



Winter 2019
Vol 30 No 239



**Gondwana and
its Legacy**

\$6.50

Australian Plants





Contents

Editorial	Merle Thompson OAM	51
Gondwana – a Global Adventure	Margaret Baker	52
Family Proteaceae: a representative and well-known Gondwanan taxon	Dr Tonia Cochran	65
Plants of New Caledonia – a hotspot of endemism on a fragment of Gondwana	Dr Barbara Briggs PSM	75
South American connections	Merle Thompson OAM (ed)	80
Plants from the End of the World	Harry Loots	82
Gondwana Rainforest WHA	Merle Thompson OAM (ed)	87
Inala Jurassic Garden	Dr Tonia Cochran	89

Front cover: *Telopea speciosissima* from Inala Jurassic garden.
Photo Brad Moriarty.

Back cover: *Serruria phyllicoida*, “Beard Spiderhead Raspberry Burst” a
Proteaceae from South Africa. Photo Brad Moriarty.

Australian Plants articles

Australian Plants is published quarterly to promote knowledge of Australian plants.

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Australian Plants No. 239 Issue of Volume 30, which comprises issues 238–245.

Published quarterly and available nationally in 3000 copies by the Australian
Plants Society NSW Ltd

© Australian Plants Society NSW Ltd 2019 ABN 87002680408 ISSN 0005-0008

Printed by Elect Printing, Fyshwick, ACT Print post approved 100009857





Editorial

Merle Thompson OAM

The impetus for this issue was a wonderful presentation at the ANPSA 2018 conference in Hobart by Fred Duncan. He described the distribution of rainforests in Australia and, more specifically, the nature of rainforests in Tasmania. He then demonstrated the similarities with those of Tierra del Fuego – the result of their origins in Gondwana, the super-continent of which Australia and South America were part.

In the following presentation Dr Tonia Cochran described the development of her garden in which Australian plants of Gondwanan origin are grown alongside those of the same family from other countries. Tonia's article on the garden concludes the issue.

Have you had a “native” floral arrangement which had South African plants included? And noticed the similarities? Or travelled in southern hemisphere lands and seen plants which seemed rather familiar? While there has been considerable plant dispersal at later stages, it is the early evolution of these plant families in Gondwanan times that resulted in these similarities. This phenomenon had been noted centuries ago but it is only in recent years that the geology has been understood. To help us understand these matters we start with a wonderful article by Margaret Baker in which she tells the fascinating saga of Gondwana and the associated evolution of plants.

To explore the botany further Tonia has also written for us on the Proteaceae family and Dr Barbara Briggs describes the interesting flora of New Caledonia and its Gondwanan heritage,

The South American connections are portrayed in photographs, including some by Hugh Nicholson, and in Harry Loots' story of his experience of the flora while trekking in the forests of Patagonia.

In New South Wales and Queensland are a number of reserves which are linked as a World Heritage Area, the Gondwana Rainforests. We



provide a small snapshot of the areas with photographs by Hugh Nicholson. Detailed descriptions of the forest types and Hugh's biographical information can be found in *Australian Plants* Vol 29 No. 2018.

Atkinsonia ligustrina, a flowering plant with a late Gondwanan heritage. Photo: Mark Baker





Gondwana – a Global Adventure

Margaret Baker

Margaret joined the Blue Mountains Group of the Australian Plants Society in the late 1970s. She has been a TAFE Head Teacher of Environmental Sciences, a landscape interpreter and a co-author of books on native plants. Plate Tectonics revolutionised her understanding of a dynamic Earth and a chance encounter with Antarctic Beech in Queensland's McPherson Ranges in the late 1960s sparked a life-long interest in environmental change.

It is amazing to consider that it was less than 50 years ago that a revolution in Geology was taking place; one that would turn on its head our understanding of the formation of the Earth's crust and of the complex history of its continents and oceans. Rumours about the changes to come in the early 1970s were started a long time ago when musings over the apparent jig-saw fit of some continents (e.g. Francis Bacon early C17; Humboldt c.1800; Snider-Pellegrini 1859) eventually culminated in the 1915 **Theory of Continental Drift** by Alfred Wegener.¹ In 1912, Wegener had given the name Pangaea ("all lands") to a single land mass that contained all of today's continents.²

The puzzle of how continents may have drifted apart was not resolved for another 50 years. In 1962 Prof. Harry Hess proposed a possible mechanism for separating continents and initiating their subsequent movement around the globe; this became known as the **Theory of Sea-floor Spreading**. Finally in the 1970s these two great concepts came together in the **Theory of Plate Tectonics**. This brought about a fundamental shift in understanding how the World had formed.



The Earth's Major Tectonic Plates: shows separation of the Indian and Australian Plates (Annenberg Learner³)





Plate Tectonics on a Dynamic Planet

Today it is known that the Earth's outer shell or lithosphere is divided into large slabs called tectonic plates that carry ancient continents and younger oceans around the globe. New tectonic plates may start to form when molten plumes of magma from the Earth's mantle begin to melt down the crustal rock of a continent. The concentrated attack of hot convective currents over time will tear through or rift-apart the former single continent into two or three smaller land masses. Continuous crustal collapse in the rift zones may ultimately cause submergence of the land beneath a new sea. The upwelling of molten magma continues beneath the sea where accumulations of new volcanic rock form a mid-ocean ridge. With constant eruptions new ocean crust will push the rifted continental blocks further apart (sea floor spreading). Dense older oceanic rocks, furthest away from the mid-ocean ridge slide (or are subducted) beneath less dense continental margins back into the mantle along the oceanic/continental plate collision zone in a constant recycling process. Such collision zones are also marked by high fold mountain ranges and volcanoes.

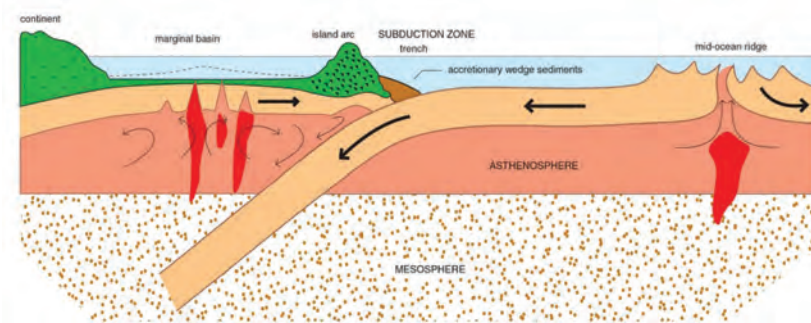


Plate Tectonics Processes: indicates the formation of a mid-ocean ridge, sea floor spreading, and oceanic and continental plate collision at a subduction zone (Australian Museum ⁴)

Plate Tectonics is a relentless conveyor system constantly moving chunks of crust about. It provides an explanation for different mountain types, volcanic activity, natural climate changes, the extinction of some species and for the evolution and spread of plants. It helps us to understand a great deal about the distribution of larger phyla, the sharing of plant families between continents and the unique speciation that occurs in long-separated biomes.

A Very Ancient Australia

The Australian continent has taken some 3,800 million years to acquire its familiar form.⁵ It has been caught up in the huge pulses of crustal





activity that have seen the Earth's continental blocks assemble together to form supercontinents then to later tear apart, disperse to all corners of the planet then reassemble into the next super-structure. It is hoped that the following account will provide an understandable interpretation of the complex geological sequencing that is involved.

Our oldest rocks are in south-west Western Australia in a large stable segment of the crust called the Yilgarn Craton (post $\pm$ 3,800 Ma i.e. millions of years ago). Plate collision and associated mountain building about 2,215 Ma joined this block to the Pilbara Craton (post $\pm$ 3,655 Ma) to form the nucleus of 'Australia'. Crustal blocks of northern and southern Australia joined the growing land mass so that by about 1,850 Ma two-thirds of the continent existed as part of the first supercontinent, Nuna. Laurentia, now North America, formed our eastern third.⁶ Cycles of rifting, sea floor spreading, continental drift and subsequent collision later tore apart Nuna, then assembled and separated the next supercontinent, Rodinia. An independent Laurentia drifted away to a new position in the northern hemisphere.



