

Summer 2021/2022
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ANPSA Kiama Conference
Part 1

Australian Plants

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Cover photo: Lord Howe Island as seen from the Malabar Hill Circuit Track, Alan House

Australian Plants articles

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Come join us in Kiama in September

An hour south of Sydney is Kiama, nestled in the luxuriant region of the Illawarra – the location of our next ANPSA Biennial Conference.

Formed around 200 million years ago – from eons of deposition, uplift and erosion – an amphitheatre of rugged cliffs and ridges defines the region.

From the windblown vegetation of the coastal plain to the rainforests of the escarpment and the floral diversity of the sandstone plateau, there is a range of fascinating locations to explore.

The theme for the conference is Australian flora – past, present, future.

Our aim is to reveal the flora which existed over 40,000 years ago, the changes since then, and what we can expect in the future, along with what we can do to conserve and protect the unique flora of the region and our country.

Starting on the Saturday 10 September 2022, with a complimentary tour and lunch of the region, a plant sale on the Sunday, the conference itself begins on the Monday 12 September and goes through to Friday 16 September. A combination of conference sessions and excursions, study group displays, celebration/award dinner and plenty of time to catchup with old friends and make new ones, we hope to bring you a rewarding experience.

Tours pre and post the conference include Lord Howe Island, the Warrumbungles and Pilliga, the Blue Mountains, Sydney and the South Coast.

Registrations open in March, although the Lord Howe tour is already sold out. We are open to both members of sister societies and the public. This is an opportunity to widely promote the beauty of our native plants.

We are adopting the highest standards of safety and Covid protection and require that all participants be fully vaccinated and meet the NSW government restrictions of the day.

We recommend booking your accommodation as soon as possible.

For more information, see our website at austplants.com.au or contact:

Ralph Cartwright on conf2022@spin.net.au or Heather Miles on president@austplants.com.au.

Look forward to seeing you in Kiama.

Australian flora – past present future

The conference program follows the theme of past, present and future and aims to engage as many people as possible, both members and the public.

The weekend before

To kick off, we are hosting a complimentary tour of the Kiama region on the Saturday 10 September, for those already in town. This will include a sumptuous lunch at a popular winery, a visit to the surprising Berry Public School nursery which hosts a rainforest plant nursery as well as a spectacular scenic drive back to Kiama through the rolling hills at the foot of the escarpment.

A range of nurseries will be selling plants, native and indigenous, during the afternoon on Sunday 11 September. These will be open to conference participants as well as the public.

Kiama is a small seaside town and there is a range of places to walk and explore close by, by car or on foot. There will be an opportunity to register for the conference during the day.

In the evening, we will be hosting welcome cocktails to give you a chance to catchup with old friends and make new ones.

The Conference

The conference is five days, of which three are conference sessions and two are full day excursions.

The first day of the conference (Monday) focuses on the past. We aim to uncover what the land and its vegetation looked like and how it was used in the thousands of years prior to 1788.

To bring this to life, we will hear from a range of speakers on:

- What is special about the Illawarra region
- Kiama's weather and tides 40,000 years ago, to the present, and what we might expect in the future
- Historical perspectives of the Illawarra rainforests, early settlers and land management observations.
- How the plants of the Illawarra were used by the Aboriginal people of the Illawarra
- Fire stick farming and what the archaeological records tell us about land and plant use

The second conference day, Tuesday, focuses on the present. Through a series of short talks and demos, we will learn about the challenges the flora faces as well as some of the successes such as:

- Regeneration of bush and agricultural land
- Greening strategies
- Propagation and promotion of Illawarra's indigenous plants
- Creating a botanic garden and planning for the future
- Threats such as weeds, clearing, ferals, and of course climate change
- Initiatives by organisations charged with conserving our bush and fauna
- And more

In the afternoon, we will learn from a number of our study group leaders about innovative research underway, how to use different species both now and in the future, as well as learning about the trees of the Illawarra, which will set us up perfectly for the excursions next day.

In the evening, we have the Award dinner, which will be a fun night. There are seating limits, so this will be on a first come, first served basis. The cost is over and above the conference fees.

The fourth day, Thursday, is focused on the future. It starts with a breakfast session, and will be focused on how our plants will fare in light of the threats of climate change, weeds, feral animals, disease and development. We will consider the bush, gardens and cities.

In the afternoon we will explore how we might collaborate, across states and with other like-minded people and organisations to make inroads into species loss and promotion to an increasingly interested community.

Excursions – getting out and about

There are two full days of excursions, with a wide variety of places to visit running on both the Wednesday and the Friday. We will see a wide variety of plant communities with options for guided walks of varying length to suit all fitness levels.

When booking your tickets, you will choose which two excursions you'd like to go on. Most of the full-day excursions will visit two and sometimes three different places.

The locations include a journey North to the Royal National Park (Wattamolla and Audley precincts) including some dry sclerophyll forest, sandstone heathland, coastal scenery and rocky sandstone ridges with several walk options for varying levels of fitness.

A little further north is Kamay National Park, the original landing place of Cook and Banks, again with several walks of varying length. A side trip to the Joseph Banks Native Plant reserve is also on that agenda. This little-known gem has been one of Sutherland Group's projects for many years, although now council owned and managed, Sutherland group have a twice monthly working bee there.

Heading inland we will visit a wonderful patch of remnant rainforest at the foot of the escarpment at Minnamurra and a commercial (sustainable) nursery which specialises in both plants for local re-vegetation projects and natives sold for retail.

At the top of the escarpment, we will visit another small patch of rainforest at Robertson and a local native plant nursery and then spend most of the day at Fitzroy Falls, with several walk options.

The Illawarra Grevillea Park at Bulli will feature on a number of the excursion options and we would expect that there will be plants for sale for those who can take them home.

Peter and Margaret Olde will open their garden, *Silky Oaks*, to visitors and the Australian Plants Botanic Gardens, Mt Annan, is another full day option which includes a guided tour of the very impressive seed bank.

Heading south, we will explore a number of interesting remnant plant communities in and around the Shoalhaven Heads area including the private garden of John Elton.

Each excursion will have a local leader to provide commentary, include morning/ afternoon tea and lunch and will of course have regular toilet stops.

Outcomes of the conference

We hope you will walk away from the conference with new ideas, knowledge and inspiration. We aim to create an environment which facilitates connections with others. We hope that you will be energised into find new ways to grow, conserve and share our wonderful native plants.

Lord Howe Island – a naturalists paradise

Ian Hutton

Ian Hutton came to Lord Howe Island in 1980, and has been studying, observing, photographing and writing about the natural history since. He has co-authored over 50 scientific papers and ten popular guide books to the island. In 2006 Ian was awarded the OAM for conservation; and in 2020 an Honorary Doctorate in Environmental Sciences. To support his environmental interests Ian runs nature tours on the island.

"Very few places of similar size can show such diversity of plants than Lord Howe Island." Joseph Maiden 1898

The great range of plant species and types found here is no doubt due to the rugged topography of the Island. The Island is the remnant of a volcano that formed a large 30km diameter island 7 million years ago. Since then, erosion has removed 97.5 percent of the Island, but left two large mountains 875 and 771 metres high at the south end. This created many diverse and specialised habitats – exposed ridge tops, heavily forested slopes and deep sheltered valleys. Additionally, the mountains stand so tall they create their own cloud by pushing up moisture laden winds that cool and condense into cloud and hence there is more humidity and more precipitation over this part of the Island. Many permanent streams run down the mountain slopes, creating even more habitats. Over time, many plants evolved to adapt to conditions in these habitats and some fifty percent of the plant species are endemic, found only here, nowhere else in the world.



In the 1970's Sydney Botanic Gardens botanist John Pickard carried out an ecological study of the Island's flora. Pickard identified seven structural formations and 25 vegetation associations, with a number of sub-formations and alliances, and another four physiographic units to identify cliffs and shorelines. However, very broadly the vegetation can be put into three types – lowland littoral rainforest, montane forest and the gnarled mossy cloud forest.

The lowland littoral rainforest is found in areas below 200 metres altitude; and higher on more exposed ridges. This forest type is dominated by several tree species, *Drypetes affinis* (locally Greybark) and *Cryptocarya triplinervis* (local Blackbutt); with some *Olea paniculata* (locally Maulwood). These species are also quite common in the littoral rainforest on the east coast of mainland Australia from Newcastle to Brisbane, and occasionally further north.

In this forest type there are also two endemic palm species from the same genus, *Howea*. One of these – *Howea forsteriana* (also known worldwide as the Kentia palm) often forms dense, almost pure monocultures.



Howea forsteriana

But there are also a number of interesting plants to be found by the keen walker, including five of the thirteen orchid species known from the island.

One of these, *Dendrobium macropus ssp howeanum*, is pictured on the next page.



*Dendrobium macropus
ssp howeanum*



Drypetes deplanchei

Around the slopes of the southern mountains, the montane forest dominates. Because of the deeper, more fertile soils, higher rainfall and bigger catchment areas above, the forest here can be much taller – often to 20 metres tall. In this montane forest there are more endemic species and also more plants with origins from neighbours to the east of Lord Howe – New Zealand and New Caledonia.





