostly dispersed, but several are attached to stems typical of *Trizygia*, that are gracile with expanded nodes. This differs from the broader forms of *Paracalamites* that can be attributed to *Phyllotheca australis*, the only other, fairly rare, sphenophyte found at the locality. Spores have been isolated from compression material within cones. Although known from a number of Late Permian (Lopingian) localities in South Africa, well-preserved specimens of *T. speciosa* are rare, typically with only one or a few consecutive leaf whorls preserved. However dense mats of stems with multiple leaf whorls are present, at the Old Wapadsberg Pass. Examination of this unusual fossil flora has provided insights into the morphology of a little-understood sphenopsid, as well as providing a glimpse of life prior to the greatest extinction event in Earth's history.

Keywords: palaeobotany, Karoo Basin, Glossopteris flora, Changhsingian, Permian-Triassic extinction.

SS33-O06 (439)

How productive were the polar forests of the Permian and Triassic of Antarctica?

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The in situ fossil forests of the Permian and Triassic of Antarctica provide a wealth of information on landscape dynamics. The anatomically preserved tree rings and *in situ* tree stumps allow for a broad range of studies from the level of the individual plant all the way up to the ecosystem. Previous studies have revealed a unique growth habit for these high latitude forests with a large amount of earlywood (cells with large lumens and thin walls) with very little latewood (cells with small lumens

and thick-walled cells). This growth regime is not seen in any environment today and the resulting biomass of these forests may differ from modern day forests with the same density. Forest densities were calculated by previous researchers (Cúneo et al. 1993, 2003, Knepprath 2006; Gulbranson et al. 2012) and forest height was calculated using the formula presented by Niklas (1994) and the diameter of the *in situ* trunks. Volume of each tree was determined using the formula for the volume of a cylinder as fossil logs preserved in deposits showed little taper. The density of the wood was calculated using the program ImageJ. The mass of the trees for the Late Permian Mt. Achernar forest averaged 65 kg, and for the Middle Triassic Gordon Valley 533 kg. The Mt. Achernar forest has smaller diameter stumps and is believed to be a young forest while the Gordon Valley forest is considered more established accounting for the differences in bole weight. The density of the Mt. Achernar forest (2134 trees/ha, Cúneo et al., 1993) and the average weight of a trunk results in the production of 171 Mg/ha. For the Gordon Valley forest (260 trees/ha, Cúneo et al., 2003) with the average weight of a tree bole as 533 kg, the biomass of the forest calculates to 140 Mg/ha. Comparing these numbers with modern day forests, e.g., deciduous forests from the northeastern United States (Buchholz et al., 2011), values are comparable between these fossil forests and extant. In conclusion, although these polar forests were growing in extreme environmental light conditions, forest productivity was on a par with forest production in some modern-day temperate ecosystems.

Keywords: fossil forests, Antarctica, Permian, Triassic, productivity.

SS33-O07 (109)

Micro and megaspore bearing equisetalean fertile shoots in the late Early Permian *Glossopteris* assemblage of Indian Gondwana

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Bracteate micro and megasporangia bearing fertile equisetalean shoots recovered from the late Early Permian (Barakar Formation) sediments of Saharjuri Basin, Jharkhand, have revealed significant morpho-anatomical features for a closer comparison with the euramerian fertile calamitalean taxa. The leafless coalified axes are articulated with ribs continuous across the nodes. The fructifications are strobili; occur in groups or single on a small stalk attached to the nodes. Whorls of bracts occur at the nodes and are basally fused and free at the distal part. Sporangia are borne at the base of the bracts. The microsporangiate structure is named as *Rajmahaliastachys elongata* and the megasporangiate one as *R. oblonga.* Microsporangium contains numerous *in situ Calamospora* type spores. The megasporangium contains fewer large megaspores. The sporangial wall of the megasporangia, however, has almost degenerated during the process of maceration. *Rajmahaliastachys* with its unique combination of the characters of ribs continuous across the nodes is similar to *Archaeocalamites,* and its bracteate cones attached to the node of the leafless axis is similar to fertile calamitalean taxa and unlike any member of the equisetalean families. The genus is thus assigned to a new family Rajmahaliastachyaceae. The equisetalean fertile shoots described so far in the Euramerican Permo-Carboniferous flora are different from *Rajmahaliastachys elongata* and *R. oblonga* in the occurrence of a distinct sporangiophore and in the heterosporous nature of the fructifications. *Rajmahaliastachys* occurs in a rich assemblage of sphenophyllalean and equisetalean plants similar to assemblages of the Euramerian and Cathaysian phytoprovinces in addition to the presence of Gondwanan *Glossopteris*, *Gangamopteris* and *Annularia* plants. *Rajmahaliastachys* is similar to the equatorial euramerian calamitalean taxa *Palaeostachya.* The anatomical features of the bracts of the fertile organs of *Rajmahaliastachys* suggest xerophytic adaptations. A warm, humid

climate with dry intervals accounting for xerophytic features is suggested for the late Early Permian in the eastern Indian basins.