Australia joins Gondwana

The name 'Gondwana' was first used in a geological sense by Henry Medlicott who in 1872 applied it to a series of coal-bearing Permian rocks in India. The name means "forest of the Gonds", the place of an ancient tribe in central India. Eduard Suess (c.1885) expanded the term to 'Gondwanaland' and used it to define an old continent that he thought had formed by now collapsed land bridges between India, southern Africa and Madagascar. Suess based this continental reconstruction on the distribution of *Glossopteris* fossils (incorrectly





interpreted as “tongue-ferns”) found in the same Permian rocks across these countries. Suess was apparently not aware that *Glossopteris* fossils also occurred in Australia, Antarctica, New Zealand and South America, all now firmly established Gondwanan continents.⁸ Today Glossopterids continue to provide the best known fossil link between all of the former continents of Gondwana.



Glossopteris Fossils from
the Permian Period
(c.298 – 251 Ma)
(Glossopteris Fossils⁹)

‘Gondwana’ today refers to an ancient supercontinent assembled during plate collision from 550 – 500 Ma. Nearly half a billion years ago Australia (minus its eastern third) slipped into a northern Gondwanan position between Antarctica (to which it remained attached until c.30 Ma), India, North China and other Asian segments. South America and Africa (including Arabia) formed southern Gondwana.¹⁰ As part of this supercontinent Australia embarked on a global adventure from north of the Equator, to near the South Pole and then back again. The meandering trajectory of Gondwana impacted on former world climates especially when a substantial segment of it remained stationary over the South Pole; an ice age and extinction event usually accompanied this emplacement.

Plants diversify in early Gondwana

While the assembly of Gondwana was taking place, major changes were occurring in the Earth’s biosphere. Photosynthetic life forms rapidly evolved during Ordovician times (470 – 444 Ma) from algae and lichens, to spore-bearing non-vascular liverworts then vascular and taller club mosses. An extinction event then accompanied an ice age as Gondwana drifted across the South Pole (Late Ordovician; c.444 Ma). When climates moderated land plants rapidly diversified and by the end of the Devonian Period (c.359 Ma) there were forests of tree-sized





Todea barbara in the Osmundaceae family; its ancestors grew in Permian times with Glossopterid forests. (Author photo)

club mosses or Lycopods including the 30 metre tall diamond-patterned trunks of *Lepidodendrons*, fork ferns and early seed-bearing plants. During the subsequent early Carboniferous Period the first cycads and conifers joined the forest communities.¹¹

On a collision course

By about 360 Ma a slow twisting plate movement swung Gondwana in a clockwise direction and brought Australia into southern temperate zones. The subsequent collision in the Carboniferous (c.335 Ma) of Gondwana with the dominant land masses of the northern hemisphere (including Euramerica/Laurussia) assembled the mega-supercontinent **Pangaea**. As part of that landmass Australia and Antarctica continued to move south across the pole and by late Carboniferous/early Permian times (c.300 Ma) a new ice cap formed triggering another global ice age. It was particularly felt in the Gondwanan countries.¹²

Vegetation changes in the Carboniferous and Permian

Significant vegetation changes accompanied the Carboniferous Ice Age. The direct impact of ice and snow resulted in extinctions and a global cooling of temperatures caused marked changes in the composition and structure of forests. From the late Carboniferous to the early Permian (by 280 Ma) the former lush tropical forests of Lycopods (club mosses) were replaced by low diversity seed-ferns then as temperatures moderated the family *Glossopteridaceae* spread across Gondwana.¹³ Glossopterids were Gymnosperms that grew in temperate swamps; their deciduous habit supplied large quantities of coal-forming leaves.



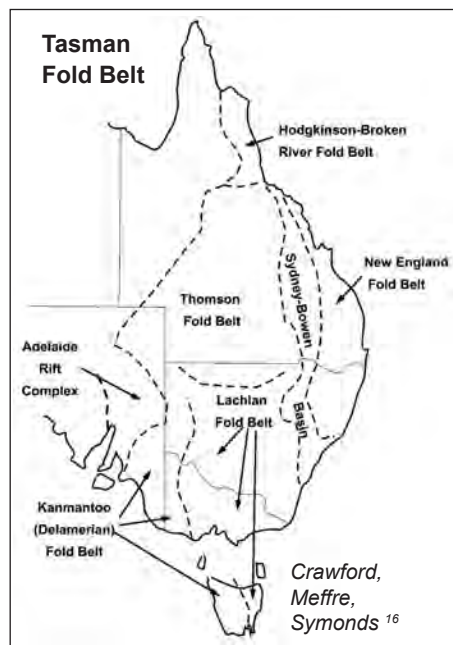


Eastern Australia undergoes a growth spurt

While the final stages of the amalgamation of Pangaea were occurring about 252 Ma, the northern outer edges of its Gondwanan half were being slowly reshaped by the rifting-apart of Asian continental fragments that were then close to north-west Australia.¹⁴ Eastern Australia on the other hand was experiencing a growth spurt. From earliest Gondwanan times through to the later stages of Pangaea (542 to 251 Ma), the convergence (or collision) of the Australian Plate with the then Pacific Plate progressively added a new eastern third to the country. This involved lengthy cycles of sediment deposition, rock formation, volcanic activity and periodic major fold mountain range building as the Pacific Plate Convergence Zone episodically moved to the east. The landscape at that time could be likened to a mirror image of today's South America where the Nazca plate is being subducted beneath the South American continental plate. The forces involved have bulldozed rocks there into the Andes Fold Mountains.

In eastern Australia this process produced a number of fold belts (mountain ranges) that roughly paralleled each other and became younger towards the continental fringe; today they are marked by granite rocks that once cooled deep in their mountain cores. Known collectively as the Tasman Fold Belt System¹⁵ one of its most extensive sub-sections was the Lachlan Fold Belt (450 – 340 Ma) that dominates the geology of New South Wales, underlies much of Victoria and extends into Queensland and Tasmania. Appropriately the Lachlan Fold Belt also links together the former land connection between Antarctica, South America, and Australia.

The Sydney – Gunnedah – Bowen Basin of Permian-Triassic times (c.310 – 190 Ma) was a more recent addition to Eastern Australia. Extending from central Queensland to south-east of Batemans Bay this structure lay within the Tasman Fold Belt System





between the mainland (the Lachlan Fold Belt) and the newer collision zone mountains of the New England Fold Belt. The Basin filled with sediments from mountain erosion (including by glaciers), volcanoes and the sea. The significant geological heritage of the Sydney-Bowen Basin includes the well-known sandstone escarpment scenery of the Greater Sydney Region and the underlying *Glossopteris*-formed Permian Coal Measures that are mined from the Illawarra to Queensland.

Extinction of the *Glossopteris*

A near-catastrophic extinction event initiated by severe volcanic activity occurred at the end of the Permian. High percentages of all life forms, including the *Glossopteris* flora, disappeared and the biosphere faced a very long recovery time. Throughout the following Early Triassic (c.250 – 245 Ma) sparse vegetation communities of herbaceous Lycopods, horsetails and early conifers slowly appeared. The seed-fern *Dicroidium* later dominated the swampy lowlands of Gondwana from the mid-to-late Triassic (c. 235 – c. 200Ma).¹⁷

The Jurassic refuge of ancient plants

Vegetation communities changed again as the geological clock ticked over into the Jurassic (c. 200 Ma). At first the last forests to contain only ancient plants grew in cool, wet environments of eastern Gondwana. Cycads, ginkgoes, tree ferns (Dicksoniaceae family), club mosses and horsetails thrived in these broad-leaved forests. Conifer families then came to dominate canopies across Pangaea.¹⁸ Included were the Gondwanan-focused Podocarpaceae and the more widespread Araucariaceae. Today this family is best known from the Southern Hemisphere genera of *Agathis* (with a few species in S.E. Asia), *Araucaria* and *Wollemia nobilis*. The centre of diversity for the Araucariaceae is now in New Caledonia.