Some of the tallest trees here are the *Syzygium fullagarii* (locally Scalybark) and *Chionanthus quadristamineous* (locally Blue plum). There are four endemic tree fern species (all in the genus *Cyathea*) found in the montane forest. The dominant palm up to about 350 metres altitude is *Howea belmoreana*, then it is replaced by the endemic *Hedyscepe canterburyana* (locally Big Mountain palm). A fourth endemic palm species found only above 800 metres altitude is *Lepidorrhachis mooreana* (locally Little Mountain palm).



Syzygium fullagarii



Hedyscepe canterburyana

On the very summit of the two mountains exists a special plant community known as the *Gnarled Mossy Cloud Forest*. Mt Lidgbird only has a very narrow summit ridge and, while it has the same species as on Mount Gower summit, the development of the mossy cloud forest here is minimal. Mount Gower itself has a summit plateau of 27 hectares, and there are a number of small permanent streams that fall over the north face into Erskine Valley.

This habitat in summer is usually shrouded in cloud, and this allows the prolific growth of mosses, ferns and epiphytes. On the summit forest 86 percent of plant species there are endemic to Lord Howe Island. Dominant trees include *Pittosporum erioloma*, *Zygogynum howeanum*, *Dysoxylum pachyophyllum*, *Negria rhabdothamnoides* (Pumpkin tree) the giant heath tree *Dracophyllum fitzgeraldi*, and the two Mountain palm species. There are 56 fern species recorded on the Island, and the majority are found on the mountain summit, including four filmy fern species. The Island has over 100 moss species, again most found in the summit forest.



Filmy fern
Leptopteris moorei



*Negria
rhabdothamnoides*



For the person interested in the Island's flora, a climb to Mount Gower summit is a must. For, along this walk, it is possible to see most of the Island plant species. Some plant species encountered along the walk have a very narrow altitudinal range, and as you climb higher, new species appear and delight the avid observer.

A few species can be found growing from all the way from sea level to the mountain summits – one of these is *Zygogynum howeanum* (locally Hotbark).

The Mount Gower walk is really a climb, and a very strenuous climb, only to be undertaken by the fit. The local administration insists visitors only go with a guide, as the track is faint and unmarked. The party usually heads off with the guide about 7.30 am and the climbing is relentless until the summit is reached about four hours later.

On the second half of the climb, the forest is stunted and the flowers of many species can be seen quite close.

Because the summit forest is very fragile with mosses and ferns on every branch, rock and piece of ground, walkers are confined to a short track on the eastern side of the summit plateau. The track leads to a lookout, where weary walkers get half an hour for a rest and lunch, and then it is four hours carefully returning down the track the same way. If there has been recent rain, this can be very slippery.

Photos by the author unless otherwise noted.



Brachyscome segmentosa, Alan House



Platycerium bifurcatum, Alan House

The Illawarra Rainforests

Kevin Mills

Kevin Mills studied the Illawarra rainforest for his PhD and has written extensively on the flora of the New South Wales south coast over the past 35 years.

“You will be surprized to see how different the vegetation is to that about Sydney, or any other place we have ever before seen. Upon the sloping land in front of the high bold land I observed there several cabbage-trees nearly in resemblance of plantain but yet a true cabbage [*Livistona australis*], and the fern which I can no otherwise describe than by calling it a cabbage tree fern, for it is to distant appearance a cabbage, but upon a close inspection the leaves are found to be fern, and beautiful fern [*Cyathea australis*]. There were many trees that I am certain have never before been known in this country; one, the most remarkably new, was about twelve feet in height, its leaves large, broad and hairy, or rather woolly...and the smaller branches of it covered most thickly with long sharp prickles [*Dendrocnide excelsa*]. Well I remember them, for in the blindness of my eyes I seized one of the branches and was handsomely repaid for my hasty curiosity by a handful of thorns”.

George Bass on the Illawarra coast, March 1796.

The rainforests of the Illawarra caught the attention of early explorers and botanists, including George Bass who was probably the first to describe a rainforest tree from the Illawarra. The forest was just so different from the vegetation and plants to be found around Sydney. While the Sydney area is underlain by sandstone, old volcanic rocks dominate much of the Illawarra. The character of the soil between the two areas could not be starker. While the sandstone, so typical of the Sydney Basin, produces nutrient poor soils with low organic material and low water-holding capacity, the fine-grained Illawarra soils are high in nutrients and occur under a high rainfall. These soil differences are responsible for the complete contrast in the floras of the two areas.

While visitors and others commented on the distinctive plants of the Illawarra, botanists were often to be seen visiting the region for those plants not to be found around Sydney. Prominent amongst the earliest botanists was Allan Cunningham, Government Botanist in the early 1800s. Cunningham and his servants collected live plants and specimens from the Illawarra on many occasions and some of the species were described by others in commemoration of the botanist;

for example, Brown Beech *Pennantia cunninghamii* and Featherwood *Polyosma cunninghamii*, both of which were described from specimens gathered in the Illawarra district.

Travelling south from Sydney, the swamps, heaths and woodlands of the sandstone country suddenly give way to tall lush forests below the sandstone cliffs that tower over the Illawarra. Cunningham, as did others, commented on the complete change in the vegetation below the escarpment cliffs, writing on a visit in October 1818:

“A sudden change takes place for in an instant upon leaving the morass [sandstone plateau] with its stunted small Eucalypt we entered as it were, within the dark shades of a tropical forest, composed of very lofty timber of the red cedar [*Toona ciliata*] *Tristania albens* or Turpentine Tree [*Syncarpia glomulifera*], large Eucalypt, of the species called Blue Gum [*Eucalyptus saligna*], and many other trees only existing in such situations. Epacridae [*Trochocarpa laurina*] with large specimens of *Corypha australis* [*Livistona australis*] and Alsophila [probably *Cyathea australis*] a tree fern of New South Wales, the whole thing being strongly bound together with immense escandent and volubious plants, that cannot fail to arrest the attention and admiration of the most indifferent observer.”

The largest area of rainforest south of the Hunter Valley occurred in the area from Shellharbour to Berry. Baron Field was referring to this rainforest, the Illawarra Brush, when he wrote in October 1823, only eight years after the initial settlement of the Wollongong area, “rode to Shoal Haven, thirty-six miles still further to the south, six or seven of which was through a mass of vegetation, requiring pioneers to penetrate it. The vines or lianas wreathed the trees, like the boa constrictor, and festooned the way...or hung dangling like the ropes of a belfry.”

Remnants of this subtropical rainforest occur throughout the Illawarra, with small patches on rocky slopes that were never cleared, regrowth stands on abandoned farmland and as single large trees left in the paddocks. Large old figs *Ficus* spp. and tall *Livistona australis* palms may indicate previous rainforest, although many figs were planted around farm buildings in the early years and are now very large. The strangler habit and high branching indicate that a tree is a forest fig and not one that has been planted; see Figure 1. Planted figs are common throughout the district; these grew in the open and exhibit a low, spreading branching habit when compared to the tall forest figs.

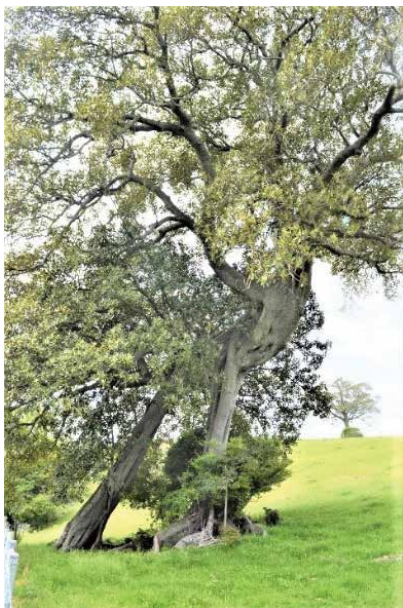


Figure 1. Known as the Twin Fig, this remnant *Ficus macrophylla* near Swamp Road, Dunmore, has grown as a strangler fig in the original rainforest, now cleared.

Few observers seemed to lament the loss of the forest as the clearing escalated during the second half of the 19th Century. Cedar-getters first penetrated the forests, followed by farmers who took up land grants issued by the government. Austrian landscape painter Eugene von Guerard visited the Illawarra forests during his excursion to New South Wales from his base in Melbourne and painted several scenes showing the Illawarra rainforest in late 1859. Guerard saw into the future, writing:

“With lofty bungalow palms [*Archontophoenix cunninghamiana*], cabbage palm, the gigantic wild fig-tree [*Ficus* spp.], and the fire tree [*Brachychiton acerifolius*] ... with its scarlet blossoms, are intermingled the nettle-tree [*Dendrocnide excelsa*], the rose-wood, the sassafras [*Doryphora sassafras*], the white-wood, the wild rose, numerous varieties of the fern and parasites [epiphytes] innumerable, the whole thing being woven together into a dense and almost impenetrable mass of foliage. Unfortunately progress of settlement is necessitating the destruction of these magnificent forests, which in many instances clothe a rich chocolate soil of especial value to the farmer. At the time this view was sketched [*Cabbage-tree Forest, American Creek, New South Wales*] numerous fires had been kindled by the wood-cutters, and the stately giants were rapidly falling before the pitiless axe of the hardy pioneers of civilisation.”