Keywords: equisetalean cone, *Rajmahaliastachys elongata*, *R. oblonga*, heterosporous, palaeoclimate and palaeoecology.

SS33-O08 (529)

Early Cretaceous angiosperms of southeastern Australia- no longer early

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Non-marine sediments of the Otway Group host some of the best Lower Cretaceous floristic assemblages in Australia. These sediments accumulated in high-energy braided-river environments within the Otway Basin during the rifting of Australia from Antarctica. These successions incorporate important reference sections for several of the Australian Cretaceous palynostratigraphic megaspore stratigraphic and phytostratigraphic zones. Plant communities of the Otway Basin were situated at 65ºS and are associated with vertebrate and invertebrate faunas, sedimentary features, and isotopic evidence indicative of high humidity and seasonal frigidity. The Devils Kitchen locality, exposing the Eumeralla Formation, has been dated as Albian, based on the presence of *Phyllopteroides dentata* leaves and taxa of the *Coptospora paradoxa* Zone. Araucarian and other broad-leafed conifers, mycorrhizal root nodules and marseliaceous ferns have been documented from the site. We use an interdisciplinary approach, incorporating sedimentology and plant fossils, to improve interpretations of floral turnover, age and depositional environments that aid palaeogeographic and palaeoclimatic reconstructions of southeastern Australia. The Eumeralla Formation incorporates 14 broadly defined sedimentary facies referable to three facies associations: gravelly channel; sandy channel/crevasse splay; and floodbasin assemblages; deposited within alluvial valley settings. Seven biofacies including a fine plant detritus association with four sub-biofacies have been defined in terms of the dominant fossil plant taxa, the plant organs represented, their preservational style, and their relationships to other biofacies and lithofacies. The Devils Kitchen flora contained many elements in common with Neocomian and Aptian to lower Albian floras of the Gippsland Basin but some new groups are represented (strap-leafed araucarians, *Molaspora*-producing heterosporous ferns, broader leafed angiosperms) and some older groups apparently disappeared (*Taeniopteris* and *Ginkgo* species). The reasons for the disappearance of these groups are unknown but their niches were probably exploited by diversifying conifers by the mid-Cretaceous, rather than angiosperms, which are interpreted to have been herbaceous plants of the floodplain undergrowth. New palynological studies of Devils Kitchen have identified the presence of *Appendicisporites distocarinatus*, a Cenomanian index. This extends the age of the Otway Group into what was previously considered to be an interval of non-deposition in the Otway and Gippsland basins and, thus, redefines angiosperms from this locality as Late Cretaceous.

Keywords: palaeobotany, palynology, biofacies, biostratigraphy, palaeoclimate.

SS33-O09 (67)

Southern Hemisphere hot spring floras: Devonian to recent

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The geological record of hot spring deposits is scant. However, the exceptional quality of plant-preservation, plus *in situ* fossilization in a setting with well-constrained physical and chemical environmental parameters, mean that such deposits can provide remarkable insights on plant anatomy and palaeoecology. This presentation provides the latest findings from three major geothermal provinces of the Southern Hemisphere. When viewed in chronological order, the deposits reveal the evolution of hot spring plant communities through time from a lycophyte-dominated late Palaeozoic flora (latest Devonian/Carboniferous, Drummond Basin, Queensland, Australia), to sphenophyte- and fern-dominated Mesozoic flora (Jurassic, Santa Cruz Province, Argentina) and angiosperm dominated Cenozoic flora (Taupo Volcanic Zone, New Zealand). Arborescent plants (e.g. gymnosperms) occur infrequently in the deposits as transported material, or where former dryland environments are immersed by prograding margins of geothermally influenced wetland. Collectively, the plants preserved *in situ* reveal a set of common anatomical, biological and ecological characteristics that have allowed the successive plant groups to colonise this stressed habitat. The most commonly preserved plant group from each deposit has living analogues that occur in modern wetland environments. Clear evidence of anatomical adaptation of the fossil species to wetland conditions, is provided by modified tissues such as aerenchyma, lacunae and reduced vascular tissues. Other anatomical adaptations provide evidence of high water use efficiency despite growth in a waterlogged environment e.g. reduced leaves, thick cuticles and sunken or protected stomata. This implies adaptation to physiological- (rather than actual-) drought caused by the presence of brackish water conditions and high concentrations of phytotoxic metals and metalloids in geothermal wetlands. Tolerance of heavy metals and high levels of in-life silicon accumulation appear to link the living analogues of the various fossil groups. A long-standing role in stress amelioration is hypothesized for this element. Other features common to all three floras include low species diversity and plants characterised by clonal-growth, vegetative (rather than sexual) reproduction and small size. Active hot spring areas of the Pacific "Ring of Fire" (e.g. the Taupo Volcanic Zone, New Zealand) provide habitats for living analogue examples of many of the plant groups represented in the fossil record of this extreme environment.