The demise of Pangaea and the suggestion of Angiosperms

Around 180 Ma (Early Jurassic) continental rifting initiated the separation of Pangaea into Gondwana and Laurasia. This was of major significance for global climates, oceanic circulation and the world's biomes. Then sometime during the major disruption to all life forms that occurred with Pangaeian rifting, Angiosperms made a quiet appearance on the world stage. New discoveries regularly provide revised dates for the arrival of flowers with a recent find from China, *Nanjinganthus dendrostyla*, being estimated at about 174 million years old.¹⁹ Gondwanan flora braced for the changes to come.





The Separation of Pangaea into Gondwana and Laurasia at 200 Ma. Australia and Antarctica are in near-polar latitudes. (ZM Science ²⁰)

A farewell to Gondwana

After having held together for some 500 million years and surviving a long incorporation into Pangaea, Gondwana began to separate in the Jurassic (from c.160 Ma) into today's southern continents, and India and Arabia. The multi-zipper-like rifting process responsible was first most active to the west of Australia/Antarctica and progressed to the east. However the direction was not consistent, the process was not a smooth one and there were false starts. In Tasmania, for example, the dramatic dolerite columns of Mt Wellington represent an early but incomplete rifting episode about 170 Ma.²¹

Africa and Madagascar parted early from about 160 Ma then a spreading mid-Atlantic Ridge split asunder South America and Africa. By 130 Ma India began a move to the north where subsequent collision (c.40 Ma) with the Eurasian Plate formed the Himalayas and the Tibetan Plateau.²² By this time eastern Africa was undergoing separation into three plates by a complex system of still-active rifts. The Red Sea Rift forced apart Africa (Nubian Plate) and the Arabian Plate from c.50 Ma and by c.25 Ma the East African Rift began to cut-off the Somali Plate from the African mainland. Modern humans are considered to have originated in the East African Rift Valley.





Tectonic activity was also focused on East Gondwana where it would forever re-define the East Australia and Antarctic coastlines. A significant rifting event began in East Antarctica about 130 Ma and progressed episodically northwards through the continental edge of Australia. Uplift of the Eastern Highlands by 100 Ma was an early consequence of this activity. Collapse of the rift valley(s) along fault lines eventually saw some land sink below sea-level and the Tasman Sea flooded into place. Sea floor spreading continued along the mid-Tasman ridge further widening the Tasman Sea until 52 Ma.²³

What happened then to the parts of East Gondwana that were torn away from the mainland by the Tasman Sea Rift? A large section of the former coastline from Queensland to Antarctica's Ross Sea was pushed offshore where it sank beneath the waves to form the almost submerged continent of **Zealandia**.²⁴ Small segments of above sea level continental rocks of Zealandia are found in New Zealand and New Caledonia. Both islands now sit precariously on or near the current collision zone between the Pacific and Australian Plates.

Flowering plants appear in Cretaceous lakes and forests

Fossil evidence indicates that flowering plants rapidly diversified and expanded their range from the early Cretaceous Period. Discoveries have included a 'magnolia', from Spain (c.140 Ma) and *Amborella* that is endemic to New Caledonia (c.130 Ma).²⁵ The oldest Angiosperm evidence in Australia is dated at 115 – 120 Ma (formerly high latitude Koonwarra lake deposit in South Gippsland, Victoria).²⁶ During the first half of the Cretaceous (145 – 100 Ma) flowering plants formed a minor component of the Podocarp/Araucaria coniferous forest mix. From that time however significant changes become evident in community structure, and phyla and family mix.

Angiosperms diversified and spread throughout Gondwana from about 98 Ma. In understanding why some families are shared today between the southern continents and others are not, it is useful to consider the dates for the different episodes of rifting (as outlined above) and to remember that the pace of separation was not always fast so that some newly evolved families were able to spread from one continent to another before seas flooded the intervening rift valleys. Antarctica also played an important role as a transit route for plants and animals while it remained linked to other Gondwanan countries.

In Australia the following early Angiosperm developments were evident in or on the edges of the temperate broad-leaved forests:





- **Proteaceae** appeared about 94 Ma, diversified quickly and were found as canopy trees by 86 Ma.²⁷ *Macadamia*, *Banksia*, *Grevillea*, *Hakea*, *Telopea* and *Xylomelum* were early genera.



- About 80 Ma the iconic Gondwanan family **Nothofagaceae** (Southern Beech) appeared in the colder parts of Antarctica and South America and just made it into Australia before the final Gondwanan separation.²⁸ By 56 Ma the family dominated southern broad-leaved forest communities. On the Australian mainland a climatic trend towards warming and drying about 5.5 Ma saw species like *Nothofagus moorei* retreat to mountain refuges. Today the family is present in Australia, South America, New Zealand, New Caledonia and New Guinea.



By the late Cretaceous (c.68 Ma) the **Winteraceae** family was present in the flora, possibly after a long journey south from tropical parts of northern Gondwana (Arabian at 105 Ma).²⁹ Today *Tasmannia* species are found throughout Oceania including in Australia.

- The **Cunoniaceae** family (photo) appeared in the late Cretaceous. Well known are the rainforest species of *Ceratopetalum apetalum* (Coachwood) and the sclerophyll-dwelling NSW Christmas Bush (*Ceratopetalum gummiferum*). The family is mostly found in those southern hemisphere countries that retained Gondwanan contact the longest as well as in “recently” separated parts of Oceania.
- **Conifers** also continued to evolve. *Wollemia nobilis*-type pollen was evident in Australia, New Zealand and Antarctica at the end of the Cretaceous.



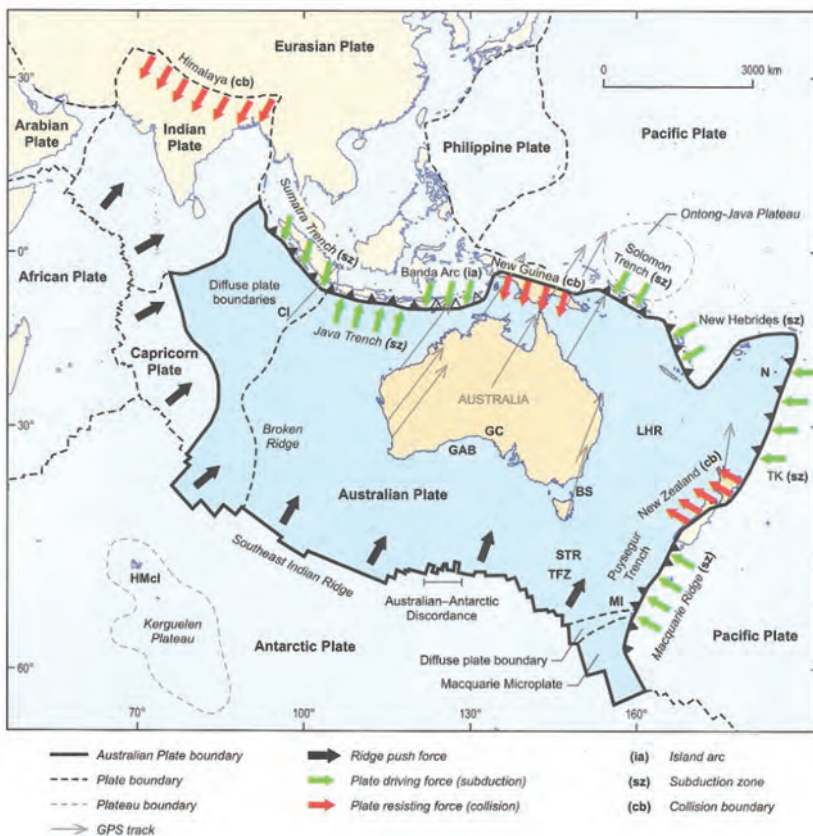
Australia becomes an island continent

The last episode in the break-up of East Gondwana is considered to have occurred when Australia and Antarctica ended their long globe-



travelling partnership in a lengthy rifting process that was powered by the still-active Southeast Indian Ridge. Separation began in the west about 155 Ma then progressed to the east towards Victoria. The final break-up from western Tasmania occurred about 34 – 30 Ma. For the first time in more than half a billion years Australia became a separate island continent and embarked on a journey towards Asia.