The escarpment forests, never completely cleared due to the steepness of the topography, are a mosaic of rainforests and tall moist eucalypt forests; see Figure 2. The district's rainforests vary greatly along gradients in altitude and rainfall from the coastal lowlands to the high altitudes of the tablelands to the west. The other key determinant of rainforest type is geology; i.e., the character of the soil. In the simplest classification, the region's rainforests can be categorised into several broad types, although in reality there is generally no distinct boundary between the types, which exhibit a continuum of change in species occurrence along the above environmental gradients. These simplified types are subtropical, warm temperate, warm/cool temperate and littoral.



Figure 2. View from escarpment overlooking Macquarie Pass, west of Shellharbour. The moist forests of the region's escarpment country are a patchwork of rainforest (bright green in photograph) and tall eucalypt forest.

Subtropical

The Illawarra is towards the southern end of the range of subtropical rainforest, with many species either reaching their limit of distribution in the region or are very rare further to the south. This rainforest reaches its most diverse on the volcanic soils of the Jamberoo valley and nearby; see Figures 3 and 4. The type is typified by very large trees and robust vines, a high number of tree species, the presence of special features such as deciduous trees and palms, and an abundance of ferns, including epiphytes, in the wettest sites. Typical trees include Figs *Ficus* spp., Giant Stinging Tree *Dendrocnide excelsa*, Illawarra Flame Tree *Brachychiton acerifolius*, Red Cedar *Toona ciliata*, Bloodwood *Baloghia*

lucida, Churnwood *Citronella moorei*, Pigeonberry Ash *Elaeocarpus kirtonii*, Black Apple *Planchonella australis*, Whalebone Tree *Streblus brunonianus* and two species of palms, as mentioned above.



Figure 3. Canopy of Subtropical Rainforest in Jamberoo Valley. The main trees in the photograph are *Toona ciliata*, *Ficus obliqua*, *Elaeocarpus kirtonii*, *Dendrocnide excelsa*, *Diploglottis australis* and, fruiting at far right, *Emmenosperma alphonsoioides*.



Figure 4. Subtropical Rainforest west of Kiama; the large trees with *Asplenium australasicum* epiphytes are *Citronella moorei*.

Warm Temperate

Warm temperate rainforest varies somewhat depending upon altitude and soil type. The most common form is that dominated by the tree Coachwood *Ceratopetalum apetalum*; see Figure 5. Associated tree species include Sassafras *Doryphora sassafras*, Native Laurel *Cryptocarya glaucescens*, Lilly Pilly *Syzygium smithii*, Featherwood *Polyosma cunninghamii* and the shrub Brush Pepperbush *Tasmannia insipida*. Ferns are particularly diverse and abundant on moist, protected sites, including three species of tree fern.



Figure 5. Warm Temperate Rainforest dominated by *Ceratopetalum apetalum*, Cambewarra Range, Kangaroo Valley.

A rainforest dominated by Ironwood *Backhousia myrtifolia* occurs on ridges within other rainforest and in protected gullies in drier country, often associated with rocky gorges. This rainforest is very simple, usually with only one dominant tree and an open understorey containing few species.

Warm/Cool Temperate

Basalt soils at high altitude support a particular type of rainforest that while associated with warm temperate rainforest contains features that reflect the high altitude at which it occurs. This type occurs in the Robertson and Sassafras areas; see Figure 6. The rainforest is similar to Warm Temperate, but there are some additional species

that prefer high altitudes; these include the trees Featherwood *Polyosma cunninghamii*, Native Mulberry *Hedycarya angustifolia*, Possumwood *Quintinia sieberi*, Plumwood *Eucryphia moorei* and Musk Daisy-bush *Olearia argophylla*, along with the Soft Tree Fern *Dicksonia antarctica*.



Figure 6. Warm/Cool Temperate Rainforest, Robertson Nature Reserve, Robertson. Typical trees are *Ceratopetalum apetalum*, *Polyosma cunninghamii*, *Quintinia sieberi* and *Doryphora sassafras*.

Littoral

Rainforest that occurs close to the sea, known as Littoral Rainforest, primarily grows on sand sheets immediately inland from the seashore; see Figure 7.

While many sites are quite floristically and structurally quite simple, others are relatively species diverse; the latter sites usually grow above a water table close to the surface. This type is related to subtropical rainforest, with a few distinct differences, namely lower plant diversity, few ferns and the presence of a distinctive suit of rainforest trees largely absent or rare in other types. These trees include Hard Corkwood *Endiandra sieberi*, Native Celtis *Celtis paniculata*, Plum Pine *Podocarpus elatus*, Ribbonwood *Euroschinus falcatus* and Celerywood *Polyscias elegans*. Large Small-leaved Figs *Ficus obliqua* occur in the best developed stands.



Figure 7. Littoral Rainforest, Comerong Island Nature Reserve, Shoalhaven. Common trees include *Elaeodendron australe*, *Endiandra sieberi*, *Syzygium smithii*, *Livistona australis* and *Clerodendrum tomentosum*.

Conservation

Today we are left with small and scattered remnants of the original rainforest. It is estimated that about 85 percent of the rainforest has been cleared since European settlement of the district that began in 1815. Thankfully, most of what remains is now protected, either within the National Parks and Wildlife Service estate, on Council reserves or under land use zoning that prohibits its removal. Most land owners place a high value on the rainforest growing on their properties, and many are managing their properties to conserve and enhance these remnant patches. The rainforest today is valued for its scenic, scientific, cultural and economic value through tourism and it now has legislated protection in most cases.

Easily accessible rainforest sites include Minnamurra Rainforest Centre in Budderoo National Park, Macquarie Pass National Park, Saddleback Mountain west of Kiama (Council reserve), Bass Point in Shellharbour (Council reserve) and Robertson

The Geology of the Greater Sydney Area

Dan Clarke

Dan Clarke is a botanical consultant in the NSW Ecological Consulting Industry. He is the Conservation Officer for Australian Plants Society, NSW.

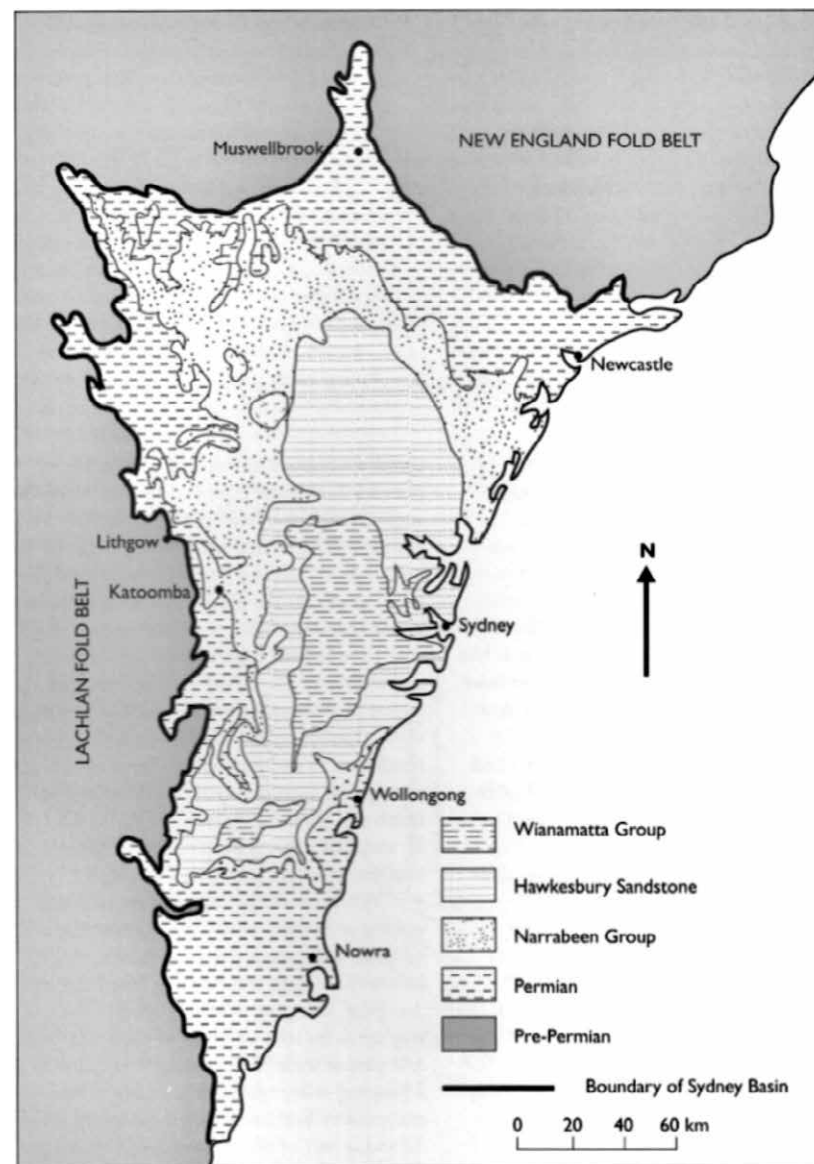
The Sydney Basin Bioregion is one of the most species diverse in Australia. This article aims to give a general overview of the geology of the Sydney basin which provides a home for the unique and well-appreciated Hawkesbury Sandstone flora of the Greater Sydney Area.