Keywords: geothermal, wetlands, ecophysiology, silica, sinter.

SS33-O10 (551)

A spore-pollen record of Early Cretaceous southern high palaeolatitude climate and vegetation variability

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Detailed "Quaternary-style" quantitative spore-pollen counts of spores and pollen from a southern high palaeolatitude terrestrial sequence in the Gippsland Basin, southeast Australia have revealed strong vegetation and climate variability during the Albian. This variability is stronger than

previously suggested by broad scale Early Cretaceous vegetation and climate reconstructions. Qualitative and quantitative data from subsurface well sections reveal periodic dry (cooler?)/wet (warmer?) climate alternations, with a periodicity closely resembling the contemporaneous deep-sea record. This is overlain by an overall trend through the sections of drying as evidenced by a decrease in total ferns and variation in podocarp and seed fern produced pollen. This record suggests global climate variability during the Albian, a stage previously considered to have had a stable (warm) equable climate in the absence of any ice sheets.

Keywords: Albian, palynology, palaeoclimate, Gippsland Basin, Australia.

SS33-O11 (325)
The opalized mid-Cretaceous ecosystem of Lightning Ridge, eastern Australia

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Lightning Ridge in northern New South Wales, Australia, is renowned as a source of commercial "black" opal. Less well known is the remarkable array of fossils recovered from the opal mines in recent years. Both plant and animal remains are preserved as finely detailed opaline casts; anatomical details are preserved via true permineralization only in a few specimens of fossil wood. The fossils occur in the early middle Albian (*ca* 109 Ma) Griman Creek Formation of the Surat Basin. This unit represents the deposits of a delta system that fed into a large inland sea that occupied central eastern Australia during the mid-Cretaceous. The fossil assemblage contains a broad array of protists, invertebrates, vertebrates and plants that derive from a range of terrestrial, freshwater and marine habitats. Furthermore, all major trophic levels are represented in the fossil assemblage – from autotrophs to hyper-carnivores. The plant assemblages are dominated by cones and leafy axes of cupressacean and araucariacean conifers with lesser fern and equisetalean remains. These groups are also present in the well-studied, slightly younger (late Albian–Cenomanian) Winton Formation of Queensland but the taxa in these assemblages differ at species or even generic level. Furthermore, angiosperms are not represented in the Griman Creek Formation flora, whereas they are co-dominant elements in the younger Winton Formation assemblages. The mixed plant/animal and aquatic/terrestrial assemblage from Lightning Ridge offers the opportunity to: (1) improve correlations between marine and continental sedimentary sequences, (2) reconstruct a complete high-latitude (*ca* 70˚S) coastal ecosystem of southeastern Gondwana, and (3) document the aquatic and terrestrial biodiversity that developed during the last stage of gymnosperm dominance of austral ecosystems at a time that saw dramatic global warming leading to the Cretaceous greenhouse maximum.

Keywords: Cupressaceae, Araucariaceae, dinosaurs, Albian, high palaeolatitude.