However this is not quite the end of the break-up story. When first separated from Antarctica, Australia drifted northwards with India on the Indo-Australian plate. This plate has now been split into three pieces beneath the Indian Ocean – the Indian Plate, the Australian Plate (c.15 Ma?) and the Capricorn Plate (c.18 Ma).³⁰ Each is heading northwards and will continue to influence regional geography.



The Australian Tectonic Plate and its boundaries – note the plate movement direction and the coloured arrows of unstable collision zones (Blewett ³¹).



Vegetation changes in the final Gondwanan breakup

Tectonic activity along the Southeast Indian Ridge had been pushing Australia to the north well before the final break-up with Antarctica; that final rifting phase merely exacerbated changes that were already taking place in Australian vegetation. While there have been distinct climatic/vegetation cycles over the last 65 million years overall trends as the continent moved from polar to tropical latitudes have included:

- An overall change in the climate to one that is hotter, drier, more distinctly seasonal and more fire-prone than in the past.
- Sclerophyll communities replaced most broad-leaved temperate rainforests from 62–60 million years ago and Gondwanan species retreated to mountain refuges or remained in Tasmania. Individual families and genera progressively appeared over time e.g. Myrtaceae from 50 Ma, with Eucalypts at 34 Ma; Fabaceae-Faboideae and Casuarinaceae from 50–55 Ma; Acacias c.20 Ma
- Desert grasslands of *Spinifex* and other arid-adapted genera expanded from about 15 Ma

While Australia was being pushed to the north, Antarctica started another journey to the South Pole. Rapid growth in the Antarctic ice sheet from 7 Ma saw temperatures plummet by 2.6 Ma initiating a new Ice Age. Since then major cycles of cold, dry climates (glacials) have alternated with warm, wetter episodes (inter-glacials) and different plant communities have retreated to refuges or expanded accordingly. Overall however the range of the more ancient Gondwanan plants continued to shrink.

The development of today's characteristic Australian flora has been the result of an existence in relative isolation on an independent island for tens of millions of years. While some plants have been inherited from prior Gondwanan connections, the high degree of endemism in the Australian flora can be attributed to the break-up of Gondwana, subsequent continental drift, climate change and fire adaptations.

Bothering the northern neighbours

Sea floor spreading away from the mid-ocean Southeast Indian Ridge is moving the Australian Plate in a north-north-easterly direction at a rate of 6–7 cm a year bringing it into collision with the Eurasian and Pacific Plates. Our northern neighbours are undoubtedly bothered by our pushiness that activates volcanoes, earthquakes and tsunamis but ironically without this plate collision many South East Asian and western Pacific islands would not exist. Significantly for Australia's natural history plate collision with





south-east Asia has provided closer proximity to northern hemisphere plants and animals. Particularly over the last 5 million years there has been an ecologically important exchange of species across the narrowing marine divide, but that interesting story will have to wait for another time.

Endnotes for text and diagrams:

The following endnotes refer to Blewett, R. (ed.) 2012, *Shaping a Nation A Geology of Australia*, Geoscience Australia and ANU, Canberra: **5 & 6** pp.92-102; **10** pp.103-107; **11** pp.131–136; **12** p.184; **14** p.108; **17** pp.138-140; **18** p.140; **21** pp.107-108; **26** pp.145-147; **27 & 28** p.144; **30** p.49; **31** p.50

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Family Proteaceae: a representative and well-known Gondwanan taxon

Dr Tonia Cochran

Tonia's fascination with natural history has led to a wide and varied career as a researcher, lecturer and tourism operator. Armed with a double major in Botany and Zoology, a BSc (Honours) degree and PhD from the University of Melbourne, Tonia moved from Victoria to Tasmania in 1987 to pursue her research in Antarctica and establish wildlife tourism venture Inala Nature Tours. Now supported by a team of around 20 staff, Tonia is still actively involved in managing her travel business and leading natural history tours around the world. She is also curator of the Inala Jurassic Garden and Nature Museum on Bruny Island Tasmania, which she designed and created to demonstrate the Gondwanan connections between plants from destinations included in Inala's international and Australian tour programs.

The Proteaceae is a large family comprised of over 1,600 species within 83 genera, which include the well-known proteas of South Africa and the banksias, grevilleas, hakeas and macadamias of Australia. The flowers of many species in this group are popular in floral arrangements while the nuts of species of *Macadamia* and *Gevuina* are widely grown commercially for human consumption. The family is named after the shape-shifting Ancient Greek God Proteus because of its seemingly infinite variety of floral shapes.

Members of this large family don't form symbioses with mycorrhizal root fungi that help to break down nutrients. Instead they produce specialised 'proteoid roots', which form a radial surface root mat which absorbs water and nutrients. They are all adapted to growing in poor, phosphorous-deficient soils and can exude carboxylates and organic



Proteaceae bed (Inala Jurassic Garden, Bruny Island, Tasmania) showing the diversity of the family.
All photos are taken from specimens in the Inala Jurassic Garden except where specifically indicated





Chilean Firetree. *Embothrium coccineum* (South America) left and Tasmanian Waratah *Telopea truncata* (Tasmania, Australia) right, showing similarities between the subtribe Embothriinae (Subfamily Grevilleoidea Tribe Banksieae).

acids (citric and malic acids) that change phosphorus into a form that can be used by the plants. This adaptation leaves them highly vulnerable to root rot fungus and intolerant of fertilizers.

The family has a Gondwanan distribution across most of the southern landmasses, with the highest diversity of species in Australia and South Africa. Molecular dating and studies of fossil pollen indicate that the Proteaceae were present in Gondwanaland in the Cretaceous Period around 90 million years ago (Anderson *et al*, 2005) and ancestors of the major subfamilies and tribes within the family may have differentiated before the supercontinent fragmented (Johnson & Briggs, 1975). Therefore, the family is often said to be a relict Gondwanan group and its species evolved by vicariance as Gondwana fragmented and separated. However genetic research using DNA sequencing which allows researchers to provide age estimates for evolutionary events within a family, has shown that the age of many taxa within the family are too recent for their dispersal to be explained by Plate Tectonics, which also indicates transoceanic dispersal (Barker *et al*, 2007). Africa separated from Gondwana early in the ancient supercontinent's break-up and many members of the family evolved in isolation there, forming endemic genera such as the genus *Protea*. South America, Australia and Antarctica maintained a Gondwanan connection for longer, and taxa such as the group Embothriinae, which contains the Australian genera *Telopea* (waratah) and *Alloxylon* and the South American *Embothrium* (Chilean firebush) and *Oreocallis* pre-date the separation of these landmasses and retain both close morphological and genetic similarities.





Incidentally, molecular research also shows that the age of the bird-pollinated Embothriinae corresponds approximately with the estimated origin of nectar-feeding birds (such as honeyeaters) in Australia (Barker *et al*, 2007).

Ancestral members of this family were almost certainly rainforest species which gave rise to the dry-adapted types that now dominate the Australian and African landscapes. The main centre of distribution of this family is in the Kwongan heathlands of the Southwest Australian Floristic Region of Australia and ecologically similar Fynbos shrublands of the Cape Floristic Region of South Africa. The evolution of specific leaf adaptations is thought to have allowed members of this family to adapt and extensively diversify in these open ecosystems as these continents warmed and dried (Onstein *et al*, 2016). Well-known representatives of these dry adapted taxa include the genera *Protea*, *Leucospermum* and *Leucadendron* in South Africa and *Banksia*, *Hakea*, *Grevillea* and *Adenanthos* in Australia. However, rainforest taxa still exist and the genera *Macadamia* and *Telopea* (from Australia), *Knightia* (from New Zealand) and *Gevuina* (from South America) are representative of these.