The Greater Sydney Area is well known for its wide variety of vegetation communities and assemblages; occurring on a multitude of different soil landscapes and geological formations. This variation, including heathlands, shrublands, dry and wet sclerophyll woodlands and forest, as well as rainforest and swamplands, results in a suite of 2,000-3,000 occurring native flora species (including a substantial number which are threatened with extinction). Everyone from APS members, to ecologists, to leisure seekers, exercisers and bushwalkers alike, can all likely name a particular bushland area in Sydney that they cherish. This love may be due to the gentle rolling topography found on the Cumberland Plain, the tall trees in steep-gully areas, the rainforest environs close to the coast, or the grandiose sandstone outcrops that are so typical in some areas, especially on Sydney foreshore and other walks.

The focus of this article is the flora which occurs on the Hawkesbury Sandstone Geological Formation. Our Sydney Sandstone (some might call it), is a geological formation that was formed some 200 - 250 million years ago, in the Middle to Late Triassic period. Modern-day geological science has determined that the deposited sand, which has been hardened and cemented into the iconic rocks, shelves and plateaus we observe today, eroded from former rocks that were 500 - 700 million years old. These source rocks were actually located in Antarctica!; - way back when the arrangement of land masses on the earth was very different (i.e. Gondwana). The sand flowed along massive river deltas, layer upon layer, to form the landscape we observe in Sydney today (the mind boggles!).

The extent of mapped Hawkesbury Sandstone along with other geological formations is shown in the map opposite.

This article will not do justice to a proper scientific explanation of the geological processes and formation of Sydney. However, for a general overview: the Sydney landscape is referred to as a “basin” or “bowl”



General distribution of major rock types in the Sydney Basin (after GH Packham (ed), 1969, 'The Geology of New South Wales', *Journal of the Geological Society of Australia* 16(1):654)

formed over 300 million years. The bowl is bordered on one side by the Pacific Ocean, with the rising Blue Mountains to the west, and with land also rising to the north and south in the form of the Hornsby and Woronora Plateaus.

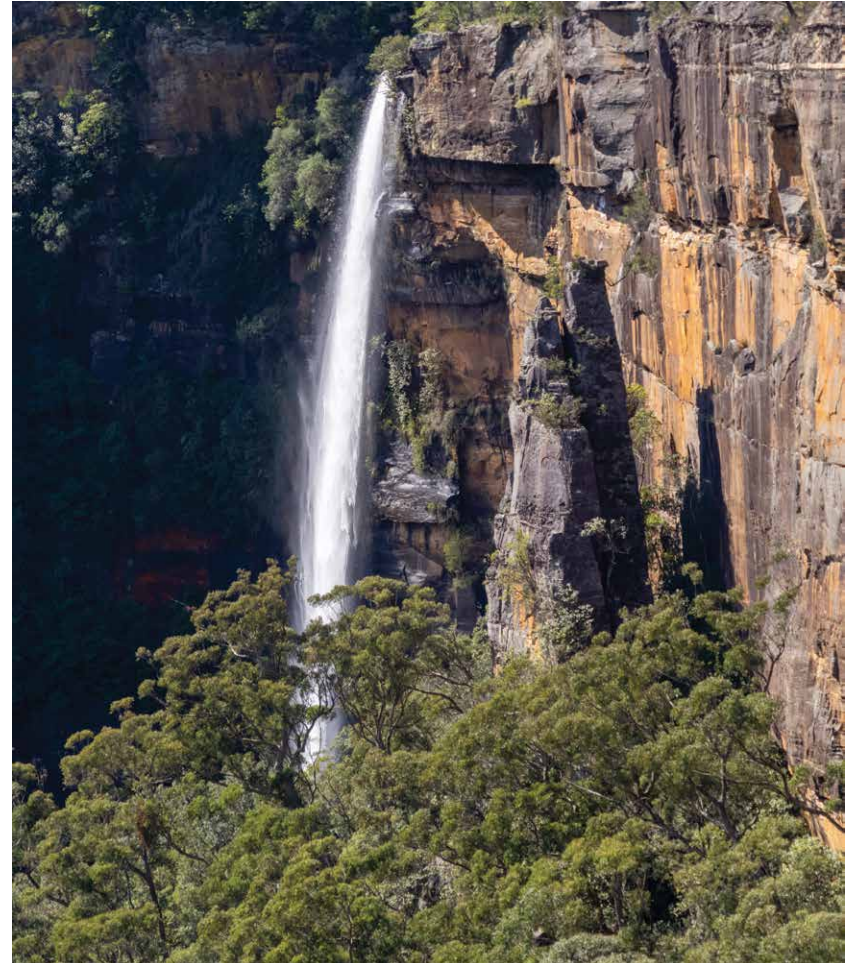
The Hawkesbury Sandstone typically lies on the higher ground, especially at the edges. The more recent Wianamatta Group shale-clay deposits of the Cumberland Plain lie above the sandstone, on lower elevations, in the middle of the basin. In many areas, the shale and sandstone can be “inter-bedded” with the deposits meeting like the locking fingers of two hands. Some areas in Sydney support *Shale-Sandstone Transition Forest* – a vegetation community which is now listed as critically endangered.

Underneath the Hawkesbury Sandstone, are older deposits referred to as the Narrabeen Group Sediments. These are shales, sandstones and claystones which do make an appearance in places such as the warm temperate rainforest in the south of Royal National Park.

Even deeper down, are the Illawarra and Newcastle coal measures, some of which has been mined from locations including Helensburgh and Balmain.



View from Bald Hill looking south towards Wollongong. The escarpment is capped with Hawkesbury sandstone, the Narrabeen Group form the slopes whilst the Illawarra coal seam lie at and below sea level. Photo: Heather Miles



Fitzroy Falls, Morton National Park, plunges dramatically over a large vertical cliff of Hawkesbury Sandstone to the valley 81m below. Photo: Heather Miles

The most spectacular overview of the interaction of these sediments can be observed in the valleys of the Blue Mountains. In a nutshell, very old Devonian mudstones (which contain marine fossils) lie on the creek beds at the base of locations such as Jamieson Valley. Above these sediments, Narrabeen Group sediments have been eroded away by water flows, continuously undercutting, in this case, Narrabeen sandstone sediments and remaining minor Hawkesbury Sandstone. Eventually, massive blocks of sandstone (with a density of 2.6 tonnes per cubic metre!) simply fall down, creating the spectacular valley views we admire today.

For a thorough and better understanding of the Sydney Basin Geology, *A Day in the Bush; Bush walks in and around Sydney* by Les Higgins and Tony Rodd gives an excellent account of the above in its early pages. In addition, *Taken for Granted; The Bushland of Sydney and its Suburbs* by Doug Benson and Jocelyn Howell, also provides a very useful overview.

The extent of the Hawkesbury Sandstone is stated as about 190 by 90 km, extending from the Sydney Coast, as far west as Lithgow, south to almost Kiama (or west of) and north to about Newcastle. There are sandstone formations as well which lie within and outside the Sydney area, such as the Mittagong Formation, Newport Formation, Bulgo Sandstone and Minchinbury Sandstone. These are classified as different sediments and occur in much lesser extents compared to the Hawkesbury Sandstone. Some of them are associated with the Narrabeen and Wianamatta Group Sediments.

In passing, in the Kiama area, you can get familiar with vegetation on “volcanic sandstones”; an oxymoron perhaps, but these are sediments which have formed through a coinciding of wet sand deposition, combined with volcanic activity.



Columnar jointing of igneous basalt, Bombo Quarry. Evidence of past volcanic activity in the Kiama area.
Photo: Heather Miles

The characteristics of the Hawkesbury Sandstone is that of a very shallow (skeletal) and nutrient-poor soil that has been leached for millions of years, without any “nutrient refreshment” from either volcanic or earthquake activity, or other deposition such as flooding. In fact, the Hawkesbury Sandstone soils can be listed as one of the most infertile in the world. Where we can relate to this, at least to some extent, is the struggle of the early colonists (or invaders if you prefer) from 1788-1810, who discovered that growing crops and vegetables in Farm Cove, Sydney, at the now Royal Botanic Gardens, was not really achievable. It is said that they had the seasons mixed-up, but the lack of essential nutrients in the soil also had a major impact. These skeletal sandy to sandy loam soils have very little phosphorus; a major ingredient needed for healthy plants. They also have low water holding capacity combined with fast drainage. Together with episodes of climate change and regular fire, the Sydney flora has had to adapt to great lengths to survive here. As we have likely observed through our interest, the flora on the Hawkesbury Sandstone has adapted strongly to the environmental and physiological conditions, displaying a wide range of features such as tough leathery leaves, tissues full of harsh chemicals, the ability to survive on little phosphorus and water, as well as the very acute ability to survive and respond after fire. The flora is incredibly diverse, given the nature of the landscape.

One of the pioneers to study these adaptations was Noel Beadle (1914-1998), a Professor of Botany, who taught at University of Sydney and then University of New England at Armidale (where the NCW Beadle Herbarium is named in his honour). Beadle (1954) intensely studied the relationship between available soil phosphorus and the evolutionary effects on plant communities, especially in sandstone areas. Beadle firmly established concepts to describe the Australian Flora such as xerophyly and sclerophyly (or xeromorphs and scleromorphs).

To be brief, these are conditions where plant-leaf tissue is highly modified, including impregnation with sclerenchyma cells and other “tougher” tissue and chemicals; reduced stomates on the leaf surface, as well as alteration in shape, size and texture.