SS33-O12 (323)
Mid-Cretaceous south polar palynology & floristic trends of the Tupuangi Formation, Chatham Islands, New Zealand

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The Chatham Islands are home to arguably the highest palaeolatitude (~ 75–80°S) mid-Cretaceous fossil localities of the Southern Hemisphere studied to date. This study records a rich spore-pollen flora, as well as a diverse leaf and cone assemblage, from the Ngaterian to Mangaotanean (Cenomanian to Turonian) Tupuangi Formation, Pitt Island. The mid-Cretaceous ecological trends (within-flora abundances and diversities) of this high southern palaeolatitude locality were derived by examining 40 palynological samples from two correlative transects of the Tupuangi Formation. The palynological assemblage diversity and abundance data were attained using a combination of 'Quaternary' palynology techniques (i.e. pollen sum counts) and a simple statistical technique to estimate and minimise the degree of taphonomic influence on the resultant diversity data; this involved correlation of lithofacies (as a proxy of depositional environment) with spore-pollen diversity to assess and eliminate samples of unacceptably high taphonomic influence. Statistical correlates were calculated for between-group absolute diversity data to estimate potential ecological competition. By examining the resultant abundance and diversity trends, there were three main findings from this study: (1) Relative abundances reveal a floral ecology dominated by conifers (primarily Cupressaceae, Podocarpaceae & Araucariaceae), with minor ferns, non-conifer gymnosperms, lycopods, "bryophytes," and angiosperms. These findings are in contrast to other high latitude fossil microflora localities, which consistently show higher fern &/or angiosperm components. This discrepancy was interpreted as being caused by climatic differences, as a result of such a high palaeolatitude for this fossil flora locality. From this basis, specific predictions can be made in regards to the floral diversity from other polar latitudes of the mid-Cretaceous. (2) There is a rise in overall angiosperm diversity and abundance throughout the Ngaterian to Mangaotanean (Turonian), in step with the increasing global climate. However, the angiosperm component is always reduced relative to lower palaeolatitude localities of the same age. This supports the theory of angiosperm proliferation at the high latitudes being primarily driven by climatic influences. (3) Preliminary data show that this increasing south polar angiosperm diversity initially resulted in an overall increase in floral species richness, but no discernible ecological overturn.

Keywords: floral ecology, palaeoclimate, Cenomanian, Turonian, correlation statistics.

SS33-O13 (143)

Aquatic plant communities from the Upper Cretaceous La Colonia Formation, Patagonia, Argentina

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Upper Cretaceous sediments are widespread in northern Patagonia, with several geological units bearing diverse aquatic paleobiotas that accumulated as the result of complex and dynamic coastal sedimentary processes. One of these units is the La Colonia Formation. The entire sequence representing this formation is dominated primarily by fine-grained clay facies that are interpreted as having been deposited in coastal fresh water lakes or lagoons sporadically affected by brackish conditions. The La Colonia fauna includes terrestrial and aquatic reptiles, mammals, and fish; the flora is largely undescribed. In this report, we discuss the aquatic paleoflora of three La Colonia Formation localities: Cañadón de los Helechos, Cerro Bosta and Cañadón del Irupé. The flora of the first two localities consists entirely of the aquatic fern *Regnellidium* (Marsileaceae), suggesting a low-diversity, perhaps monospecific plant community. The last locality, in contrast, is dominated by

angiosperm taxa belonging to the families Nelumbonaceae and Araceae, and also includes the remains of ferns belonging to the families Marsileaceae and Salviniaceae. Modern species of these groups have a worldwide distribution and comparable extant taxa are found in freshwater lakes or lagoons, suggesting a similar environment for the fossils. Each of the localities is characterized by a relatively high accumulation of biomass, which, along with the excellent preservation of delicate plant organs, indicates that deposition was autochtonous. This corroborates the inference from taxonomic affinities that these plants inhabited low-energy aquatic environments. The presence of a diverse tetrapod fauna and palm remains in the surrounding landscape is a clear indication that climate conditions in Patagonia at the close of the Cretaceous were warm enough to sustain a diverse biota.

Keywords: Mesozoic, ecosystem, Nelumbonaceae, Araceae, Marsileaceae.

SS33-O14 (262)

Cretaceous plant mega- and meso- fossils from James Ross Island, Antarctica

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Plant mega- and meso-fossils were recovered from marine sediments of the Santa Marta Formation (Santonian-Campanian) of James Ross Island, Antarctica during the field investigations in seasons 2009-2010. The Santa Marta Formation conformably overlying the Hidden Lake Formation consists of approximately 1000 m of silty and muddy sandstones marls with concretionary beds. It is rich in fossils of marine fauna including ammonites, bivalves and gastropods. The majority of fossil plants are found in the Lachman Crags Member formed by sandstones, and mudstones. Their remains are preserved as twig and leaf impressions. In particular places, leaf compressions, dispersed cuticles and well preserved charcoalified meso-fossils including conifer twigs, megaspores, seeds and fruits were recorded. Plant meso-fossils were found in variable content in calcareous concretions. Due to low content of the material for bulk maceration it was preliminarily bulk macerated in the field laboratory; where dissolved by and cleaned by HF. The flora is diverse and consists of pteridophytes, conifers and numerous angiosperms. Plant taphocenoses include remains of lycopods (megaspores *Hughesisporites* sp.), axes of putative lycopods, fern leaves (*Delosorus* sp. and some unidentified ferns) isolated sporangia and indusial (probably several other genera of Matoniaceae), conifer twigs (*Brachyphyllum* sp., *Pagiophyllum* sp. of araucarian affinity), conifer cones, angiosperm leaves (*Cocculophyllum – Cinnamomophyllum* – type) and their reproductive structures – fruits and seeds.