The fossil record of this family in some areas such as New Zealand and Tasmania has a greater biodiversity than currently exists, indicating a high level of extinction over the last 60 million years during the Cenozoic Era and a great reduction in number of species. For example, while fossilised *Banksia* have been recorded in the Oligo-Miocene Period in New Zealand around 23 million years ago (Carpenter *et al* 2010), there are now only two living species now represented there (Rewarewa-*Knightia excelsor* and *Toru-Toronia toru*. Australian endemic genus *Persoonia* (commonly known as geebung and snottygobble) is closely related to the New Zealand Toru and a sister group to the Tasmanian endemic Mountain Rocket- *Bellendena montana* (Weston & Barker 2006). Phylogenetic studies often place *Bellendena* as a basal taxon (one of the earliest offshoots) of the Proteaceae and the group that includes *Bellendena*, *Persoonia* and *Toronia* has diverged from the rest from the rest of the family early in Proteacean evolution (Weston & Barker 2006).

The family Proteaceae is divided into five subfamilies: Bellendenoideae, Persoonioideae, Symphionematoideae, Proteoideae and Grevilleoideae, which are further divided into tribes and subtribes (Weston & Barker 2006; Mast *et al*, 2008). Examples of each group are represented pictorially as follows to demonstrate similarities of species from landmasses which are now separated by considerable distances:





Subfamily Bellendenoideae: The most primitive sub-family with a single living species, the endemic Tasmanian Mountain Rocket (*Bellendena montana*).



Mountain Rocket *Bellendena montana* flower (above) and seed (right) (Tasmania, Australia).



Subfamilies Persoonioideae and Symphonematoidea:



Persoonia gunnii (Tasmania, Australia) left and centre, representing Subfamily Persoonioideae. Tribe Persoonieae. White Waratah *Agastachys odorata*. (Tasmania, Australia) right, representing Subfamily Symphonematoidea. Photos: JJ Harrison & Mitra Vathy1001. Wikimedia.





Subfamily Proteoidea: is a large taxa comprised of four Tribes



Variable Smoke-bush *Conospermum taxifolium* (NSW Australia) left, representing Tribe Comospermeae. Photo: John Tann, Wikimedia; and Channel-leaf Featherbush "Bronze Haze" *Aulax cancellata* (South Africa) right, represents Tribe Petrophileae.

The best-known tribe within this Subfamily is Tribe Proteeae, represented below by the King Protea (white flowered form) *Protea cynaroides* (South Africa).





Tribe Leucadendreae is comprised of three subtribes represented by a diverse group of genera



Drumsticks *Isopogon cuneatus* (South-western Australia) Subfamily Subtribe Isopogoninae (left) and Woollybush "Bronze Glow" *Adenanthos sericeus* (South-western Australia) right, represents Subtribe Adenanthinae

Subtribe Leucadendrinae is represented by the genera *Leucadendron*, *Serruria*, *Leucospermum* and *Mimetes*.



Coneflower "Harvest" *Leucadendron stelligerum* left, and Coneflower "Jester" *Leucadendron salignum* x *L. laureolum variegata* right (both from South Africa).



Serruria "Blushing Bride". *Serruria florida* (left) and Common Pagoda "Crackerjack Red". *Mimetes cucullatus* (right), from South Africa.





Pincushion hybrid "Mardi Gras Ribbons". *Leucospermum glabrum* x *L. conocarpodendron* (South Africa). Subfamily Proteoidea Tribe Leucadendreae.

Subfamily Grevilleoideae: is also a large diverse group comprised of four tribes.



Rewarewa *Knightia excelsa* (New Zealand) left and Variable Orites *Orites diversifolia* (Tasmania, Australia) above represent Tribe Roupaleae.





Banksia is a genus of around 170 species which is the sole representative of the Subtribe Banksiinae (Tribe Banksieae).



Showy Banksia. *Banksia speciosa* (left) and Red Swamp Banksia. *Banksia occidentalis* (right), both from Western Australia.

All but one species of *Banksia* is restricted to Australia (the exception is *B. dentata* which extends into New Guinea and the Aru Islands from northern Australia).

Tribe Emborrhieae is represented by four subtribes. The genus *Lomatia* (from eastern Australia and South America), represents Subtribe Lomatiinae.



Funique. *Lomatia ferruginea* (South America) left and Guitar Plant *Lomatia tinctoria* (Tasmania, Australia) right





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Corrections, Australian Plants Summer 2018/19 Vol. 29 No 237

Thank you to those subscribers who have drawn my attention to some errors in *Australian Plants* Summer 2018/19 Vol. 29 No 237, which was devoted to Australian carnivorous plants. I apologise unreservedly for my oversight in not thoroughly proof reading this issue, or perhaps, as the television advertisement proclaims, I “need to visit Specsavers”.

Correction 1 – Page 361

The text in red below does not appear on p. 360–361 (possibly due to the block of photos and the subscription insert):

A proportion of the pygmy *Drosera* species, particularly the orange-flowered ones, have dark centres, a feature associated with beetle pollination; indeed, the most commonly observed insects on pygmy *Drosera* flowers appear to be Melolonthids – chafer beetles.

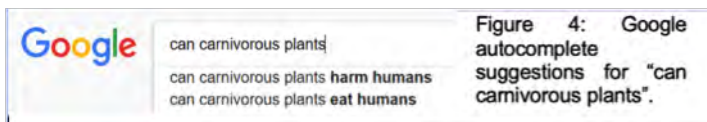
The pygmy *Drosera* rank amongst some of the most classically pretty of all carnivorous plants, with a natural diversity of flower colour and form that rivals many horticulturally desirable plant genera.

Correction 2 – Pages 371 and 372

Two paragraphs found on page 371 “Pots should be stood in saucers” and “The best medium for growing these plants” were duplicated on page 372. For some inexplicable reason I did not note our proof reader’s comments on the draft that these two paragraphs on page 272 should have been deleted.

Correction 3 – Page 381

The following Figure 4 mentioned on page 381 was missing.



Once again, my sincere apologies to our subscribers and to the authors of the two articles for my oversight.

John Aitken, Co-editor *Australian Plants*





Embothrium and Telopea are members of the subtribe Embothriinae



Chilean Firetree. *Embothrium coccineum* (South America) left and Waratah "Braidwood Brilliant". *Telopea speciosissima* x *T. monganensis* hybrid (NSW, Australia)

The subtribe Hakeinae (Tribe Embothrieae) contains the well-known genera *Grevillea*, comprised of around 360 species from Australia, New Guinea, New Caledonia, Sulawesi and other Indonesian islands east of the Wallace Line and *Hakea* an Australian endemic genus of around 150 species.



Banks' Grevillea "Loopy Lou". *Grevillea banksii* cultivar (Eastern Australia) left, and Grey Hakea *Hakea cinerea*. (Western Australia) right belong to the Subtribe Hakeinae.





The tribe Macadamieae includes the genera *Macadamia* and *Gevuina*



Macadamia tetraphylla (eastern Australia) left, and Chilean Hazel *Gevuina avellana* (South America) right.

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Plants of New Caledonia —a hotspot of endemism on a fragment of Gondwana

Barbara G Briggs

Barbara is an Honorary Research Associate of the Royal Botanic Gardens, Sydney and was Senior Assistant Director, heading the scientific programs there, for many years. Her research has included studies on Proteaceae, Myrtaceae and other Southern Hemisphere plant families. Her second visit to New Caledonia was in 2017.

New Caledonia is noted for the richness and high levels of endemism in its flora and fauna as well as the diversity of its habitats. Part of the main island is continental crust that broke away from the Australian part of Gondwana some 70 million years ago, but its southern end derives from ancient sea floor, laden with heavy metals, particularly nickel, which is extensively mined in the ultramafic areas. The central spine of mountains divides the evergreen rainforest on the east from the savannah on the west, mainly used for cattle-grazing, and the ultramafic areas in the SE and as isolated massifs scattered over the island. Conifers and some of the more ancient flowering plant groups are prominent in the flora, and appear to be relics of the Gondwanan flora, though much of the flora is derived from dispersal across the ocean to these isolated islands. Such dispersal may have been through mud on birds' feet, seeds eaten by birds or bats and excreted unharmed, wind or ocean currents. A relatively stable climate has enabled relic groups to survive here while Australian climates became drier.

Among conifers, best known are the tall spires of *Araucaria columnaris*, but twelve species of that genus occur in other habitats, and there are 30 other endemic conifer species, including giant trees of *Agathis lanceolata*.