A primary example of a xeromorph would be *Hakea sericea* (Silky Hakea) with its prickly and tough foliage capable of reducing water loss to almost zero, along with inedible foliage where herbivores are concerned.

Eucalyptus sclerophylla (and many other eucalypts) is a good example of a sclerophyllous plant with large amounts of sclerenchyma in the



Left: *Hakea sericea* (Silky Hakea) Photo: John Aitken

Below: *Eucalyptus sclerophylla* Photo: Alan Fairley



leaves, along with less photosynthetic material and thickened leaf edges (cuticles) to prevent water loss and herbivory. Generally, sclerenchyma cells are toughened woody-like or fibrous cells made of more complex compounds which make leaves harder, less easily broken-down and more resistant to harsh environments. Mature sclerenchyma is actually dead but still forms a part of leaf and stem tissues.

Beadle found that Australian xerophyllous and sclerophyllous plant tissues typically have lower leaf-phosphate content, compared to rainforest species (termed mesomorphic) with softer leaf tissue. Beadle made larger conclusions about the long-term evolutionary results for Australian flora generally in response to the lack of nutrients, primarily phosphorus in the soil (which again links back to long eons of erosion and leaching, without large-scale volcanism and other geological activity).

Whilst research continues around the country, it can likely be accepted that Beadle's insights ring true for the Hawkesbury Sandstone flora. As one person once stated to me, whilst on a bushwalk through Sydney sandstone heathland: "*So many of these plants are so nasty and prickly*" (I don't think she liked natives). But we can understand how this process has come about.

References

Further information on the geology of the Sydney basin is freely obtained through the NSW Planning, Industry and Environment website. Images of geological maps can be downloaded, and files can also be downloaded for incorporation into GIS software at search.geoscience.nsw.gov.au/product/135.

The mapping code on these maps, indicating the Hawkesbury Sandstone, is "Rh", and it can be seen on many polygons across the landscape. In addition, associated government soil landscape mapping is also freely available from the NSW Espade website at www.environment.nsw.gov.au/eSpade2Webapp

If you take some time to use it, you can bring up soil landscape mapping, and download description profiles in the form of pdf documents at

www.environment.nsw.gov.au/Salis5app/resources/spade/reports/9029ha.pdf

Mapping is not available for all areas, but Sydney is well covered as is most of the NSW east coast, and so you may well be able to get familiar with your underlying soil landscape at your property.

Dan's second article on the flora of the Greater Sydney Area will appear in the next issue of "Australian Plants". [Ed]

The Greater Blue Mountains World Heritage Area

Margaret Baker OAM

Margaret 'discovered' the Blue Mountains on school holidays from Newcastle. After moving to the area she and husband Mark joined the Blue Mountains Group of the SGAP in the late 1970s. She has been a TAFE Head Teacher of Environmental Sciences and a co-author of books on native plants. In her 'retirement' Margaret wrangles a group of rowdy native plant identifiers who supply information to the NSW Herbarium, BioNet and iNaturalist.

On the 29th November 2021 we celebrated the 21st anniversary of the declaration by UNESCO of the Greater Blue Mountains World Heritage Area (GBMWH). World Heritage listing was a special acknowledgement of the antiquity, diversity and uniqueness of the plants and communities to be found here. Set against a backdrop of stunning scenery the special qualities of this region have attracted those seeking the sublime and the fascinating for centuries.



The Grose River Valley: diverse habitats support a great range of plants ^{MWB}

Eight protected areas comprise the 1.03 million hectare GBMWH Property that is located to the west of Sydney. Managed by the NSW National Parks and Wildlife Service and extending from the Hunter Valley to the Southern Highlands of New South Wales, the national parks of Wollemi, Yengo, Gardens of Stone, Blue Mountains, Kanangra-Boyd, Nattai and Thirlmere Lakes and the Jenolan Karst Conservation Reserve form one of Australia's largest intact areas of protected bushland. The great range of natural habitats here supports an impressive diversity of plants. At the time of nomination 152 families, 484 genera and about 1500 species were recognised.^{1, 2}

The main focus of this article is the central part of the Blue Mountains National Park that extends from the edge of the Newnes Plateau towards the Cox's River, and rises from Lapstone (100m) and Kurrabung (150m) to Mt Victoria and Bell (1100m). It is crossed by the main transport lines that lead west from Sydney. Long-occupied by Aboriginal people, today it supports ribbons of settlement in towns and villages that include Glenbrook, Springwood, Katoomba and Bilpin.

Geo-heritage of the Greater Blue Mountains

Although the declaration of Greater Blue Mountains World Heritage Area was made because of the special qualities of the plants and their communities, the region is well known for its outstanding scenery. The Blue Mountains were formed by the upwelling of the molten mantle beneath the Earth's crust that resulted in the episodic uplift over nearly 100 million years of plateau blocks that jostle together like huge steps across the landscape. Dissected and sculpted by rivers and waterfalls, the region presents breathtaking valley views, sheer escarpment walls, pagodas and a myriad of other stone decorations.



Wentworth Falls exemplifies stream erosion at plateau edges. The amphitheatre provides niches for exposed heaths to sheltered rainforest ^{MWB}

The GBMWH is a place of considerable geological antiquity. Old rocks occupy the south-western parts of the region and include the Jenolan Caves limestone (430 Ma)³, and the quartzites of Kanangra Walls (370 Ma) that were folded during the uplift of the ancestral Kanimblan Highlands (340 Ma). The younger rocks of the central

Blue Mountains were formed within the western part of the geological Sydney Basin from sediments that were laid down on top of the eroded Kanimblan Highlands (Permian-Triassic; 300-220 Ma). The deeply dissected valleys of the region reveal the main sedimentary rocks and the environments in which they were formed.

The oldest Permian-aged rocks of the region formed on the eastern margins of 'Australia' that, as part of Gondwana, had drifted into southerly latitudes initiating an 'ice-age'.⁴ So in the depths of the Jamison Valley (south of Katoomba) the sedimentary rocks are erosion-resistant glacial moraine gravels.⁵ Thick layers of volcanic silt largely transported by the sea then covered the moraines (Berry Siltstone) and, much later, coal formed in swamps of river deltas (Illawarra Coal Measures). These formations are readily weathered and eroded, processes that are largely responsible for the widening of the upper Mountains Valleys and their high-angled lower slopes.



Most of the western Sydney Basin rocks can be viewed from Katoomba. The iconic Three Sisters are formed in Banks Wall Sandstone and are divided by vertical joints. The vegetated bench is Mt York Claystone.

The Triassic-aged Narrabeen Group of rocks dominate the escarpments of the Jamison and Grose Valleys. The lower layers of Caley Formation sandstones and shales provide an unsteady base to the more solid cliffs of riverine Burra-Moko and Banks Wall Sandstones. The sandstones are separated by a bench of Mt York Claystone and are capped by yet more sandstones and shales of the Burrell Formation. Cliff-face collapse can be quite dramatic where weathering and erosion of the

weaker rock layers (Coal Measures, Caley Formation and Mt York Claystone) undermines the resistant Narrabeen Sandstones. Left unsupported, massive blocks eventually fall along vertical joint lines or cracks into the valley below.

Vertical joints in the escarpment sandstones play a role in the sculpting of isolated rock pillars. The focusing of water down the joints weathers and erodes the adjacent rock faces eventually leaving them isolated. The effect is best seen on the Newnes Plateau where dense lines of intersecting vertical joints divide the surface into rock grids; blocks of sandstone separated from each other take on shapes that are often reminiscent of oriental pagodas. The final detailing of each is determined by the presence or absence of horizontal layers of ironstone. Where streams take advantage of the joints, canyons add another dimension to a landscape that is full of hidden surprises.

At lower altitudes the cliffs and ledges of narrower stream valleys are mostly formed in riverine Hawkesbury Sandstone. Later inundation by an ancient sea left coastal shales and sandstones of the Wianamatta Group (c. 220 Ma) that outcrop on the plateau surfaces from Lapstone to Falconbridge and from North Richmond to Mt Tomah. Hawkesbury Sandstone forms valley sides of steps or benches for giants. Where streams like Glenbrook Creek and the Grose River cut through the eastern escarpment valleys are deep and dramatic.



Hawkesbury Sandstone in the gorge of Glenbrook Creek where it cuts through the Lapstone Structural Complex; looking west towards Glenbrook Fault ^{MWB}

About 200 Ma (Jurassic) volcanic diatremes exploded through the rocks and later eroded into rounded valleys. In the lower Mountains



The basalt cap of Mt Hay above the Grose Valley; a range of habitats support Tall Open Eucalypt Forest on the Mount, open forest and woodland on the upper slopes, heath in the exposed places and swamps where it is damp. ^{MJB}

examples include Euroka Clearing and Sun Valley. Further tectonic activity has particularly marked the last 100 million years producing major changes in the configuration and elevation of the landscape. Upwelling of hot mantle currents about 100 Ma, associated with the break-up of Gondwana, elevated the Great Dividing Range dragging with it the western edge of the Sydney Basin and activating today's Coffs River. Further uplift of the region occurred about 40–60 Ma.