Keywords: Antarctic palaeobotany, Cretaceous, Santonian-Campanian.

SS33-O15 (68)

The palynology and megaspores of Cretaceous (Aptian) high latitude, vertebrate-bearing fluvial sediments from the Gippsland Basin, south-eastern Australia

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The Gippsland Basin, south-eastern Australia, has yielded several valuable vertebrate fossil sites. Sediments are composed primarily of rift basin fluvial successions from the Early Cretaceous, deposited during the initial rifting between Australia and Antarctica. These fluvial successions of the Strzelecki Group have yielded a diverse vertebrate fauna together with a diverse macroflora described from the lagerstätten deposits of the Koonwarra Fossil Bed. Fossil floras are indicative of humid climates with strong seasonality at a high palaeolatitude (65°S). Previous palynology and megaspore biostratigraphic zonations, from Helby *et al*. (1987) and Tosolini *et al.* (2002) respectively, are built upon in this study. Using the Dinosaur Dreaming Fossil Site as a reference site, spore-pollen and megaspore biostratigraphy are used to give age constraints on the dinosaur-bearing strata of coastal outcrops at Black Head. Further analysis of the site includes high-resolution palaeoenvironmental analysis, stratigraphic logs with high resolution sampling of 7.5 m with, where possible 10 cm gaps, for spore-pollen fine fraction with the coarse fraction kept for megaspore analysis. Using coarse fractions of palynologically investigated spore/pollen samples from Dinosaur Dreaming Fossil Site, with known spore-pollen ages as a comparison, changes in species are observed. These megaspores will be strongly linked to ages ascertained by spore-pollen analysis at Black Head. The results of these observations are expected to include new age-diagnostic species in the megaspore biostratigraphy and prove to be a valuable data set in the exploration and interpretation of Cretaceous strata, locally as well as inter-continentally across Gondwana.

Keywords: spore-pollen, Strzelecki, dinosaurs, mammals, palaeoenvironments.

SS33-O16 (16)

An early Eocene macrofossil flora from the Mwadui kimberlite pipe, Tanzania

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An early Eocene (52 ± 2 Ma) flora from the Mwadui kimberlite pipe in Tanzania includes ten leaf morphotypes, small seeds, fossil wood allied to *Cynometra* (Detariae, Caesalpinoideae, Leguminosae), and a sparse palynoflora. The leaf flora is characterized by microphyllous and notophyllous entire-margined leaves that although many cannot be confidently placed in modern families they are suggested to be allied to the Euphorbiaceae and legumes,. The wood is the oldest member of *Cynometroxylon* and confirms that the Detarieae were diverse by the early Palaeogene. The low diversity and sparse palynoflora suggests a restricted catchment with little input from the regional vegetation. The sediments accumulated in a freshwater lacustrine environment with palynological input from the crater walls that were covered by sparse vegetation. This is supported by the leaf floras. Although the leaf floras are more diverse with nine morphotypes identified, the small leaves (microphyll to notophyll) suggest a water-limiting palaeoenvironment. This is supported by the low diversity and abundance of fern and bryophyte spores. The presence of a single wood taxon not only indicates that there were large trees around the crater-lake but that the arboreal component was of low diversity. These observations suggest an open woodland-like setting, while the taxonomic affinities of the wood (*Cynometra*) suggest a humid microclimate. This deposit is another example of inland localized vegetation and climate that reflects a brief moment in time. Other, younger sites, such as Mahenge in Tanzania; Orapa, Gross Brukkaross and Stompoor in southern Africa, have similar crater-lake facies and fine-grained sediments that can preserve the flora and fauna in exquisite detail. Although these sites present an opportunity for vegetation

reconstruction, their isolated nature means they might well not be representative of the regional palaeoenvironment.