Araucaria columnaris, a species of calcareous coastal habitats.



Towering trees of *Agathis lanceolata* the Kaori de forêt.





A remarkable endemic conifer is the endangered *Retrophyllum minus*, in family Podocarpaceae, that grows rooted in water at the edge of streams or lakes.



Retrophyllum minus, a conifer only 2–3 m tall with stout tapering trunks, growing in water at a stream edge.

Another endangered podocarp, *Parasitaxus usta*, is the world's only parasitic gymnosperm, lacking photosynthetic activity and connected by a fungal mycelium to its host.



Amborella trichopoda, in fruit. (Photo Peter Cuneo)





Amborellaceae, one of five endemic plant families, is of great scientific interest since DNA data show its only species, *Amborella trichopoda*, is the only survivor of the first branch on the evolutionary tree of the flowering plants, sister-group to all other Angiosperms. This understory shrub or small tree with cream flowers shows ancestral features in the wood lacking vessels and flowers lacking styles. But having separate male and female plants is not an ancestral feature.



Zygogynum pancheri

As well as Amborellaceae, several other early-evolved Gondwanic plant families, including Winteraceae, Proteaceae and Cunoniaceae, are well represented. *Zygogynum* in the Winteraceae is pollinated by a moth and fossil records similar to the plants and the moths extend back to the Cretaceous.

Proteaceae has six endemic genera, including *Kermadecia* with five species and twelve in *Beauprea*, ranging from rainforest trees to plants of dry shrubland. There are also representatives of more widespread genera, such as *Stenocarpus* and *Grevillea*. The latter would be relatively recent dispersals to New Caledonia.

Myrtaceae includes *Tristaniopsis*, *Xanthostemon* and many species of *Syzygium* but most widespread is *Melaleuca quinquenervia*, known there as Niaouli, which forms woodlands in drier regions. There are no native eucalypts but *Arillastrum gummiferum*, the only species of its genus, is related to *Corymbia* and *Angophora*.



Above: Peter Weston (left) and Peter Ollerenshaw hold huge juvenile leaves of *Kermadecia*.



Right: *Stenocarpus umbelliferus* (Photo Peter Cuneo)





Grevillea meisneri, a rare shrubland species. (Photo Peter Weston)

Gymnostoma in the Casuarinaceae has a fossil record in Australia, New Zealand and Patagonia dating back to the Eocene, 55 to 39 M years ago, but is now found only in northern Australia, the western Pacific and Malesia. New Caledonia has the greatest concentration of these trees and tall shrubs.



Syzygium acre flowers are borne on the trunk. (Photo Peter Cuneo)



Melaleuca quinquenervia

Another family well represented in the Southern Hemisphere is the Rutaceae, with 18 genera and 74 species in New Caledonia. Some of the links between Australia and New Caledonia may be ancient but others imply relatively recent dispersal, such as *Boronia* with species in both regions.

Families that may be familiar to us often have unfamiliar endemic genera, such as *Montrouzieria* in the Clusiaceae (Mangosteen family).

Although New Caledonia is more than 1,000 km from other substantial lands, and has been isolated for some 56 M years, some genera and species found widely in the old-world tropics have dispersed to it. One such is the Holly Mangrove, *Acanthus ilicifolius* (Acanthaceae) which is widespread in SE Asia and northern Australia.





Arillastrum gummiferum flower-buds



Gymnostoma in fruit, one of the eight endemic species.

The New Caledonian flora is notable for the ancient gymnosperm and angiosperm families that have survived there. More recently evolved families such as Asteraceae, Lamiaceae and Poaceae have low representation in the native flora. Many of its endemic species are endangered, despite important conservation reserves, and their conservation is of outstanding scientific and cultural importance.



Montrouzieria verticillata



Boronia verticillata, a small aromatic shrub



Acanthus ilicifolius





The South American connection

Compiled by editor

The Gondwanan connections between Australia and South America are many, with Tasmanian plants of special interest. Some of the most significant are coniferous families especially Araucariaceae and Tasmanian genera. Proteaceae are also well represented in the plants of Gondwanan heritage. Two other genera which occur on both continents are *Nothofagus* (family Nothofagaceae) and *Eucryphia* (family Cononiaceae), the latter being featured in the article on the Inala garden.

The following photos depict related genera from the two continents. Unless otherwise indicated the photographer is Hugh Nicholson.

Family Araucariaceae



Left: *Araucaria bidwillii*, Bunya pine
Bunya Mountains, Queensland

Below: *Araucaria araucana*, Monkey
puzzle tree (with *Nothofagus*) Chile





Family Proteaceae



Gevuina bleasdalei Eungella NP Queensland



Oreocallis grandiflora Peru



Gevuina avellana Chile



Alloxylon flammeum (Brian Walters)

Family Nothofagaceae



Nothofagus gunnii (Autumn colour), Tasmania
Photos: Dick Burns





Deciduous Nothofagus forest Chile

Plants from the End of the World

Harry Loots

Harry Loots is an APS (NSW) member who In January 2018 flew to Chile to walk in Patagonia.

I had gone to Patagonia for spectacular mountain landscapes, to walk around Argentina's 3,375 m high FitzRoy Mountain and Chile's Torres Del Paine massif with its equally impressive 2,800 m granite Torres or towers and glaciers. I was not in Patagonia to see the flowers but the botanical references were distracting. When wandering Santiago's Cerro Santa Lucia Park I found an inscription commemorating the naturalist Charles Darwin's 1835 visit. My first destination, Argentina's FitzRoy Mountain was named after the HMS Beagle's Captain Robert FitzRoy in 1834. On the Beagle were Darwin and Conrad Martens, later of Sydney, the ship's artist. Illustrations of Chile's national flower Copihue or Chilean bellflower (*Lapageria rosea*), found growing along streams high on the Patagonian feldmark, were on matchboxes. I had to pass through the new Argentinian town, El Calafate named after Calafate (*Berberis microphylla*), a common plant with large purple berries and treacherous thorns which is used as an herb.

The unrelenting severity of the Patagonian weather has determined the nature of plants that survive. The westerly winds, the Roaring Forties,





a consistent force swirling around Antarctica, drove clipper ships in the past. This wind clips, trims and dries the Patagonian Steppe's short Pampas vegetation. Puffs of mushroom shaped clouds lift off the FitzRoy tower as moist westerlies blow across. Usually there is a shroud of cloud, more ominously dark grey cloud. The local indigenous people, the Tehuelche (Aonikenk), called FitzRoy, Chaltén meaning "smoking mountain". The mountain smokes in its attempt to repel strangers. A 100 kph wind blew me out of FitzRoy. Even carrying a 16 kilo pack, I was frequently picked up and my step challenged as I wanted to go in one direction while the wind determined another. If I loosened my hold on my walking sticks they were blown horizontally, when I turned my face my glasses were blown down the track and having a pee was a disastrous spray in the face even with my back to the wind. In one gale prone area in Torres Del Paine I was awake for two nights with a constantly flapping tent; flattening onto my face as the gale howled to vent its strength.

In the deep valleys and easterly facing slopes of the Patagonian Andes forest provides shelter for delicate plants as well as protected campsites. The beech forest consists of three different *Nothofagus* species, which can tolerate temperatures of -30°C . In alpine areas where I walked there was Nire (*Nothofagus antarctica*), which was distinguished by lighter green small irregular leaves. It is deciduous and is sometimes decorated with the mistletoe Chinese Lantern - Farolito Chino (*Misodendrum punctulatum*). Nire is the southernmost tree on earth. On dryer slopes there is Guindo forest (*Nothofagus betuloides*), an evergreen with a darker green regular leaf. Here I first heard a giant woodpecker (*Campephilus magellanicus*), as it hammered into a tree. It is the largest of the three woodpeckers with the male having a red head. There was a female about but on the other side of a tree. Apparently the hammering was to attract the female. Lenga beech in the Mapuche language (*Nothofagus pumilio*) is a deciduous tree dominant in protected forests. In Autumn Lenga are yellow, orange and fire-red on the mountain slopes. It is felled for its timber used in furniture, shingles and construction. The Torres Del Paine National Park huts were built of Lenga.