Outpouring of basaltic lava (14–20 Ma)⁶ then capped the sedimentary rocks in the area bounded today by Mounts Wilson, Tomah, Hay and Banks. A complex set of earth movements as recently as 10 Ma set in place the eastern 'escarpment' of the Blue Mountains (the Lapstone Structural Complex) that rises from the Cumberland Plain of western Sydney along east-facing monoclines, and faults including those of Kurrajong and Glenbrook. This relatively recent period of instability altered landforms and streams, impacted on climate and provided new habitats for plants and animals in the eastern Blue Mountains.

World Heritage Plants and Communities

The Greater Blue Mountains World Heritage nomination criteria focused on the long history and resilience of plants and communities:

- *The long and continuous evolution of living plant groups*
- *The continued presence of primitive species with Gondwanan affinities*
- *Highly unusual juxtaposition of ancient and modern plants and communities*

Plants with an Ancient Lineage

The evolution of living plant groups in the GBMWHa has taken place against changes in global position, regional geology, landforms and climate. The first primitive liverwort-like plants were non-vascular (lacked xylem and phloem). When they first appeared on land, eastern 'Australia' was part of Gondwana, north of the Equator and beneath the sea (Ordovician 450 Ma). Liverworts later colonised dry land here; at least 120 species grow in the Blue Mountains today.⁷ As Gondwana drifted south and climates changed, plant groups evolved. Initially all were spore-bearing and showed a range of vascular tissue types. Some became extinct while others adapted and survived.

An interesting example is the Lycopodiopsida (club mosses) whose tree form was the 30m tall *Lepidodendron*. It populated forest communities from the Devonian to the Carboniferous (c. 370 – 320 Ma). Though *Lepidodendron* is long extinct, herbaceous Lycopods grow in the Blue Mountains today. *Lycopodium deuterodensum*, that resembles a miniature conifer, inhabits Eucalypt woodland in the upper Mountains, and the fragile *Selaginella uliginosa* is a component of regional swamps. Ferns also thrived in the early Club Moss forests. Today the primitive *Psilotum nudum* (Skeleton Fork Fern) emerges from damp sandstone crevices and *Tmesipteris parva* (Hanging Fork Fern) is pendent from Mt Wilson tree fern trunks.



Post-fire Club Moss *Lycopodium deuterodensum* just 20cm tall. ^{MJB}



Abundant true mosses on the trunk of a rainforest Coachwood. ^{MJB}

Club Moss forests declined as a late Carboniferous Ice Age chilled Gondwana and tundra expanded. True mosses became more prominent in the regional flora and today form a diverse group of 225 species particularly in rainforest. In all some 348 species of primitive Bryophytes (liverworts, moss and hornworts) make up a significant component of some of our communities and bare rock surfaces.⁸

As climate moderated in Permian times (c.300 Ma) Glossopterid forests spread across Gondwana, then became extinct about 252 Ma. Glossopterids were broad-leaved, seed-bearing Gymnosperms that grew in temperate swamps. Their deciduous habit supplied enormous quantities of coal-forming leaves as evidenced in the Sydney Basin coal seams today. The Osmundaceae family of ferns grew in Glossopterid forests and the best-known descendant is the King Fern, *Todea barbara* that today enjoys stream banks and waterfall fringes.



The King Fern
Todea barbara from
ancient Gondwanan
Glossopterid forests
now on a South
Lawson stream bank
beneath eucalypts. ^{MJB}

Plant groups took quite a long time to recover from the Permian extinction and in the early Triassic (c.252 – 245 Ma) sparse vegetation communities of herbaceous Lycopods, horsetails and early conifers dominated. One conifer family from this period is the Cupressaceae; it continued to evolve new genera at least into the Palaeogene Period (35 Ma) including our dry country *Callitris muelleri* and *C. endlicheri*.

The last forests to contain only ancient plants grew in cool, wet environments of eastern Gondwana from the Jurassic to the early Cretaceous (from 200 – c.140 Ma). Conifer families dominated the canopies and included the Podocarpaceae that was first evident in

the late Permian; it then diversified across southern Gondwana (more below). The Araucariaceae were also significant. At the height of its diversity the family had spread across the mega-continent Pangaea, then about 65 Ma it contracted its range leaving two genera, *Araucaria* and *Agathis* in southern latitudes. They were joined by the tenth and most modern Araucarian conifer, *Wollemia nobilis*, about 62 Ma (Palaeogene) but more of that below.

The understorey plants of ancient forests bear interesting survival stories. Cycads, ginkgoes, club mosses, horsetails and tree ferns thrived in damp, temperate conditions. Tree ferns are still to be found in the region's rainforests and Tall Eucalypt Forests. Species of the late-Jurassic Cyatheaaceae family, including *Cyathea australis* (Rough Tree Fern), were joined in the early Cretaceous by the Dicksoniaceae. *Dicksonia antarctica* (Soft Tree Fern) prefers rainforest on basalt soils.

Attaching a definite lineage to Zamiaceae family cycads presents a conundrum. As with many other ancient groups there has been a continuous emergence of new cycad genera. Although cycads appeared about 280 Ma, the Zamiaceae family has a fossil record dating from 200 to 54 Ma. The Australian endemic *Macrozamia* may have evolved quite recently, certainly after Gondwana began to break-up and the forests were filling with 'modern plants'. The four Blue Mountains species that include *Macrozamia communis* and *M. spiralis* are at home in the understorey of eucalypt forests often on poor soils.



Left: Ancient tree ferns in a rainforest with a flowering plant canopy (Coachwood Glen). ^{MJB}

Above: *Macrozamia communis* in an open eucalypt forest (lower Blue Mountains). ^{MJB}

The Heritage of Flowering Plants

Flowering plants (Angiosperms) rapidly diversified and expanded their range from the early Cretaceous Period. At first they formed a minor component of the Podocarp/Araucaria coniferous forest mix but from about 100 Ma significant changes become evident in community structure, and phyla and family mix as Angiosperms diversified and spread throughout a Gondwana that was separating into today's southern continents. For eastern 'Australia' this time marked the start of the separation of the mainland from Zealandia and the formation of the Tasman and Coral Seas, promoting major changes to landforms and elevation. The Great Dividing Range was uplifted and blocks of the Sydney Basin were jostled into new positions; flows of lava came and went, rivers changed course and all the while the country drifted north into hotter and drier latitudes. In the Blue Mountains flowering plants grew against a backdrop of changing habitats. Alterations to climate and fire regimes were highly significant in determining which plants would survive to the present and those that would not.



'New' conifers appeared as modern flowers spread: *Wollemia nobilis* with male and female cones at Lithgow Community Nursery. ^{MWB}

Cool temperate rainforest with a mix of old and new plants predominated at first with more sclerophyllous communities forming on its fringes. A new fern genus, *Blechnum*, appeared; species now grow abundantly in moist conditions. Some ancient families evolved new taxa. In the Podocarpaceae family the best known 'new' member is *Pherosphaera fitzgeraldii* (Microstrobos or Dwarf Mountain Pine) that grows in the spray-zone of just seven waterfalls of the southern escarpment (Wentworth Falls to Katoomba). The latest Araucarian conifer recruit is *Wollemia nobilis* (62 Ma).⁹ The story of the discovery of the Wollemi Pine in 1994 by NPWS officer David Noble, is now legendary. It remains today a lone surviving emergent species in a secret rainforest ravine in the northern Blue Mountains.

Flowering plants quickly gained a presence as new families evolved in the late-stage Gondwanan Rainforests. From about 94 Ma there is an expanding fossil record of plants that are familiar today including the Proteaceae (*Lomatia*, early Banksias and Grevilleas), Orchidaceae (possibly arboreal species), Winteraceae (*Tasmannia insipida* and *T. lanceolata*), Loranthaceae (including the World's oldest extant root parasite *Atkinsonia ligustrina*) and the Cunoniaceae (*Ceratopetalum apetalum* Coachwood). The iconic Gondwanan family Nothofagaceae (Southern Beech) dominated the broad-leaved forest communities. As Australia drifted north into drier, warmer, and fire-promoting climates the Southern Beech gave way to sclerophyllous families. By 5.5 Ma *Nothofagus moorei* (Antarctic Beech) had retreated to mountain refuges, including Barrington Tops, further to the north.



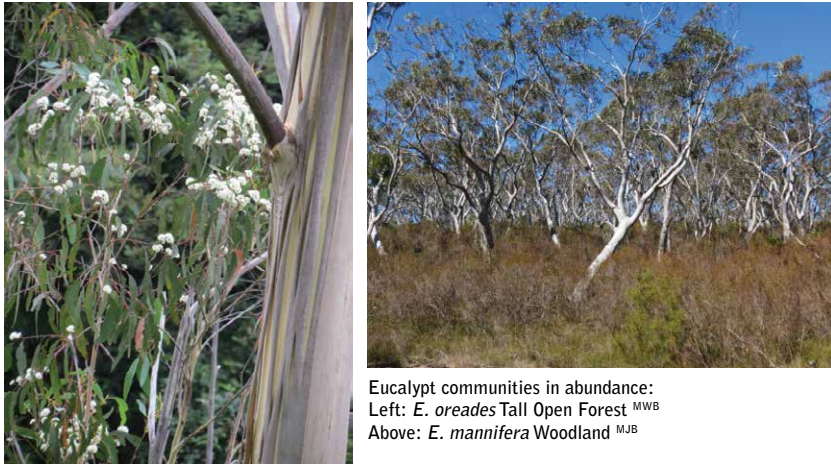
Early flowering plants:
Above: *Tasmannia insipida* ¹⁰
Right: *Atkinsonia ligustrina*



The separation of Australia from Zealandia (from c.80 Ma) and the completion of the rift with Antarctica (45 Ma) set Australia free from Gondwana. Isolation promoted rapid speciation and the distinctive Australian flora was born. By 62 – 60 Ma sclerophyllous plants in flammable communities had notably replaced some fire-sensitive rainforests. Research by Crisp *et al* (2011)¹⁰ states that this was enabled by the new post-fire resprouting abilities of early Myrtaceae, including Eucalypts, that were better able to survive new climate conditions. Familiar families appeared in the new sclerophyllous communities. Asteraceae, Fabaceae, Casuarinaceae and Poaceae joined new Proteaceae and Myrtaceae species.