Keywords: Caesalpinoideae, diamond pipes, Paleogene, dicot leaves, *Cynometroxylon.*

SS33-O17 (495)

Is southern Africa different? An investigation of the relationship between leaf: physiognomy and climate in southern African mesic vegetation

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It has been well established, that whilst the leaf physiognomy of angiosperm floras responds in a predictable and consistent manner to differing climate variables (hence allowing leaf physiognomic character states to be used as proxy indicators of climate), there are regional variations. Two of the major causes of the variations observed between leaf physiognomic characters and climate occur either as a result of specific community-scale leaf functional adaptations to climate, or as the result of a high level of endemism often due to common biogeographical history. Leaves from 24 South African vegetation localities, were assessed by LMA (Leaf Margin Analysis), LAA (Leaf Area Analysis) and CLAMP (Climate Leaf Multivariate Program) to determine the effect of endemism on these three palaeoclimate proxies. We also examined whether existing calibrations for CLAMP using globally gridded climate data were appropriate for South Africa, or whether new region-specific calibrations provided more accurate results. We observed differences in regression line slope and intercept with climate station versus gridded climate data for LMA; the gridded data generated slightly cooler temperature estimates when the percentage of entire-margined species exceeds 25%. However, the differences are small and both gridded and local climate station calibration data can be used with equal accuracy. With the exception of Fynbos sites, we observed small differences between xeric and mesic sites in the relationship between leaf margin proportion (LMP) and MAT, when less than 65% of the flora is entire margined. Fynbos sites plot up to 8 °C cooler for a given leaf margin percentage (LMP) than do other sites. The non-Fynbos sites plotted within the parameters characterized by the existing CLAMP, PHYSG3BRC data set, indicating that they had a leaf physiognomic response to climate consistent with the rest of the world. However, the African non-Fynbos sites filled a previously unoccupied void within physiognomic space, indicating the existence of a regional variance from the global pattern. This suggests that endemism *per se* does not prevent CLAMP from yielding reliable climate predictions. The inclusion of African non-Fynbos sites into the calibration improved the ability of CLAMP to predict Fynbos site climate, although this remained poor. The addition of the African non-Fynbos vegetation sites to the global PHYSG3BRC calibration did not significantly degrade its predictive capabilities, especially for key climatic variables such as enthalpy.

Keywords: CLAMP, leaf physiognomy, climate, leaf margin.

SS33-P01 (63)

Palynofacies analyses of Lachman Crags Member, Santa Marta Formation

(Santonian-Campanian) of the north-west James Ross Island, Antarctica

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Palynofacies analysis is an interdisciplinary approach in that not only the palynomorphs in the palynological slides are investigated, but the entire organic content of the slides. The particles are viewed as sedimentary components that reflect original conditions in the source area and the depositional environments. The interpretation of different paleoenvironments using palynofacies analysis was the main objective of this study, based on one section through the Lachman Crags Member of the Santa Marta Formation in the northwest of the James Ross Island. This member has been interpreted as a sub-storm wave base, mid to outer shelf deposit. The palynofacies analyses were carried out on 16 samples. In each sample 300 particles were counted using transmitted light microscopy and transformed in percentages, which were analyzed using the multivariate statistical techniques of cluster analysis. The cluster analysis based on R-mode revealed four palynofacies (Pf): Pf-1: amorphous organic matter (AOM), amorphized cuticles and resin; Pf 2: spores, dinoflagellates and pollen grains; Pf 3: translucent biostructured and non-biostructured and cuticles; and Pf 4: opaque lath and equidimensional. The Lachman Crags Member is strongly dominated by dark brown phytoclasts from Palynofacies 3 combined with moderate percentages of the terrestrial palynomorphs. The very low abundances of AOM indicate normal circulation within the site of deposition. The evident values of the phytoclast size measurements agree with shallow marine settings. Three intervals were revealed based on cluster analysis by Q-mode (IA to IC). Palynofacies 2 with a high content of palynomorphs, in particular with marine remains is mainly included in Interval A. Palynofacies 3 shows high percentages in intervals B and C, but in IC moderate content of opaque particles (Palynofacies D) is observed. The major break that occurred between intervals IA and IC is strongly related to the relative abundance of the phytoclast group from Palynofacies 3. The palynofacies analyses allowed recognition of a long-term regressive trend in the intervals. The paleoenvironmental history is strongly marked by the progressive increase of land-derived inputs into the marine area. The data confirm that the changes were controlled by sea-level during the deposition of the Lachman Crags Member.

Keywords: sea-level, Cretaceous, sedimentary organic matter.