There is an ancient connection between the Patagonian forests and Australian Temperate Zone forests. The Patagonian beeches are related to Australia's *Nothofagus moorei*, growing in high altitudes in eastern Australia, *Nothofagus cunninghamii*, growing in Victoria and Tasmania and *Nothofagus gunnii*, which grows in Tasmania. This is because Patagonia, New Zealand, Antarctica and Tasmania were once





connected as part of the supercontinent Gondwana. While geologists were developing the hypothesis of plate tectonics and continental drift, botanists recognised similar groups of plants on distant continents and came to the same conclusion. In 1853 Sir Joseph Hooker (1817-1911), the wealthy naturalist and close friend of Charles Darwin put forward theories 4-5 years prior to Darwin that Lomatia and Proteaceae species in Tasmania, New Zealand's north island, Chile and Argentina were related.

Hopping over boulders of the glacial moraine below FitzRoy and two weeks later walking along the track besides the Grey Glacier in Torres Del Paine I was gobsmacked to find a plant with large green leaves and red flowers that reminded me of a grevillea. It was Norto or Fire bush (*Embothrium coccineum*), which grows in alpine areas.



Norto is actually related to that bright splash of red in the Sydney bush, *Teleopea speciosissima*, the Waratah. The Waratah was originally called *Embothrium speciosissima*. The subtribe Embothriinae's origin and floral appearance must predate the splitting of Gondwana into Australia, Antarctica, and South America over 60 million years ago. Both Norto specimens grew in positions exposed to high winds and freezing temperatures. Norto growing on the moraine was only 50 cm high while on the slope above the Grey Glacier it was 1.5 m.

My four-hour amble alongside the great natural wonder of the Grey Glacier was one of the most impressive walking experiences. It is an awe-inspiring 6 km wide, 28 km long and over 30 m high - a broad blue, white and black ethereal presence coming from a white mountainous distance I could barely see, exhibiting forces of compression and flow that I never imagined. Why is some ice so blue? In Torres Del Paine the ice-god has left his mark. I saw many ice rivers in all forms, cascading off cirques and flowing down valleys.

Vertical ice carved rock walls vividly exhibit the force of two tectonic plates colliding where rocks have folded and risen to form the Andes. Dominating the Torres Del Paine massif's south west landscape the Cuervos, the Horns, are two toned vertical cliff faces that divide into two horns, the Cuervo Norte and the 2,600 m Cuervo Principal. On top of black clay stone at the valley's base rise the precipitous light





coloured Paine granites and these in turn are capped by the Cuernos or horns. The Horne's black caps are fine-grained metamorphic hornfelds. A medieval romantic could imagine these as dark towns on massive ramparts. Imposing granite walls are painted a mixture of white recently exposed rock, orange lichen and light grey weathered granite. This is geological history writ large, unburdened by vegetation or other rock debris.



In the beech forest I came across four different orchids. There is no Gondwanan connection to Australian orchids, only their beauty. Gavilea Orchid (*Gavilea lutea*) has quite small closed yellow flowers and bulbs on a spike. The largest and most attractive orchid is the light mauve Porcelain Orchid (*Chloraea magellanica*).



Palomita or dog orchid (*Codonorchis lessonii*) which grows in small groves in the forest has a single white flower on a stem as does the White orchid (*Chloraea chica* now *Gavilea chica*).

There are genera growing in the Patagonian forest that are found around the world including Australia as garden plants, possibly weeds. Boston de Oro (*Ranunculus peduncularis*) is a yellow daisy growing in a rock crevice over the raging glacier-fed Rio Los Perros. Fuegian Edelweiss (*Perezia azul*) is a blue daisy-like flower that grows in patches under trees. Don Diego de la Noche, aka Evening Primrose (*Oenothera stricta*) with its large yellow petals is in cultivation and naturalised throughout NSW. The pink *Oxalis debilis*, is a common Australian weed. The Magellan Pea (*Lathyrus magellanicus*) found throughout the Beech forests is now a naturalised NSW plant. El chilco (*Fuchsia magellanica*), native to southern Patagonia's glacial valleys, is now an ornamental plant in domestic gardens around the world. Of course it will survive frost. Its first scientific description was by John





Sims in 1788. This fuchsia's medicinal uses are linked to the discomfort of menstruation and it was used as a traditional wool dye.

There are more benign botanic connections between Patagonia and Australia, especially Tasmania. The *Nothofagus* genus and *Embothrium*/*Telopea* genus are the stars of the Gondwanan connection story but some other genera should be considered. *Paramela* (*Adesmia boronioides*) is a small yellow pea flower growing on a spike that looks very much the same as any number of Australia's yellow pea flowers, possibly a *Daviesia*. Patagonia's Prickly Heath or Chaura (*Gaultheria mucronata*), an Ericaceae with its tiny white drooping flowers shares its genus with the Tasmanian alpine plant *Gaultheria depressa*. Walking along the track it was possible to eat the tasty small red berries of the Fruitilla del Diablo or Devils strawberry (*Gunnera magellancia*). This is of the same genus as the Tasmanian alpine plant *Gunnera cordifolia* that is abundant near streams and in swampy areas. On Patagonia's windswept freezing Feldmarks Cushion Plants or Llaretila (*Azorella trifurcata*) crawl over rocks and spread out sideways if at all. This Cushion Plant genus also exists as *Azorella macquariensis* on Australia's Macquarie Island. Maybe in the near future botanists will find more Gondwanan connections.



Left: The large purple berries of the Calafate (*Berberis microphylla*). It is common and used as a herb.



Right: El Chilco (*Fuchsia magellanica*).





Gondwana Rainforest of Australia

Compiled by the Editor

Eastern Australia holds a number of reserved areas, including national parks, containing rainforests in which there are species of plants which are, or are closely related to, ancient species occurring before the break-up of Gondwana. Many of these areas have been linked under the title "Gondwana Rainforest of Australia" and listed by UNESCO as a World Heritage Area. The included areas are circled in red on the map. The initial listing was in 1986 and included reserves within New South Wales. In 1994 additional areas were added and, later, this name was ascribed to them. The reserves are spread over a wide area which covers the northern half of New South Wales and some areas in southern Queensland.

A visit to some of these areas provides insight into the types of habitats and species which occurred in certain periods within. Gondwanan times.

Information and maps can be found in the factsheet obtainable from Gondwana Rainforests Executive Officer c/- NSW NPWS PO Box 1236 Coffs Harbour NSW 2450 Email: gondwana@environment.nsw.gov.au or the following websites:

Department of the Environment, Water, Heritage and the Arts –

www.environment.gov.au/heritage/places/world/gondwana/index



Hoop pines and *Brachychiton discolor* Mallanganee National Park All photographs by Hugh Nicholson





UNESCO World Heritage – whc.unesco.org/en/list/368

Queensland Environmental Protection Agency – www.epa.qld.gov.au

New South Wales National Parks and Wildlife Service –
www.environment.nsw.gov.au



Vines – Terania Creek



Elaeocarpus grandis Big Scrub



Antarctic beech, *Nothofagus moorei* Barrington Tops National Park





Inala Jurassic Garden, Bruny Island Tasmania: concept design and aim

Dr Tonia Cochran

Tonia's biography appears on page 65.



Figure 1. General view of Inala Jurassic Garden

The Inala Jurassic garden is located on my private 1,500-acre property on South Bruny Island in Tasmania. It is currently only small - around five acres in size- and is dwarfed by the surrounding conservation-covenanted native forest that covers most of the rest of the property. At the time of writing, the garden includes 650 fully labelled species, subspecies and cultivars with a strong emphasis towards 'true' or wild species. Although the garden is only in its infancy at 5 years old, the concept is a culmination of ideas formed over a period of around 20 years and has been inspired by Tasmania's Gondwanan connections. As the last piece of Gondwana to separate from the Antarctic continent, Tasmania is well-placed to demonstrate this connection, both in terms of its native flora and as an ideal base to showcase the garden. Over the past 25 years that I have been leading nature tours, the concept of Gondwana has frequently arisen, mostly during Tasmanian tours where Gondwanan floral relics abound, but also in other areas of Australia such as south-western and eastern Australia and more recently, several





of the international destinations that we now visit on tour, such as South Africa, South America, Papua New Guinea and New Zealand.