Climate and fire regime changes accelerated about 15 – 20 Ma as northern Australia crossed the Tropic of Capricorn. The trend of older fire-intolerant plant communities slowly retreating into suitable landscape refuges continued. A recent phylogenetic study by Thornhill

(2019) indicated that ‘many of the eucalypt forests of south-eastern Australia are new in evolutionary terms (10 million years or less) ... and this includes many of the tall eucalypts that grow in the wet forests of southern Australia’. The *Eucalyptus* genus has in fact exhibited a uniquely rapid degree of diversification in just the last 2 million years.¹¹ This makes the dominance of Eucalypts in the Greater Blue Mountains all the more remarkable.



Eucalypt communities in abundance:
Left: *E. oreades* Tall Open Forest ^{MWB}
Above: *E. mannifera* Woodland ^{MJB}

Today in the GBMWH there is an impressive array of 70 vegetation communities; nearly half are endemic and most are dominated by Eucalypts with understoreys of modern flowering plants. Really old rainforests no longer exist. Today's replacements in sheltered places are a mix of Gondwanan relics of the primitive (liverworts and moss), the ancient (tree ferns), more recent ferns including *Blechnum*, and early modern flowering families (Coachwood and Sassafras). Where shaded rainforest encounters more exposed conditions on its fringe, the understorey plants of the older forest blend into the sclerophyll community exemplifying well the nominating criterion of a *highly unusual juxtaposition of ancient and modern plants and communities*.

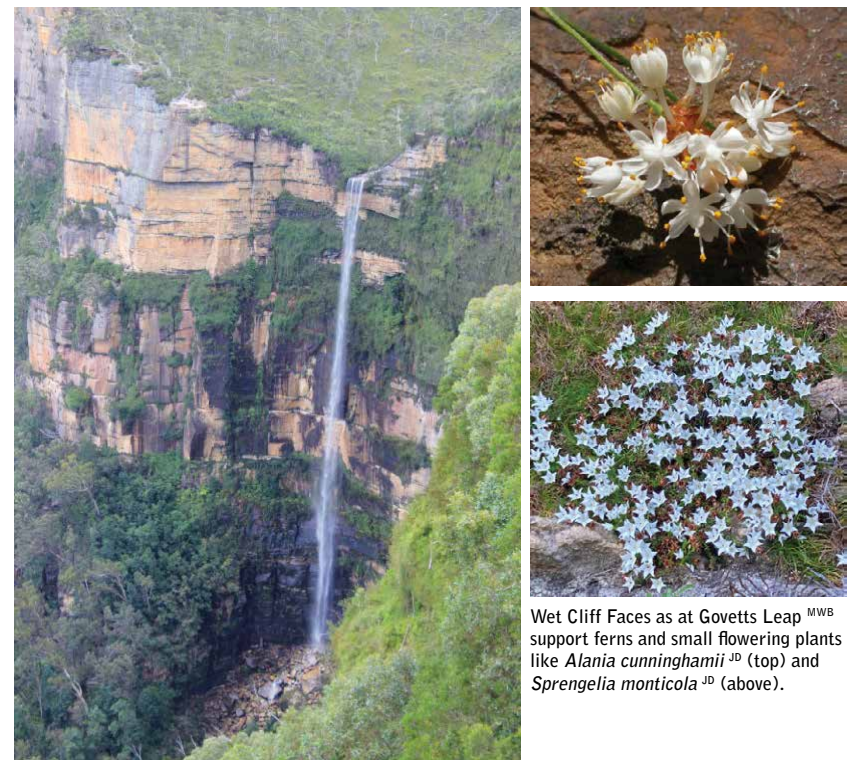
An exceptional diversity of plant habitats

The World Heritage nomination recognised an *exceptional diversity of plant habitats* in the Blue Mountains resulting from altitudinal effects on climate, different geological strata and soils, landforms and microclimates of dissected plateaus, and the presence of fire. The mix of plants in each habitat also strongly reflects the history of plant evolution in the region and the requirements for shelter of most species with an ancient lineage. So varied are the habitats available that the

GBMWH is home to more than 1500 species from over 484 genera and 152 plant families gathered into 500 associations.^{12, 13}

Looking out over large valleys in the upper Mountains a generalised range of habitats can be readily seen. On the lower slopes Tall Open Forests are supported on soils of varying depths and fertility. Trees include *Eucalyptus deanei* (Mountains Blue Gum), *E. piperita* (Sydney Peppermint), *E. punctata* (Grey Gum) and *Angophora costata* (Smooth-barked Apple). Warm Temperate Rainforest with *Ceratopetalum apetalum* (Coachwood) and *Doryphora sassafras* (Sassafras) may pattern the upper slopes a darker green but this community normally inhabits deep clefts in the escarpment rocks.

Vegetation of the sandstone escarpments is mostly limited to layers of claystone that provide some nutrient and moisture. Mount York Claystone supports a shrubby band mid-way between the sandstones. The Wet Cliff Face community of sometimes rare or endangered flowering plants, like *Isopogon fletcheri*, *Alania cunninghamii* and *Sprengelia monticola* populate the spray zones of waterfalls.



Wet Cliff Faces as at Govetts Leap ^{MWB}
support ferns and small flowering plants
like *Alania cunninghamii* ^{JD} (top) and
Sprengelia monticola ^{JD} (above).

Nestled in crevices of the cliff-top Burrallow Formation are surprisingly tall specimens of the majestic *Eucalyptus oreades*. Plateau edges with low nutrient, shallow soils, and exposure to drying conditions and fire, support extensive areas of Heath. Here *Banksia ericifolia* flowers are highly prized by honey-eating birds that migrate through the region in autumn. Towards the centres of ridges where sandy soils are a little deeper, Eucalypt woodlands with *E. sieberi* (Silvertop Ash) and *E. piperita* (Sydney Peppermint) may replace Heath.



Closed Heath on Kings Tableland with *Banksia ericifolia* and *Allocasuarina nana* looking south over Tall Open Eucalypt Forests towards Mt Solitary. ^{MJB}

In the lower Mountains a more uniform covering of sclerophyllous Open Eucalypt Forests dominated by *E. piperita*, *Corymbia gummifera* and *Angophora costata* grow on extensive Hawkesbury Sandstone surfaces where temperatures are warm to hot, soil dry and infertile, and fire regular. Canopy and understorey species show some variation from one ridge to the next but differences are greatest from the ridges into the valleys where taller forest species like *E. deanei*, mesic shrubs and ferns prevail. Where clay soils form on Wianamatta Shale different species including Stringybarks grow. Moist sites support Tall Shale Cap forests of *E. deanei* (Mountains Blue Gum), *E. punctata* (Grey Gum) and *Syncarpia glomulifera* (Turpentine).

Localised habitats provide opportunities for specialised communities. In the Sun Valley volcanic diatreme the moderate fertility of the clay soil supports *E. amplifolia* (Cabbage Gums) and *E. eugenioides* (Thin-leaved Stringybark) while in Euroka Clearing the Eucalypts include *E. deanei*, *Angophora floribunda* and *A. subvelutina*. In the Moist

Basalt Cap Forests that grow on deeper, moister and more nutrient-rich clay soils, the large eucalypts include *E. viminalis* (Ribbon Gum), *E. blaxlandii* (Blaxland's Stringybark) and *E. fastigata* (Brown Barrel). Warm Temperate Rainforest occurs on the basalt Mounts where eucalypt forests provide shelter, and on south-facing slopes and in ravines. Primitive and early flowering plants find refuge there.



'Hanging' and riparian swamps of shrubs and/or sedges near Katoomba ^{MJB}

In the upper and middle Mountains where ironstone or impermeable clays channel groundwater out onto the surface of slopes, areas of soggy peat soils support valley-side swamps of shrubs and/or sedges that may extend along streams. These are unique associations that play an important role in maintaining stream flow. *Blue Mountains Swamps in the Sydney Basin Bio-region* is listed as a Threatened Ecological Community under NSW and Commonwealth legislation. In the lower Mountains valley swamps have formed on the western side of the Lapstone Structural Complex where earth movements disrupted drainage. They include Burrallow and Shaw's Creek Swamps, and the open water wetlands of Mountain and Glenbrook Lagoons.

Forests and Woodlands of Eucalypts

The World Heritage nomination very much focused on the criterion that there is an *exceptional representation of major eucalypt groups, their evolution and ecological domination* in the Greater Blue Mountains. Very significantly the GBMWH is considered to be a centre for the diversification of the Eucalypt group, providing an 'outstanding record of the products of evolutionary processes associated with the global climatic changes of the late Tertiary and Quaternary' as outlined above.¹⁴ The 1998 nomination listed 90 species in the group Eucalypts.

Currently 99 species and sub-species are included in the three component genera: *Angophora* (6; 50% of all species), *Corymbia* (4) and *Eucalyptus* (89 or about 13% of the world's total).¹⁵ This number is considered to indicate a higher degree of divergence of the *Eucalyptus* genus into individual species than would normally be expected from an area the size of the World Heritage property. Today 56 temperate eucalypt forest and woodland communities dominate the vegetation cover of the region particularly where there are interactions with fire.



The three Eucalypt genera: *Angophora*, *Corymbia* and *Eucalyptus* MJB
Angophora lack a calyptra and have papery or thinly-wooded ribbed capsules *Corymbia* have a variable calyptra and capsules with a steeply insert disc *Eucalyptus* have a full calyptra and thick woody capsules

Other observations were made about the *Eucalyptus* genus:

- There is a good representation of the main sub-genera:
 - Symphyomyrtus: Blue Gums, Grey Gums, Mountain Gums, Red Mahoganies, Ironbarks and Boxes
 - Monocalyptus/Eucalyptus: Peppermints, Stringybarks, Ashes, Mallee Ashes, Scribbly Gums, Snow Gums
 - They grow in a variety of vegetation formations from Tall Open Forest to Woodlands and Heath
- Species come in many shapes and sizes from the 30 metre tall, straight *E. oreades* (Blue Mountains Ash), to lignotuberous mallees like *E. stricta* (Blue Mountains Mallee Ash)
- At least eleven species are legislatively classified as vulnerable or endangered including *E. benthamii* (Camden White Gum)
- One is almost extinct: *E. copulans*
- There are 10 rare (ROTAP¹⁶) species with 3 being endemic mallees: *E. burgessiana*, *E. cunninghamii* and *E. bensonii*¹⁷
- Species demonstrate a range of fire tolerances: *E. oreades* is killed outright by fire and takes decades to recover from seed; other

tree species like *E. sieberi* (Silvertop Ash) and *E. piperita* (Sydney Peppermint), and mallees including *E. stricta* and *E. burgessiana* are more fire-tolerant resprouters.



Resprouting after fire: *E. sieberi* (left) MJB and *E. cunninghamii* (right) MJB

Species numbers in major plant families in the Greater Blue Mountains World Heritage Area
 18; MJB & MJB

Scleromorphic taxa

World Heritage nomination recognised that in the Greater Blue Mountains there is a *high diversity of scleromorphic taxa from major Australian plant families*

Most vegetation associations in the region are populated by scleromorphic taxa with hard-leaves that are also often much reduced in size. They can withstand dryness and low-fertility soils. The presence and abundance of scleromorphic Eucalypts has already been outlined. They mostly grow in association with a diverse range of scleromorphic shrubs and groundcovers that provides displays of colour for the visitor and resources for wildlife. The following significant observations were made during nomination:

- Most scleromorphic plant taxa have high levels of species diversity and many belong to one of 20 plant families. Some indication of this diversity is illustrated in the accompanying photographs where approximate numbers of species are given.¹⁸
- Genera with the greatest number of species are *Eucalyptus* (89) and *Acacia* (98)



Myrtaceae 196



Orchidaceae 186



Poaceae 156



Fabaceae-Faboideae 139



Fabaceae-Mimosoideae 98



Proteaceae 98

Species numbers in major plant families in the Greater Blue Mountains World Heritage Area. ^{18; MWB & MJB}

- About 114 scleromorphic species are endemic including:



Almaleea incurvata. ^{MJB}



Grevillea acanthifolia subsp. *acanthifolia*. ^{MJB}

- Under the now superseded ROTAP listing, 127 plants were recorded as either rare or threatened with a high proportion of these found in communities restricted by small habitats including *Alania cunninghamii*, *Atkinsonia ligustrina* and *Lissanthe sapida*.
- Post-nomination 95 threatened plants have been protected under State and Commonwealth legislation. They include the following flowering species that are also endemic: *Acrophyllum australe*, *Epacris hamiltonii*, *Isopogon fletcheri* and *Persoonia acerosa*.



Vulnerable *Acrophyllum australe*. ^{MWB}



Endangered *Leucopogon fletcheri* subsp. *fletcheri*. ^{MWB}

- Following nomination, and particularly since the 2019/2020 bushfires, research has been directed at fire ephemerals, short-lived plants that are dependent on direct burning or on smoke for seed germination. The best known of these is *Actinotus forsythii* (Pink Flannel Flower) that flowered spectacularly in late 2020.¹⁹ They remind us that there is still much to discover and admire about the special plants of the GBMWA.



Above: *Actinotus forsythii* a fire ephemeral. ^{MJB}



Right: *Blandfordia cunninghamii* a post-fire re-sprouter. ^{MWB}

Heritage under threat

Changes are occurring in the Greater Blue Mountains Heritage Area and not all for the good. Degrading impacts have come from a range of sources including external urban and infrastructure development, and coal mining. The possible expansion of Lake Burragorang behind a higher Warragamba Dam wall presents a serious threat.

Climate change and associated fire regimes that have driven much of the diversification of the Greater Blue Mountains species and communities over millions of years, now present a great challenge for our much-loved plants and their ecosystems. Overall the region is becoming hotter and drier, with increased storm intensities, lightning strikes and ferocious winds. The 2019/2020 fire season demonstrated that a combination of these factors has the capacity to stir-up fires of the intensity and extent that have not been previously recorded.



This single fire season saw the burning of over 80% of the Blue Mountains National Park and at least 68% (c.700 000 ha) of the GBMWH. Millions of mammals, birds and reptiles also died. While regeneration occurred quickly for some plants, others like the icon *Eucalyptus oreades* are killed outright by fire and take a long time to re-establish. For the first time in living memory a significant proportion of the region's Gondwanan rainforests were burned.²⁰ Will they have the time and opportunity to fully recover? We really just don't know.

The conferring of World Heritage is a great honour for any natural area and for the people who dwell nearby. However it carries serious management obligations that must be met to ensure the survival of its special values well into the future.

Photographic credits

AP: Alan Page; JD: Jill Dark; MJB: Margaret Baker; MWB: Mark Baker

Endnotes

1. These are 1998 figures; many more species are now recognised.
2. Habitat diversity that sustains many (c.400 species) mammals, birds, amphibians and reptiles was also recognised in the GBMWH nomination. For a comprehensive study see Smith, J., Smith, P. & Smith, K. 2019, Native Fauna of the Greater Blue Mountains World Heritage Area, P & J Smith Ecological Consultants, Blaxland. It provides details of 432 species.
3. Ma – millions of years ago
4. For a more detailed account of Gondwana refer to Baker, M.J. 2019, 'Gondwana – a Global Adventure', Australian Plants, 30(239): 52-64
5. The author does not agree with the application of the name Snapper Point Formation to the breccio-conglomerates of the Shoalhaven Group.
6. Van der Beek, P., Pulford, A. & Braun, J. 2001, 'Cenozoic Landscape Development in the Blue Mountains (SE Australia): Lithological and Tectonic Controls on Rifted Margin Morphology', The Journal of Geology, 10 (1): 35-56
7. Downing, A.J., Brown, E.A., Oldfield, R.J., Selkirk, P.M. & Coveny, R. 2007, 'Bryophytes and their distribution in the Blue Mountains region of New South Wales', Cunninghamia, 10(2): 225-254
8. As per endnote 7
9. Gilmore, S. & Hill, K.D. 1997, 'Relationships of the Wollemia Pine (*Wollemia nobilis*) and a molecular phylogeny of the Araucariaceae', Telopea, 7(3): 275-291
10. Crisp, M.D., Burrows, G.E., Cook, L.G., Thornhill, A.H. & Bowman, D.M.J.S. 2011, 'Flammable biomes dominated by eucalypts originated at the Cretaceous–Palaeogene boundary', Nature Communications 2:193
11. Thornhill, A. 2019, 'A detailed eucalypt family tree helps us see how they came to dominate Australia', The Conversation, April 9
12. Figure may be closer to 2000 plant species
13. As per endnote 2
14. NPWS NSW and Environment Australia 1998, The Greater Blue Mountains Area World Heritage Nomination (NPWS NSW)
15. Page, A. 2021, Eucalypts in the Greater Blue Mountains World Heritage Area (99 not out!), bmnature.info/docs/flora-fauna/gbmwha-eucalypts-2021.pdf
16. ROTAP was a listing of Rare or Threatened Australian Plants (CSIRO)
17. Hager, T. & Benson, D. 2010, 'The Eucalypts of the Greater Blue Mountains World Heritage Area: distribution, classification and habitats of the species of Eucalyptus, Angophora and Corymbia (family Myrtaceae)', Cunninghamia, 10(4): 425-444
18. Species numbers change - statistics compiled by Alan Page are used here: bmnature.info/docs/flora-fauna/flora-gbmwha-species.pdf
19. Thompson, M. 2021, 'Rare Experiences', Australian Plants, 31(248) Spring: 131-135
20. Baker, M.J. 2020 'Resilient plants survive tough times', Australian Plants, Autumn Bushfire edition, 30(242) Autumn: 20

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