A series of incidents inspired the actual creation of the garden. The Commonwealth Government was offering funding on a \$ for \$ basis for 'innovative tourism projects in regional areas', I met a couple of plant collectors who specialised in Gondwanan species and I sold the last of the stud cattle herd that I had farmed for the previous 25 years. The natural progression (in my mind) was to plant a few specimens in a five acre area of pasture previously used as a cattle paddock to demonstrate the concept of Gondwana in terms of its flora so that we could use this as an educational tool, both on our tours and for access to the general public. On being advised of the success of the Commonwealth grant in 2013, landscaping began in earnest, with the addition of shallow lakes, huge locally sourced Jurassic dolerite boulders, concrete easy access paths and topographical changes to the garden beds using local contractors and huge machinery (figure 2).

Researching and collecting specimens was also reaching the obsessive level and an important decision also had to be made regarding what constituted a Gondwanan taxon. My main interest was plant families of ancient lineage that occurred by vicariance (geographical separation as a result of continental drift/plate tectonics and consequent speciation on the separate continents formed by the break-up of the Gondwanan Supercontinent). But I also decided to include for interest and comparison, those species of more geologically recent taxa with a Gondwanan distribution that may have occurred by past dispersal after the separation of the Gondwanan Supercontinent.



Figure 2. Landscaping with Jurassic dolerite rocks and constructing an easy access path.





The time had also come to decide how the garden was to be planted. At first, the concept was to plant the species together within their respective continent of origin, so that one passed from separate garden beds containing Australian, New Zealand, New Caledonian, South African and South American plants. I quickly realised this wasn't going to work, either from a plant management point of view, or in terms of demonstrating the concept as people moved between similar-looking beds. Planting specimens from different Gondwanan countries together in family groups seemed to solve both problems: the similarity between species was much more apparent by direct comparison.

My theory was that species from the same family would probably require similar cultivation requirements. The paddock was therefore divided into sections where I thought (and hoped) that the different families would do best: for example, water-loving members of the families Gunneraceae and Restionaceae were planted near the waterholes and waterlogged areas of the paddock while members of the Proteaceae were planted in well-drained, sunny positions (figure 3). The first specimens were planted in mid-October 2013.

Figure 4 shows the results of hybridization between two species of *Eucryphia* (*E. lucida* from Tasmania, Australia and *E. cordifolia* from South America), demonstrating the close genetic relationship that exists between the two species despite separation of their continents of



Figure 3. Part of the Proteaceae bed planted in a sunny, well-drained part of the garden.





Figure 4. Hybrid *Eucryphia lucida* and *E. cordifolia* ('Penwith')

origin over an extended time (time of separation estimated at around 180 million years).

After planting, we heavily mulched with *Eucalyptus* bark to provide good preliminary garden preparation which would reduce consequent weeding and watering. Each specimen was also labelled with the name of the family to which they belong, their common and scientific name, their

country of origin and a catalogue number specific to each species which also included the year it was planted. Further catalogue notes as to where and when the plants were sourced, cultivation notes, approximate size of specimens and additional notes on the requirements of each species in their wild state were also collated into a spreadsheet, updated as required and kept on file for reference and further research.

Within two weeks of installing the plant labels, we found that birds such as robins were irresistibly attracted to them to use as perches and consequently, they became quite heavily covered with guano. All labels are now supplied with heavy wire 'poo deflectors' which are higher than and pointing behind the label which have been a huge success.

The next major task was to keep the specimens alive and healthy. My previous experience with growing plants was a cactus collection when I was a child, some carnivorous plants and orchids in the Inala office and native plant cultivation, including a 5-acre commercial Brown Boronia (*Boronia megastigma*) plantation (comprised of around 35,000 plants) which was harvested annually for the essential oil industry. It was therefore a huge learning curve to suddenly determine the various requirements of hundreds of different specimens comprising around 50 plant families from around the world. In addition to extensive research on the natural conditions of each taxa in the wild, I extrapolated this information to soil types and fertility levels of each Gondwanan country. For example, I worked on the assumption that the New Zealand species would require more fertilizer because of the rich, volcanic soils of their native country, while Australian specimens were given small amounts of native fertiliser and products such as seaweed extract as required. This has largely been successful, and we try to learn from our relatively few failures (and take those to heart). I have also been lucky to have the help of a good team, including the Inala property manager Steven "Boris" Morris, who spends much of his time in the garden and like me,





Figure 5. Family Araucariaceae. *Araucaria bidwillii* (left) from Australia and *A. araucaria* (right) from South America.



Figure 6. Family Winteraceae. *Tasmannia lanceolata* (left) from Australia and *Drimys winteri* (right) from South America.



Figure 7. Family Podocarpaceae. *Podocarpus lawrencei* (left) from Tasmania, Australia and *P. nivalis* (right) from New Zealand.



Figure 8. Family Cunoniaceae. *Eucryphia lucida* variegated form (far left) from Tasmania, Australia and *E. cordiifolia* (left) from South America.





has learnt about the various requirements of the different plants through trial and error. Various weeders such as Linley and Kerry also help keep the garden looking immaculate, which is so important for a garden that is open to the public.

Watering was another issue that needed to be addressed. Because of the amount of mulch applied, the water requirement is much reduced and due to the individual needs of each plant we have elected not to water with sprinklers or any broad-range method, choosing instead to hand-water as required. For this we have designed a reticulated system with strategically placed taps around the garden for easy access. Additional water is periodically applied to the water-loving plants by soaking the whole area using a hose. Additional water is gravity fed into the shallow pools within the garden to keep them full over summer. As the garden has grown and root systems develop, the need to water is further reduced. Frost is another issue that has become less of a problem as plant develop and canopies thicken, although we still put 'blankets' over the tender young plants when we anticipate conditions that will lead to a frosty morning. And thick *Cypress* and *Acacia melanoxylon* windbreaks have strategically been planted to reduce potentially damaging northerly and southerly winds.

In addition to the labelling of every species in the garden, interpretive signs for each family have been installed throughout the garden and the entrance sign includes an introductory explanation on Gondwana and the theory of plate tectonics. Boris and I also run guided tours of the garden for those people who request additional interpretation. The content of the tour varies according to whether the visitors are school and community groups, garden societies, private individuals or those with a more academic interest. In all cases, we aim to provide education and increase awareness and to contribute to conservation. The latter is undertaken by growing many species that are threatened in their natural environment with the aim of providing insurance specimens and perpetuating the species through provision of stock plants to other botanic gardens throughout Australia.

These two philosophies underpin our business ethos at Inala, from covenanting the natural forest on the property, to the aims of our tourism company. The garden is open to the public and entry fees and sales from merchandise go towards the Inala Foundation for the conservation of natural habitat and threatened flora and fauna. The garden is also complemented by the Inala Nature Museum, which contains fossilised representatives of some of the taxa growing in the garden. For example, figure 9 shows the comparison between an image of the foliage of a live





Figure 9. Extant Araucarian species *Wollemia nobilis* (left) and extinct fossilised specimen of *Agathis jurassica* (right). Both specimens are from NSW.

Wollemi Pine (*Wollemia nobilis*) which is growing in the garden and a 175-million-year-old Jurassic fossil of the extinct species *Agathis jurassica*, showing the morphological similarity between the foliage these two members of the Araucariaceae.

Inala Jurassic Gardens is now registered as a Botanic Garden. We are now members of Botanic Gardens Australia and New Zealand Inc (BGANZ) and the Gondwana Plant Network, with the aim to share specimens and knowledge with other Botanic gardens around Australasia and to preserve threatened flora through growing insurance specimens of species that are threatened in the wild. I would also welcome collaboration with interested ANPSA members so please don't hesitate to contact me at inala@inalantauretours.com.au.



An aerial view of the garden.



